MAPPING A HISTORY OF WATER SECURITY IN THE PERUVIAN ANDES: A CASE STUDY OF MULLAK'AS-MISMINAY

by

© Nicole Renaud

A Thesis submitted to the

School of Graduate Studies

in partial fulfillment of the requirements for the degree of

Master of Arts

Department of Geography

Memorial University of Newfoundland

November, 2011

St. John's Newfoundland

Abstract

Marginalized populations in peripheral regions of the Andean highlands are among the most negatively affected by climate change and other social and environmental stresses. These communities' experiences with hardship have led to innovative adaptation strategies. This research provides an illustration of water security in Mullak'as-Misminay, Peru. Local knowledge systems contribute to water security, however their cohesiveness is diluted by pressures that devalue subsistence farming for sake of modern approaches to water management and agricultural production. Yet the stress from these pressures may also accentuate manifestations of Andean reciprocity that have traditionally informed water security. Lessons from the region demonstrate that water security is not exclusively a matter of quantitative calculations, but one that requires qualitative considerations informed by the local socio-cultural context. An Andean model of water rights may provide avenues for communities such as Mullak'as-Misminay to meet water security challenges.

Acknowledgements

This thesis would not have been possible without the support, help, and patience of the people of Mullak'as-Misminay, as well as those in Maras. You kindly took me under your wing and introduced me to your community and region, were infinitely patient with my less than ideal Spanish, and shared food, drink and stories with me without reservation. The friendliness of this community makes it difficult to stay a stranger for very long, regardless of linguistic or cultural barriers. Your kindness and generosity made for a memorable field season, and made this research, which I hope can in some way contribute to your well-being and prosperous future, a truly rewarding pursuit.

The foundation of this thesis has been my supervisory committee, whose endless encouragement, hard work, and insight ensured that the process moved forward. Dr. Vodden's positivity encouraged me to carve out my own vision, as well as linking that vision to geographical theory. Her genuine passion for community development has helped shape my approach to this research. Dr. Catto's physical geography expertise brought a vital perspective, especially to the climate change-related research, while his field work experiences guided me forward with my own. Dr. Earls's extensive experience with Andean community research, in particular with Mullak'as-Misminay, helped inform the socio-cultural and political context, while providing a very valuable critical eye regarding the interplay of modernity and state politics. Dr. Mather's expertise on market liberalization and farm workers bring an important lens to this research, and for that I am very grateful. The Geography Department at Memorial

University has been an inspiring and inviting learning environment, and one that has allowed me to grow academically.

The CIDA-funded Students for Development program through the Association of Universities and Canadian Colleges allowed me to pursue an internship with CARE Peru and for their support I am thankful. CARE Peru offered a warm and hospitable environment while also providing a deeper understanding of the political and economic complexities of water-related multi-level government, governance and development in the country. This understanding added the depth that I needed to develop my work, and my CARE supervisor and friend, Nella Canales, has been wonderful in this regard.

On a more personal note, my colleague and friend, Ryan Gibson, has been an incredible guide in always encouraging and educating me on the thesis-development process, and without his guidance I would not be this far ahead. Last, but certainly not least, my fiancé Karl Reid's loving support has infused me with the confidence and determination to pursue all of my ambitions, this one included, and always stay the course no matter how long and winding the road.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

The most profound meaning of the Andes thus comes not from a physical description, but from the cultural outcome of 10 millennia of knowing, using, and transforming the varied environments of western South America. (Gade, 1999: 34)

The Peruvian highlands have a long history of innovative approaches to water management in an environment that outsiders might consider poorly suited for agriculture. In fact, only 4.5% of Peru's Andes is arable (Hudson, 1992). The irregular availability of water has been one of the most hindering components of societal development in the Andes (Parry et al., 2007). Pre-Columbian societies have risen, developed, and fallen, with local ecological knowledge evolving alongside of these experiences. Despite a long history of adaptation, the multiple intersecting stressors facing Andean communities today cascade throughout their respective socio-ecological systems and exert various impacts on their water security. Antagonistic forces such as privatization legislation, political instability, ethnic marginalization, and international financial institutions profiting from intensified agriculture compound these stressors. Water insecurity threatens to create rigidity or a socio-ecological system poverty trap, where the system is not able to sustainably reorganize itself and the conditions which lock a system into a poor state are persistent, self-reinforcing and maladaptive (Silverman, 2008). In such a trap, the system cannot re-enter the adaptive cycle functionally nor provide effective responses to the disturbances faced.

Many of the longest traditions practiced in the Andes were born of local ecological knowledge and are often intimately linked with hydrological cycles. These have been tried and tested in the challenging mountain environments, and remnants of these customs remain today, albeit in fragmented forms. They have manifested as strategies and mechanisms to serve as buffers during difficult times, while also enabling risk distribution (Newshamand and Thomas, 2009). Various adaptation strategies have been codified into the fabric of Andean belief systems that help coordinate water access, availability, and use. However, multiple stresses, exerted by both local behaviours and multi-level relationships, have served to hinder the communities' adaptive capacity in relation to water security.

1.1 Water Security

A report by the Intergovernmental Panel on Climate Change has defined water security as a "reliable availability of water in sufficient quantity and quality to sustain human health, livelihoods, production, and the environment" (Bateset al, 2008: 182). Schultz and Uhlenbrook (2007:1) provide a more comprehensive definition that includes the, "sustainable use and protection of water systems, the protection against water related hazards (floods and droughts), the sustainable development of water resources and the safeguarding of (access to) water functions and services for humans and the environment." Addressing droughts and floods is an important consideration for Andean water security, where these phenomena can be commonplace (Manners et al., 2007). Water sources may also need protection from stresses deriving from human-induced events in order to be water secure, whether that be excessive agrochemical use contaminating water sources, or policies that facilitate privatization of natural resources and thus compromising local water rights (Embassy Brasilia, 2008). The availability of sufficient water is not only determined by physical geography but also largely determined by adequate access and sustainable utilization of the resource. Political and socioeconomic factors play an important role in enhancing or diminishing access and opportunities for sustainable water use.

For the purpose of this research, water security is defined as a sustainable availability of sufficient and good quality water for multi-dimensional purposes, including human use, ecosystem functions, and long-term access. The unstable nature of weather patterns and climatic shifts needs to be taken into account when considering sufficient available water supplies. For this reason, adaptation practices and other responses that help buffer against disruption to water supplies can enhance overall water security of a socio-ecological system.

1.2 Climate Change in the Peruvian Highlands

With climate events anticipated to occur with greater frequency and magnitude, the intensity is expected to be even greater at higher altitudes (Perez et al., 2011). As the balance between temperature, precipitation, and evapotranspiration changes, water patterns may become less predictable and increasingly difficult to adapt to. Rising temperatures are impacting this balance in significant ways, by increasing evapotranspiration in plants and in turn increasing the requirements of water needed for irrigation purposes (Gobierno Regional Cuzco, n.d.). Precipitation patterns are growing erratic with projected rainfall decline in the Andes (World Bank, 2009). Regional estimates for the Andes indicate considerable declines in water availability by 2030, with a substantial reduction by 2050 (Embassy Brasilia, 2008). The Andes' spatial and seasonal variability combine to create a chronic water shortage during the dry seasons, which is compounded by the frequent floods and droughts this region is subjected to (Olson, 2007). The frequent floods affecting this area negatively impact water quality and aggravate water pollution (Bates et al., 2008).

As temperatures increase, Andean ecosystems are gradually migrating upwards, with mountain tops no longer cold enough to sustain the former hydrological cycle balance that maintained renewed glacier formation (Tahirkheli, 2010). Andean water security literature emphasizes increasing water stress, largely attributed to the rapid and accelerating glacier retreat of Peru's tropical glaciers. It is projected that glaciers found below 5,500m, the majority of glaciers in Peru, will disappear between 2015 and 2020 (Portillo, 2008). Between 1977 and 2007, glaciers have experienced a 23% loss in mass, and glacial recession is a highly visible indicator to farmers that their lands are undergoing rapid and profound changes (Leavell, 2007). The impact that glacier retreat and accelerated runoff will have on Andean communities, hydropower generation, and farming is severe, and the future of water security can be precarious, particularly at the local level (Vuille et al., 2008).

1.3 Marginalization and the Rural Indigenous Poor

Indigenous, rural Andean populations over-represent the poor and systematically experience inadequate access to natural resources and land (Griffiths, 2002). Historically, indigenous Andean communities have encountered multiple stressors that have created or exacerbated conditions of marginalization. Many have demonstrated remarkable resilience by learning from difficulties and applying lessons through practical water management strategies.

Rao (2007: 223) describes marginalization as occurring when "people are systematically excluded from meaningful participation in economic, social, political, cultural and other forms of human activity in their communities and thus are denied the opportunity to fulfill themselves as human beings." The characteristics of marginalization considered in this community case study of Mullak'as-Misminay are indigeneity, monetary poverty, and location in the rural periphery.

1.4 Study Community: Mullak'as-Misminay

Andean highlands have been occupied by humans for almost 11,000 years, and possess diverse organizational heterogeneity within modern nation state boundaries (Beall, 2007; and Earls, 1996). In Peru, there exist 5,500 indigenous communities, with each retaining various degrees of their traditional, pre-conquest organizational structure (Earls, 1996).

Mullak'as-Misminay is an agropastoral Andean community located six km from the Town of Maras within the District of Maras, in the Province of Urubamba (Figure

1.1). Urubamba is located in the Cuzco Department of Peru. Mullak'as-Misminay is composed of five sectors: Pillahuara, Tayancayoc, Pucamachay, Santa Ana, and Misminay.

Figure 1.1: Map of Maras District with Inset of Peru

This community is populated by indigenous Quechua farmers who speak the Quechua language, which was the language of the Inca (Hornberger, 1996). Many are bilingual and speak Spanish also; however some of the elders speak only Quechua. The residents are the descendents of the Inca and pre-Inca, who constituted some of the first settlements in the region (Cavero et al., 2005). In 2005, the population of Mullak'as-Misminay was 1,087, and its projected annual rate of increase is 1.36%, which is slightly higher than the overall District's 1.2% population increase projection (Cavero et al., 2005). While the population is steadily rising, rural outmigration has been on the rise since 1987, and accelerating at alarming rates. The primary reasons for outmigration in Mullak'as-Misminay are for work and school (Cavero et al., 2005).

The Andes have been classified into eight biogeographic natural regions according to altitude and climate. Mullak'as-Misminay is situated within the "quechua" ecoregion (2,300-3,500 metres altitude), as well as partly within the "suni" ecoregion (3,500 – 4,000 metres altitude) (Pulgar Vidal, 1979; Cavero et al., 2005). The community has a semi-arid climate with dry winters (Gobierno Regional Cusco et al., 2005) The region is defined by a semi-annual seasonal division of rainy and dry seasons. The community does not possess any lakes or rivers, nor are there any sub-basins that connect to the province's main watershed; the Vilcanota River. There are eight water sources in Mullak'as-Misminay, all in the form of small springs (Cavero et al., 2005; and Wright, 2008). Water yields from the community's springs are highly variable, and in October of 2005 ranged from 0.1 to 150 L/minute (Wright, 2008). The community relies on this rainfall pattern for agriculture, and residents coordinate their harvest around this seasonal division. Farmers depend on rain-fed agriculture, often storing rain in the reservoirs for use in the dry season. They use rudimentary farming technology such as cattle for ploughing. Some crops grown in the District use improved seeds, and the main crops grown in Mullak'as Misminay are beans, corn, several varieties of potato, quinoa, and wheat, along with a few others (Urton, 1981).

Agricultural tasks for certain crops are carried out in correspondence with the moon and sun phases, structuring the agricultural duties accordingly. Table XXX illustrates the different duties in planting throughout a year in Mullak'as-Misminay, and provides an approximation of the times for each crop and task.

Duties		July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June
Planting	Early potatoes												
	Wheat												
	Oca/ollucu												
	Corn												
	Quinoa/beans												
	Peas												
	Wheat/potatoes												
Hoeing	Hallmiyoq												
	P'oqroy												
Breaking the Earth													
Harvest	Early potatoes												
	Peas												
	Potatoes												
	Quinua/beans												
	Wheat												
	Oca												
	Corn												
Ploughing													

Adaptation of Gary Urton's (1981) "An Ethnographic and Calendrical Descripion of Misminay: The Duties of the Month"

The majority of residents are involved in agricultural production. The chart below demonstrates the principal economic activities undertaken by the community population, of which agriculture represents 79% (Cavero et al., 2009).

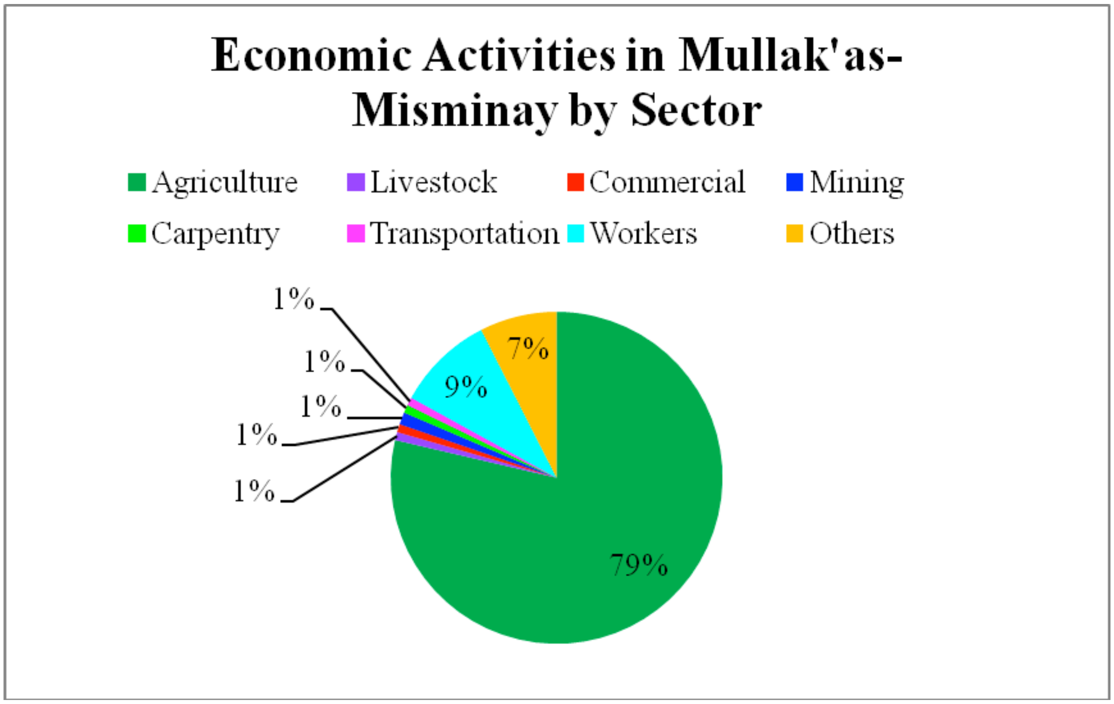


Figure 4.5. Economic Activities in Mullak'as-Misminay by Sector.

Data from Cavero et al., 2005.

Mullak'as-Misminay is also where the pre-Hispanic archaeological site of Moray is located. Moray is a circular vertical agricultural terrace system that is believed to have been used as a centre for agricultural experimentation. Some of the conditions that support this hypothesis include the presence of significantly variegated microclimates across terrace levels, most notably the fact that the microclimatic distribution relates to the artificial terrace construction rather than the naturally-occurring geographical layout (Earls, 1998). This suggests that the inhabitants who constructed this terrace system had developed an effective strategy that enabled environmental manipulation in order to artificially recreate conditions of local microclimates. The system thoroughly incorporated Cuzco's agricultural calendar and its key dates dictating agricultural tasks and planning (Earls, 1998). This vertical terrace is especially complex, and was constructed using extensive local expertise to coordinate the geologic and hydrologic features within the landscape (Wright et al., 2011). The terrain had its own water source and was irrigated with a nearby aquifer until approximately 60 years ago, when the water was channelled away from the system and redirected to Maras for the District's use (Wright et al., 2011; and Earls, 1998). Without the irrigation system, crops are not regularly grown here, although a photo image search reveals that attempts have been made using rain. It currently serves as a major tourism attraction, drawing increasingly large numbers of tourists to the region (Cavero et al., 2005).

1.5 Vertical Terraces

Maintaining vertical terraces required an extensive amount of coordinated labour and socio-environmental control (Erickson, 2000). This was achieved through the Andean system of reciprocity and cooperative labour known as "ayni". "Faenas" are communal tasks that contribute to the ayni labour system. These communal works are for the benefit of the community, and in turn the participants of the labour also become the recipients of the work's benefits (Erickson, 2000). Terrace systems have a long history in the region, with evidence dating back from 2,200 BCE – 100 AD of rudimentary terraces developed and seemingly employed as a response to an increased frequency of soil erosion events (Kendall and Chepstow-Lusty, 2006). The benefits of vertical terracing go beyond soil erosion mitigation, as they also help to diminish frost and drought impacts, conserve soil, expand crop opportunities, and increase potential yields, with some crop outputs increasing by as much as 65% (Altieri, 1996).

1.6 Perturbations in Socio-Ecological Systems

Throughout their development, many Andean societies became thoroughly acquainted with the character of their environments. Their environmental history has included on-going disturbances, as well as punctuated shocks, ecological or human-induced. If a disturbance exceeds a socio-ecological system's adaptive capacity, then the community risks losing its organizational cohesion and its ability to recover (Janssen and Osnas, 2005). The depletion crisis model in the conservation field discusses the learning involved following a resource depletion crisis. It argues that water security issues can prompt further learning in response to depletion, as a matter of necessity (Berkes and Turner, 2006). As perturbations allow socio-ecological systems to self-organize, learn, and adapt, it follows that suppressing perturbations or stresses can inhibit the learning process involved in maintaining and enhancing adaptive capacity (Berkes and Turner, 2006). Smaller disturbances help build experience and assist systems in building resilience for larger or more prolonged perturbations (The Sustainable Scale Project, n.d.). Although many factors influence the pathways as well as the rise and decline of entire civilizations, certain experiences in the physical environment have contributed in determining opportunity and disadvantage for socio-ecological system development. Transient and protracted disturbances have also contributed to both innovative response and societal stagnation (Dillehay and Kolata, 2004). The prolonged drier periods from 1,050 and 1,100-1,400 and 1,450 AD around Lake Titicaca in the Peruvian Andes had created incentive that contributed to increased regional specialization, advances in irrigation and terrace development. Eventually, the stress of the dry periods exceeded the adaptive capacity and the region experienced a marked decline in agricultural production, culminating in total field abandonment (Binford et al., 1997; Kendall and Ouden, 2008). Experiencing such disturbances is part of the learning process involved in resiliency and allows societies the opportunity to develop and employ various mechanisms and strategies in light of the water security problems they encounter.

1.7 Local Ecological Knowledge

Multi-generational local ecological knowledge has greatly contributed to Andean communities' adaptive capacity in light of water security. This cumulative compendium of knowledge evolved out of observation, exposure and experiments, and continues to be transmitted to contemporary generations, albeit multi-level relationships have greatly influenced their cohesion, valuation, and application (Berkes, 2005; and Valdivia et al., 2003). Although elaborate knowledge systems provide tools to anticipate and plan, rural Andean societies may lack the ability or be prohibited from effectuating coping strategies. They may also lack the higher level of articulation and coordination required to enact successful adaptation mechanisms.

Many Andean communities, including Mullak'as-Misminay, have developed methods of anticipating growing conditions for the year based on biotic and abiotic indicators (Gilles and Valdivia, 2009). Certain applications of ethnoastronomy provide an excellent illustration of a local ecological knowledge-guided abiotic indicator used to forecast rainfall and the strength of El Niño events. Farmers in Mullak'as-Misminay observe the Pleiades constellation and use the strength of star visibility as a rainfall guide to plan their agricultural schedule (Urton, 1981; and Orlove et al., 2000). The social learning involved in this sort of traditional knowledge helps Andean societies cope with the uncertainty and unpredictability of their ecosystems, and in particular the hydrological cycle, through innovative management strategies (Berkes et al., 2000). A seemingly productive and stable season in the Andes can suddenly experience a disruption in temperature and rainfall patterns that can prompt unexpected frost that spoil crops (Earls, 1998). While the timing of specific shocks themselves may be unexpected, their occurrence is not. Disruptions can be particularly difficult to withstand in subsistence societies, and in order to endure these unforeseen contingencies, Andean societies must possess the capacity to plan and re-plan their agricultural approach in order to be resilient in the face of such fluctuations and perturbations (Earls, 1998). The ongoing and projected climate changes may bring further uncertainty and make local knowledge systems invaluable. With diminishing access and control over local water resources, such as through prohibitive land tenure arrangements or market pressures dictating higher crop demands, the conditions that allow the practice and feasibility of these knowledge systems may be hindered (Charnley et al., 2008).

1.8 Multi-Level Relationships and the Pressure to Modernize

Multi-level relationships have influenced Andean communities since pre-colonial times. The Inca Empire employed multi-level administration that functioned at all scales. In the absence of a market system, the Inca economy promoted local self-sufficiency while social exchange through barter or controlled trade existed to secure products not locally available (McEwan, 2006). Empire citizens were provided with basic needs and did not need to buy anything. The Highland Economic Model, introduced by Rostworowski de Diez Canseco (1999) which operated according to a subsistence pattern of usually rainfed agriculture. The relationship or the ruling body had to its citizens changed drastically with Colonial (1532-1821) and Republican (1821-1930) periods. The nation-state did not function in the same manner but rather to erode kinship alliances while facilitating exploitation (Andrien, 2011). Post-colonial patterns have persisted within modern nation state administration and legislation, and to an extent, indigenous populations continue to experience the effects of colonialism regarding reduced access to land and water.

External influences have historically impacted local practices surrounding water management, either by introducing new or foreign elements into the society that alter the community's relationship to water, or by extracting critical components that formerly allowed local ecological knowledge to flourish. This can include the introduction of production-oriented exotic tree species that displace water security-enhancing native tree species. It can also manifest through the diversion of community water sources away from their own subsistence crops, with redirection to commercial-bound crops outside the community (Earls, 1998; and Cavero et al., 2005). While local ecological knowledge across Andean communities has traditionally facilitated resiliency in the face of varying perturbations, its applicability can be diminished and perceived as less relevant in modern contexts. This sort of disconnect can be a profound disservice to rural populations and their ability to maintain or enhance water security.

The push to privatize through modernization mechanisms is immense, and particularly emphasized in the agricultural sector. Agricultural exports are becoming increasingly prominent for Peru's economic growth and development. In 2005 this sector brought 1.6 billion dollars, amounting to more than 10% of the sum of exports (Olson, 2007). The debate over implementing improved irrigation is largely oriented around concerns over efficiency, profit returns, and scale. Governments and international financial institutions implement policy and legislation and propose incentives to adopt more modern and economic approaches to agriculture and irrigation (Gonzales, 2000). The external drive to modernizing traditional and indigenous ways of life in rural agricultural communities is concretely rooted in profit incentives, strongly focusing on water's market value and greatly ignoring its social value and cultural meaning (Escobar, 1998; López Gonzales, 2008). Even as modernity interventions in the agricultural and irrigation sector can lead to climate change adaptation solutions, often they are integrated with monetary poverty reduction strategies with the belief that poverty and environmental degradation are inextricably linked (Forsyth and Leach, 1998). Inclusion in these schemes usually requires profitable returns that may not be of benefit to the local populace, or even feasible (Kastelein, 1998; Vera Delgado and Zwarteveen, 2008). Avenues to modernity include standardized, top-down, market-oriented, Western scientific techniques and technology (Vera Delgado and Zwarteveen, 2008). The debate surrounding irrigation is especially relevant, as currently practiced traditional methods employing gravity become displaced by the more efficient pressurized improved irrigation schemes (Embassy Brasilia, 2008).

Peru's National Water Authority estimates traditional irrigation techniques such as flood irrigation have an average water use efficiency of 35% - 40%, while the World Bank's estimate is 35% (Comisión Técnica Multisectorial, 2004; and Olson, 2007). These estimates do not appear to consider some of the more efficient traditional systems employing vertical terraces, as well as the more cohesive traditional irrigation strategies that conserved water through an egalitarian system of contiguous distribution and a more coordinated labour force (Trawick, 2003; and Boelens and Gelles, 2005). Trawick (2002) has observed in his field work however that efficiency of flood irrigation is very relative, with Andean case study communities' water management ranging from highly efficient to very wasteful. The best practices of efficient traditional irrigation practices are seldom cited in government and international financial institution position papers, leaving an impression of homoegenous wastefulness trapped at a low efficiency rate of 35% - insufficient as the country's glaciers rapidly recede and water resources are increasingly threatened by climate change. With Peru's General Water Law and the newly reformed law mandating water management to be both "economical" and "efficient", the country's legislative framework couples with national policy and international funders to actively promote pressurized irrigation (Trawick, 2003).

Pressurized (also designated as "Improved") irrigation uses pressurized pumps to draw water to the crop locations, and can operate at a 70% efficiency rate (Johnson, 2002). Given these efficiencies, multi-level actors, including government and non-governmental organizations, have actively been promoting pressurized irrigation as a viable climate change adaptation and monetary poverty reduction strategy. However, even when pressurized irrigation schemes were implemented in Cuzco, some case studies have demonstrated disappointing results with unchanged production output (per unit of labour). This was largely due to the shortage of human capital and the conflicting cultural context that did not support the sustained operation of pressurized irrigation. While these systems helped increase water availability, the outcome did not produce the desired food production, and soil erosion rose sharply (Kastelein, 1998). Many irrigation interventions over-emphasize the role of infrastructure in development schemes and fail to take into account the local cultural and social context determining water management strategies and mechanisms. The cement-lined canals of pressurized irrigation systems also diminish aquifer recharge, which can compromise long-term local water security (Foster & Garduño, 2006).

Locally-established irrigation schemes in the Andes tend to operate by a method of water rights development that is determined by a person's contribution to the construction, maintenance, or repair of the irrigation system (Kastelein, 1998). When external interventions do not recognize this system of rights that drives participation, infrastructure with increased efficiency rates may therefore yield poor results when the technological expertise required to construct and maintain such systems alienates labourers from meaningful contributions towards water management.

1.9 Water Availability

Peru's per capita renewable water availability has been continuously decreasing as the population increases. In 1950, water availability was 5,241 m^3/person/year, which declined to 1,700 m^3/person/year by 1995 (Gardner-Outlaw and Engelman, 1997). In order to be considered water-stressed, a country or region needs to have between 1,000 to 1,667 m^3 per capita of annual freshwater availability. Peru reached this mark in 2000 when availability declined to 1,559 m^3/person/year (Gordon, 1998; Gardner-Outlaw and Engelman, 1997). Water availability is projected to decrease to 1,126 m^3/person/year by 2025, a figure which approaches the water scarcity criterion of 1,000 m^3/person/year (Gardner-Outlaw and Engelman, 1997). Under the medium and high United Nations population models, Peru is projected to become water scarce by 2025 (I Valls, n.d.).

As Peru possesses an enormous disparity of physical water availability between regions, it would be more meaningful to focus on regional water availability, while acknowledging extra-local water displacement through aquifer diversion. Furthermore, use and access to water supplies is largely related to socio-economic and political power and marginalization. Thus, a region with the least water and the largest population, such as the coast, may have the greatest access to water for uses that serve to consolidate its power. It is important to not only consider physical availability but also the power distribution influencing regional water security.

Approximately 82% of the water withdrawn in Peru goes towards agriculture (Central Intelligence Agency, n.d.). Of the 82% attributed to the agricultural sector, 97% of irrigation water is drawn from surface water sources in the Andes (Embassy Brasilia, 2008). Thus, water use efficiency in agriculture plays a significant part in the determination of water security.

There are plans underway to channel water from Andean aquifers, thus taking water away from subsistence farmers in order to maintain large-scale irrigation projects (Fraser, 2009; and Olson, 2007). Draining water from extra-local aquifers that are being used by subsistence farmers already facing contending pressures and ecological stressors can be very problematic for water security, not only from an ecological perspective, but from a political standpoint, pitting the competing interests of powerful agribusiness against smallholder Andean farmers (Fraser, 2009; Keen, 2010). These developments are made possible through private and government support, which aim to increase agricultural export production as well as enhance extra-local market integration.

1.10 Integrated Water Resource Management and the New Water Law

A new legal instrument has been introduced in Peru that is anticipated to have far-reaching consequences for the country's water resources. The recent Water Resources Law (known as *Ley de Recursos Hídricos*, or LRH), legislated in March 2009, has redefined water rights and enshrines water as an economic good. LRH has many of the elements necessary for integrated water resource management, including decentralizing governance to regional levels. However, it has been criticized as maintaining decision-making powers in Lima (Hancco et al., 2009). LRH has removed the clause stipulating that water resource administration will not be for profit, and has been heavily criticized by community groups who have concerns that it will be a gateway to water privatization. This legislation is believed to be particularly beneficial to large corporate interests such as mining, industry, and export agriculture that rely on significant amounts of water for operational purposes (Hancco et al., 2009).

Efficiency in water management can understandably be very appealing to smallholder farmers whose agriculture may rely entirely on limited seasonal availability that continues to change – sometimes in alarming ways. Young and Lipton (2006) have reported that access to irrigation systems present the greatest ongoing worry for Andean people. The Andean farmer's world has changed dramatically, and many uncertainties lie ahead. Past trends indicate that Andean communities have the adaptive capacity necessary to weather current and future challenges to local water security, so long as external actors do not exert exceedingly negative influences (Young and Lipton, 2006). Even so, the facets of marginalization may have contributed to the development of innovative responses by pushing Andean communities to compensate for elements of vulnerability challenging their socio-ecological system.

1.11 Latifundia-Minifundia, and the Emerging Microfundia

One recurring challenge that rural Andean people have faced is the expropriation of land and natural resources. Following the Spanish conquest, the most fertile lands were expropriated and indigenous populations displaced to more marginal zones (Griffiths, 2004). With the formation of the nation-state, the highly unequal latifundia-minifundia system emerged, that saw the creation of large, typically 500 hectare-minimum latifundium estates using indigenous land and operated by commercial landowners. In Latin America, latifundia are also referred to as haciendas. Minifundia were much smaller lands, usually less than five hectares, and granted to smallholding indigenous and peasant farmers (Griffiths, 2002). Smallholdings became even smaller as rural populations grew and these small plots of lands were further divided among the descendents (Griffiths, 2002). Many plot sizes have been reduced to less than one hectare in size, and these are termed microfundia. With many microfundia resulting in reduced agricultural terrain, some Andean farmers compensate by planting upwards of twenty small plots, experiencing great variety from field to field, as evidenced in Carol Goland's (1993) field work in Puno, Peru. Agricultural tasks, decision-making, schedules and degree of collaborative labour vary from field to field, effectively reducing variance of overall crop yields. Crop destruction probability has been shown to be greatly reduced by this approach to risk distribution in field scattering. (Goland, 1993). This system has served to disperse risk, as agricultural characteristics and crop yield results hold a high degree of diversity from plot to plot.

The latifundia-minifundia system produced profit for the landowners using indigenous slave labour, and has contributed to the concentration of wealth at the expense of immense rural poverty – monetary and otherwise (International Encyclopedia of the Social Sciences, 2008). The "encomienda" system of Spanish-based law served to establish a system of forced slave labour for the latifundia in order to develop the agricultural sector of the economy. This system was officially disbanded in the 18th century. The hacienda system operated in a similar fashion until the 1969 land reform following a coup by General Velasco Alvarado, when the state expropriated and redistributed land in order to break up the hacienda system. The reform was largely considered unsuccessful and did not create the egalitarian opportunities in land tenure and agricultural autonomy it sought to establish (Kay, 1998). Egalitarianism and improving the representation of the rural poor have also been promised by Maoist-inspired guerilla movements. Growing out of Ayacucho, one of the most water insecure Andean departments, the Shining Path preyed on sentiments of disenfranchisement of the rural poor with ambitions for equality bringing only violent political instability (Guran, 2008). Once more, promises of egalitarianism failed to be manifested, and the embers of rebellion continue to burn with the potential to flare up if governments continue to ignore the rural poor (Gregory, 2009). Given the 1,000 conflicts that erupted during 2009-2010 in Cuzco over the water law, discontent among the rural peasantry is very prevalent (Guardian News, 2010).

1.12 Smallholder Farming and Bartering Networks

The majority of farmers in the Peruvian Andes are smallholder farmers, who mostly produce food for their own subsistence and have limited to no market interaction (Kastelein, 1998). As of 1994, 60% of Peruvian farmers owned less than five hectare plots of land (Escobal and Torero, 2006). The majority of smallholder rural farmers live below the national poverty line, with around 70% considered to be poor or extremely poor (Swiss Contact, 2011).

Bartering has long existed in the Andes, possibly for 8,000 years, and pre-dating the Inca Empire (Beyers, 2001; and Hawkes, 2000). The vertical archipelago, first described by John Murra (1974), has described the tradition of Inca-era inter-community bartering by vertical exploitation. This allowed farmers to optimize agricultural opportunities at varying altitudes (Custred, 1979). The products of this vertical exploitation were often bartered through a horizontal regional exchange, though post-conquest, the presence of bartering became increasingly scarce (Custred, 1979; Beyers, 2001). Bartering was often grounded in systems of reciprocity based on kinship ties and allowed networks to diversify local products, which distributed risk and helped communities better sustain shocks such as droughts and floods. In the Quechua language, there is no word to signify monetary poverty. Rather, the closest translation for being "poor" means to be "without social ties" (Miyashita, 2009). Networks and kinship connections are reciprocity-based and shape traditional social dynamics as well as livelihood strategies.

Fujimori-era (from 1990-2000) neoliberal policies aiming to integrate Andean communities into cash markets through agricultural intensification for long-term growth and stability have stretched smallholder farmers' local food systems thin, stressing water systems and resulting in heightened food insecurity and malnutrition (Marti and Pimbert, 2007; Slaughter-Holben, 1999). As such, former subsistence farmers attempted to extend their output to meet urban demands, which led to more intensive agriculture in decreasingly appropriate circumstances while they had difficulty meeting their own subsistence needs (Marti Sans, 2005). Intensifying production entails a range of strategies that may operate contrary to traditional low-impact agricultural approaches that have been seminal in supporting Andean rural livelihoods. Monocultivation is promoted for market growth but is functionally contrary to agricultural diversification (Valdivia, 2003). Native crops better suited to meet household needs are often replaced by market-oriented crops, with greater agrochemical use to suppress pests and diseases (Marti Sans, 2005).

Bartering-based market networks in Cuzco have strengthened as a response to these intensifying conditions of marginality. This response has an important history in the region, and the local ecological knowledge present in the social customs of even heterogeneous Andean communities enables its mechanisms to resurface in times of need.

1.13 Research Objectives

In order to be resilient, a socio-ecological system must have the ability to buffer perturbations, self-organize, and adapt and learn (Tompkins and Adger, 2004). A water-secure socio-ecological system would have mechanisms and structures in place that would allow it to absorb shocks without those disturbances affecting its core functionality. This could come in the form of upgraded infrastructure capable of capturing greater releases of water from variable rainfall, for example. It would also possess the ability to self-organize, such as when water users and farmers change their coordinated labour activities in irrigation and rotational agriculture patterns while transitioning to more drought-resistant crops during a multi-seasonal drought (Earls, 2006). The ability to learn and adapt may be demonstrated through both examples as people take the local ecological knowledge accumulation over the generations of interaction with their environment and its ecological events and apply adaptations accordingly based on those observations and lessons learned. In this way, water security is enhanced, which in turn contributes to overall social-ecological system resilience.

This thesis research is guided by the following objectives:

1. Identification of the key events and shocks that have caused disturbances to water security in the past within the case study community of Mullak'as-Misminay and surrounding area;
2. Better understanding of the evolution of the community-water relationship, which incorporates both shocks and community responses, including times when adaptation strategies may have emerged; and
3. Identification of innovative practices contributing to resiliency and lessons learned in this community and surrounding region that can help to promote adaptability and good water governance.

The key questions governing this research are:

1. What multiple stresses have acted as perturbations to water security in Mullak'as-Misminay in the past?
2. What practices have been developed to respond to these stresses?
3. How is marginalization related to the impacts of and responses to these perturbations?
4. Have multi-scale relationships supported or hindered water security, resiliency, and adaptive capacity?

These questions incorporate the concepts of marginalization and multi-level relationships, both of which are critical to the vulnerability and response capability of socio-ecological systems, particularly as they relate to shared decision-making and multi-level governance. Examining the historical context of water security for this case study community and the surrounding region will delineate the dynamic adaptive processes that characterize the socio-ecological system resiliency in Mullak'as-Misminay.

Chapter 2: Literature Review

This chapter reviews seminal literature on water security and examines the role of adaptive capacity in water management and socio-ecological system resilience. In reviewing this literature, this chapter considers the manner in which marginalization and multi-level governance influence water security in the rural Andes, and provides an illustration of regional water security.

2.1 Water Security

Water security is a relatively new term, covering broad areas of what it means to be water secure. Initial water security concepts emerged during a time focused on resource expansion and large-scale infrastructure in the face of a rising global population, increased demands from a higher standard of living and the expansion of irrigation (Gleick, 2000; Cook and Bakker, 2010). The concept of water security has since evolved to address competing pressures and sustainability.

The Ministerial Declaration of The Hague on Water Security in the 21st Century (Second World Water Forum, 2000) provided seven key themes embodied by water security: meeting basic needs; securing food supplies; protecting ecosystems; sharing water resources; managing risk; water valuing; and good water governance (Cook and Bakker, 2010).

This approach operationalizes water security as meeting the needs of both ecosystems and human needs as part of socio-ecological systems. By addressing the ecological and human dimensions of water use and need, a socio-ecological system water security view does not over-emphasize one consideration within the system over others, such as economic priorities. Furthermore, the scale of a socio-ecological system water security addresses the local level and considers the influences that multi-level relationships exert upon a community's water supplies and its sustainability.

Water security is increasingly being recognized as a multi-level priority as global water demand rises alongside of population growth. Water security can be assessed in terms of availability by considering water scarcity and water stress (Winpenny, 2010).

2.1.1. Water Scarcity

Water scarcity is typically calculated at the national level and generally refers to annual per capita renewable freshwater availability falling below 1,000 m^3 (Winpenny, 2010). Water scarcity can impact the land in different ways, depending on its duration and intensity, and the geography of the land itself. A water scarcity regime illustrated in Table 1 shows the duration and cause of dry land areas, divided by short and long-term durations, as well as by ecological or anthropogenic causation.

Table 2.1: Water Scarcity Regime

Water Scarcity Type	Natural	Human activity
Long-term	Aridification	Desertification
Short-term	Drought	Water deficiency

(Adapted from Pereira et al., 2002)

Water scarcity is further divided into three categories: climatically-induced water scarcity, soil water scarcity, and blue water scarcity (FAO, 2000). Climatically-induced water scarcity refers to the aridity of a region based on its hydro-climatic condition, based on the relation between precipitation and evapotranspiration. The transformation of a region to a state of increased aridity refers to the long-term process of aridification, and can heighten existing scarcity or transition an area into a water scarce state. A semi-arid state usually includes irregular precipitation, chronic droughts, high evapotranspiration, and sporadic water availability (FAO, 2000).

Soil water scarcity refers to low soil moisture levels that can influence crop production and can be especially challenging in aridity-prone areas with erratic rainfall or semi-annual rainy-dry seasons (Rockstrom et al., 2003). Soil-water holding capacity can be improved with the help of certain plants and trees that draw and retain rainfall moisture. Soil-water is also referred to as green-water, and includes water used by flora and evaporated into the atmosphere. Blue water refers to the liquid water in rainfall, together with that which flows through water bodies and aquifers (Falkenmark and Rockstrom, 2006).

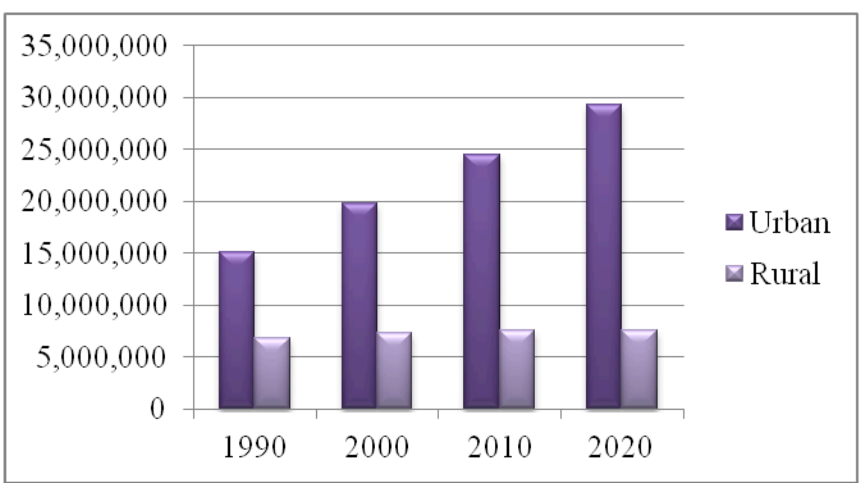
2.1.2. Water Stress

Falkenmark (1989) coined the term “water stress” to denote water scarcity leading to intense political tensions (Wolf, 1998). Water stress in this sense emerges when conditions, whether of human or ecological dimension, deprive a group of people from accessing the water they require, to an extent that prompts conflict. Homer-Dixon (1994) demonstrated the correlation between arable land scarcity and water scarcity leading to increased probability of conflict. Water stress is a manifestation of water scarcity or water shortage and may take the form of crop failure, food insecurity, or inter-basin water conflicts between users. The concept of water stress describes situations where there is not enough water for all the users, which causes conflict.

Climate, rainfall patterns and evapotranspiration are primary determinants of total freshwater availability (I Valls, n.d.). While the world's freshwater quantities have remained virtually unchanged for the past 2,000 years, human land-use patterns, environmental manipulation and population growth nearing seven billion, have all impacted freshwater dynamics and water security characteristics (I Valls, n.d.).

The population of Peru is steadily increasing, with large demographic and economic disparities between rural and urban regions. Table 2 indicates the demographic trends since 1990 and projections to 2020.

Table 2.2: Rural-Urban Population of Peru



(Adapted from McDevitt, 1999).

The disparity is accelerating as rural outmigration continues. Urban population growth, combined with increased economic activity, augments water demands, which in turn takes water resources from other users including ecosystems. Urbanization causes communities to swell, with an increasingly concentrated core, and therefore requires greater water infrastructure investment to meet expanding service delivery requirements. Aquifer depletion is being driven by population growth, which in turn is responsible for the corresponding increases in human consumption, including irrigation demands (Wada et al., 2010). While insufficient quantitative per capita water availability can drive conflict, there are many other qualitative determinants, especially those determining use and access, which are important to consider in determining water security.

Climate change is marked by rising global temperatures, while hydrological cycle disruptions pertaining to increased evaporation, precipitation pattern changes, droughts, floods, and snow cover will undergo significant changes. Aquifer depletion is predominantly the result of unsustainable water withdrawal such as through pressurized irrigation (Bates et al., 2008). Rainfall patterns have begun to change, mostly manifested through increased variability, and chronic water shortfalls are especially present in semi-arid and arid regions (Watson et al., 1997). Single-point water systems, drawing water from either a reservoir or bore hole, are common. This makes for a particularly vulnerable situation, as single-point systems represent the primary water supply and are being affected by disruptions or shortages. Mountain regions will especially be vulnerable to flooding and its damages, as well as droughts and chronic water shortages.

Overall, specific climate change impacts on the hydrological cycle on the large-scale include changing precipitation patterns in intensity and extremes, and soil moisture and runoff changes (Bates et al., 2008).

A cycle of extreme events that influences Andean water security is the El Niño-Southern Oscillation (ENSO), although it is not clear if there is a correlation between climate change and ENSO (Bates et al., 2008). ENSO events are composed of El Niño and La Niña phenomena in Latin America. In the Urubamba basin, El Niño has been associated with droughts (SENAMHI, 2011). These phenomena have stressed water availability, as droughts restrict water supply available for irrigation and in some instances reduce river flows (Ordinola, 1997; and DuHamel, 2011).

The Andean mountains possess mostly semi-arid to arid climates and are experiencing climate changes and variation, and enhanced weather events. The increased precipitation will most likely occur at higher altitudes, with precipitation decreases occurring in subtropical or lower regions (Bates et al., 2008). In fact, ecoclimatic variability increases at higher altitudes (Earls, 1998). Additionally, the changed precipitation patterns are projected to increase flooding and drought probability, with lands experiencing rain-based floods and drought in a more extreme manner. These events will compromise water quality surface runoff by increasing the possibility for pollution. Increased incidence of extreme flooding and drought lead to increased sedimentation, and pests and pathogens (encouraging pesticide use), which will impact water security (UNFCCC, 2007).

Key water security issues identified in Latin America and the Caribbean include groundwater contamination, depletion, water use, and access conflicts (Gardiner, 2002). Major industrial activity from mining and agriculture accounts for contamination by metals, chemicals and toxic waste, while untreated sewage creates unsanitary conditions ripe for cholera (Gardiner, 2002). There are also many pollutants created as a result of weakly-regulated economic growth that contribute to decreasing water quality. National water policies are generally lacking in regulatory mechanisms resulting in weak management, environmental regulations and water access approaches (Gardiner, 2002).

2.2 Adaptive Capacity and Water Management in Socio-Ecological Systems

Systems theory evolved to view ecological systems operating in nonlinear, unpredictable states, giving rise to complexity theory. Emphasis changed from individual system parts to relationships between system nodes (Capra, 1996). The importance of emphasizing relationships over nodes is illustrated in Figure 2, which depicts a local ecological knowledge web. The web represents the relationship between knowledge elements as culturally encoded within a socio-ecological system. Andean reciprocity is directly linked to environmental knowledge and codes of ethics. In order to engage in reciprocity, a certain degree of trust and sense of community is present to help ensure future collaboration and exchange (Folke et al., 2005).

2.2.1. Local Ecological Knowledge

Local ecological knowledge greatly influences the manner in which reciprocal relationships operate. This knowledge encapsulates the intricate marriage between social and ecological systems and the cumulative evolved knowledge grown from multi-generational socio-ecological system co-existence and knowledge transmission, which then becomes part of a system's memory. Local ecological knowledge is culturally coded into a community's organizational structure, effectively resulting in a management system based on lessons from experience through generations (Berkes and Folke, 2000).

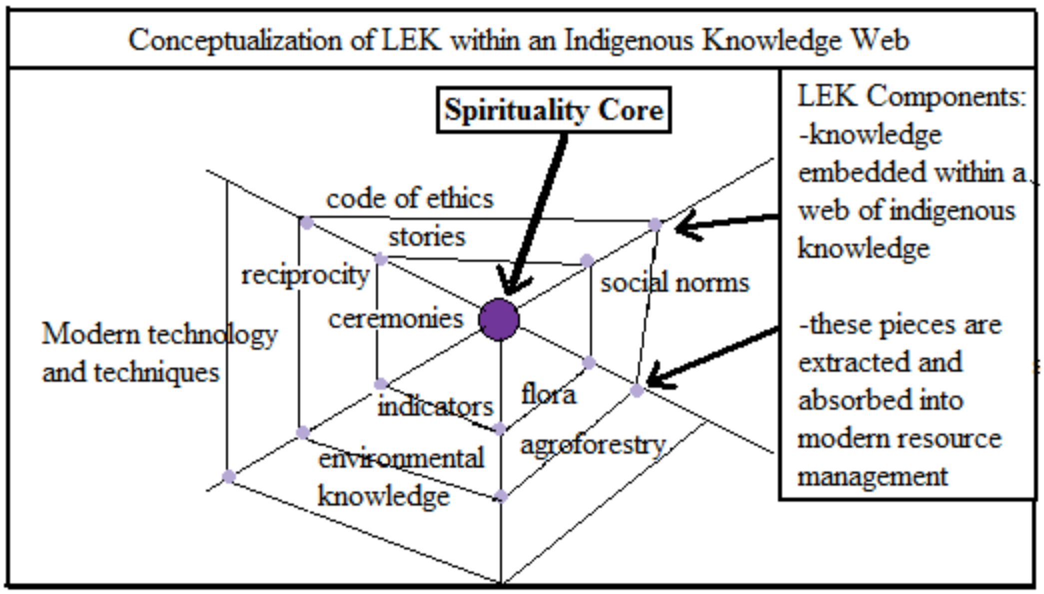


Figure 2.1: Local Ecological Knowledge Web
(Adapted from Casimirri, 2003).

Local ecological knowledge is often unappreciated by extra-local actors and may even be threatened. External actors may extract certain elements from the web without consideration of its relationships with other network nodes, or the impact this will deliver. Historically, colonial efforts were furthered using portions of local ecological knowledge that proved most beneficial, with the remainder discarded or distorted to better suit administration and execution of colonial rule (Hudson, 1992).

Local ecological knowledge is a critical component of Andean adaptive capacity (van Kerkhoff and Lebel, 2006). Overall system adaptive capacity helps reduce vulnerability to stresses brought on by changing conditions (Gunderson and Holling, 2001). Despite a long history of adaptation, the multiple intersecting stressors facing Andean communities today are sending shockwaves across their respective socio-ecological systems. Antagonistic forces such as new forms of legislation, political instability, ethnic marginalization and foreign companies profiting from privatized water compound these stressors. Water insecurity faced by Andean communities threatens to create a socio-ecological system poverty trap, where the system is not able to sustainably reorganize itself and the conditions which lock a system into a poor state are persistent, self-reinforcing and maladaptive (Silverman, 2008). In such a trap, the system cannot re-enter the adaptive cycle functionally and provide effective responses to the disturbances faced.

2.2.2. Vulnerability

The adaptive capacity of a system is also shaped by the ways and degrees in which it is vulnerable to system shocks. Vulnerability can be defined as the extent to which socio-ecological systems are put at risk due to internal or external perturbations (Stadel, 2008). An example of vulnerability can be water scarcity, and likewise, a coping strategy may be to implement increased or new conservation efforts in the face of this scarcity. For indigenous Andean rural farmers, the concept of complementarity serves a crucial function in maintaining agricultural and rural subsistence. Complementarity refers to the configuration by altitude of Andean ecological zones, and the manners in which Andean farming communities complement their economic activities with these different zones through colonization (Stanish, 1989).

Examples of complementarity include vertical terracing used for optimizing agricultural opportunities along steeply sloping mountain terrain; rotational systems for rotating systems for shifting crop and field use; traditional agricultural mechanisms using irrigation strategies and structures; the balanced interaction of growing crops, rearing and herding animals; afforestation; rotational agriculture; and livelihood diversification (Earls, 2006). Many of these activities are oriented by reciprocity, which is embedded in the socio-cultural coordination and beliefs of Andean communities, and is a great contributor to rural Andean socio-ecological system viability. In tandem, they help maintain a cohesive resilience despite vulnerabilities.

Table 2.2: Vulnerability and Survival Strategies in Andean Rural Areas

Economic	**Social**	**Ecological**
Poverty and marginalization	**Crisis Situation** Collapse of social networks	Water insecurity
	↓	
Marginal livelihoods, insufficient income, water	**Vulnerability** Inadequate social security	Inadequate conservation, unsustainable environmental exploitation
	↓	
Enhancement of subsistence production, livelihood diversification	**Survival Strategies** Improved organization and networking	Conservation, resource protection, alternative resources use
↓	↓	↓
Improvement of economic situation	Local socio-political power enhancement	Enhancement of environmental quality

(Adapted from Stadel, 2008:22)

Figure 2.2 depicts the interaction between economic, social, and ecological components and the flow of experiences within a socio-ecological system. It also shows the interaction vulnerability has with other components of socio-ecological system resiliency, and the possibilities for innovation and strengthened strategies emerging out of marginalization.

The depletion crisis model provides an interesting and pertinent analysis of how conservation knowledge and its application in socio-ecological systems developed through the difficult lesson that resources can be depleted (Berkes and Turner, 2006). (Merino and Robson, 2005) argues that there are numerous mechanisms by which communities develop conservation knowledge, including the gradual learning that comes with the natural progression of time. Nonetheless, this model examines the prescriptive behaviour and productive outcomes of strife that directly compensate for resource depletion.

2.2.3. Adaptation and Resilience

In the Andean context we can emphalize not only conserving biodiversity and traditional management techniques, but also its adaptive capacity to implement changes in the face of stresses. Adaptation can be defined as the “process, action, or outcome in a system in order for the system to better cope with, manage or adjust to some changing condition, stress, hazard, risk or opportunity”, and is described as “adjustments in a system’s behaviour and characteristics that enhance its ability to cope with external stress” (Smit and Wandel, 2006: 282; Brooks, 2003).

In sustainability science, resilience has taken on two different meanings. The first is classified as engineering resilience , referring to the amount of time required for a system to return to its equilibrium point post-perturbation, and is concerned with the system's elasticity (Brand and Jax, 2007). The second meaning transcends the assumption of an equilibrium-steady regime and considers the amount of perturbation a system can absorb until it can settle into a newly stable state for a period (Jiang and Shi, 2009). That state is defined accordingly by its own properties and structure, not necessarily matching the former state but retaining essential system components such as structures, processes, and feedbacks. Based on this definition, the majority of ecosystem categories can function in differing forms of stability. This double stability orientation is referred to as bi-stability, with multiple states of stability possible. Hence, pathways to stability may not be returning to anything, but rather evolving into something new.

Capra (1996) has discussed the contrast between the old values and thinking concerning self-assertive systems theories, and its new ones after its conceptual shift to integrative thinking and values. The evolution in thinking has transitioned rationality into intuition, analysis into synthesis, reductionism into holism, and linearity into non-linear forms of understanding (Capra, 1996). The shift in values has transitioned expansionism to conservation, competition to cooperation, quantity to quality, and domination to partnership. These are reflected in the newly emergent Integrated Water Resources Management policy (Comision Tecnica Multisectorial, 2004). Disciplines themselves, as well as their practical applications, including in the realm of international development, have increasingly oriented towards an inclusion of the intuitiveness of local ecological knowledge. The depth of these transitions may be argued, especially by critics of development politics such as Paul Trawick, Arturo Escobar, and Paul Gelles. These authors have provided insightful analyses concerning post-colonial patterns that continue to resonate in development projects such as pressurized irrigation schemes that focus heavily on quantitative efficiency calculations while devaluing qualitative assets (Trawick, 2003; Escobar, 1998; Gelles, 2005).

2.2.4. "Tragedy of the Commons"

In discussing property rights in socio-ecological systems, Berkes and Folke (2000) examine the "tragedy of the commons", a term first coined by Hardin (1968). The tragedy of the commons refers to the environmental degradation of commonly shared resources. Hardin (1968) explains this tragedy is caused by individualistic gain of formerly communal land, which creates a shared disadvantage. The importance of this work lies in the problematic nature of morality under the modern nation state concerned with profit and maximizing yields, and suggests, in a world of finite resources and an expanding global human population, no technical solution will sufficiently extend the world's resources to satisfy the insatiable demand. Resources considered valuable in a community will result in a local system of rights and responsibilities, which are subject to co-evolution as circumstances change. Hardin's tragedy, Berkes and Folke (2000) contend, occurs when the institution fails to control resource access and implement collective use decisions. Interfering external factors or interior institutional weaknesses may either contribute to existing institutional failures or create new ones.

If a socio-ecological system is of a multi-equilibrium nature, a disturbance may potentially propel the socio-ecological system into an alternative equilibrium regime and may remain there until it encounters a further perturbation or experiences necessary changed variables that alter state conditions (Gunderston and Holling, 2002). Gunderson and Holling (2002) suggest that the prospect of an equilibrium transition through a perturbation is contingent upon the magnitude of the perturbation as well as socio-ecological system resilience in its present equilibrium regime.

The three characteristics of socio-ecological system resilience are defined by Resilience Alliance (cite reference) as:

1. quantity of change a system can undertake without losing its core functionality and structure,
2. the extent of a system’s capacity for self-organization, and
3. the capacity of a system to evolve based on experience, learning, and adaptive response.

A system can experience rigidity when it becomes fixated on an unchanging repetitive pattern and is not sufficiently flexible to implement adaptations (Carpenter and Brock, 2008; and Silverman, 2008). A poverty trap, on the other hand, is a more profound manifestation, which Silverman (2008) describes as a “persistent maladaptive state” that is self-reinforcing and is maintained through generations (Azariadis and Stachurski, 2005). A disruptive event such as the introduction of a new opportunity or inspired innovation relative to the profundity of the trap may be required in order to liberate the system from its stagnant state (Matsuyama, 2008).

Socio-ecological system resiliency can contribute to a system's enrichment as well as its poverty. Strongly resilient systems may prevent beneficial opportunities to 'release' and reorganize as vulnerable states may allow for growth and change (Peloquin, 2007). Additionally, what is considered resilient today may be vulnerable tomorrow, as conditions change and become favourable to different elements. While calculations for reorganization outcome predictions in nonlinear complex systems yield various possible results, the manner of reorganization is contingent upon the history of a socio-ecological system (Berkes et al., 2003). Gunderson and Holling (2002) argue the desirable equilibrium to achieve is a sustainable future; however, societal-ecosystem responses and impacts during reorganization may yield equilibrium results that are unpredictable. Governing organizations should approach its sustainability goals as an ongoing, evolving, fluid process, building on system memory and enhancing multi-sector capital (Berkes et al., 2003).

2.3 Impacts of marginalization and multi-level governance on water security

Global structures as well as social, political and economic processes at multiple levels impact distribution and access to water resources and services. The fourth IPCC report states resource-based populations are most vulnerable to climate changes due to historical, social, political and economic exclusion (Parry, 2007). Economic exclusion focuses on the marginalization experienced due to the market system, as markets systematically do not accommodate the poor as they typically lack the ability to participate in their profit-oriented production scheme (Altamirano et al., 2004). Marginalization resulting from political exclusion addresses the inequality of individual and communal rights access. Access rights will differ in accordance to social, economic and cultural capital individuals and communities possess, as well as demographic considerations such as ethnicity, gender, and age. The poor are particularly susceptible to human rights violations given their diminished access to capital, understanding and ability to engage with societal institutions, and lack of time to mobilize and participate in political processes (Altamirano et al., 2004). Social inequality, poor political representation, and structural violence involved in resource allocation across both public and private realms are important considerations in the processes involved in marginalization (Altamirano et al., 2004).

2.3.1. Indigenous People and Marginalization

Marginalized people, such as indigenous populations, have often been allocated the most undesirable lands that are especially fragile and less productive, which also contributes to diminished access to resources and other opportunities (Macchi et al., 2008). Marginalization can be inherited and socially reproduced, with its generational transferability highly dependent on the degree of social mobility relative to the social constraints in a particular society. In a World Bank report (1994, in Eversole et al., 1994), indigenous people are described as experiencing "overlapping fields of vulnerability." Because marginalization results in the lack of the ability to secure opportunities that would contribute to well-being, their capacity to adapt and respond to change, including changes in climate and water supplies, is often compromised.

In response to a marginalized people's interaction with their fragile lands, unique coping strategies have emerged in the face of varying ecological stresses. Their experiences contribute to a host of knowledge which can be applied to a range of future hazards. Under climate change, the magnitude of future events may manifest beyond the capacity of marginalized people's ability to cope, particularly in the instance of their unequal access to resources that would otherwise contribute to their adaptive capacity. Indigenous populations living in the Andes rely on a handful of key crops for their food security. The effects of climate change are altering and even limiting the areas available for crop growth (Seltzer and Hastorf, 1990). Food and water security for Andean traditional indigenous smallholder farming populations will be at risk by 2055 (Macchi et al., 2008).

2.3.2. Water Politics in the Andes

Boelens et al. (2010:138) state, "Irrigation bureaucracies and the dominant national cultures...are not inevitable or necessarily more rational and equitable, but rather are historically produced and represent the power of a dominant ethnic group". Further, the authors argue that it is crucial to expose the continued discriminatory practices present in contemporary Andean water politics. This embedded system of discrimination is reproduced through continuous inequitable access to water, leaving those amidst marginal lands and policies.

Gelles (2006) notes that in Andean countries, state intervention laws and policies on highland water use and management may be imposed by national or international actors and discount traditional water management practices, norms and rights of highland communities. The external imposition of water management policies and water laws while disregarding local traditions can be understood in the historical and cultural context of colonialism to which present cultural policies are related (Boelens et al. 2010).

Andean cultures have conversely been depicted as utopias. This often comes across as being in harmony with nature. Krech's The Ecological Indian: Myth and History (1999) details the stereotype of the "Noble Savage" as this utopian projection, while the "Ignoble Savage" is portrayed as that of inhuman, ferocious, animalistic irrationality. At times these two stereotypes combine to form a simplistic hybrid that produces a version that is non-reflective of reality. Both versions take heterogeneous complex societies with long histories that have developed through learning, decision-making and interaction with their environment and effectively reduce their cultural agency to simplistic, child-like societies (Krech, 1999). As such, either view denies the complex cultural processes involved in the development of indigenous societies and the local ecological knowledge they harbour.

In 2003, an organization of Andean indigenous people produced a document entitled "The Andean Vision of Water". This document discusses the shared experience of colonialism that has served to disarticulate long weaving histories of innovative water management adaptations to challenging mountain environments. Traditional technologies have been abandoned, some forgotten. However the necessity of innovative approaches to balancing socio-ecological system interaction with water is needed more than ever. In the face of increasingly erratic rainfall patterns and rapidly melting glaciers while also facing modernity and privatization pressures, Andean people are presenting models of resilience for sustainable living which encompass Andean cosmological principles of reciprocity and complementarity. This model brings the marginalized into the realm of inclusion where rights and access are more available (Trawick, 2003).

2.3.3. Monetary Poverty in the Rural Peripheral Andes

Rural populations possess unique situations of marginalization in terms of their physical distance from urban centres that concentrate opportunity and power. Their location creates a challenge in accessing governance and policy development (Sumner et al., 2008). Stadel (2008) argues both agricultural and rural livelihoods have been significantly impacted by increasing market and profit orientations. The resulting impact on certain regions has been manifested as a widening socio-economic disparity. The rural economically-poor face distinct hurdles that include remoteness, decreased political access, and diminished capacity for coordinating and engaging in political processes (Sumner et al., 2008). These constraints exist in addition to other indicators present in monetary poverty settings such as low literacy rates, resources, and decreased ability to comprehend the subjects that prevent meaningful participation in policy-related discussions. Monetary poverty, particularly in rural areas, can present itself as a trap that offers little opportunity for social mobility.

One fourth of the Peruvian population lives in extreme monetary poverty (Rural Poverty Portal, n.d.). The lack of economic opportunity in rural areas often leads to urban outmigration, which further impacts rural economies. In the rural Andes, mixed crops represent the majority of agricultural systems (Leon-Velarde et al., 2008). Subsistence farming is highly prevalent, and livestock serve not only as food, but also create assets, act as buffers to system shocks such as ecological stresses (i.e. climate change), and provide a measure of security against malnutrition from agricultural difficulties threatening water and food security. The multiple intersecting stresses facing Andean rural populations increase difficulties for growing populations and encourage rural outmigration, a widespread phenomenon which has mixed impacts on smallholder rural communities (Gray, 2009). Gray (2009) argues that while rural outmigration may not dramatically alter the agricultural activities of a socio-ecological system, communities tend to experience changes in agropastoral management approaches.

Peru's national poverty rates have fluctuated over the course of the country's numerous encounters with destabilizing factors such as the Maoist-inspired terrorist movements that laid a shadow over the Andes, and the "lost decade" of the 1980s that plagued Latin America with hyperinflation and skyrocketing foreign debt (The Andean Observer, n.d.; Hayes, 1988; Gregory, 2009). Numerous authors (Chacaltana 2006; Tanaka and Travelli 2002; Yamada and Castro 2007) demonstrated that monetary poverty rates increased more during periods of economic decline, and decreased during periods of economic prosperity. Rural monetary poverty is most persistent in the Andes and the jungle regions of the country. In the rural Andes, 80% are living in monetary poverty with 57% of that number living in extreme poverty (International Food Policy Research Institute, n.d.).

The high prevalence of monetary poverty and associated pressures placed on local food and water systems has resulted in an increase in traditional bartering networks emerging in response to economic marginalization (Marti and Pimbert, 2007). Gertz (1963) differentiates between a formal, or 'firm' economy, and an informal, or 'bazaar' economy. While this latter form has existed since pre-Hispanic days, it has been shown to become accentuated in response to government failures in sustaining those mechanisms that maintain resource, capital and asset distribution (Altamirano et al., 2003). In Quechua cultures, disconnection from social networks equates to deprivation, and the importance of such networks is linked to opportunities for survival or well-being (Altamirano et al., 2003). While the informal economy swells in response to governance failures and inadequacies, their structure is the outcome of a history of cooperative networks and alliances, and reciprocal communal works.

2.3.4 Linking Poverty and Environmental Degradation

While environmental degradation has often been attributed to monetary poverty and overpopulation, Forsyth and Leach (1998) argue these elements are not necessarily correlated and self-affirming. Conventional views understand monetary poverty as forcing people to "degrade landscapes in response to population growth, economic marginalization and existing environmental degradation" (Forsyth and Leach, 1998: 2). The assumption that monetary poverty and environmental degradation are inextricably linked has resulted in government and development bodies pushing for bundled solutions targeting monetary poverty alleviation and climate change together.

Environmental degradation typically refers to natural resource depletion beyond its rate of renewability as well as pollution that hinders an ecosystem's capacity to sustain itself (Bucknall, 2000). Varying perspectives have painted the monetarily poor as either victims or driving forces of environmental degradation, but there is growing recognition that the environmental degradation and monetary poverty connection is interceded by numerous micro and macro influences (Shyamsundar, 2002). Such examples have included unsustainable agricultural policy administered by multi-level governments that favour intensified techniques requiring high agrochemical use and monocultivation over smaller-scale agriculture that uses crop rotations and organic pest control measures (Agudelo, 2003). While rural and monetarily poor populations face multiple constraints that diminish flow of resources and access to capital that enable sustainable practices to be implemented or maintained, it has also been noted that such populations are rich in other assets that enable conservation while upholding livelihoods (Agudelo, 2003).

Forsyth and Leach (1998) contend the monetarily poor have in some cases developed responsive strategies through communal collaboration that mitigate the negative impacts of multiple stressors on local ecologies, and such strategies often remain unrecognized by multi-level actors. Overlapping economies co-exist in the rural Andes, and while state economies perceive lack of monetary wealth as poverty, traditional bartering-based Andean economies would be impoverished by a lack of elements that enable its function: reciprocity, networks, and kinship alliances (Pimbert, 2005). In both economic systems, the decision-making process is driven by information or knowledge restrictions, labour decisions, and the risks they are prepared to take (Shyamsundar, 2002). An example drawing from the Quechua context is the local conceptualization of poverty relating to social networks, which contrasts significantly to the state quantification of what it means to be monetarily poor. Were the locally-understood sources of wealth – kinships, networks, and reciprocity – broken down, then environmental management would certainly be negatively affected, as these elements help maintain socio-political labour coordination, enable knowledge-sharing, and distribute risk.

2.3.5 Development Politics and Multi-Level Relationships

Escobar (1988), a key author and critic of development discourse, argues that the development field operates in a manner which exerts power over others. This is done through two avenues: the professionalization of development and the institutionalization of development. The former refers to the strategies and processes through which knowledge and the validity of knowledge is produced, disseminated, and manipulated in order to construct “truths” and norms about the developing world. The institutionalization of development establishes the institutions that facilitate development discourses and techniques by creating, documenting, altering, and putting the information into execution (Escobar, 1988). Such institutions include multi-lateral and bi-lateral agencies, including financial institutions and United Nations bodies, non-governmental agencies such as CARE and Oxfam, as well as national and sub-national developing world institutions. These institutions converge to hold programs, forums, conferences, and other expert gatherings where knowledge on development is generated, diffused and validated. These institutions make up a host of actors interacting with and influencing multi-level governance.

Zoomers (1999) examined the inconsistency of development policy and projects aimed to decrease poverty and the persistence of poverty for rural Andean farmers despite the poverty reduction projects. Possible answers have emerged as low development cooperation, as well as insufficient continuity in development schemes given lack of funding, short-term duration, or logistical constraints due to isolation. Another explanation brought forward for the shortcomings of development project results has focused on the demand-side of development aims. This is attributed to the incompatibility of outside development concepts with Andean rural reality. This latter explanation sees the fault lying in the concept of the development discourse itself due to the foundational epistemologies and applications being unsuitable for indigenous Andean rural smallholder farmers (Zoomers, 1999). Zoomers (1999) believed a balance can be struck by crafting development policy that is suitable and relevant to Andean rural development by serving as a complementary mechanism to the heterogeneity of livelihood and survival strategies woven throughout the Andes.

Different stages of economic poverty impact the effectiveness of development projects. While Andean farmers may be perceived as permanently economically disadvantaged, this may be a transient phase, which will be surpassed once opportunities can be embraced and applied in future stages. Throughout their lives, rural farmers may pass through differing degrees of economic disadvantage, and even when chronic, it may not necessarily be static. Additionally, conditions informing Andean livelihoods are not static either. Zoomers (1999: 6) explains "[t]he tendency of poverty alleviation programmes to overlook chronological factors...is remarkable. The seasonable and variable nature of rural life renders the time factor even more important than usually assumed." Localized stresses such as crop failure can make the importance of aid even greater during these temporary times. It would be useful to consider not only the group being assisted, but also the spatial-temporal context of their water security and sustainable development needs.

2.3.6 Integrated Water Resource Management

Integrated Water Resource Management (IWRM) possesses the water policy characteristics of need, efficiency, allocation, integration, participatory management, collaborative decision-making, decentralized adaptive management, source supply flexibility, efficiency of economic principles, and human behaviour (Huppert, 2007). As socio-ecoogical systems are highly integrated and complex, actors acting independently of one another can lead to unexpected and unstable outcomes. Each stakeholder has a different interest, different degree of organization, a different history, differing amounts of power, access and rights, and due to these differences, acknowledging interconnectivity is difficult (Bouwen, 2004; and Dongier et al., 2001).

IWRM has become the dominant framework in international water policy. Peru recently implemented the legislative and policy frameworks to support a transition to IWRM. While the origins of the concept emerged at the 1977 United Nations Water Conference, IWRM was formally adopted at the International Conference on Water and the Environment, and its principles inform the basis for the United Nations Agenda for protection of freshwater resources (Engle et al., 2011; Connected Water, n.d.). The Global Water Partnership (2000, 2008), IWRM is defined as "a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems." At the operational level, IWRM draws from the knowledge of multiple disciplines and stakeholders to with the intent of implementing an efficient, equitable, and sustainable approach to water management (Dutch Portal to International Hydrology, n.d.). As part of the decentralization component and collaborative governance, IWRM can be applied at the river basin level. Management at the regional level offers a good framework applicable to the specific geographical and hydrological basin characteristics that considers both upstream and downstream issues and the socio-economic and environmental factors involved.

From a management perspective of multi-level water governance, system learning processes would enable involved actors to enhance interactions into a fluid, decision-making collective acknowledged as authoritative and relevant. The legitimacy derived amplifies its inventive capabilities as well as its combined intelligence (Minero, 2007). It has been postulated within the executive summary of the Second World Water Assessment Report (2006) that IWRM and its accompanying reforms and values of increased participation, transparency and decentralization are unlikely to be effective in enabling water security if the government in question does not have a strong system of embedded political rights and civil liberties. As such, water stress is amplified under conditions of social, political and economic constraint. Water sector reform must be accompanied with governance reform in order for IWRM and its principles to positively affect water security.

Adaptive management has influenced IWRM approaches, and combined the two seek to achieve increased effectiveness, legitimization through decentralized and participatory decision-making, incorporation of technological knowledge, and advocacy of adaptability (Engle et al., 2011). These goals have rarely been met, such that IWRM has been critiqued as impeding adaptive management. The participatory decision-making goals often do not take into account the disparate power and positions of the multiple actors involved in the process. In particular, institutions have difficulty deviating from their operational mandate and have been described as highly “path dependent”, and thus may lack the flexibility in interaction required. There have also been criticisms of costly tradeoffs that have been downplayed in implementing IWRM, and these have led to mounting tension (Engle et al., 2011; Moss et al., 2010). Peru’s new water law (*Ley de Recursos Hidricos*) combines the principles of IWRM with privatization, and this trade-off has led to mounting tensions between smallholder Andean farmers and governments (Ministerio de Transportes y Comunicaciones, 2009). Another questionable outcome concerns the degree in which decision-making and power has been decentralized. In Peru, it has been argued that governance was decentralized to regional levels, while decision-making power remained concentrated in Lima (Hancco et al., 2009).

Trawick (2002) discussed the similarity in experiences and water management paths embarked upon by people once resources become limited. To avoid commons tragedies in Andean societies, Trawick (2002) made four targeted suggestions for improving the Andean commons with respect to water. The first is to restore water autonomy at the community-level through reservoir division outflows, the system in place before 1940. He contends such a restoration would re-establish a balance between land and water-use at the village level. The second suggestion is to modify the law in order to make water management concepts based on the assumption of water being in a constant state of water scarcity, rather than a belief of sufficient or ample water availability. In turn, a law based on the concept of water scarcity should be reinforced with an equitable sharing approach that water laws currently do not include. Current water laws are oriented towards irrigation and technology efficiency concerns, and do not sufficiently consider social concerns. The third suggestion expands upon the legislative framework by defining equity more explicitly, which emphasizes a consistent use of irrigation from principle water sources for all users, as well as demonstrating proportionate representation in user rights and duties, including a proportionate use of water based on the specific requirements of each crop. Trawick (2002) discussed the differential distribution of landholdings and water use at various altitudes, making equity without proportionate allocation illogical. The final suggestion put forth is to strengthen the water law with a required water distribution outline, making full compliance mandatory.

2.4 Conclusion

In conclusion, multi-level actors have created policies and practices containing postcolonial structures, resulting in the ongoing marginalization and control over indigenous Andean populations. Gelles (2006) stated that in Andean countries, state intervention laws and politics may be imposed by national or international actors, ignoring customary practices such as the traditional water use and management by highland communities. Overall, the challenge for effective change and reform lies in addressing all elements of human impulses, which tackles the self-interest drive in people as well as the moral, social, and collective elements within society (Trawick, 2002).

Chapter 3: Methodology

This human geography research project was constructed using primarily qualitative research and case study methodologies. Some quantitative research was used in discussing hydrological and climate data. This chapter presents the research methodology and specific methods used to understand the human relationship to water in the case study community's socio-ecological system. The methods used included semi-structured interviews, photograph analysis, participant observation through two field work seasons, and some archival research.

3.1 Methodology and Methods

The purpose of this investigation was to understand the human-water relationship in the rural indigenous Andean community of Mullak'as-Misminay. The decision was made to use a nested case study, which is the use of a single case study – in this case a community – within the context of this research (Andean Peru) (Crabbé & Leroy, 2008). The research from this case study could be regionally relevant to rural indigenous Andean communities.

3.1.1. Conceptual Framework

Haan et al. (2001) have presented a framework for food security that has been adopted as the basis for analysis in this research, and modified accordingly. They specify its purpose as functionally operational rather than theoretically comprehensive in order to best represent food access, availability and use. This framework provided an excellent outline, as the social and ecological dynamics influencing resource access, availability and use help effectively characterize the complexities of water security. Furthermore, the outer layer incorporates the influence multi-level relationships have upon the social and ecological dynamics. The historical development emphasizes the interacting complexities that fluctuate as time unfolds. The decision to select this framework was made due to its applicability to the research criteria and characteristics of the socio-ecological system in question. It also serves as a suitable guide to help navigate the research questions examining stresses, responses, marginalization, and multi-scale relationships.

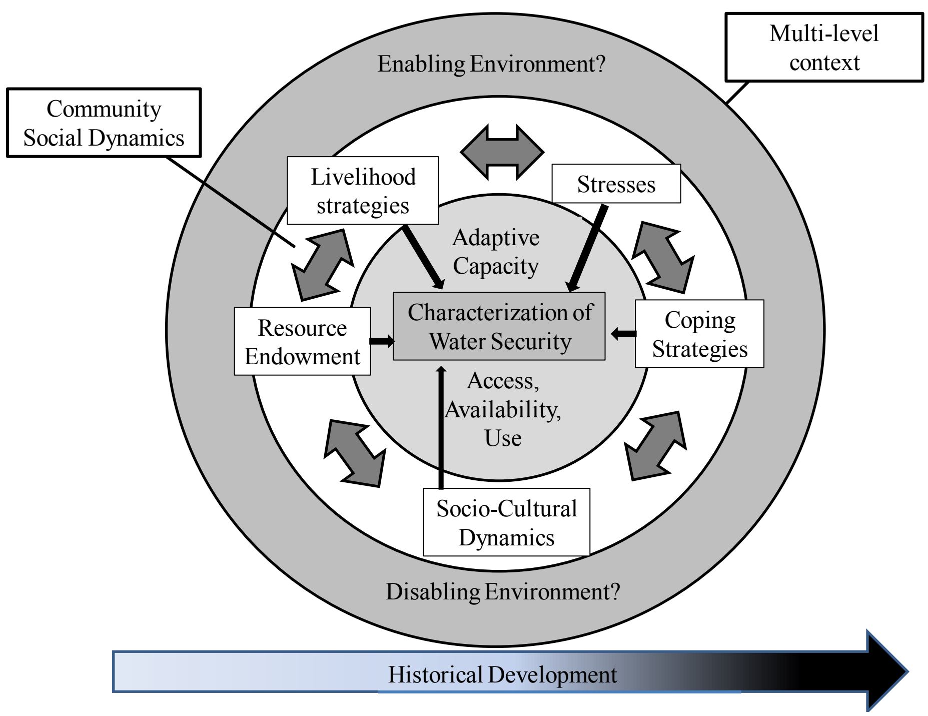


Figure 3.1: Conceptual Framework for the Characterization of Water Security
(Adapted from Haan et al., 2001).

The modifications for this framework include changing the central category from "Characterization of vulnerability" to "Characterization of water security", as this analysis extends beyond vulnerability and looks at the resilience of a socio-ecological system in terms of water security. The elements of characterization (livelihood strategies; stresses; coping strategies; socio-cultural dynamics; and resource endowment) are specifically applicable to illustrating the state of water security in Mullak'as-Misminay. The stresses and local adaptations that have emerged in interview results can be categorized within the community livelihood dynamics of this framework and the relationship between the interacting elements help answer the research questions.

3.1.2. Development of community case study criteria

Developing community case study criteria was originally motivated by the researcher's long-term interest in the Latin America and Caribbean region, climate change, water politics, and evidence of innovation arising from deprivation. The rising tensions surrounding water insecurity in the developing world that are being fuelled by multi-level stressors and amplified by climate change made these criteria pertinent.

The criteria for case study selection were to locate a socio-ecological system that possesses the characteristics of study and has experienced the issues prominent for the area. The study community, Mullak'as-Misminay, has a long history of innovative adaptations inspired by social and ecological components of marginalization. Deprivation, challenges and opportunity compelled creative responses through adaptations and innovative responses. The Peruvian Andes have hosted civilizations that had not only sustained the difficulties of living in marginal lands, but had organized themselves in a manner that capitalized on the unique geographical circumstances they lived in. The current climate shift of aridification of mostly semi-arid lands transitioning to increasingly arid states creates a contemporary context that could prompt further innovative responses derived from traditional local ecological knowledge.

3.1.3 Community Selection

The first field work season took place in Ollantaytambo, Peru. The first two months were dedicated to case study community selection. The case study community chosen was Mullak'as-Misminay. This decision was made upon the advice of Dr. John Earls, as well as the advice of a local anthropologist, both who had conducted previous research in the community and felt it was suitable for the project. While the community is not glacier-fed, the water conservation techniques developed over millennia with scarce water supplies and the presence of Moray provided thematic benefits to the topic.

3.1.4 Establishing community contact and liaison

Ollantaytambo, a central town in the Sacred Valley around 25 kilometres from Mullak'as-Misminay, was an optimal choice to be stationed in as it allowed for accessible travel to departmental, provincial, and district capitals with relative ease, while offering sufficient amenities assisting in the research process.

The District of Maras's municipal staff had established relationships with the communities within their jurisdiction and one staff member working in the social work and environmental projects sector was particularly instrumental in introducing the author to the community and in particular to the community president. Once introduced, the project was explained to the president and permission to conduct research in the community was requested and granted.

3.1.5 Internship with CARE Peru, Lima

Nearly three months of field work were with CARE Peru's national office in Lima with the Climate Change team. CARE is a non-governmental organization with an international scope that addresses poverty alleviation and climate change adaptation through program-delivery designed to strengthen community self-sufficiency. The specific project sought to incorporate rural stakeholders in irrigation policy formation, and identify strategies and mechanisms that enabled the rural poor improved access to water systems. It aimed to create policy arguments to finance pressurized irrigation systems at the parcel-level for glacier-fed communities with market access. Pressurized irrigation was the primary climate change adaptation and the focus on glacier-fed communities reflected the emphasis of glacier retreat in climate change literature. Communities with market access were a prerequisite for consideration as the investment in pressurized systems required a profitable return by intensifying agriculture to produce cash crops for extra-local markets. This internship's duration was from early September to the end of November, 2009.

Two field site visits were conducted in Mullak'as-Misminay during the second season. The first was from September 23rd – 30th, while the second was in November with visits from the 22nd – 26th, where interviews were conducted in both. The latter interviews focused on water organization members.

3.1.6 Semi-structured Interviews

The decision to make semi-structured interviews rather than structured or unstructured was consistent with the nature of this field work setting. The high number of uncertain variables made semi-structured interviews the best choice to provide conversational guidance while maintaining flexibility as to not restrict the participant observation and community engagement.

Themes

The interviews were oriented around the following themes.

1. Ecological matters concerning water
2. Governance
3. History
4. Multi-level and sector actors

Interview questions were constructed prior to going into the field. Consent forms were written in Spanish and English with the option of oral consent for interviews and photographs. Telephone interview consent forms were also created in the event interviews were to be conducted in this manner. Additionally, a one-page project summary was drafted in both Spanish and English.

3.1.7 Respondent Selection During the Two Field Seasons

A total of 21 semi-structured interviews were conducted. Nine were gathered in Mullak'as-Misminay, with one of these interviews consisting of a group of people. The breakdown of respondents consisted of 13 in Mullak'as-Misminay (10 individual and one group interview with three respondents), three in the District of Maras, one in Urubamba, three in Cuzco, and one in Lima. There were also two interviews with Andean farmers near the Ausangate glaciers that provided regional perspectives. The majority of local respondents were farmers, and those who were identified as having a different primary occupation still helped with farming activities. Multi-level respondents represented non-governmental organizations and governmental bodies.

Table 1

Interview Respondent	Location	Occupation or Industry	Date
Respondent 1	Maras	District social and environmental worker	August 3, 2009
Respondent 2	Maras	District engineer	August 5, 2009
Respondent 3	Cuzco	IMA	August 7, 2009
Respondent 4	Ollantaytambo	Regional Tourism	August 8, 2009
Respondent 5	Pucarrumi	Farmer	August 8, 2009
Respondent 6	Ausangate region	Farmer	August 8, 2009
Respondent 7	Mullak'as-Misminay	Farmer	August 10, 2009

Respondent 8	Mullak'as-Misminay	Farmer	August 10, 2009
Respondent 9	Mullak'as-Misminay	Farmer	August 10, 2009
Respondent 10	Cuzco		August 12, 2009
Respondent 11	Urubamba	Ministry of Agriculture	August 13, 2009
Respondent 12	Ollantaytambo	Tourism	August 13, 2009
Respondent 13	Mullak'as-Misminay	Farmer	September 25, 2009
Respondent 14	Mullak'as-Misminay	Farmer	September 25, 2009
Respondents 15, 16, 17 (Group Interview)	Mullak'as-Misminay	Store owner and farmer, farmer, farmer	September 25, 2009
Respondent 18	Cuzco	Asociacion Andes	September 29, 2009
Respondent 19	Lima	CONDESAN NGO representative	October 23, 2009
Respondent 20	Maras	Maras District	November 23, 2009
Respondent 21	Mullak'as-Misminay	Water organization	November 24, 2009
Respondent 22	Mullak'as-Misminay	Water organization	November 24, 2009
Respondent 23	Mullak'as-Mismiany	Water organization	November 24, 2009

Input was sought from farmers, elders, group organizers, and water organization members. Among these, an attempt was made to find a representative proportion of women respondents, but this proved to be difficult as the task was often deferred to a husband or male relative. While much effort was sought to obtain more input from elders, logistical constraints, such as translators neglecting to meet at the agreed time to visit elders who spoke exclusively Quechua, resulted in a slightly different composition of interviewees. Consent forms proved to be a barrier in interviews, as some would refuse to sign or immediately felt uncomfortable with the formality of the process. In retrospect, conversations flowed best in group settings and in particular when undertaking group work, such as when out in the field farming, looking after some of the farmers' children, or when shelling the corn from the cob with the other women.

The location was generally accessible during the dry season, although weather sometimes proved to act as a barrier to access. Some interviews were conducted during a hail storm under tree cover. During such events mobility is greatly reduced due to the mostly vertical mud paths lining the community. Political unrest with road blockades blocked the highways leading to Mullak'as-Misminay, and this hindered community access. Interviews were conducted in Spanish and those conducted with people who only spoke Quechua required a translator.

3.1.8 Coding responses and pattern analysis

Interview responses have been coded in accordance to the following themes.

- Description of climate and climate change
- Stresses, effects and contributing factors
- Solutions, adaptations
- Multi-level relationships

Responses were colour-coded according to these themes and further categorized based on patterns that emerged. Similar answers provided by different respondents were then grouped together. Interview responses provided the foundation for the Findings chapter. Data has also been retrieved from literature and documents, and was used to support interview results.

This research is being summarized into a community report and will be translated in both Spanish and Quechua, and then made available to all the organizations who contributed to this project.

3.1.9 Documents, photographs and archives

Public archives

Church records may contain valuable local history in terms of past natural events such as floods and droughts. There were no records in neighbouring Ollantaytambo, and access to the church in Maras proved to be exceedingly challenging. After numerous visits and attempts, permission to access records was denied.

The main Cuzco library held an older topographic map of Maras but did not contain the information anticipated. Book stores on PUCP campus as well as in Lima and Cuzco contained pertinent books. Museums were also visited and photographs related to this study were taken. The meteorology station, SENAMHI (Servicio Nacional de Meteorología e hidrología del Perú), possessed historical meterological data however the expensive cost of purchasing the information proved to be prohibitive.

Photographs

Photographs were taken in the community. The photographs depict the general geography of the area, the surrounding mountains, agricultural fields, the local population, and water management infrastructure.

Strategic plans and IMA

Plans were acquired from Maras, Urubamba, and Ollantaytambo. The District of Maras's district strategic development plan (2005-2015) was acquired from the District office and contains information specific to Mullak'as-Misminay (Cavero et al., 2005). Urubamba's provincial government office provided the provincial development and strategic plan for 2007-2020. Ollantaytambo's 2009-2022 Strategic Plan was also acquired in the event it contained information that could be useful to the general region's history and current geography.

The Instituto de Manejo de Agua y Media Ambiente (IMA), which is the institute for water and environmental management, was located in Cuzco and proved to be very helpful. It provided the researcher with numerous articles, position papers, documents, and Arc GIS maps of the entire Cuzco region.

Chapter 4: Water Security in Mullak'as-Misminay

In this chapter, the results of data collected through field work and literature will be presented. The first section will examine stresses impacting water security. These include the interactions of ecological stresses with community and regional resource endowments. Discussion of stresses relating to social dynamics and human dimensions of water security at the local and regional levels will follow. Finally, the history and contemporary context of local adaptations in the community, as well as the region at large will be explored. Community livelihood dynamics, including strategies, stresses, and resource endowments, contribute to the characterization of water security. Coping strategies have developed to distribute risk, while enabling Andean communities, such as Mullak'as-Misminay, to develop innovative strategies and mechanisms to cope with and respond to the various stresses encountered. Such strategies and mechanisms are often embedded in community livelihood dynamics, and can influence access, availability, and use of water resources. Over time, multi-level relationships have served as both enabling and disabling factors to community water security. The pressure and influence these relationships have exerted upon Andean communities continue to test socio-ecological resiliency, as they respond to and are shaped by multiple perturbations, with varying degrees of vulnerability and adaptive capacity.

4.1 Stresses Affecting Water Security

Mullak'as-Misminay and the surrounding region are affected by various stresses of both human and ecological dimensions that are affecting water security. These are identified and discussed below.

4.1.1 Ecological Stresses and Resource Endowments

Water, soils, and forestry were dominant topics discussed by interview respondents when questioned about water security. While there are nearby glaciers, none of their waters feed into the community's water system. "Glacier melts have produced lagoons, however the water from these lagoons is lost to the Vilcanota River. We want to transport these waters to the zones in Maras where reservoirs are being built. This would help replenish the springs" (Respondent 2, August 5, 2009). These lagoons are visible in Figure 1.1 in Chapter 1. Some of these community water sources have been evaluated by the District of Maras as sufficient to serve pressurized irrigation projects. Previous studies have shown that water sources from the community have served Moray, and are currently supplying Maras's population (Cavero et al., 2005).

Figure 4.1. Water Supplies in Mullak'as-Misminay

Left: Moray's former water source is fenced off and now supplies Maras's pressurized irrigation system. Right: The main water source for drinking water in Mullak'as-Misminay.

Photo by Nicole Renaud

Cavero et al. (2005) have determined that Mullak'as-Misminay possesses necessary and sufficient water flow to meet current demands. This perspective is not necessarily shared by all community members. "And there may be water wars. But bringing these waters [from away would allow us to] have water for longer", said Respondent 13 (September 25, 2009). This sentiment was shared by Respondent 2 (August 5, 2009) who stated "if we don't care about [our natural resources], in 10 or 15 years we will have many problems. Presently there are many fights, and lawsuits, and it has even come to the point where people kill for water." The prospect of escalating water conflicts was thus discussed if water is not better conserved (Respondent 2, August 5, 2009; and Respondent 13, September 25, 2009).

IMA has classified Maras as possessing low agricultural soil quality (10_ Valor Productivo). Only 10% of Maras's soil is considered suitable for pasture and able to accommodate livestock, much of which is concentrated in the hills surrounding Mullak'as-Misminay (Cavero et al., 2005). The soil's shallowness and climate make the area unsuitable for intensive livestock rearing. "Agricultural production has diminished, agricultural terrain are not as fertile as before", stated Respondent 2 (August 5, 2009). Forest cover comprised 3.64% of land area in the District in 2005, and there are many native plant and tree species possessing beneficial properties that could positively impact water security.

4.1.2 Climate Change in the Peruvian Andes

The climate change process will likely bring instability and disequilibrium in the Andean environment, with climate change impacts expected to be more intense at higher altitudes (Earls, n.d., and Perez et al., 2010). Projected climate change impacts for the Peruvian Andes include an increase in temperature, a reduction in precipitation, and an increase in frequency and magnitude of extreme events (World Bank, 2009, and Earls, n.d.). Climate events are projected to deviate substantially from the long-term norm and communities will experience fluctuating atypical local weather variations (Earls, n.d., and Earls, 2008). Some of the water-related regional manifestations anticipated as a result of climate change include slower, ongoing events such as: aquifer changes, groundwater reduction, and soil erosion, while more rapid manifestations include erratic precipitation and temperature patterns, droughts, floods, frosts, disease and pests, and landslides (Earls n.d., Agrawal, 2008, and Perez et al., 2010).

4.1.3 Temperature change

Peru's First National Communication projects an increase in summer temperature in Peru by 1.3 C, with summer humidity declining by 6% by the year 2050 (Comision Nacional de Cambio Climatico, 2001, and World Bank, 2009). The average temperature increase rate in the Andes is projected to be two to three times more than nearby lowland regions (Perez et al., 2010). Community residents have observed a changing trend in local temperatures (Respondent 13, September 25, 2009; and Respondent 22, November

24, 2009). This has included observations of a heat increase, as well as greater extremes with hot and cold temperatures, which puts them behind on harvests. "The seasons are warmer than they should be", stated Respondent 13 (September 25, 2009), "sometimes the temperature changes and it starts to rain when there shouldn't be rain, and sometimes there are droughts longer than normal." One community respondent remarked on the cold and the impacts it has on their harvests. "It's not the same as before, the winters are colder. It's hotter in the dry season and colder in the winters. The fact is it's too cold and we're behind in the harvests", said Respondent 8 (August 10, 2009).

4.1.4 Reduced precipitation, dry conditions, and water deficiency

The Urubamba province is subject to recurring droughts (Comision Multisectoral de Reduccion de Riesgos en el Desarrollo, 2003). Peru's First National Communication projects a 14% and 19% reduction in precipitation in the Southern and Central part of the Andes respectively by 2050 (World Bank, 2009). Respondents 2 (August 5, 2009), 6 (August 10, 2009), 7 (August 10, 2009), 8 (August 10, 2009), and 12 (August 13, 2009), reported reduced precipitation during the rainy season in recent years, exceptionally dry seasons, as well as a disruption in expected seasonal patterns. An overall reduction in water availability in Mullak'as-Misinay during the past ten years was also observed, and dry spells were said to be lasting longer than usual (Respondent 8, August 10, 2009; Respondent 9, August 10, 2009; and Respondent 13, September 25, 2009). Some respondents (Respondent 13, September 25, 2009; Respondent 21, November 24, 2009); and Respondent 22, November 24, 2009) have commented on the water deficiency as causing plants to dry up and agricultural difficulties such as the inability to harvest crops.

“Sometimes there are droughts longer than normal. We sow with rain and sometimes the quantity of rainfall varies, we cannot recover what we invest in agriculture”, Respondent 13 (September 25, 2009) stated. One respondent reported less rain in the rainy season and longer dry seasons compared to 20-30 years ago, while another reported overall diminishing water sources in the past three years (Respondent 11, August 13, 2009; and Respondent 14, September 25, 2009). Commenting on the diminishing water, Respondent 14 (September 25, 2009) stated “we cultivate little corn and barley because of the lack of water, and we grow beans. We work less - there is land, but no water.”

4.1.5 Increased precipitation

Peru’s Second National Communication to the UNFCCC projects extreme rainfall to peak by 2030 for most of Peru, followed by a decline (Comision Nacional de Cambio Climatico, 2001). An abundance of rain can be detrimental to cornerstone crops such as corn. Although the dry season is typically without rain, Mullak’as-Misminay residents were reporting unusual seasonal changes. “The rainy season should begin in November through March. In April there shouldn’t be rain,” commented Respondent 13 (September 25, 2009), “but now it rains at any time.”

Gradual erosion was cited as one of the primary agricultural concerns impacting the Maras District, as it impoverishes slope soils. Heavy rainfall in the District causes surface runoff and erosion (Cavero et al., 2005).

Figure 4.2. Gradual erosion in Mullak'as-Misminay.

Photo by Nicole Renaud.

4.1.6 Natural hazards

The Andes are considered to be one of the most at-risk regions for climate-related hazards, with hydro-meteorological hazards (in particular floods and droughts) representing the majority of events experienced in the region (Comunidad Andina, 2007). From 1995-2007, natural hazards had grown by 650% in Peru. Heavy rain-induced flooding and landslides are linked to extreme events such as El Niño. Comunidad Andina (2007) has detailed some of the impacts both El Niño and La Niña (ENSO) events have delivered on Andean communities, which included damages to productive sectors, infrastructure, social services, and utilities. Local and regional influences of El Niño were also mentioned by some community respondents (Respondent 10, August 12, 2009; and Respondent 12, August 13, 2009), with impacts including mudslides and flooding in the Andes, as well as negative effects on corn production in the Urubamba Valley. "El Nino affects the presence of rainfall, and where the rainfall has been altered is in the highlands of Cuzco where there are no adequate irrigation systems" (Respondent 10, August 12, 2009).

4.1.7 Frosts

Changing temperatures and humidity will also impact frost occurrence. Perez et al. (2010) have discussed the impact of frost on agriculture in the Peruvian Andes, although that impact will depend on the type of frost experienced. Advective, or white frost, forms when cold air, wind, and high humidity conditions occur, and generally does not damage agriculture. Radiative, or black frost, however, forms during cool cloudless and dry nights and causes plants to freeze with black spots and is overall more harmful. Radiative frost is also the most commonly occurring form in the Andes. Frost days can occur up to 200 days in a given year and most frequently happen between January and March. Frost days in the summer are projected to increase (World Bank, 2009). Frost is considered to be one of the most significant hindrances to agriculture (Perez et al., 2010). Frost occurrence is also a climate change manifestation, with a SENAMHI (2005) study observing that frosts are decreasing in some areas of the Urubamba basin and increasing in others, which may be related to growing irregularities in precipitation patterns. This is significant considering planting in the community follows frost periods (Urton, 1981). Future studies need to consider the white and black frost difference.

Frost occurrence was commented upon by four respondents (Respondent 2, August 5, 2009; Respondent 9, August 10, 2009; Respondent 14, September 25, 2009; and Respondent 20, November 23, 2009). "In May, June, and July there is more frost," said Respondent 20 (November 23, 2009), "in rainy seasons there is no frosts, but frosts are happening more lately." It was also observed that frosts were occurring in August, which is unusual (Respondent 14, September 25, 2009). One respondent even deemed frost a significant environmental concern for the community alongside of water shortage, warming temperatures and increased hail (Respondent 9, August 10, 2009). More intense frosts were identified as a recent environmental change in Mullak'as-Misminay impacting agriculture (Respondent 9, August 10, 2009; and Respondent 14, September 25, 2009).

4.2 Stress Related to Social Dynamics and Local Behaviours and Impacts

Community water security experiences challenges from local behaviour and the various impacts these behaviours have on water systems. Many behaviours have evolved out of a loss of ecological knowledge, the influence of multi-level relationships, and as a result of the demands of living in a marginal environment.

4.2.1 Forest management

The prevalence of forestry concerns, and specifically, growth of eucalyptus, was an issue affecting water security that emerged out of the interviews. Eucalyptus was frequently described as a mixed blessing according to the differing opinions expressed. Some were concerned over the excessive water extraction and negative impact it has on nearby agriculture (Respondent 2, August 5, 2009; Respondent 10, August 12, 2009; and Respondent 23, November 24, 2009). "Many people in Maras plant eucalyptus trees around the springs, and they capture all of the springs' waters and cause them to dry. It uses too much water to grow", said Respondent 2 (August 5, 2009). The benefits of eucalyptus were also described. "The population want [eucalyptus] because the people use it for wood, for the rooftop of their houses, and in the mining tunnels", stated Respondent 3 (August 7, 2009). Respondent 4 (August 8, 2009) stated there are local tree alternatives, however, he said, "these trees don't grow rapidly. This is why they want the eucalyptus trees." Eucalyptus trees, native to Australia, were introduced in Peru around the 1850s, and promoted through large-scale agroforestry initiatives by the state during General Velasco's Agrarian Reform with one hundred thousand hectares planted throughout the highlands in 1976, including in Maras (Dickinson, 1969, Luzar, 2007, and Inbar & Llerena, 2000). During this decade, the Maras District had reforestation programs that are responsible for the current presence of weeping willows, elderberry, and eucalyptus (Cavero et al., 2005). This was done in an attempt to add to the Andean peasants' resource endowment by providing them with a sturdy and fast-growing source of fuel and construction material.

Both eucalyptus and pine have been described as trees encroaching agricultural areas and causing excessive moisture withdrawal from the soil (Respondent 2, August 5, 2009; Respondent 10, August 12, 2009; Respondent 11, August 13, 2009; and Cassinelli Del Sante, 2000). Respondent 2 (August 5, 2009) even said 60-70 years ago, water was abundant but the deforestation of native species and afforestation of eucalyptus has led to water problems. Fjeldsa (2002) cautions against planting eucalyptus in areas that experience water scarcity and soil erosion. One study has determined that eucalyptus absorbs 10-25% of the water that its leaves encounter, which exhausts water supplies, increases soil acidity, and possibly depletes soil nutrients (Luzar, 2007).

One native tree species, known as polylepis (*Queuñoa de Altura*, *Polylepis tarapacana*) is present in Mullak'as-Misminay, and can provide a sustainable option for afforestation programs while benefiting water security (Cavero et al., 2005; and Respondent 13, September 25, 2009). The soil surrounding these trees is rich in organic matter and highly fertile, and is also effective in maintaining soil moisture (Ramsay & Aucca, n.d.). The local government provides seedlings to plant polylepis to help in water recovery in times of difficulty (Respondent 13, September 25, 2009). Human activity has contributed to the reduction of polylepis through practices such as overgrazing, burning of grasslands, and the conversion of forested areas into cultivation zones (Fjeldsa, 2002, and Ramsay & Aucca, n.d.). Due to the soil quality around these trees, these forested areas are often converted to cultivation areas, without necessarily replacing the lost trees. Overall, the forest areas of polylepis continue to be reduced to smaller patches, and in the District native tree species have been negatively influenced by local practices (Fjeldsa, 2002; and Respondent 2, Interview, August 5, 2009). Polylepis, along with other native tree species in the Maras District, have reportedly diminished considerably in recent years as a result of resource exploitation, as well as competing vegetation such as the dominant eucalyptus tree (Cavero et al., 2005).

Deforestation contributes to soil erosion, diminishes crop yields, and reduces water retention potential (Poveda, 2007). These impacts often result in greater flooding events after heavy rainfall, as well as reduced water availability. Deforestation was listed as a problem in the community and Cuzco region, and one that is intensifying (Respondent 1, August 3, 2009; Respondent 3, August 7,2009; and Respondent 21, November 24, 2009). Some deforestation issues described include forest and tree zones being converted to agricultural lands and livestock ranches (Respondent 3, August 7, 2009). “Cuzco’s main problem is deforestation caused by the eradication of forests that have been converted to agricultural lands and livestock ranches, and soil erosion is accelerating due to the rains”, stated Respondent 3 (August 7, 2009). Cavero et al. (2005) describe deforestation as a concern to the district with the degradation of forests and vegetation. The plan attributes the disappearance of rotational practices as principally to blame for an alarming loss of native tree species, although it did not specify if it referred to agricultural or forest management rotational practices.

Figure 4.3. Trees surrounding agricultural areas in Mullak’as-Misminay.

Photo by: Nicole Renaud

4.2.2 Agricultural Management

Decisions and practices relating to agricultural management were cited as areas of concern for Mullak’as-Misminay’s water security. The region has a history of soil erosion, as evident in the nearby Marcacocha core sediments displaying a significant presence of inorganic particles between 700-1000 AD. The onset of this erosion occurrence is believed to be as a result of overgrazing. This coincided with a rise in temperature after a cold phase that had inhibited agriculture (Chepstow-Lusty & Winfield, 2000).

Diminishing ecological knowledge and traditional values have been linked to natural resource degradation (Respondent 2, August 5, 2009; and Respondent 3, August 7, 2009). "In the past, during the time of the Incas people took better case of water resources and prevented soil erosion", stated Respondent 2 (August 5, 2009). "Soils need the cover of trees, grass and shrubs", said Respondent 3 (August 7, 2009), "unfortunately in Peru lands are burned as the farmer believes that if you burn the land, production improves, but it erodes", adding that lands are used in an indiscriminate manner, including by overgrazing, as farmers do not comply with agreed commitments. While the burning of grasslands is considered a temporary measure for improving soil productivity, it was also mentioned as one of the leading causes for erosion, soil degradation, and loss of vegetation cover in the community (Respondent 3, August 7, 2009, Cavero et al., 2005). The loss of vegetation cover, cited as another one of the primary environmental concerns in Mullak'as-Misminay, contributes to soil erosion (IMA, n.d.). In one Andean case study, sloped areas with 50% of the area unprotected by vegetation cover can produce a 16 t/ha loss of ground in one heavy rainfall episode (Ramirez & Cisneros, 2006). Respondent 3 (August 7, 2009) believes that farmers who advocate the burning of grasses believe it temporarily improves land production. However, once bare the land erodes. Some disagree with burning grasses, with two respondents (Respondent 3, August 7, 2009; and Respondent 4, August 8, 2009) saying it diminishes water supplies.

Some of the impacts of burning on water systems identified by IMA (Suyo Flores, n.d.) are:

- increased water surface runoff
- alteration of the hydrological cycle's aquifer recharge
- interruption of the recycling of soil nutrients

Another agricultural practice creating stress on water systems is monocropping. The emphasis is on producing high yields in the short-term for increased intensity, and growing the same crops in consecutive years, without rotating different plant types. While monocropping can be interpreted as economically beneficial for extra-local markets, controversy lies in the impact it has on local food security and soil health in a place with already fragile soils. Of note, is that Carol Goland's (1993) field work in the neighbouring Puno Department has demonstrated insignificant crop yield differences between monocropped and polycropped fields, with the exception of monocropped bean crops showing greater yields. Monocropped fields are susceptible to ecological stresses, including plant diseases, pest outbreaks and weather events such as floods and droughts (Goland & Bauer, 2004). Floods and droughts can incite pest outbreaks and diseases, both of which are occasionally a problem in the Maras District (Cavero et al., 2005). Goland and Bauer (2004) further draw a connection between the distance food travels and declining biodiversity as a result of the monocropping produced for extra-local markets.

Monocropping, alongside of improper mechanized farming techniques for sloped agrarian lands, can be significant contributing factors to soil erosion (Ramirez & Cisneros, 2006). Additionally, without crop rotations, pests and diseases can occupy niches, and may require pesticides (Perez et al., 2010). Rotations allow soils to replenish their nutrient content and can help in providing sustainable crop growth through organic methods. The pressure to transition to monocropping is often related to the push for market-oriented food production in urban centres (Maskrey, 1993).

An Urubamba representative (Respondent 11, August 13, 2009) in the agricultural sector did not believe rotations happened any more in the province and attributed the rise in pests and plant diseases to monocropping. The community, however, practices crop rotations (Respondent 3, August 7, 2009; and Respondent 22, November 24, 2009). Respondents and community members commented on the rotational system of agriculture that is prevalent. However the District Strategic Plan and respondents (Respondents 15, 16, and 17 September 25, 2009; and Respondent 23, November 24, 2009) commented on the negative impacts of the loss of rotational practices (Cavero et al., 2005).

4.2.3 Pollution

Pollution of water bodies is a prevalent concern in the region. It is believed that few streams are clean and external support is required to improve water quality (Respondent 2, August 5, 2009). Untreated wastewater and, particularly in rural areas, agrochemical contamination is a major contributing factor to water contamination in Peru (Ore, Castillo, Van Orsel & Vos, 2009).

Water quality issues due to contamination are perceived by Respondent 12 (August 13, 2009) some to be the most pressing problem, including during droughts. Cavero et al. (2005) outline some of the main contaminants that are problematic for the District, which include plant agrochemicals. Pests and plagues, linked to climate conditions as discussed above, were mentioned by interview respondents as a concern that compels them to use chemical pesticides, and in turn creates growing resistance to pesticides (Cavero et al., 2005).

Pesticides can contaminate water supplies in a variety of ways, including by surface runoff after a rainfall and by soil infiltration (Ore, Castillo, Van Orsel & Vos, 2009). Agriculture grown for export is under stricter regulations for toxic pesticide use than products destined for national markets, and thus subsistence and local market-bound food production may include greater toxicity. The Peruvian National Agricultural Census states that 80% of the agricultural sector uses insecticides, fungicides and herbicides, and Urubamba is the province with the most intensive use (Cavero et al., 2005).

One respondent believed agrochemical use is concentrated in the lowlands and highland communities mostly farm organically (Respondent 4, August 8, 2009). Agriculture in the community seems to be mostly organic, such as using bovine manure. However, it has been noted that agrochemical use does increase when pests and diseases are present (Respondent 4, August 8, 2009; and Respondent 23, November 24, 2009). Some of the main sources of pollution described by interview respondents include the agrochemicals mentioned above, as well as waste (Respondent 1, August 3, 2009).

Figure 4.4. Open lined canal flood irrigation in Mullak'as-Misminay.

Photo by Nicole Renaud. Open canals leave water exposed to contaminants, as well as surrounding waste.

4.2.4. Infrastructure and Services

The topic of infrastructure and services was raised by some community respondents. It was observed that there are no water treatment and sewage plants, and as a result the sewage waste and polluted water drains into the water system (Respondent 2, August 5, 2009). Since 2005, a water chlorination system has been installed in Maras and water is pumped to the upper part of the District in a reservoir where people can access clean drinking water (Respondent 2, August 5, 2009). There are still areas lacking chlorination, and this is primarily responsible for the prevalence of diarrhea and intestinal parasites, principally affecting children (Cavero et al., 2005, and I11). These issues were not encountered during community field work in the 1970s, and suggest they have developed over the course of the past few decades (personal communication, November 4, 2011).

Ore et al. (2009) also discuss the consequences of water contaminated by sewage on human health. Bacterial contamination increases the chance of transmitting illnesses, including skin diseases and intestinal infections being the most common. One of the biggest barriers identified to implementing sanitation services throughout the District is unplanned development, with Mullak'as-Misminay singled out (Cavero et al., 2005). With a population continuing to expand and no urban or development plan guiding the expansion, the lack of sanitation services results in people using open fields for their basic needs.

Development expansion was also listed as a stressor to agriculture as it reduces available agricultural areas (Respondent 11, August 13, 2009).

4.3 Local Adaptations

These stresses that have manifested throughout history and more recently in the Andes, and in the Maras district and Mullak'as Misminay area more specifically, have prompted the development of multiple responses and adaptations. These include crop diversification, the manipulation of different ecological levels in order to maximize crop varieties, as well as using biotic and abiotic indicators, astronomical observations and weather forecasting for agricultural planning.

Past and present adaptations will be reviewed in the following section. One of the objectives in this research is to draw out the connection between challenges and adaptations that have emerged in response to these difficulties.

4.3.1 Ayllu and social labour organization

Kinship-based indigenous Andean communities are referred to as *ayllu*, and they have been considered to be a regionally-specific societal adaptation to the challenging mountain ecology. Isbell (1997) has suggested that ayllus emerged as a collection of innovative mechanisms to maintain community autonomy in the face of expanding societies. Ancient customs of social labour organization such as ayni, minka and faena are maintained throughout the Maras district. Regional customs are passed from generation to generation through oral histories that show them how to work the land, and their education is rooted in experience (Respondent 9, August 10, 2009). Faenas are a form of reciprocal social labour conducted with large community groups where goods, especially foods, are exchanged for services rendered that benefit the community (Respondent 1, August 3, 2009; and Erickson & Candler, 1989). "Water is distributed in an equal manner in accordance with the organization or board that receives the water… [and] the person that doesn't assist in the faena [for] irrigation will not receive water", says Respondent 1 (August 3, 2009).

People receive rewards for contributing to faenas. This includes giving "small prizes that can include corn beer [or] potatoes", says Respondent 1 (August 3, 2009). If people do not contribute through labour, they need to pay instead, or have their water service cut (Respondent 1, August 3, 2009). The duration of the labour will vary based on the given task. Faenas organized for flood irrigation in the community, for example, are done for two months (Respondent 21, November 24, 2009). They are organized by the community president for the benefit of the community, or they can also serve to assist a particular family (Respondent 4, August 8, 2009; Respondent 7, August 10, 2009; Respondent 9, August 10, 2009; and Respondent 12, August 13, 2009). When faenas are performed for the benefit of a family, this is called ayni or minka (Respondent 4, August 8, 2009).

A faena underway during the field work season was working to open up a community road (Respondent 7, August 10, 2009; and Respondent 9, August 10, 2009). This was considered beneficial to the entire community as the road would protect people and animals from falling from paths during the rainy season. Aynis and other reciprocal works can operate as a sort of credit system, in that a family or group who received help can be counted upon to give help to a previous helper during a future need. Faenas have proven helpful during events such as droughts, and help deliver adequate water quantity (Respondent 12, August 13, 2009). Based on these traditional ways of organizing, during times of water scarcity neighbours will pull together to help one another out (Respondent 8, August 10, 2009). A common phrase heard when describing faenas, and aynis in general is “today is for me and tomorrow is for you” (Respondent 9, August 10, 2009). The phrase demonstrates reciprocity and continuity of labour. Lisa Poliak’s article, Peru: Life of the Quechua, gives an account of this same phrase in her discussion on the challenges for youth in the Andes (Poliak, 2007). One of her interview respondents who works with remote Andean communities explains that she does not believe survival and farming would be possible in harsh Andean climates without the ayni concept. Traditionally, aynis organized agricultural labour in order to meet ecological needs in mostly subsistence agricultural communities. Mayer (2005) has defined three realms of goods exchange that the Andean household is a part of: household-to-household; national market-household; and the realm in between the two on the fringes of market and social relationships. Bird (2010) argues that with aynis increasingly integrating with extra-local market systems and the greater inclusion of a cash economy has complicated traditional kinship-based social exchanges, as well as the manner in which natural resources are allocated. This sentiment was discussed in one interview. "The implementation of policies is oriented at forcing us to enter the world capitalist market", says Respondent 18 (September 29, 2009), representing a Cuzco NGO. "Our economy [has elements] like solidarity, training, and reciprocity, and with a capitalist market that would disappear. We make tradeoffs; I give you potato and you give me wool or corn. Money is used by the state to keep us caught" (Respondent 18, September 29, 2009).

The influence of markets within Andean communities has created additional livelihood strategies such as market-bound food crop production rather than food grown for consumption (Valdivia et al., 2003). Currently, Mullak'as-Misminay produces mostly entirely subsistence agriculture using its flood irrigation. On the other hand, Maras's agricultural production grown with the assistance of its pressurized irrigation system fed by Moray's spring is sold to extra-local provincial and regional markets. As of yet, production in the District does not reach national or international markets (Cavero et al., 2005). Valdivia et al. (2003) observe that households who pursue this livelihood strategy can be particularly vulnerable to climate impacts such as droughts.

4.3.2 Livelihood diversification

Climate change will have challenging impacts on rural Andean livelihoods. Agrawal, (2008) has organized these impacts into three categories:

1. greater environmental risks
2. fewer livelihood prospects
3. increased pressure on social institutions (Agrawal, 2008)

In order to endure these challenges, including threatened water security, smallholder farmers have learned to diversify the livelihoods they practice. Some of the food produced may be bartered within social networks and others sold to local markets, for example. One respondent mentioned that when there is not enough water, this leads to poor harvests and some farmers sell cattle to survive (Respondent 4, August 8, 2009). The bartering system of the Andes was discussed by interview respondents, where produce is used in tradeoffs (Respondent 1, August 3, 2009; Respondent 18, September 29, 2009; and Respondent 9, August 10, 2009). A farmer who grows potatoes can exchange their produce with a farmer who spins wool, for example (Respondent 18, September 29, 2009). Inter-community interaction exists for bartering and product exchanges (Respondent 9, August 10, 2009). Many farmers also consider a certain degree of market participation as an important livelihood strategy to distribute risk (Perez, Nicklin & Paz, 2010). While providing another income source, the introduction of money is understood as contrary to the bartering system, incorporating farmers in the capitalist system. Many people in small rural agropastoral communities engage in farming tasks to varying degrees, but some diversify their livelihoods by also engaging in other economic activities that help supplement income such as tourism, hostel, crafts, and small store operation (conversation with locals, September 2009). Moray as a tourist attraction in particular offers avenues for livelihood diversification. The amount of tourists visiting Moray is steadily rising, with 91,000 recorded tourists in 2008 (Luque, 2009). The attraction provides additional livelihood diversification for many residents, who sell crafts and offer guide services.

The strategies employed by highland peoples are largely determined by access to networks, different resources, and organizations (Valdivia et al., 2000). It has been shown that during ecological difficulties, household strategies shift their activities to tasks that are less vulnerable to climate. When ecological stresses that decrease resource availability are exerted upon a community, people can alter and even utilize the diversity of their livelihood strategies to sustain themselves while sharing goods with one another during the disruption. In particular, this may include tapping into networks, temporarily migrating, off-farm work or an increase in livestock production.

The benefits of diversifying strategies not only help withstand ecological shocks but also those originating from political and economic perturbations. By growing a diversity of crops and livestock for both consumption and income, for example, rural Andean farmers have been able to weather stormy market conditions and price declines (Respondent 8, August 10, 2009).

4.3.3 Agricultural Strategies

The foundation of Andean crop cycles is especially grounded in the opportunities presented at various ecological levels (Golta, 1980; and Lopez-Ocon, 1987). As such, several agricultural cycles are conducted in order to maximize available growing days in the agricultural calendar.

In the face of the array of perturbations that frequent the Andes, the reordering of agricultural activities helps avoid larger-scale crop loss. The farmers in Mullak'as-Misminay practice a rotational system of agriculture, along with a continuously irrigated corn (personal communication, November 4, 2011). With potatoes, a field will be used for one to two years, and the fields will remain fallow for a number of years (Orlove, et al, 2002, and Respondent 23, November 24, 2009). This allows the soil to recover its fertility, while also minimizing the impact of a worm pest known as nematodes, which target potato crops. When fields are fallow, pest presence decreases, however constant cultivation encourages pest populations to increase (Orlove et al., 2002). Beans, corn and potatoes were some of the crops mentioned that are part of the rotation (Respondents 16, 17 & 18, September 25, 2009; and Respondent 23, November 24, 2009). Urton (1981) has described what he terms the most important crop rotations in the Misminay-portion of the community as those of the three-year rotation with wheat and five-year rotation with potatoes. Rotations performed not only allow for soil nutrition replenishment through fallowing but also alternates between agricultural and pastoral uses. Twenty-two fields in the community area were used to rotate potatoes, although it is uncertain whether all these same areas continue to be used through rotational practices (Urton, 1981).

The coordination of rotations is highly rainfall-dependent, as farmers must work around rainfall patterns, and less rain is expected to decrease crop yields (Respondent 23, November 24, 2009). Interview respondents noted that the schedule regarding the agricultural duties is greatly changing because crop cycles are oriented around seasonal rainfall, with crops planted after rainfall (Respondent 10, August 12, 2009). With rainfall patterns changing, the associated duties change accordingly as well, with three community farmers mentioning that they always suffer from water shortages and that water is not as prevalent as it used to be, with the past ten years showing a particular decline in availability (Respondent 7, August 10, 2009; and Respondent 8, August 10, 2009; and Respondent 9, August 10, 2009).

Certain local plant varieties found in the community are resistant to some of the extreme weather events experienced in the region. These include olluco, which is drought and frost-resistant, quinoa which is drought and frost resistant, and some potato varieties that are frost-resistant (Cavero et al., 2005; and Rubio, 2007).

One of the other important guiding principles assisting local farmers in organizing their crop planting decisions is their ability to forecast seasonal weather using a combination of biotic and abiotic indicators (Gilles & Valdivia, 2009). Gilles and Valdivia (2009) discuss traditional forecasting indicators for Andean communities based on abiotic and biotic indicators. Indicators in the abiotic category include forecasting rainfall from the Pleiades constellation, as well as wind direction during key days (e.g. winter solstice, equinox, and a few other days) (Orlove et al., 2002). Biotic signs include flowering patterns, bird nesting behaviour, as well as the behavior of certain insect species (Orlove et al., 2002; and Gilles & Valdivia, 2009). Gilles and Valdivia (2009) mention that animal behaviour (e.g. locations where foxes defecate, the places where birds lay eggs, as well as different species' patterns of migration) help forecast the wet and rainy seasons as well as appropriate planting locations. Plant patterns informs the farmer's decisions on times to plant based on temperature and soil moisture (Gilles and Valdivia, 2009; and Sherwood and Bentley, n.d). Combined with the complement of local ecological knowledge, decisions regarding where, when and what to plant are made accordingly. Urton (1981) has observed that in Misminay, the serpent, toad, llama and fox were animals represented in the Pleiades constellation, and has argued that there is a relationship between the local ethnoastronomy representation of these animals to their behavioural patterns of the animals in the area. Environmental stresses are causing local species populations to decline. "The number of animals such as frogs, toads, and snakes have declined", stated Respondent 2 (August 5, 2009).

One of the best documented abiotic indicators in forecasting rainfall in Mullak'as-Misminay is based on astronomical observations of the Pleiades constellation. Respondent 4 (August 8, 2009) from Ollantaytambo states "there are people who predict climate change using stars, while others read futures." Orlove et al. (2000 & 2002) explain that Andean farmers have a tradition of predicting interannual rainfall variations for the summer and fall harvests. The dimness of the Pleiades can also be indicative of a strong El Niño year, which influences both precipitation and temperatures, and impacts drought-sensitive crops (Orlove et al., 2002). When a reduction in rainfall is expected, potato planting dates can be modified accordingly.

Figure 4.6. Farmers in Mullak'as-Misminay taking a break from working the fields. Photo by Nicole Renaud.

Pre-Hispanic Andean populations under the Incan empire practiced crop cultivation of upwards of 70 species, with storage capacities to maintain populations for ten years. Post-conquest relocation and population decimation led to a sharp decline in biodiversity, although communities that practice crop rotations with native plants help preserve local biodiversity (Chepstow-Lusty & Winfield, 2000).

The local ecological knowledge assisting in the coordination of crop rotations is also helpful in managing crop migration as temperatures increase. Altitudinal limits of agriculture have been extending upwards. Over the past 50 years, crop and animal husbandry ranges have increased by 300 m (Perez et al., 2007, and I12). This is predicted to continue over the next hundred years as it is projected that the agricultural limit will rise by at least 500 m (Perez et al., 2010).

4.3.4 Vertical Terraces

Vertical agricultural terraces are agronomically well-suited to mountain terrain and climates (Treacy, 1987). Terraces can help reduce frost and drought impacts, preserve soil, as well as increase crop range and yield potential due to their functioning in conjunction with highly localized microclimates (Altieri, 1996). They can also facilitate water delivery, and make efficient use of available water. Vertical terraces consist of flat terrace levels and may have been developed in this manner in response to drought, drastic daily and seasonal temperature changes, or due to the suitability for irrigating corn.

Since the first millennium AD, the Tiwanaku, Wari, and Inca pre-Columbian civilizations' development was greatly steered by their experiences with and responses to increased prevalence of water-related extreme events such as droughts (Kendall & Ouden, 2008). Kendall & Ouden (2008) state that there is no firm evidence for the presence of vertical agricultural terraces until the first millennium AD, but their predecessors, rudimentary ground terraces, have been found some thousands years BCE. The presence of rudimentary ground terrace systems in the Marcacocha region between 2,200 BCE-100 AD is believed to have served the function of stabilizing sloped agricultural fields in the face of frequent erosion occurrences (Kendall & Chepstow-Lusty, 2006).

Kendall & Ouden (2008) have argued that the Wari and Inca civilizations have developed in response to climate changes and in particular the severe droughts accompanying them. These civilizations were sustained with their own respective irrigated agricultural systems, and in particular on the basis of irrigated vertical terraces.

A severe drought in 1050 AD with periodic manifestations lasting until 1250 AD helped serve as a point of departure for a new era of infrastructure expansion with greater irrigation works. Such severe stresses to Andean water security have arguably spurred socio-ecological system interactions in the form of innovative water management in response to significant challenges. Innovations by the Inca include creating more stability in terrace walls along with different soil layers in order to maximize soil retention and facilitate drainage.

The Inca developed 700,000 ha of terraces in the Andes, which was accomplished with a large and highly-coordinated labour force (Alegria, 2007). One of the barriers to vertical terrace systems is the extensive labour involved in their maintenance, which is estimated to range between 350 and 500 workers per day per hectare (Altieri, 1996). One estimate suggests that 2,000 worker days are needed in order to construct one hectare of terrace, not including the myriad of other tasks associated with creating a functional terrace system, including building canals for water delivery (Treacy, 1987).

Development, operation, and maintenance of these terrace systems in the Inca era drew upon a system of labour known as the mit'a Inca state labour system, which entailed rotational labour service. Once the Incan empire disintegrated, so did the system of labour that allowed the widespread development of vertical terraces on the scale it had once taken, although some continue to be maintained and even revived today.

Vertical terracing systems may be devalued in agricultural modernizing schemes, because of the extensive labour required, the incompatibility with plough equipment and machinery, as well as the difficulty in growing cash crops as opposed to subsistence corn, which can grow quite successfully in terrace systems (Treacy, 1987). While the additional water retention produced by the terraces can lead to greater crop yields, the space required for their construction may negate the surplus they can create in a given location (Posthumus, 2005). Given the high labour requirements, as well as the lack of suitability for intensive farming aimed at highly productive cash crops, terraces have become devalued as modernized farming has occurred.

While terraces have the potential to enhance water security, they can become a hindrance it if not maintained properly. Abandoned agricultural terraces accelerate erosion as the walls lining the levels collapse, also leading to slope failures (Inbar & Llerena, 2000, and Stanchi et al., 2011). Maintaining the irrigation canals and water reservoirs supplying the water to the terraces is vital in sustaining terrace agriculture. Steep terraces lacking a vegetative layer experience increased runoff from rainfall compared to less steep terraces on vegetated slopes (Inbar & Llerena, 2000). Mullak'as-Misminay possesses some unmaintained vertical terraces that are overgrown with thick vegetation (Respondents 16, 17 & 18, September 25, 2009). While there are some present, they did not appear to be very extensive.

Figure 4.7. Abandoned terraces in Cuzco region.

Photo by Kelly Vodden.

Its most renowned vertical terrace, however, is Moray, which is maintained as a tourist attraction rather than a centre for agricultural development. Moray is located at 3,380 m altitude and covers an area of 31.7 ha (Cavero et al., 2005).

Figure 4.8. One of the sinkholes of Moray.

Photo by Nicole Renaud.

Moray is made of four sinkholes and was constructed using the natural topography of the hills and depressions of the area, and required a massive pre-Columbian undertaking of labour (Wright, 2011, and Cavero et al., 2005). The largest “bowl” ranges from 40 m – 60 m in depth and the lowest 24 m contain 12 terraces (Earls, 2011). The structure possessed a subsurface irrigation and drainage system that was crafted in such a way as to facilitate water delivery to specific crops, while also bringing stability to the terrace structure (Wright, 2011).

When the terraces are in vertical mountain terrain, the spatiotemporal requirements must also coordinate with the altitude of the terrain level as the water requirements for crops will differ by altitude and the irrigation system needs to compensate for the changes (Earls, 2011). Each terrace level within Moray has an artificially-constructed microclimate consisting of descending steps made up of a consistent geometric pattern and materials, with the levels functioning as regulators for altitude, crop cycles, and water requirements.

In the Andes, temperature decreases by 6.5 C° for every 1000 m elevation increase. Earls (2011) suggests that an additional growing day is required for every 10 m increase in altitude, causing the maturation cycle to delay by one month over a 300 m difference. A plant’s water needs will differ based on the growth rate and therefore altitude is a determining factor in water distribution.

Earls (2011) hypothesizes that Moray was used as a centre for agricultural experimentation and control. Its function likely helped standardize agricultural calendar cycles alongside of the seasons, while synchronizing the cycles with other terrace systems in the region by using the Cuzco agricultural calendar as a guide. It is of interest to note that Moray, and vertical terraces, was only mentioned in passing in an interview

(Respondents 16, 17, & 18, September 25, 2009). In conversations with locals, people merely commented that terraces are no longer used there as they once were.

4.3.5 Irrigation

Andean communities have a long history of using irrigation systems. Anthropologists and archaeologists had long believed these were developed approximately between 530 AD and the Spanish conquest of the 16th century (Zimmerer, 1995). However, archaeological discoveries in recent years have led experts to believe that irrigation may have developed much earlier. Unearthed Andean canals date as far back as 5,400 to 6,700 years ago, with designs that indicate a capacity to control and measure water flow to enable continuous water delivery to fields (Dillehay et al., 2005). At this time, the region was becoming increasingly arid, as well as experiencing punctuated droughts (Dillehay et al., 2005, and Chepstow Lusty et al., 2003).

In Inca years, irrigation systems were of sophisticated design and reliant upon a system of water distribution that corresponded with public rituals and agricultural celebration events (Mazadiego et al 2009, and Orlove et al., 2000). These customs helped solidify the cohesion contributing to the communal collaboration that was required for the adequate functioning of traditional systems. With the disarticulation of traditional elements, traditional systems have often been partially or wholly replaced with centralized schemes that included pressurized irrigation systems.

The town of Maras has a pressurized irrigation system, although the surrounding communities in the district do not. The District town of Maras has a sprinkler pressurized irrigation system, and it provides water to the entire lower part of Maras, with water channelled from Mullak'as-Misminay (Earls, 1998). Mullak'as-Misminay, on the other hand, strictly employs traditional flood irrigation.

Figure 4.9. Flood irrigation in Mullak'as-Misminay.

Photo by Nicole Renaud.

Unpressurized traditional irrigation systems usually have a water use efficiency of 60% (Caswell & Zilberman, 1985). Pressurized system pressurized irrigation has a potential system efficiency of 75% - 95% (Phocaides, 2000). In the Andes, agricultural fields are mostly supplied with water through uncovered water network canals oriented towards land parcels mostly dedicated to subsistence agriculture. The water losses of unlined canals can be upwards of 40% while lined canals see a water loss of 25% (Phocaides, 2000).

Figure 4.10. Unpressurized lined and unlined irrigation canals in Mullak'as-Misminay. Photo by Nicole Renaud.

Pressurized irrigation was discussed as a desirable upgrade by six community farmers and a government representative, with some even stating that it should be the state norm to help satisfy farmers' main demand, which they said is access to water to irrigate their land (Respondent 3, August 7, 2009; Respondent 9, August 10, 2009; Respondent 13, September 25, 2009; Respondent 20, November 23, 2009; Respondent 21, November 24, 2009; and Respondent 23, November 24, 2009). Three sectors of Mullak'as-Misminay (Pillahuara, Tayancayoc and Pucamachay) possess water flows that the Maras Strategic Plan identifies as viable for pressurized irrigation as well as greater agricultural terrain extension. One respondent did not understand why pressurized irrigation is predominantly funded on the coast and not the Andes, stating that water requirements on the coast are 1000 m^3/s while the Andean requirement is 180 m^3/s.

Figure 4.11. Cuzco government pressurized irrigation funding sign for Maras

“Regional Government of Cuzco. Project: Maras Irrigation” – Photo by Nicole Renaud.

Four respondents stated they would like spray irrigation in the community, while two would like to see drip irrigation (Respondent 9, August 10, 2009; Respondent 13, September 25, 2009; Respondent 14, September 25, 2009; Respondent 20, November 23, 2009; and Respondent 23, November 24, 2009). One respondent did not believe that drip irrigation would provide sufficient water delivery, while another believed drip was the best choice (Respondent 22, November 24, 2009; and Respondent 20, November 23, 2009).

It was believed that pressurized irrigation can help meet the growing challenge of climate change-instigated water insecurity, and was described as the biggest concern for the community (Respondent 23, November 24, 2009). Respondent 23 (November 24, 2009) mentioned that without water they cannot do any irrigation and when water is available they can breed cattle. There was discussion in the community of drawing water from outside the community. Some say that one water source is located approximately 10km away (I18). Llanapolla was the phonetic name provided of the location of the water source.

Community respondents expressed an interest in building more reservoirs in the community to capture additional rainwater. The construction of reservoirs was described by six respondents as an avenue for water security, in order to provide a buffer supply during dry periods and droughts (Respondent 2, August 5, 2009; Respondent 12, August 13, 2009; Respondent 14, September 25, 2009; Respondent 19, October 23, 2009; Respondent 22, November 24, 2009; and Respondent 23, November 24, 2009). They were even attributed to improved erosion mitigation and water management during Inca times (Respondent 2, August 5, 2009). It was even suggested that reservoirs help improve water quality, and could diminish the incidence of parasitic intestinal worms in children (Respondent 12, August 13, 2009).

Figure 4.12. A reservoir in Mullak'as-Misminay.

Photo by Nicole Renaud.

One respondent stated that the current reservoirs and artificial ponds in the community were built at a time when water was more abundant, and suggested that ground and rain water are less abundant, and perhaps less reliable water sources than they once were (Respondent 2, August 5, 2009). One Maras respondent explained that given the increasing shortage in drinking and irrigation water, the local administrative boards respond with water rationing, and allocating water to each user for a certain number of hours, while also refraining from irrigating certain areas (Respondent 1, August 3, 2009).

Additionally, underground water pumps to pump water from reservoirs were suggested, although electricity costs are likely to proven to be too great a barrier for implementation, based on the experience of the neighbouring District of Chinchero (Cavero et al., 2005; and Respondent 9, August 10, 2009). Cavero et al. (2005) indicated research was currently underway in the District to investigate solutions for ways of tackling the lack of potable water. Some see drawing water from the lower parts of Maras as a way to use much needed water in the higher altitudes in the community that is otherwise being lost down slope, although it was unsure if the source referred to was the same as "Llanapolla", 10 km away (Respondent 2, august 5, 2009). Improving water distribution was described by one respondent as one of the biggest challenges facing the community (Respondent 1, August 3, 2009).

4.3.6 Forestry as mechanism for water security

The planting of native species was promoted by interview respondents as a method to improve water security. Five species in particular were mentioned as beneficial to water security: aliso (*Alnus Jorullensis*), chachacomo (*Escallonia Resinosa*), colle (*Buddleja Coriacea*), polylepis (*Queu***ño***a de Altura*, *Polylepis tarapacana*), and saúco (*Sambucus Peruviana*).

Colle and Chachacomo were provided as good examples for focus (Respondent 23, November 24, 2009; Cavero et al., 2005; and Cassinelli Del Sante, 2000). Colle is a highly cold-resilient tree that grows between 3,399 m – 4,496 m and is known as an appropriate tree for Andean reforestation. It provides firewood and wood for building. Chachacomo is an Andean tree prevalent at altitudes of 2,697 m and 3,999 m. Its beneficial properties include the fact it is drought-resistant and helps stabilize erosion and vertical terraces (Cassinelli del Sante, 2000). Minimizing erosion can reduce runoff and water contamination. Its drought-resistance properties can allow it to continue to provide its erosion-control benefits throughout drought periods of which the area is susceptible to.

The shrub Saúco (Sambuca) grows up to 3,505 m and its leaves are reputed to repel insects (Cassinelli del Sante, 2000). Polylepis species range from 3,000 m up to the snowline. Its aridity limit in the Andes ranges from 100 mm, with ideally 500 mm of rainfall, although it is not present in extremely humid conditions.

Aliso, colle, chachacomo, sauco, and polylepis are disappearing at a rapid rate in the District and are considered vulnerable (Cavero et al., 2005). The Maras District wants to develop a comprehensive recovery program to enhance the vegetative cover of these native species. Chachacomo and polylepis in particular are considered overexploited and are contrasted to the productive and dominant tree species eucalyptus (Cavero et al., 2005). Chachacomo and polylepis now only exist in limited areas of the community around people's homes.

Figure 4.13. Some of the trees and shrubs present in Mullak'as-Misminay.

Photo by Nicole Renaud.

Incas had conserved polylepis woodlands and also conducted agroforestry on a large-scale. Pre-Hispanic societies employed agroforestry measures to help secure timber supplies, as well as mitigate soil erosion (Inbar & Llerena, 2000). Pollen records from the region, including nearby Marcacocha, demonstrate a marked lack of arboreal pollen prior to 4,000 years ago, with evidence suggesting intensive agricultural practices (Chepstow-Lusty & Winfield, 2000).

Polylepis trees are considered to be one of the most threatened trees of the neotropics (Ramsay & Aucca, n.d.). Their contribution to water security is particularly seen in their leaves that collect precipitation from mountain fog, which gives farmers an additional water source for the dry period. Additionally, polylepis forests including the understory vegetation help control water flow and decrease peak discharge as well as provide drought protection. Polylepis trees help rejuvenate the soil by increasing organic content, and also act to reduce erosion. Its canopy shields the ground from the impact of heavy rain (Ramsay & Aucca, n.d.).

Respondents advocated the use of native tree and plant species near springs to help preserve diminishing water sources, with sauco and aliso provided as examples (Respondent 1, August 3, 2009; Respondent 4, August 8, 2009; Respondent 10, August 12, 2009; Respondent 11, August 13, 2009; and Respondent 13, September 25, 2009). One respondent has said that they are attempting reforestation of native plants (Respondent 13, September 25, 2009). It was lamented that some plant eucalyptus near springs which causes them to dry (Respondent 2, August 5, 2009). One respondent stated that native plants should thus be the focus of local afforestation rather than non-native flora such as eucalyptus (Respondent 23, November 24, 2009). Another mentioned that the community does not receive any real support for forestry programs and that they are left to pay for afforestation initiatives themselves (Respondent 6, August 8, 2009). It was said it is important to teach children not to destroy grasses, shrubs or trees, with the concern that if these practices continue they will not have water (Respondent 4, August 8, 2009).

Chapter 5: Marginalization, multi-level relationships and consequences for adaptation

One of the thesis questions examines whether multi-scale relationships support or hinder water security, and their role in the community's adaptive capacity. This question is addressed in the enabling environment section of the conceptual framework. It considers the influence of relationships of environmental, political, economic, and social contexts. A brief overview of the historical progression of these multi-level influences on the community's water security will be discussed below. In reviewing these relationships links to the notion of marginalization are also considered, addressing a secondary research question.

4.4.1 History

As demonstrated above, pre-Hispanic Andean cultures developed agricultural and water management approaches grounded in local ecological knowledge and bolstered with multi-level coherence that provided varying degrees of stability in their dynamic yet marginal environments. Water security has historically faced numerous challenges, as socio-ecological systems are confronted by ecological stresses, as well as anthropogenic activities that have been greatly influenced by the interplaying levels of governance and their influence on local populations over time.

Local water traditions have clashed with colonial Spanish traditions as the latter sought supremacy as well as the demise of Andean water customs, which they referred to as “diabolical practices” (Delgady & Zwarteveen, 2008). Colonialists were appalled by the perceived lack of private property, and this perception served to validate the ascribed stereotype of savage barbarians, or alternatively as testament to their nobility and lack of greed (Boelens & Zwarteveen, 2005). There was private property under Inca rule, however it was less common than communal land arrangements (Toland, 1983).

Andean peoples have undergone numerous political transitions as political control over the territory continued to exchange hands. The Inca rule lasted from 1400-1532, with its political centre located in Cuzco. They retained many social customs from Andean societies in order to consolidate political control (Andrien, 2001).

Land and natural resources – most notably water – were generally communally owned and controlled, with labour and productive outputs paid as tax to the Inca Empire with surplus and the bulk of the fruits of labour retained by and redistributed among highland communities (Strong, 1992).

The Inca’s rule ended with the conquest, which prompted a lengthy Colonial period (1532-1821). Up until the 18th century, the Spanish implemented the encomienda system of law in order to establish slave labour from indigenous populations to bolster their extractive and agricultural industries (Encyclopedia Britannica, 2008). In accompaniment to Spanish law, fragments of Andean socio-political and economic systems were extracted with the remainder discredited or altered in order to facilitate colonial administration (Hudson, 1992). Subsuming existing Andean reciprocity and labour practices helped direct colonial projects and governance (Gose, 2008).

Through such mechanisms, the Spanish claimed the most fertile lands and indigenous populations were relegated to the least arable lands, where subsistence livelihoods were further challenged by the burden of increasingly marginal areas (Barraclough, 2001). Many of the ayllus were relocated or condensed on unfavourable lands known as *reducciones* in the 1570s, and these served the function of assimilating indigenous people and reinforcing newly established colonial structures (Wernke, 2007, and Hudson, 1992).

From 1821-1930, the Republican period dominated until the alternating democracies and military rules of the 20th century. These different rules impacted indigenous Andean water rights and how a community such as Mullak'as Misminay accessed and utilized variable water supplies (Zimmerer, 1996, and Ortiz, 2006). When modern nation-states emerged, large hacienda-style land tenure structures were formed using stolen indigenous lands and managed by indigenous slave labour (Griffiths, 2004). Many traditional water management structures, in particular vertical terracing systems, were destroyed for the less labour-intensive, and in some instances, more wasteful slope watering technique of continual-release styled flood irrigation (Trawick, 2002). While certain communities manage to balance flood irrigation with high efficiency, the socio-political disruption led many to transition to less efficient methods. This uneven distribution of land, diminished freedom, and erosion of water rights were driving forces behind the arguments for the 1969 Agrarian Reform, while a history of uneven power distribution and disenfranchisement fuelled political discontent that manifested in the form of leftist Maoist-styled rebellion in the 1980s – most notably the Shining Path and the Túpac Amaru Revolutionary Movement groups (Muller et al. 1991). They declined in influence under President Fujimori's right-wing neoliberal government, which sought to repress their resistance movements, although conflicts are still ongoing to a limited extent. Gregory (2009) has noted that the Shining Path's continued presence could flourish in the rural areas that are ignored by government.

4.4.2 Failure of Agrarian Reform

There was much political tension leading up to Velasco's agrarian reform Decree Law 17716 in 1969 (Albertus, 2010). The reform claimed to promote poverty reduction and indigenous farming values through cooperative tenure systems. It is also credited for liberating numerous indigenous people from providing unpaid and forced labour, while creating top-down policies that often excluded the indigenous rural poor while aiming to benefit commercial farms (Respondent 12, August 13, 2009; and Respondent 13, September 25, 2009).

Peru's agrarian reform of 1969, lasting until 1980, was highly controversial and implemented after General Juan Velasco Alvarado led a coup and overthrew the previous president (Albertus, 2010). One of its main initiatives was to expropriate Andean estates larger than 15-55 hectares (Long & Roberts, 1994; and Albertus, 2010). Within a decade of its implementation, 15,000 properties covering nine million hectares were appropriated and distributed to 300,000 families (La Serna, 2010). The reform saw 45% of agricultural land in the country appropriated and redistributed as mostly small cooperatives of around 5,000 ha (Albertus, 2010). One respondent describes this as the disappearance of large farms and the formation of rural communities composed of smallholder farming systems

(Respondent 11, August 13, 2009). Small land holdings contributed to sprawl and the development associated with an expanding tourism industry, which encroached upon agricultural lands.

The reform came up frequently in interviews and conservations in Peru. Prior to Velasco's reform, peasants were deprived of food and education, whereas now some youth can read and write (Respondent 13, September 25, 2009). One respondent believes there has been progress for Andean peasants; however, the government forgets about them still (Respondent 13, September 25, 2009). The division of power between the Andean peasants and the urban rich was seen as the reason for support for Agrarian Reform (Respondent 12, August 13, 2009).

Boelens (2006) believes that indigenous and communal irrigation management organizations, their livelihoods and water security itself are threatened by contemporary neoliberal policy due to what is perceived as an excessive emphasis of water value in market and profit terms. Important questions to ask are, who controls water access and rights, and how water reforms influence this control. Like agrarian reforms, water reforms alter rights to a resource vital to agricultural production (Boelens & Zwarteveen, 2005). It was argued that a transfer of entitlements to water, therefore, will not necessarily be readily accepted without protest. Centralizing and privatizing water for market purposes is constructed for profit and allows a water market to develop.

This market grew increasingly unstable due to lack of monitoring, and General Velasco attempted to improve upon this by establishing his General Water Law (17752).

This codified water law was in place until 1969 (Condori Luque, 1995). The new law declared that all water become the property of the state, and absorbed hacienda owners into water user groups, with all the rights and responsibilities defining this theoretically more collective and egalitarian water arrangement (Trawick, 2003). The state appropriated all water, in particular privatized water sources, and redistributed it to the communities. An important point made by Trawick (2003) was that the money redistributed from privatized sources was not necessarily re-delivered to the communities from which they originated, and the disparity that has been exacerbated by long-term privatization policies have continued.

Most indigenous highland land holdings continue to exist within the unevenly distributed agrarian system consisting of latifundios (over 500 ha commercial estates) and minifundios (under 5 ha mostly subsistence smallholder indigenous farmers), despite the agrarian reform's land redistribution (Griffiths, 2004). Increasingly, population growth has been transitioning minifundios into microfundios (less than 1 hectare of landholding), which is inadequate for subsistence farming. The emergence of microfundios was described by a community farmer, and said that with this, smallholder farming has begun to disappear (Respondent 11, August 13, 2009). It was stated by a community farmer that the area for cultivation per farmer has become too small, with each farmer having less than a hectare of cultivation, which is insufficient to feed an average family. As of 2005, only 25% of farmers in the District have more than 3 hectares of land, so the remainder often survive on less than 100 soles of monthly family income – a situation compounded by the fact that at least 60% of agricultural production is for subsistence purposes and does not generate an income (Cavero et al., 2005). By feeding themselves with their own production and engaging in barter, however, little money is spent on food (personal communication, November 4, 2011).

Even with a sound agricultural policy, agriculture cannot advance if cultivation areas are too small (Respondent 11, August 13, 2009). The diminishing access to adequate land also reflects diminishing water rights. Without adequate land to irrigate, maintaining irrigation schemes becomes increasingly difficult. As a result, it has become increasingly difficult to produce surplus food, and has contributed to an increased incidence of outmigration (Griffiths, 2004). The stress of rural outmigration is felt in Mullak'as-Misminay, not only due to population loss, but also because of what is described as a shift in values (Respondent 13, September 25, 2009).

4.4.3 Disenfranchisement and Rebellion

The disenfranchisement created out of uneven distribution of power, and manifested by diminished access to resources and opportunity, helped sow discontent. The Shining Path first emerged out of Ayacucho, an Andean department neighbouring Cuzco, and the region with the lowest percentage of people having access to clean water (Guran, 2008). The country had experienced a profound history of not only great economic disparity, but also suffered under weak governments. These elements all created the conditions necessary for the Marxist-inspired Shining Path as well as Tupac Amaru Revolutionary Movements to flourish; events whose roots were laid around the same time as Velasco's coup and subsequent reform (Respondent 12, August 13, 2009). These movements especially took hold in the 1980s, coinciding with the era in Latin

American and Caribbean history referred to as “the lost decade” of broad financial crisis (Garcia, 1998). One respondent contended that the terrorism brought some degree of respect from to Andean people from the rich urban people (Respondent 12, August 13, 2009). The sentiment of ongoing disrespect for Andean customs and rural people by the government was expressed (Respondent 9, August 10, 2009).

4.4.4 Government

The Lima Declaration in March of 2008 promoted the adoption of IWRM through institutional and legislative mechanisms, while also building capacity for water markets (Global Water Partnership, n.d.). The National Water Authority (ANA) emerged in that same year as a result of the Lima Declaration and the National System for Water Resources followed shortly after.

Both the 2009 Water Law and the 2004 National Water Resources Management Strategy helped lay the foundation to implement integrated water resource management in Peru (Comision Tecnica Multisectorial, 2004). The National Water Resources Management Strategy combined sustainable and integrated water management with the conceptualization of water as an economic good (Olson, 2007). One farmer in Mullak’as-Misminay described how they did not always have to pay for water, but they now have to pay, which may be the result of the National Water Resources Management Strategy implementation (Respondent 14, September 25, 2009). One respondent mentioned there may be increases in water fees (Respondent 1, August 3, 2009).

The new water law establishes water markets, which have been criticized by farmers as diverting water away from local irrigation and channelled to serve extra-local economic benefits, potentially at the expense of local social good (ibid, and Olson, 2007). IWRM also emphasizes the implementation of comprehensive water rights, although the manner in which these rights manifest, and how they interact with water markets may remain to be seen (Poveda, 2007).

IWRM has been defined as “a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems." (GPW, n.d.). The principles of IWRM surround participatory, basin-scale water management through the integration of policy sectors, decentralization, and a legal acknowledgement of water as both a social and economic benefit (Comision Tecnica Multisectorial, 2004). International financial institutions, such as the World Bank, have taken an active interest in IWRM transitions, supporting the expansion of market-oriented production through decentralized governance (Garcia, 1998).

IMA and its partners are involved in projects to bring water from other areas to supply drinking water to Maras (Respondent 3, August 7, 2009). Organizations that the government collaborates with include Plan Meriss Inka, IMA, Seda Cuzco (municipal that provides basic sanitary services), the water user boards, a committee of irrigators and regional watershed councils (Respondent 10, August 12, 2009; and Respondent 18, September 29, 2009). The regional government has created a platform for managing water resources (Respondent 10, August 12, 2009). It is comprised of public and private bodies as well as water users (users including for irrigation, mining, and consumption). This platform aims to develop a strategy to administrate water resources and enable the development of plans to improve water management in the Cuzco region. While it was acknowledged that the government has funded some infrastructure and education projects, one respondent has said it has not funded agricultural initiatives in Mullak'as-Misminay (I13).

4.4.5 The Road to Privatization and Modernity

Privatization has enhanced haciendas' private rights at the expense of indigenous communities' water rights, which caused considerable opposition and conflict (Boelens & Zwarteveen, 2005). Under the hacienda system, many of these large estate owners appropriated water from indigenous Andean communities, claimed the water as private property, and diverted its flow to populated colonial areas down the mountain. This system of water privatization was legislated in 1902, and led to a large-scale transition in irrigation water (Trawick, 2003). In 1931, the Official Procedures for Water Administration were implemented in Peru. A communal-private local water market emerged, where estate water originating from communities could be bought and sold. At times peasants purchased the water that originated from their communities to supplement insufficient water supplies to meet subsistence needs.

The 1969 General Water Law No. 17752 included a series of new regulations that were meant to improve the water situation, but did not (Respondent 3, August 7, 2009). The respondent believes that the creation of watershed councils empowered to plan, manage, and administrate water resources under the new law that is part of the IWRM process makes it more effective and also approaches management in a more integrated manner, rather than the segregated components covered under the 1969 law (Respondent 3, August 7, 2009).

When Paul Trawick wrote his critique of water privatization in the Peruvian Andes in 2003, he warned that a privatization law would "such a reform would only turn the clock back, making the countryside a much less viable place for peasants to live in than it is, and ultimately only encourage their flight to the cities, thereby worsening the plight of the country instead of improving it" (Trawick, 2003: 992-993). The elements of privatization are one of the most prominent reasons that make the Water Law Reform so contentious and have made villagers "very angry" (Respondent 4, August 8, 2009; and Respondent 12, August 13, 2009). The issue of contemporary water tension was identified by respondents. One respondent even mentioned that water was such a contentious issue that there are many court cases involving water, and she mentioned that people even kill for water (I3/4). This anger has created response in the form of a general strike in August 2009 in protest of this law (Respondent 4, August 8, 2009). Protests across Urubamba were occurring months earlier, with a general strike launched in January by the National Water Users Board and Irrigation Districts. This strike took the form of road and rail blockades, and strikers were specifically resistant to the privatization process, which they believe will increase irrigation costs. They also believe it could result in an increasingly threatened resource be allocated to commercial farming interests (Peruvian Times, 2009). At the time, the Environment Ministry reported over

1,000 water-related conflicts in Cuzco (Guardian News, 2010). A wave of protests swept through Cuzco in September 2010 as well, as one case in the Cuzquenan province of Espinar had peasants protesting the government's construction of a large reservoir, leaving residents and those from adjacent provinces worrying they will lose their water (Statesman, 2010; and Respondent 10, August 12, 2009). Given this conflict, the province of Espinar is suing the central government and demanding that the Cuzco government defend the water resources of the area (Respondent 10, August 12, 2009). This case is an example of water being drawn from the higher Andes and redirected for export commercial food production (Guardian News, 2010). The use of water in agriculture is very different on the coast than in the Andes, and as such the new law is critiqued for being too general and coast-biased despite its decentralized basin-style management approach (Respondent 10, August 12, 2009). This bias has resulted in Andean agriculture stagnating due to lack of government support (Alegria, 2007). It was stated that the contents of the new water law, 29338, favour the coast, as seemingly the coast uses less water with their centralized pressurized irrigation systems and efficient use of water. Implementing these irrigation systems requires a significant financial investment. One respondent sees investments in irrigation projects as an opportunity to prevent the springs from drying, but believes these investments depend on the government committing to finance a project to bring in water (Respondent 13, September 25, 2009). Changes in the water law and the manner in which they will impact irrigation costs were referred to by respondents (Respondent 12, August 13, 2009; and Respondent 18, September 29, 2009). It was stated that even when farmers are not using water for agriculture, they will still be charged, and that state policy is moving towards privatization in the effort to maximize resource use and management, and this results in communities' water being delivered to companies who then gain rights to the resource and local people losing their autonomy in their control over their own resources (Respondent 18, September 29, 2009). This manifestation is disconcerting to the respondent as he expressed preference for communities to retain administrative control over their resources, as they have traditionally held (Respondent 18, September 29, 2009).

One of the main sources of contention surrounding the new law can be found in Article 2. A portion of Article 2 of the law was removed, which explicitly stated that the administration of water resources will be not for profit, instead leaving in its place that water is not privatized. Additionally, the Peasants' Confederation of Peru (CCP) argues that while the law discusses decentralization through regional governments, the decision-making remains concentrated at the national level (Hancco et al., 2009). Privatization is promoted through private operators setting prices, state promotion for private sector participation in the construction and maintenance of water systems, and overall promotion by the state for private investment. Article 112 of the law explicitly states that it supports private investment for the collective use of groundwater and the provision of its respective services (Autoridad Nacional del Agua, 2009). Additionally, water projects and infrastructure are likely to be executed and managed by the private sector, and those currently managed by public funds will likely be delivered to private management.

Privatization is occurring in various sectors as well, with the government privatizing mining and land, which has led to mining companies buying lands and using local waters for their own purposes (Respondent 9, August 10, 2009; and Respondent 19, October 23, 2009). The region receives mining royalties; however the respondent does not know how it benefits the region (Respondent 9, August 10, 2009).

Many Latin American countries, including Peru, implemented agrarian reforms in the 1950s and 1970s that included land redistribution with the intent of modernising the agricultural sector (Griffiths, 2004). Beginning in the 1950s and in particular the 1960s, the green revolution swept through the developing world through the export of modern Western agricultural technology in order to create abundant food production, including the use of high-yield crop varieties and pressurized irrigation (Gonzales, 2000, and Shiva, 1991). Modernizing agriculture includes accompanying infrastructure such as roads, along with machinery, and encouraging market-oriented food production.

The main argument behind the green revolution was advocating food security and autonomy for farmers in the developing world. However, some have argued that in reality the beneficiaries of this revolution were predominantly the international aid organizations and agrochemical corporations, whether this was the intended result or not (Shiva, 1991). Combined with the 1969 Agrarian Reform, the green revolution paved the way for intensified agriculture in the Peruvian highlands, which resulted in the general use of agrochemicals in Maras in 1975 (Cavero et al., 2005). This was largely the result of outreach programs, technology transfers and promotions geared towards increasing production.

Additional strategies included the pressure to implement crop specialization through monocultivation, and combined this fed the export agribusiness industry (Gonzales, 2000). Proponents have hailed it as a success, crediting the end of widespread famines to the increased grain production, with global food production increasing between 1966 and 2000 (Khush, 2001). Peru saw an overall increase in its grain production, with an overall increase in national corn production of 530.9% between 1960 and 2010 (Index Mundi, 2011).

Critics of the green revolution have linked its implementation to additional environmental degradation such as soil erosion experienced, as well as decreased soil fertility due to salinization, the exacerbation of existing water scarcity and the creation of new shortages, and more pests and diseases (Shiva, 1991). Additionally, Shiva (1991) cautions against embracing technology, such as pressurized irrigation, as the answer to scarcity and road to abundance, in that such methods can lead to increased soil water scarcity in the interest of short-term gain and at the expense of long-term water and food security.

Peru has been actively promoting its agricultural sector through a series of policies aimed to increase competitiveness in the world market (Encyclopedia of the Nations, 2011). To this end, hundreds of bills were passed to help intensify agriculture, including land privatization and land ownership regulations.

Steps towards modernization in the agricultural sector have included mechanization and agrochemical use, which were not part of sustainably managed traditional agricultural practices (Altieri, 1996). These steps are taken to help intensify production for greater market interaction, which critics argue degrade lands, erode local knowledge, and disempower rural Andean populations. Some mechanized technology such as tilling can lead to greater soil erosion. Intensified agrochemical use also exposes water systems to toxins (Sherwood et al, 2000). These modernizing trends have resulted in reduced crop varieties, shorter fallow times, as well as favouring monocropping of high-yield species over rotational agricultural systems that employ a diversity of species to preserve soil nutrients (Sherwood et al., 2000; and Halloy, et al, 2005). The less-intensive approach involved in rotational practices may result in lower yields, however may prove to be more sustainable in the long-term. Widespread monocultivation in the Andean highlands can further deplete soil fertility and the diminished productivity may not be sufficient to meet the needs of subsistence communities (Lopez-Ocon, 1987). Diminished productivity has been cited as a concern, with community residents soon not able to produce their own food (Respondent 1, August 3, 2009).

Genetically modified food was discussed as an environmental, economic, and community hazard, as well as a threat to sovereignty (Respondent 18, September 29, 2009). In November 2011, Peru's Congress has approved a ban on genetically modified crops for the next decade – a decision which the Cuzco regional government has supported since 2007 in order to help preserve native plant varieties (Agence France Presse, 2011). GMOs were represented as a threat to food security, due to transgenic deterioration in native plants. This occurs when native plants are crossed to form hybrids, which then become sterile. Additionally, gene-modified crops often respond to extreme environmental conditions in unpredictable ways, making risk management difficult (personal communication, November 4, 2011). Successful manipulation of plant diversity in coordination with dynamic mountain microclimates is one of the critical manners in which Andean communities are able to survive in their environments. Thus preserving and promoting plant diversity is an important part of Andean resilience. Some locals perceive native potato species as the foundation for future solutions for production, diseases, and adaptation, and economic and political systems threaten the livelihoods that maintain this plant diversity (Respondent 18, September 29, 2009).

Biopiracy was an issue that arose in one interview as well. Biopiracy can be defined as the "commercial development of naturally occurring [materials] by a technologically advanced … organization without fair compensation to the peoples … in whose territory the materials were originally discovered" (The Free Dictionary, 2009). This phenomenon was identified by one respondent as a threat to Andean communities of Cuzco, who mentions that the regional government has dedicated itself to conserving biodiversity through the protection of ancestral local ecological knowledge. However, implementing this is a challenge when it comes to education (Respondent 10, August 12, 2009).

4.4.6 Financing and Equity Issues

Pressurized irrigation has been lauded as one mechanism to enhance market-integration for Andean farmers. One of the greatest obstacles to implementing local pressurized irrigation in the community was believed to be the state's policy and laws, with few supporting local water security (Respondent 18, September 29, 2009; and

Respondent 23, November 24, 2009). While the regional government has provided financial support for the irrigation system in Maras, farmers of smaller communities such as Mullak'as-Misminay find it more difficult to secure support for their own projects (Respondent 20, November 23, 2009). The pressurized irrigation system provides sufficient water to Maras, although one respondent believed Mullak'as-Misminay does not have enough (Respondent 5, August 8, 2009). Boelens and Bustamante (2005) describe both neoliberalism and government downsizing that lead to public sector cutbacks as well as cutbacks in water management. As a result, the state is able to fortify its control over local water sources. It has been observed that the local irrigation committee and the state share different goals regarding water, with the state being profit-driven (Respondent 18, September 29, 2009). Furthermore, respondents have remarked how little the government represents or supports rural indigenous farmers and communities, and their privatization schemes shows disrespect for Andean customs (Respondent 18, September 29, 2009; and Respondent 22, November 24, 2009).

There was discussion of government assistance during times of water scarcity. For example, when there is less rain the government provides limited support through the provision of basic necessities such as sugar, however this is considered insufficient (Respondent 13, September 25, 2009). The local government has provided community members with seedlings to assist in water recovery during times of stress. What is needed is the tools to secure a good harvest and the food produced will be long-lasting (Respondent 13, September 25, 2009).

4.4.7 Enabling and Disabling Role of Development and Aid

Poverty alleviation and environmental issues are often addressed in tandem by multi-level actors. Such is the case with the LIFT-UP project with CARE Peru that aimed to find strategies to finance pressurized irrigation projects at the parcel-level for smallholder farmers that can produce a given return through market integration. This poverty alleviation focus was bundled as a climate change adaptation project to better utilize increasingly variable water sources. The poorest farmers with the least market access were omitted from consideration, as were those communities not undergoing glacier retreat (Conversation with Climate Change Team, October 2009). The prevalence of glacier retreat in the literature helped create the emphasis on adaptation and water security for communities directly affected by that particular phenomenon, even though adjacent communities without glaciers face increasing water security challenges from current and future stresses.

Respondent 3 (August 7, 2009) has mentioned there is a lack of long-term support to address the root cause of poverty, with government focussing on short-term solutions. Instead of giving a small amount of money for food, Respondent 3 (August 7, 2009) suggested giving poor people credits to develop a productive project that can be transformed into a long-term source of income.

"There are many challenges with respect to water", according to Respondent 2 (August 5, 2009). "There are many projects but now there is no money, and these projects are not done. If there were NGOs that really gave their support it would be really good, but there are many NGOs that only come to earn money" (Respondent 2, August 5, 2009).

There are many NGOs in the Urubamba province that lend support to farmers' work in livestock rearing and reforestation initiatives, according to a representative from the Ministry of Agriculture (Respondent 11, August 13, 2009). Plan Meriss Inka and IMA have done three large water projects throughout the Maras district (Respondent 10, August 12, 2009).

4.4.8 Water Rights

As Boelens & Dávila (1998:1) have said, "[i]n the field of irrigation, it is especially peasant and indigenous populations who are losing control over the process of water management and its benefits, while carrying most of the burdens". One of the most resounding patterns of that burden includes recurring threats to water security. (Delgado et al., 2008) have shown through case study examples that the smallholder Andean farmer's irrigation and water rights are not always adequately recognized.

A community respondent has discussed a concern regarding a shift in water access with users, whereas before each farmer could carry the amount of water required for their individual needs, whereas now water allotment is measured to ensure everybody is granted the same amount of water (Respondent 13, September 25, 2009).

The Fujimori's neoliberal government modified water user association rules, including transferring decision-making powers from smaller water rights holders to more powerful ones. The question of property rights also comes into play, as those who control rights also control the allotment, distribution, and management of water. As such, conflicts over the water law reform have revolved around controlling what a water right is (Boelens & Zwarteveen, 2005).

The Water Resources Law recognizes customary law governing water resources so long as it is not contrary to formal law. Under Peruvian customary water management systems, water rights are distributed to households within a community, based on a hierarchical system. Existing water rights are often governed by turn, a right to irrigate a plot of land in rotation with other legitimate users of the same resource (GOP Peru Water Resources Law 2009a; Trawick 2003).

The topic of water rights was explicitly addressed by Respondents 13 (September 29, 2009) and 19 (October 23, 2009) representing non-governmental organizations. Both suggest approaching water use optimization and management in communities from a rights perspective. In addition, two respondents mentioned farmers are ready to fight for water, and see education as a form of empowerment that supports this fight (Respondent 9, August 10, 2009; Respondent 13, September 25, 2009; and I16).

One respondent believes that there should be studies that not only optimize water use and management, but do these in combination with respecting the rights of people (Respondent 18, September 29, 2009). Some believe the water tension could be mitigated by empowering local communities to strengthen localized control over community needs (Respondent 13, September 25, 2009). To this end, regaining control entails educating children in the community to enable them to gain key positions within the community. Several respondents discussed the need for community training, in particular with agricultural and water conservation capacity-building (Respondent 2, August 5, 2009; Respondent 3, August 7, 2009; Resondent 7, August 10, 2009; Resondent 11, August 13, 2009; Respondent 18, September 29, 2009; Respondent 13, September 25, 2009; and Respondent 20, November 23, 2009).

Boelens & Zwarteveen (2006) argue that upholding water rights provides the opportunity to assign maintenance duties to those who are also beneficiaries of the water source. Within irrigation schemes, water rights can consist of a protocol for distribution as well as involvement in meetings and organizations. Water delivery regimes as well as rotation schedules can be understood as manifestations of water rights. (Boelens & Zwarteveen, 2005). As such, the manner in which water rights are expressed can be highly-localized and based on the needs of the specific context of Mullak'as-Misminay.

Chapter 5: Discussion and Conclusion

This study examined numerous elements that have, and in some cases continue to, impact water security in the indigenous community of Mullak'as-Misminay. The highland area is prone to ecological events making it susceptible to erratic water supplies. In combination with the multiple, intersecting anthropogenic influences exerted upon the Mullak'as-Misminay, the state of the community's long-term water security remains precarious. This chapter reviews the four research questions of this thesis. Each question is examined based on data collected through interviews, personal observations, and supporting literature, followed by a conclusion arguing for an indigenous Andean model for water rights and an exploration of the implications of this research for the realms of policy, practice, and research. Through this study, the thesis objectives aiming to identify the key shocks and responses in the community and region; understand the evolution of the community-water relationship; and identify the innovative practices leading to resiliency have been met to varying extents. Additional research would be ideal to further explore these, and in particular to more fully illustrate the evolution of community-water relationships in the Peruvian highlands.

5.1.0 Multiple Stresses to Water Security

The first thesis posed in this thesis asked what multiple stresses have acted as perturbations to water security in Mullak'as-Misminay. Throughout the region's history, the climate has fluctuated between dry and wet periods, at times bringing extreme events such as long-lasting droughts that diminished water supplies as well as reduced vegetation cover. Human developments and adaptations have emerged when favourable ecological conditions provided fortuitous opportunities, as well as innovations born of necessity in the face of challenges. With some adaptations and responses, optimum conditions allowed societies to exploit local resources, although sometimes producing excessive or maladaptive behaviours that proved detrimental to water supplies.

The main ecological stresses affecting water security in Mullak'as-Misminay pertain to climate change and in particular temperature change, precipitation changes, frost occurrence, and changes with pest and diseases affecting plants. The local climate does not offer an abundance of water, and requires careful spatio-temporal planning in order to meet the socio-ecological system needs. The semi-annual seasonal regime has become increasingly unpredictable, with erratic rainfall patterns giving way to droughts as well as heavy rains. The community's water endowment does not include glaciers, large rivers or lakes, and therefore the main water sources are surface springs, groundwater and rainfall. While glacier-retreat occupies a prominent place in climate change literature for the region, the phenomenon should not overshadow the processes occurring in semi-arid and arid Andean communities with even fewer sources of water and overall availability such as Mullak'as-Misminay.

One of the main groundwater springs in Mullak'as-Misminay used to lead to Moray, but was re-diverted to the Maras District where it feeds into the pressurized irrigation project funded with the assistance of the Cuzco regional government. This is a significant event, as Moray represented the platform for an evolving local ecological knowledge and the calculated spatio-temporal delivery of water with this specific water source. Previous research suggests that the use of Moray greatly developed local ecological knowledge pertaining to water and agricultural management in manners that bolstered resilience and buffered risks common to the region's microclimates. However it no longer served its original function due to water diversion but also the decline of terrace systems.

The main stresses relating to local behaviour that impact water security in the community involve forestry, agricultural management, pollution, and inadequate infrastructure and services. The exotic eucalyptus tree species is more detrimental to water security than it is beneficial, as it extracts too much water from an already semi-arid climate, and can contribute to soil water scarcity. Loosely regulated zoning combined with an expanding population has led to the takeover of forested areas by agricultural fields and human settlement.

Native tree species have diminished considerably either through mismanagement or by the prioritization of invasive or exotic species such as pine and eucalyptus trees. Additionally, the management of drought and cold-resistant vegetation that complemented surrounding crops by enhancing soil moisture and fertility are part of the compendium of local ecological knowledge contributing to water security. The region, and possibility the community, are faced by pressures to focus on monoculture and non-native production-oriented tree species.

Agricultural management problems are also linked to water security issues. In particular, agricultural management practices such as the burning of grasslands have contributed to soil erosion and loss of soil fertility. Soil erosion can contaminate water supplies. Agrochemical use pollutes water supplies through surface runoff. Poor waste management practices can lead to contamination, which unlined and open canal systems such as those in Mullak'as-Misminay are particularly vulnerable to.

Inadequate infrastructure and services are a problem in the community, with water at risk of being contaminated by human waste, and lack of chlorination leaving water untreated. This has caused bacterial contamination and parasitic intestinal worms, most notably in children. Unplanned development sprawl that is currently occurring in Mullak'as-Misminay is considered to be a continuing barrier to the implementation of sanitation services.

5.1.1 Community and Regional Responses to Stress

The second research question asked what practices have been developed in the community and region over time in order to respond to the stresses encountered. These have included reciprocal social labour coordination, livelihood diversification, agricultural strategies and in particular vertical terraces, irrigation methods, and agroforestry management. These have all been developed through local ecological knowledge and guided the evolution of water security in Mullak'as-Misminay.

Ayllus have historically orchestrated social labour in such a way as to meet the water needs of their challenging environment by optimizing verticality and controlling the different microclimatic niches in terrace agricultural systems, among other strategies. This was achieved through reciprocity and kinship organization in the form of shared responsibilities and benefits that sought to optimize water and crop use potential, as well as growing days. Reciprocity is practiced through the ancient social customs of ayni, faena, and minka. With these practices, participants who contribute to the projects to benefit the community also get to derive their benefits. Survival in such harsh mountain environments throughout history has been attributed to these systems. A long-standing tradition in the Andes has been to barter through networks in order to exchange goods that were produced through vertical resource management. Local economy and exchange systems overlap with the neoliberal modern state, although bartering systems have been increasingly relegated to more marginal interactions as network relationship dynamics change.

Livelihood diversification has also been a key strategy in the Andes. When socio-ecological systems face perturbations that disrupt water security, the ability to shift livelihood emphasis helps people adjust to the new social or ecological parameters created by the disturbance. This flexibility is particularly relevant to smallholder farmers who may need to diversify skills and who often manage to maintain a household-level subsistence lifestyle. In Mullak'as-Misminay, residents engage in diverse economic activities involving the tourism, commercial and mining sectors. However, as 79% of the economically active population engage in agriculture, this represents the dominant economic sector and one that is especially dependent on careful water management (Cavero et al., 2005).

Agricultural strategies have developed through the careful application of local ecological knowledge in order to make the best use of scarce water resources. With proper planning, highland people learned to use drought-resistant crops in areas more prone to drought, while diminishing the severity of frost impacts on yields. Rotating crops is another strategy that has been employed by people in the community to maintain soil fertility, while diminishing the incidence of pests and diseases. Further, agricultural schedules are developed around seasonal rainfall patterns. As rainfall patterns change, agricultural duties are adjusted accordingly. This, however, has become increasingly difficult with the change in biotic and abiotic indicators used to forecast seasonal weather conditions, and the increasing variability in weather conditions. Local ecological knowledge informs the reading of indicators used to forecast rainfall, and this includes by interpreting the Pleiades constellation throughout the summer months. The process of interpretation, planning, and application is embedded within local cultural rituals and celebrations. These customs help codify the communal collaboration that enable traditional agricultural systems to function.

Vertical terraces were critical to pre-Hispanic agricultural management, and employed an efficient spatio-temporal water delivery system along each level. These constructions helped address the challenge cultivating on slopes. They were particularly useful in mitigating water-related weather risks such as droughts. In Mullak'as-Misminay, Moray is a monument to the combination of applied local ecological knowledge for water and crop management. Moray is no longer used as an experimental agricultural terrain, and its use has been reduced to a tourist attraction. Many vertical terraces face abandonment due to socio-political changes or have already been abandoned. While vertical terrace systems help improve water security, unmaintained terraces can lead to greater erosion and hinder it instead.

The area also has a long and complex history of irrigation, and one that is undergoing significant changes with pressurized irrigation systems. Recent evidence has found irrigation canals in the Andes dating to 5,400 to 6,700 years ago, when the region was experiencing increased aridity. This suggests that the development of irrigation may have been a corresponding response to the increased need for water, by controlling access to avoid fluctuations. Large-scale traditional systems were developed in areas where water is scarce and these were likely achieved through heightened political coordination that could organize the labour required.

Mullak'as-Misminay possesses flood irrigation only; a traditional method contrasting pressurized irrigation of modernized systems. However, residents have expressed the desire for pressurized irrigation, which is a more expensive option to implement and maintain. The building of reservoirs was also listed as an important adaptation to increasingly erratic rainfall, in order to store more water for the dry season. This was especially important given the challenges associated with pressurized irrigation.

Planting was identified as another mechanism contributing to local water security. Native plant and tree species have produced significant benefits to water security. Large-scale agroforestry was particularly important to the Inca empire, which helped mitigate soil erosion. Vertical terraces were stabilized to diminish erosion with the help of flora species. Native tree species possess important properties that can bolster water security. Some are especially suited to withstand high altitudes, cold temperatures and droughts, while conserving water and boosting soil fertility.

5.1.2 Relationship between Marginalization, Stresses and Responses

The third question posed in this research examined how conditions of marginalization related to the impacts of and responses to climate change and water security-related perturbations. Since the conquest, indigenous people have faced systematic marginalization enforced by legal, political, and cultural instruments. This resulted in a mass population collapse, large-scale population resettlements in reducciones, largely unequal land holdings under the latifundio-minifundio system that resulted in diminished access to water as well as land, and devaluation of traditional societies. Given that many of the world's most vulnerable populations are at risk of suffering the most negative climate change impacts, it is very useful to explore not only the consequences but also the manners in which advantages may have spawned out of disadvantages, and provide a fresh perspective on the role of vulnerability in resiliency.

Interview questions were specifically structured around the following elements of marginality: indigenous status, poverty, and location in the rural periphery. The difficulties discussed by respondents in terms of drivers for adaptive responses often pertained to ecological stresses rather than anthropogenically-driven system shocks. Attempts to generate in-depth discussions on this topic were unsuccessful. In particular, community respondents did not discuss historical topics, and responses reflected a more recent history.

5.1.3 Role of Multi-Level Relationships in Water Security

The final question investigates how multi-scale relationships supported or hindered water security, resiliency, and adaptive capacity. This question is best answered by embedding the issue of marginalization within the interacting levels of governance and relationships. Since the Spanish conquest, multi-level relationships became particularly problematic for water security in highland ayllus. The colonial period consisted of laws, policies, and practices that worked to marginalize indigenous populations through forced assimilation and, to a great extent, destruction of their customs, while appropriating local socio-political traditions that benefited their conquest. With the conquest, water management practices and values were vastly different than those formerly in place. Consequences to water security included a departure from communally-owned water resources and the reciprocal labour formations that managed them, with diminished water access and weakened control over local resources for indigenous populations.

To some extent, post-colonial patterns reverberate through modern nation-states, and marginalization of the rural indigenous poor continues to this day. Integrated water resource management is adding complexity to multi-level relationships in the Andes, as the participatory multi-stakeholder and decentralized management approach promoted through the new Water Law is also interwoven with privatization.

A few recent examples of local responses manifested in the region surrounding Maras in the form of political and socio-economic mobilization. Protests in the form of general strikes and civil disobedience rippled throughout Cuzco in response to the privatization elements of the recently enacted Water Law reform. One road blockade prevented the researcher from entering Maras from Urubamba. Smallholder farmers were especially concerned about the impacts these developments would deliver upon their access to water, which had the potential to deepen their marginalization.

Multi-level governments along with international financial institutions have been increasingly pressuring Andean populations to intensify their production by modernizing their water and agricultural technology and approaches. The global green revolution reached far into the Andes, rigorously advocating strategies to increase crop yields and intensify production. Many of these strategies, such as monocropping, agrochemical use, and pressurized irrigation, were poorly suited for the fragile mountain terrain and precarious water supply – two areas requiring specialized knowledge of the geographical landscape and hydrological cycle in order to maintain a balance. While agricultural output rose sharply, critics such as Shiva (1991) consider this a short-term success, sometimes at the expense of long-term water security due to erosion, salinization, and soil depletion. The more financially profitable the agricultural output, the more it has been prioritized by government. The diversion of water away from traditionally irrigated Moray to feed the Cuzco government-funded pressurized irrigation projected in the District town of Maras provides such an example of this prioritization. Agricultural output produced in the District, and particularly Maras with its pressurized irrigation system, are sold in provincial (Urubamba) and regional (Cuzco) markets, but do not reach national or international markets. The communities such as Mullak'as-Misminay making up the Maras District engage in mostly subsistence agriculture. The District views low crop yields combined with lack of market integration as the reason for the lack of profitability, stating that smallholder farmers have not made investments to modernize their productivity because they prefer traditional technological approaches to agricultural production, and do not have a concept of money (Cavero et al., 2005). This example demonstrates the tension between traditional and modernizing agriculture and water management, as well as continued perception of the “ecological Indian” myth of indigenous societies lacking greed or being naive by ‘refusing’ to modernize for sake of traditional practices.

The issue of water management is subject to heated debate among Andean farmers in the region, with many desiring pressurized irrigation that is seen as a solution to increase efficiency and bring more stability amidst increasingly erratic rainfall. Pressurized irrigation does have the potential to increase productivity, with drip irrigation being particularly efficient, however the terms laid out by extra-local actors funding these systems for small communities may lead to short-term gain – gains especially enjoyed by urban markets – and long-term uncertainty for local recipients. The recipients of development and project assistance may not always be the primary beneficiaries.

Privatizing water for irrigation projects has long been promoted in Peru by various actors, including the World Bank. While the reforms in the Water Law contain the elements for integrated water resource management and a multi-stakeholder participatory process, the language implies a commoditization of this resource. Most notably, it supports the development of greater water markets. However, this may result in more water diversions away from local sources already utilized by subsistence farmers with promises of profitable returns that may not manifest themselves locally. The loss of local water supplies will increase the vulnerability of farmers already experiencing water-related stresses in an area expected to experience greater scarcity and unpredictable climatic changes.

The impacts climate change will have on the livelihoods of Andean farmers have led many organizations to combine climate change adaptation with poverty reduction strategies in an effort to enhance adaptive capacity and promote greater water security. Such is the case with CARE Peru, whose LIFT UP program for financing pressurized irrigation addressed climate change adaptation and poverty alleviation by embedding two prerequisites in their case studies for consideration: that the communities be glacier-fed and have market access. The prevalence of glacier retreat in Andean-focussed climate change literature is the reason for the glacier-fed prerequisite, while the need to produce a profitable return by expanding food production and distribution beyond the subsistence level is the reason for the market access prerequisite. Pushing subsistence economies to transition to market integration can produce unrealistic expectations and is something to be approached with prudence. Those communities that are the most distant from urban centres markets are often more isolated and poor, yet are rendered ineligible for consideration for this public investment scheme. And communities such as Mullak'as-Misminay that are not glacier fed yet still facing increasing climate change-driven water security challenges are exempt as well. Those communities can often be overshadowed by the more dramatic phenomenon of adjacent communities directly experiencing disappearing tropical glacier waters.

The inefficiency of traditional flood irrigation on slopes is cited in arguments for pressurized irrigation. Formerly ubiquitous traditional systems maintained by a complex body of labourers, which have not only functioned for centuries but were able to produce surplus food production, do not seem to be acknowledged in analyses promoting pressurized irrigation. Current water management strategies over-emphasize technological benefits and employ definitions of efficiency strictly related to the technology. This contrasts starkly with the historic Andean water management models rooted in reciprocity and complex socio-environmental control.

General Velasco's Agrarian Reform spoke of the emancipation of indigenous farmers from the slave labour that bound them to haciendas, and entailed a massive redistribution of land. The reform, however, failed to meet its goals of egalitarianism (Albertus, 2010). Similarly, the Maoist-inspired rebellions of the Shining Path grew out of deeply entrenched sentiments of disenfranchisement, yet manifested as violent, destabilizing guerrilla warfare that saw the very people it claimed to emancipate suffer the greatest casualties (Guran, 2008). Neither of these reforms and movements achieved any significant egalitarianism, as postcolonial patterns of unequal land holdings persist in the ongoing latifundio-minifundio system. As populations grow, the emergence of microfundios exacerbates the inequality experienced by indigenous farmers, while continuing to threaten water security.

5.1.4 Recommendations for Moving Forward

One theme that seems to emerge throughout the question of and quest for water security is that of water rights. Indigenous Andean water rights models in a manner that do not merely present platitudes for social justice but concretely address the needs, perspectives, and experiences of smallholder farmers should be further considered as an option. Specifically, flexible models that acknowledge and apply the layers of culturally-embedded local ecological knowledge combined with options presented by new technology and markets would be very valuable for amplifying water security.

Bibliography

Abrams, Len (2000). Water scarcity. The water page. Water Policy International Ltd. FAO. Retrieved from http://www.africanwater.org/drought_water_scarcity.htm

Agrawal, A. (2008). The role of local institutions in adaptation to climate change. Paper prepared for the Social Dimensions of Climate Change, Social Development Department, The World Bank: Washington DC. Retrieved from http://www.icarus.info/wp-content/uploads/2009/11/agrawal-adaptation-institutions-livelihoods.pdf.

Agudelo, C., Rivera, B., & Tapasco, J. (2003). Designing policies to reduce rural poverty and environmental degradation in a hillside zone of the Colombian Andes. In World Development, 31:11, 1921-1931. Elsevier Ltd: Great Britain. http://ibcperu.org/doc/isis/8828.pdf

Albertus, M. (2010). Redistribution by revolution from above: Land reform in Peru, 1968-1980. Stanford University research paper.

Altamirano, T., Copestake, J., Figueroa, A., Wright-Revolledo, K., (2003). Universal and Local Understanding of Poverty in Peru. In Global Social Policy, 4(3), 313-336. Doi: 10.1177/1468018104047490. Retrieved from http://www.welldev.org.uk/research/workingpaperpdf/wed05.pdf

Alegria, J. F. (2007). The challenges of water resources management in Peru. The University of Wisconsin Green Bay. http://www.uwgb.edu/envsustain/Full_paper%20Challenges%20Water%20Resources%20_JF%20Alegria_.pdf.

Al-Kaisi, M. M., Hanna, M., Licht, M. (2009). Soil Erosion & Water Quality. Edited by Tracy S. Petersen. Iowa State University: Iowa. Retrieved from: http://www.extension.iastate.edu/Publications/PM1901E.pdf.

Altieri, M. (1996). Indigenous knowledge re-evalued in Andean agriculture. ILEIA Newsletter, 7 – 8, Vol. 12, nº 1. Retrieved from http://www.agriculturesnetwork.org/magazines/global/mountains-in-balance/indigenous-knowledge-re-valued-in-andean

Andrien, K. (2001). Andean worlds: Indigenous history, culture and consciousness under Spanish rule, 1532-1825. University of New Mexico Press: New Mexico.

Armitage, (2008). Governance and the commons in a multi-level world. International Journal of the Commons, 2(1), 7-32.

Autoridad Nacional del Agua. (2009). Ley de Recursos Hidricos No. 29338. Lima, Peru. Retrieved from http://www.agrorural.gob.pe/dmdocuments/LeydeRecursosHidricos_29338.pdf

Azariadis, C. & Stachurski, J. (2005). Poverty Traps. In S. Durlauf and P. Aghion (eds) *Handbook of Economic Growth*, 2005, 326.

Agudelo, C., Rivera, B., & Tapasco, J. (2003). Designing policies to reduce rural poverty and environmental degradation in a hillside zone of the Colombian Andes. In World Development, 31:11, 1921-1931. Elsevier Ltd: Great Britain. http://ibcperu.org/doc/isis/8828.pdf

Barraclough, S. L. (2001). Agrarian reform issues and initiatives in three Andean countries in
South America. In K. G. Ghimire & B. H. Moore, Whose land? Civil society perspectives on land reform and rural poverty reduction. Italy: IFAD. http://www.landcoalition.org/pdf/whoseland_ch8.pdf.

Bates, B.C., Kundzewicz, Z.W., Wu, S., & Palutikof, J.P., (Eds.). (2008). Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 210 pp. ISBN: 978-92-9169-123-4
Retrieved at: http://www.ipcc.ch/pdf/technical-papers/climate-change-water-en.pdf, 2008: 182

Beall, C. M. (2007). Two routes to functional adaptation: Tibetan and Andean high-altitude natives. Proceedings of the Nationall Academy of Sciences U S A. 104(1):8655-8660.

Berdegue, J. A., & Escobar, G. (2001). Agricultural knowledge and information systems and poverty reduction. Agricultural Knowledge & Information Systems/Animal Resources. AKIS/ART Discussion Paper. The World Bank. Rural Development Family. Santiago, Chile. http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2001/06/29/000094946_0106150417535/Rendered/PDF/multi0page.pdf

Berkes and Folke, (2000). Linking Social and Ecological Systems: management practices and social mechanisms for building resilience. UK: Cambridge University Press.

Berkes, F., Colding, J., & Folke, C. (2000). Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications,* 10(5), 1251–1262 by the Ecological Society of America http://institutionalorganizationalecologies.files.wordpress.com/2011/01/trad-knowledge-adaptive-management.pdf

Berkes, F. (2005). Traditional ecological knowledge. In Taylor, Bron (Ed.), *Encyclopedia of Religion and Nature* (pp. 1646-1649). London & New York, Continuum. Retrieved from http://umanitoba.ca/institutes/natural_resources/canadaresearchchair/Encyclopedia%20of%20Religion%20And%20Nature%20Traditional%20Ecological%20Knowledge.pdf

Berkes, F., & Turner, N. J. (2006). Knowledge, learning and the evolution of conservation practice for social-ecological system resilience. In *Human Ecology*, 34(4), 479-494. Springer. Retrieved from http://www.cefe.cnrs.fr/ecores/RDV-SHS/Articles/Berkes%202006.pdf

Beyers, C. (2001). Directions in ethnohistorical research on the Inca state and economy. Centre for research on Latin America and the Caribbean Occasional Papers. North York, Ontario: CERLAC. Retrieved from http://www.yorku.ca/cerlac/documents/Beyers.pdf

Binford, M. W., Brenner, M., Abbott, M., Janusek, J.W., Seddon, M.T., & Curtis, J. (1997). Climate variation and the rise and fall of an Andean civilization. **Quarternary Research**. 47:235-248, article no. QR971882.

Bird, M. (2010). Critique of reciprocity: Shifting uses and meanings of ayni among Andean groups. In R. C. Marshall (Ed.) Cooperation in Social and Economic Life. (Ed) Cooperation in Social and Economic Life. (pp. 55-80). Society for Economic Anthropology Sea Monographs. AltaMira Press and the Society for Economic Anthropology. Toronto. http://faculty.wwu.edu/rcm/10_460_Marshall_1sts.pdf#page=77.

Boelens, R., & Gelles, P. H. (2005). Cultural Politics, Communal Resistance and Identity in Andean Irrigation Development. Irrigation and Water Engineering Group, Wageningen University, Wageningen, the Netherlands, USA
Bulletin of Latin American Research, 24(3), 311–327.

Boelens, R., Getches, D., & Guevara Gil, A., (2010). Out of the Mainstream: Water Rights, Politics and Identity. UK: Earthscan.

Boelens, R. & Davila, G. (1998). Searching for equity. Conceptions of justice and equity in peasant irrigation. Royal Van Gorcum: The Netherlands. Retrieved from http://www.iapad.org/publications/folderEquityADV+contents.pdf

Boelens, R. & Zwarteveen, M. (2005a). Prices and politics in Andean water reforms. In Development and Change, 36:4, 735-758. Wiley-Blackwell.

Boelens, R., & Zwarteveen, M. (2005b). Anomalous water rights and the politics of normalization. Collective water control and privatization policies in the Andean region. ESRC-funded Seminar Series: Water governance – challenging the consensus. Seminar 3: Politics, institutions and participation. Economic & Social Research Council & Wageningen University: The Hague. http://www.brad.ac.uk/acad/des/seminar/water/seminar3/waterConsensusSeminar3-BoelensZwarteveenPaper.pdf

Boelens, R. & Bustamante, R. (2005). Formal law and local water control in the Andean region: A field of fierce contestation. International workshop on 'African Water Laws: Plural Legislative Frameworks for Rural Water Management in Africa', 26-28 January 2005, Johannesburg, South Africa. Retrieved from http://www.dfid.gov.uk/R4D/PDF/Outputs/Water/R8323-Proceedings.pdf#page=139

Bohle and Kruger (1992) (BOHLE, H.-G. & F. KRÜGER (1992): Perspektiven geographischer Nahrungskrisenforschung.
In: Die Erde 123: 257-266.

Bookhagen, B., & Strecker, M. R. (2010). Modern Andean rainfall variation during ENSO cycles and its impact on the Amazon drainage basin. In C. Hoorn & F. P. Wesselingh (Eds.), Amazonia*, landscape and species evolution: A look into the past*, 223-241(1st ed.). Blackwell Publishing. Retrieved from http://www.geog.ucsb.edu/~bodo/pdf/bookhagen_ch14_enso_rainfall_color_figures.pdf

Bouwen, R., Taillieu, T., (2004). Multi-party Collaboration as Social Learning for Interdependence Developing Relational Knowing for Sustainable Natural Resource Management. In the Journal of Community & Applied Social Psychology, Vol. 14, Issue 3, (pp. 137-153), May/June 2004. Doi: 10.1002/casp.777

Brand, F.S., and K. Jax (2007). Focusing the meaning(s) of resilience: Resilience as descriptive concept and a boundary object. Ecology and Society, 12(1), 23. Retrieved from http://www.ecologyandsociety.org/vol12/iss1/art23/

Brooks, N., 2003. Vulnerability, Risk and Adaptation: A Conceptual Framework. Working Paper 38, Tyndall Centre for Climate Change Research, University of East Anglia, Norwich.

Brundtland, G. H. (et al.) (1987) 'Our common future', report of the World Commission on Environment and Development, Oxford: Oxford University Press.

Brush, S. B. (2004). Farmer's Bounty: Locating crop diversity in the contemporary world. Encountering crop diversity. Yale University Press. Retrieved from http://yalepress.yale.edu/yupbooks/excerpts/brush_bounty.pdf.

Capra, F. (1996). The web of life: A new synthesis of mind and matter. Hammersmith, London: HarperCollins.

CARE, n.d. CARE Peru.

Carpenter, S. R., & Brock, W. A. (2008). Adaptive capacity and traps. *Ecology and Society* 13(2): 40. Retrieved from http://www.ecologyandsociety.org/vol13/iss2/art40/

Casimirri, (2003). Problems with integrating traditional ecological knowledge into contemporary resource management. XII World Forestry Congress: Quebec City, Canada. Retrieved from http://www.fao.org/DOCREP/ARTICLE/WFC/XII/0887-A3.HTM#P24_2299

Cassinelli Del Sante, Gino. (2000). Trees and Bushes from the Sacred Valley of the Incas. Tierra Firme Ediciones SAC.

Caswell, M., & Zilberman, D. (1985). The choices of irrigation technologies in California. In American Journal of Agricultural Economics, 67:2, 224-234. Retrieved from http://www.jstor.org/pss/1240673

Cavero et al., (2005). Diagnostico y plan de desarrollo 2005-2015. Municipalidad distrital de Maras.

Central Intelligence Agency (n.d.) The World Fact Book: Peru. Retrieved on August 30, 2011 from https://www.cia.gov/library/publications/the-world-factbook/geos/pe.html

Chacaltana, Juan (2006) “Se puede prevenir la pobreza?” [Can poverty be prevented?]. Mimeograph, Lima: CIES. Retrieved from at:http://www.consorcio.org/novedades/SEMA2005/MM/JCH.pdf

Charnley, S., Fischer, A. P., & Jones, E. T. (2008). Traditional and local ecological knowledge about forest biodiversity in the Pacific Northwest. Gen. Tech. Rep. PNW-GTR-751. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. http://www.fs.fed.us/pnw/pubs/pnw_gtr751.pdf

Chepstow-Lusty, A., Winfield, M. (2000). Inca Agroforestry: Lessons from the Past. In Royal Swedish Academy of Sciences, 29: 6, 322-328. Retrieved from http://www.ecosaf.org/publicaciones/Inka-Agroforestry.pdf

Chepstow-Lusty, A., Frogley, M. R., Bauer, B. S., Bush, M. B., & Herrera, A. T. (2003). A late Holocene record of arid events from the Cuzco region, Peru, Alex Chepstow Lusty et al, 2003. Journal of Quaternary Science. 18(6) 491-502.

Clarke, R. (1993). Water: The International Crisis. Cambridge, Ma: MIT Press

Comisión Nacional de Cambio Climatico. (2001). Comunicación Nacional del Peru a la Convención de Naciones Unidas sobre Cambio Climatico. Primera Comunicación. Consejo Nacional del Ambiente. Biblioteca Nacional del Peru: Manati S.A., Jesus Maria. Retrieved from http://unfccc.int/resource/docs/natc/pernc1.pdf

Comision Multisectoral de Reduccion de Riesgos en el Desarrollo & Direccion General de Programacion Multianual del Sector Publico - MEF. (2003). Mapa de zonas afectadas por sequias recurrentes. Estrategia nacional de reduccion de riesgos para el desarrollo. http://www.vivienda.gob.pe/pgt/documentos/Material_Divulgacion/Mapa_Area_Afectadas_x_Sequias_Recurrentes.pdf.

Comisión Técnica Multisectorial. (2004). Politica y estrategia nacional de recursos hidricos del Peru. Autoridad Nacional del Agua (Ed.). Lima, Peru.

Comisión Técnica Multisectorial. (2009). Politica y estrategia nacional de recursos hidricos del Peru. Autoridad Nacional del Agua, Ministerio de Agricultura, Peru. Retrieved from http://www.ana.gob.pe/media/290336/politicas_estrategias_rh.pdf

Comunidad Andina, (2007). Where do we start: The Andean community's top climate change priorities. General Secretariat of the Andean Community, the United Nations Environmental Programme, and the Spanish International Cooperation Agency: Peru. Retrieved at http://www.comunidadandina.org/public/cambio_climatico_donde_comenzamos_english.pdf.

Condori Luque, H. (1995). Las leyes de agua en el Peru. Planes hidrologicos de cuencas. In monografia sobre leyes de aguas. Constitucion politica del Peru. Lima: Fondo Editorial de la Pontificia Universidad Catolica del Peru. http://www.monografias.com/trabajos19/ley-de-aguas/ley-de-aguas.shtml.

Connected Water: Managing the linkages between surface water and ground water. Integrated Water Resource Management. Australian Government. Retrieved from http://www.connectedwater.gov.au/water_policy/integrated_mgt.html

Cook, C., and Bakker, K., (2010). Water Security: Emerging debates in policy and academia. Working Paper: manuscript submitted to Water Alternatives, January 19, 2010. http://www.watergovernance.ca/PDF/WP_WaterAlternatives_Cook_Bakker.pdf

Custred, G. (1979). Hunting technologies in Andean culture. http://www.persee.fr/web/revues/home/prescript/article/jsa_0037-9174_1979_num_66_1_2168

Damman, S. (2005). Nutritional vulnerability in indigenous children of the Americas – a human rights issue. In R. Eversole, J. A. McNeish, & A. D. Cimadamore (Eds), Indigenous peoples & poverty: An international perspective. Norway: CROP International Studies in Poverty Research; London: Zed Books.

Dickinson, J. C. (1969). The eucalypt in the Sierra of Southern Peru. In Annals of the Association of American Geographers. 59:2, 294 – 306. University of Florida: Gainesville.
Retrieved from http://www.jstor.org/stable/2561632.

Dillehay, T. Eling Jr., H. H. & Rossen, J. (2005). Preceramic irrigation canals in the Peruvian Andes. Proceedings of the National Academy of Sciences of the United States of America, 102:47. The National Academy of Sciences. Retrieved from http://www.pnas.org/content/102/47/17241.full.

Dillehay, T., Kolata, A. (2004) Long-term human response to uncertain environmental conditions in the Andes. **Proceeding of the National Academy of Sciences**. 101(12): 4325-4330. Retrieved from http://www.pnas.org/content/101/12/4325.long

Dongier, P., Domelen, J. V., Ostrom, E., Ryan, A., Wakeman, W, Bebbington, A., Alkire, S., Esmail, T., & Polski, M. (2001). Community driven development. In World Bank, Poverty Reduction Strategy Paper Sourcebook. Vol. 1. Washington, D.C.

DuHamel, Jonathan. (2011). El Nino behaviour, climate models, predict opposite of what really happens. Tuscon Citizen. Retrieved from http://tucsoncitizen.com/wryheat/2011/08/18/el-nino-behavior-climate-models-predict-opposite-of-what-really-happens/

Duraiappah, A. (1996). Poverty and environmental degradation: A literature review and analysis. CREED Working Paper Series, No. 8. London: International Institute for Environment and Development. Retrieved from http://www.ce.cmu.edu/~gdrg/readings/2006/09/19/Duraiappah_PovertyAndEnvDegradation_LiteratureReviewAndAnalysis.pdf

Dutch Portal to International Hydrology. (n.d.). IWRM guidelines at river basin level. Retrieved from http://www.hydrology.nl/ihppublications/169-iwrm-guidelines-at-river-basin-level.html

Earls, J. (1996). Rotative rank hierarchy and recursive organization: The Andean peasant community as a viable system. G. Urton (Ed.) *Structure, Knowledge, and* Representation on the Andes: Studies presented to Reiner Tom Zuidema on the Occasion of his 70th Birthday. Journal of the Steward Anth. Soc. V.24 (1,2).297-320

Earls, J. (1998). The character of Inca and Andean agriculture. Conference in Israel. Peruvian Embassy in Israel and PUCP. http://macareo.pucp.edu.pe/~jearls/documentosPDF/theCharacter.PDF

Earls, J. (n.d.). La adaptabilidad del sistema Agricola peruano ante el cambio climatico.

Earls, J. (2006). The Andes and the evolution of coordinated environmental control. PUCP.

Earls, J. (2008). Inestabilidad y cambio climatic en el Peru. In Boletin IDEA-PUCP. 5:41, 3-5. Retrieved from http://inte.pucp.edu.pe/docs/bol41.pdf

Earls, J. (2011). Calendar and Coordination in high mountain Inka terrace systems: The case of Moray, Peru. [Abstract].

Embassy Brasilia, (2008). Andean Glacier Melt Portends Shortages Of Water And Hydropower. Retrieved from http://www.cablegatesearch.net/cable.php?id=08BRASILIA1341

Empowering Small Farmers in Markets (ESFRIM), 2011. AGRINATURA-EEIG http://www.esfim.org/

Encomienda." *Encyclopædia Britannica*. 2008. Encyclopædia Britannica Online. 13 October 2008. Retrieved from http://www.britannica.com/EBchecked/topic/186567/encomienda
Encyclopedia of the Nations. (2011). Peru – Agriculture. Advameg, Inc. Retrieved from http://www.nationsencyclopedia.com/economies/Americas/Peru-AGRICULTURE.html.

Engle, N. L., Johns, O. R., Lemos, M. C., Nelson, D. R., (2011). Integrated and Adaptive Management of Water Resources Tensions, Legacies, and the Next Best Thing. In Ecology and Society. Retrieved from http://www.ecologyandsociety.org/vol16/iss1/art19/main.html, Dublin, 1992

Erickson, C. L. & Candler, K. L. (1989). Raised fields and sustainable agriculture in the Lake Titicaca Basin of Peru. In J. O. Browder Fragile lands of Latin America: Strategies for Sustainable Development. Westview Press, Boulder CO (pp. 230-248). Retrieved from http://www.csun.edu/~hmc60533/CSUN_630E/studentpresentations_S2007/Robinson_Peru_traditional_raised_fields.pdf

Erickson, C. L. (2000). The Lake Titicaca basin: A pre-Columbian built landscape. In **Imperfect balance: Landscape transformations in the precolumbian Americas**. Edited by David Lentz, pp. 311-356.Columbia University Press, New York. http://www.sas.upenn.edu/anthro/system/files/EricksonLentzvol.pdf

Escobal, J., & Torero, M. (2006). Access to Dynamic Markets for Small Commercial Farmers: The Case of Potato Production in the Peruvian Andes. Markets, Trade, and Institutions Division Discussion Paper No. 99. Washington USA: International Food Policy Research Institute.

Escobar (1988). Power and Visibility Development and the Invention and Management of the Third World. Cultural Anthropology, 3(4), 428-443.

Escobar, A. (1998). Whose knowledge, whose nature? Biodiversity, conservation, and the political ecology of social movements. In *Journal of Political Ecology*, 5, 53-82. http://www.cddc.vt.edu/ept/eprints/3escobar.pdf

Falkenmark, Malin. "The Massive Water Shortage in Africa -- Why isn't it Being Addressed?" Ambio. 1989. 18:2, pp.112-18.

Falkenmark, M., & Rockstrom, J. (2006). The New Blue and Green Water Paradigm: Breaking New Ground for Water Resources Planning and Management. In Journal of Water Resources Planning and Management, May/June 2006. ASCE. Retrieved from http://scitation.aip.org/getpdf/servlet/GetPDFServlet?filetype=pdf&id=JWRMD5000132000003000129000001&idtype=cvips&doi=10.1061/(ASCE)0733-9496(2006)132:3(129)&prog=normal&bypassSSO=1

Falkenmark & Lindh 1976, quoted in UNEP/WMO. "Climate Change 2001: Working Group II: Impacts, Adaptation and Vulnerability". UNEP. Retrieved 2009-02-03.

Farming Online, (2011). Peru Congress bans GM crops. Farming Online Ltd. Retrieved from http://www.farming.co.uk/articles/view/4140.

FAO, (2000). New dimensions in water security: Water, society and ecosystem services in the 21st century. Rome: Land and Water Development Division. Retrieved from ftp://ftp.fao.org/agl/aglw/docs/misc25.pdf

Feenstra, J. F. (1998). handbook on methods for climate change impact assessment and adaptation strategies. United Nations Environment Programme. Retrieved from http://hdl.handle.net/1871/10440

Figueroa, A., Altamirano, T. and Sulmont, D. (1996) 'Social exclusion and inequality in Peru', Research Series 104, International Institute for Labour Studies, Geneva.

Fjeldså, J. (2002). Polylepis forests – vestiges of a vanishing ecosystem in the Andes. In *Ecotropica*, 8: 111-123. Society for Tropical Ecology. Zoological Museum, Universitetsparken 15, DK-2100 Copenhagen, Denmark.

http://www.gtoe.de/public_html/publications/pdf/8-2/Fjelds%E2%20J%202002,%20Ecotropica%208_111-123.pdf

Folke, C., L. Pritchard, F. Berkes et. al. (1998). The Problem of Fit between Ecosystems and Institutions. IHDP Working Paper, No.2. International Human Dimensions Programme, Bonn, Germany.

Folke, Carl, Carpenter, Steve, Elmqvist, Thomas, Gunderson, Lance, Holling, C. S., Walker, Brian, (2002). Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformations. In A Journal of the Human Environment 31(5): (pp. 437-440). Doi: 10.1579/0044-7447-31.5.437. Retrieved from http://www.bioone.org/doi/abs/10.1579/0044-7447-31.5.437

Folke, C., Hahn, T., Olsson, P., & Norberg, J. (2005). Adaptive Governance of Social-Ecological Systems. In Annual Review Environmental Resources. 2005. 30:441-73. Doi: 10.1146/annurev.energy.30.050504.144511. Retrieved from http://www.steps-center.org/PDFs/Folke%20et%20al%202005%20ARER.pdf

Forsyth, T., & Leach, M. (1998). Poverty and environment: Priorities for research and policy. An Overview Study. Prepared for the United Nations Development Programme and European Commission. UK: Institute of Development Studies. Retrieved from http://eprints.lse.ac.uk/4772/1/Poverty_and_environment-priorities_for_research_and_study.pdf

Fraser, B. (2009). Glaciers go, leaving drought, conflict and tension in Andes. The Daily Climate. http://wwwp.dailyclimate.org/tdc-newsroom/2009/05/glaciers-go-leaving-drought-conflict-and-tension

Garcia, L. E. (1998). Integrated water resources management in Latin America and the Caribbean. Technical Study. No. ENV-123. Washington, DC. Retrieved from http://www.pnuma.org/agua-miaac/PERIODISTAS%20BOLIVIA/MATERIAL%20ADICIONAL/BIBLIOGRAFIA-WEBGRAFIA/Agua/Integrate%20water.pdf.

Garcia, C. (2005). Peru: El banco mundial busca privatizar el agua destruyendo el modelo Andino. Radio Clima: Santiago de Chile. http://www.radioclima.org/upimages/files/47447bbc74d06_10.pdf

Gelles, Paul, (2006). Pueblos indigenas, identidad cultural y derechos de agua en las naciones andinas. In Agua y Derecho: Politicas Hidricas, Derechos Consuetudianarios e Identidades Locales. Wageningen University.

Gertz, G. (1963), Peddlers and princes: Social change and economic modernisation *in two Indonesian towns*, Chicago: Chicago University Press.

Gilles, J. & Valdivia, C. (2009). ¨Local Forecast Communication in the Altiplano.¨ Bulletin of the American Meteorological Society BAMS (1 January): 85-91. Retrieved from http://pdf.usaid.gov/pdf_docs/PNADU404.pdf

Gleick, Peter (2000). The Changing Water Paradigm: A Look at Twenty-first Century Water Resources Development. In Water International, Vol. 25 No. 1 (pp. 127-138). March 2000. International Water Resources Association. Retrieved from http://www.unc.edu/~charack/pdf/Gleick_Article.pdf

Global Water Partnership. (n.d.). Lima declaration for IWRM. http://www.gwp.org/en/gwp-in-action/South-America/News-and-Activities-GWP South-America/Lima-Declaration-for-IWRM/.

Gobierno Regional Cuzco, n.d. *Implicaciones del cambio climatico en la gestion de los recursos hidricos*. Gerencia Regional de Recursos Naturales Y Gestion Del Medio Ambiente. Retrieved at http://www.regionCuzco.gob.pe/dirvivienda/attach/CAMBIO%20CLIMATICO%20-%20GESTION%20DEL%20AGUA.pdf

Goland, C. (1993). Field scattering as agricultural risk management: A case study from Cuyo Cuyo, Department of Puno, Peru. Mountain Research and Development, 13(4), 317-338.

Gonzales, T. A. (2000). The cultures of the seed in the Peruvian Andes. International Development Research Centre. Retrieved from http://network.idrc.ca/geh/ev-98735-201-1-DO_TOPIC.html

Gose, P. (2008). Invaders as ancestors: On the intercultural making and unmaking of Spanish colonialism in the Andes. Toronto: University of Toronto Press Incorporated.

Gray (2009). Rural out-migration and smallholder agriculture in the Southern Ecuadorian Andes. Population & Environment, 30(4-5), 193-217. http://paa2009.princeton.edu/download.aspx?submissionId=90064

Gregory, K. (2009). Backgrounder: Shining Path, Tupac Amaru (Peru, leftists). Council on Foreign Relations, Inc. http://www.cfr.org/terrorism/shining-path-tupac-amaru-peru-leftists/p9276.

Griffiths, T. (2004). Indigenous peoples, land tenure, and land policy in Latin America. *Land Reform, Land Settlement, and* Cooperatives, No. 1, 46-64. Rome: Rural Development Division, FAO. http://siteresources.worldbank.org/BOLIVIA/Resources/Indigenous_peoples_and_Agrarian_Reform_FAO.pdf

Guardian News. (2010). Have the climate wars begun? Poverty matters blog. Retrieved from http://www.guardian.co.uk/global-development/poverty-matters/2010/sep/21/climate-wars-machu-picchu-irrigation

Gunderson, L.H. & C.S. Holling, editors (2001). Panarchy: Understanding Transformations in Human and Natural Systems. Island Press, Washington.

Guran, N. (2008). Insurgency in Peru, Retrospective analysis of the Sendero Luminoso's (Shining Path). Master's thesis. Marine Corps University: Virginia. Retrieved from http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA491139&Location=U2&doc=GetTRDoc.pdf

Gurung, Ghana S. & Kollmair, Michael, (2005). Marginality: Concepts and their Limitations. IP6 Working Paper No. 4. Retrieved from http://www.nccr-pakistan.org/publications_pdf/General/Marginality.pdf

Haan, N., G. Farmer & R. Wheeler. (2001). Chronic Vulnerability to Food Insecurity in Kenya: A WFP Pilot for Improving Vulnerability Analysis. WFP.

Hancco, M. L., Sumari, J. P., Quispe, M. V., & Cruz, R. L., (2009). La ley del agua es privatista y centralista las aguas seran administradas por operadores privados con fines de lucres. Confederacion Campesina del Peru. Retrieved from http://www.movimientos.org/imagen/Comunicado%20CCP%20Ley%20de%20Aguas.pdf

Hardin, G. (1968). The Tragedy of the Commons. Science, 162, 1243-1248.

Hayes, Margaret Daly, (1988). The U.S. and Latin America: A Lost Decade? In America and the World. Retrieved http://www.foreignaffairs.com/articles/44007/margaret-daly-hayes/the-us-and-latin-america-a-lost-decade

Hoffman, 2010

Hornberger, N. H. (1996). Quechua literacy and empowerment in Peru. In N. H. Hornberger (Ed.) *Indigenous Literacies in the Americas: Language Planning from the Bottom Up* (pp. 237-251). Mouton de Gruyter.

Horner-Dixon, Thomas F. (1994). Environmental Scarcities and Violent Conflict: Evidence from Cases. Part 1. Peace and Conflict Studies Program, University of Toronto International Security, Vol. 19, No. I (Summer 1994), pp. 5-40. Retrieved from http://www.library.utoronto.ca/pcs/evidence/evid1.htm

Hudson, R. A., ed. (1992). *Peru: A Country Study*. Washington: GPO for the Library of Congress. Retrieved from http://countrystudies.us/peru/

Huppert, Walter, (2007). IWRM and Water Governance – Striving for 'Incentive Compatibility' in the Water Sector. Catchment and Lake Research. Retrieved from: http://www.uni-siegen.de/fb10/fwu/ww/publikationen/volume0607/huppert.pdf

IFAD. (2011). Rural Poverty Report: New realities, new challenges: new opportunities for tomorrow's generation. Rome, Italy: International Food and Agricultural Development. Retrieved from http://www.ifad.org/rpr2011/report/e/rpr2011.pdf

Inbar, M., Llerena, C. A. (2000). Erosion processes in high mountain agricultural terraces in Peru. In Mountain Research and Development, 20:1, 72-79. International Mountain Society. http://www.bioone.org/doi/pdf/10.1659/0276-4741%282000%29020%5B0072%3AEPIHMA%5D2.0.CO%3B2

Index Mundi, (2001). Peru Corn Production by Year. Retrieved from http://www.indexmundi.com/agriculture/?country=pe&commodity=corn&graph=production.

Instituto de Manejo de Agua y Medio Ambiente. (n.d.). Cosecha alto Vilcanota Diagnostic. Cuzco, Peru.

I Valls, J. X.. (n.d.). Water Scarcity. Doctoral Thesis. http://tdx.cat/bitstream/handle/10803/6987/09CAPITOL7.pdf?sequence=10

Kastelein, W. (1998). Irrigation development in the Peruvian Andes. In *LEISA Magazine*, 14(1), 6-7. Retrieved from http://www.agriculturesnetwork.org/magazines/global/challenging-water-scarcity/irrigation-development-in-the-peruvian-andes

Kay, C. (1998). Latin America's agrarian reform: Lights and shadows. In Land Reform, Settlement and Cooperatives. Vol. 2, (pp. 8-31). Italy: FAO. ftp://ftp.fao.org/sd/sda/sdaa/LR98_2/LR98_2.pdf

Keen, M. (2010). The fight for water: climate change raises conflicts in the Andes. Climate Action: UNEP. Retrieved from http://www.climateactionprogramme.org/news/the_fight_for_water_climate_change_raises_conflicts_in_the_andes/

Kendall, a. Chepstow-lusty, (2006). Cultural and environmental change in the Cuzco region of Peru: rural development implications of combined archaeological and palaeoecological evidence. In P. Dransart (Ed.) Kay Pacha: Cultivating Earth and Water in the Andes (pp. 185-197). Retrieved from http://www.cusichaca.org/pdf/2-Cultural_and_%20Environmental_Change_2006.pdf.

Kendall, A., & Ouden, G. (2008). Sesion 1: Historia Agraria y Agricultura Sostenible: Terrazas, una infraestructura agrícola como contribución a las estrategias de manejo de riesgos climáticos. Congreso de historia agrarian, Cordoba, Palacio de Congresos. http://www.seha.info/congresos/01_05.pdf

Kerkhoff, L., & Lebel, L. (2006). Linking knowledge and action for sustainable development. Annual Review of Environment and Resources, 31, 445-477. Annual Reviews. Retrieved from http://www.sustainability.ethz.ch/projects/akademie_som/so2011/Linking_knowledge_action_sustainable_development.pdf

Khush, G. S. (2001). Green revolution: The way forward. Nature Reviews: Genetics. Vol 2, (pp. 815-822). Macmillan Magazines Ltd. Retrieved from http://www2.biologie.uni-halle.de/genet/plant/staff/boch/lectures/biotech2007/Talks/3_GreenRevolution/3_Literatur/khush.pdf.

Krech, S. (1999) *The Ecological Indian: Myth and History*. New York: W.W. Norton.

Larsen, S. T. L. "Lack of Freshwater Throughout the World".Evergreen State College. Retrieved 2009-02-01.

La Serna, M. (2010). Living to tell the tale: Peruvian agrarian reform as told by its protagonists. In A Journal on Social History and Literature in Latin America, 7:3, 543-546. http://www.ncsu.edu/acontracorriente/spring_10/reviews/LaSerna_rev.pdf.

Long, N. & Roberts, B. (1994). The agrarian structures of Latin America, 1930-1990. In L. Bethell (Ed.) Latin America since 1930. Economy, society, and politics. Press Syndicate of the Cambridge University Press: Cambridge.

López Gonzales, Marcos Yván (2008). Andean Communities, Irrigation and conflict: A case study in Peruvian Andes _ Ayacucho. Irrigation and Water Engineering Group. Wageningen University, The Netherlands. Retrieved from http://edepot.wur.nl/15177

Lopez-Ocon, L. (1987). Sobre 'la racionalidad de la organizacion andina'. Revista de Indias. Vol. XLVII: 179. Instituto de Estudios Peruanos: Lima. http://digital.csic.es/bitstream/10261/17129/1/20090616091815593.pdf.
Leon-Velarde, C., Quiroz, R. A., Valdivia, R. E., Reinoso, J., Holle, M., (2008). Evolving from farming systems research into a more holistic rural development approach: Experiences in the Andean region. Natural Resources Management Division Working Paper, No. 2008-1.

Leavell, D. N. (2007). The impacts of climate change on the mountain glaciers of the central Andes, and the future of water supply in Lima, Perú. *Presented at the Third International Conference on Water and Climate, Helsinki, Finland, September, 2007.*

Luque, J. (2009). Encuentro economic region Cuzco: Evolucion del sector turismo. Casa Andina. http://www.bcrp.gob.pe/docs/Proyeccion-Institucional/Encuentros-Regionales/2009/Cuzco/EER-Cuzco-Luque.pdf.

Luzar, J. (2007).The political ecology of a "forest transition": Eucalyptus forestry in the Southern Peruvian Andes. Ethnobotany Research & Applications. 5:085-093. Retrieved from http://lib-ojs3.lib.sfu.ca:8114/index.php/era/article/viewFile/121/107.

Macchi, M., Oviedo, G., Gotheil, S., Cross, K., Boedhihartono, A., Wolfangel, C., Howell, M. (2008). Indigenous and Traditional Peoples and Climate Change. IUCN Issues Paper. Retrieved from http://www2.ohchr.org/english/issues/climatechange/docs/IUCN.pdf

Manners, R.B., Magilligan, F. J., & Goldstein, P.S. (2007). Floodplain Development, El Niño, and Cultural Consequences in a Hyperarid Andean Environment. *Annals of the Association of American Geographers*, 97(2), 229-249. DOI: 10.1111/j.1467-8306.2007.00533.x. Retrieved from http://www.fsl.orst.edu/wpg/events/W09/FloodplainDevelopment.pdf

Marti, N., & Pimbert, M., (2007). Barter markets for the conservation of agro-ecosystem multi-functionality: the case of chalayplasa in the Peruvian Andes. In International Journal of Agricultural Sustainability, Vol. 5, No. 1, 2007, (pp. 51-69). Earthscan. Retrieved from http://www.ingentaconnect.com/content/earthscan/ijas/2007/00000005/00000001/art00007

Marti Sans, N. (2005). La multidimensionalidad de los sistemas de alimentacion en los Andes peruanos: los chalayplasa del valle de Lares (Cuzco). Doctoral Thesis. Universidad Autonoma de Barcelona, Barcelona. http://tesisenred.net/bitstream/handle/10803/4067/nms1de2.pdf?sequence=1

Maskrey, A. (1993). Vulnerability accumulation in peripheral regions in Latin America: The challenge for disaster prevention and management. Eds. P. A. Merriman, C. W. A. Browitt. 1993. Natural disasters: protecting vulnerable communities: proceedings of the conference held in London, 13-15. London: T. Telford.

Matsuyama, Kiminori (2005). Poverty Traps. in L. Blume and S. Durlauf, eds., *the New Palgrave Dictionary of Economics*, 2nd Edition, Palgrave Macmillan. May 2005 Version.

Mazadiego, L. F., Puche, O., & Hervas, A. M. (2009). Water and Inca cosmogony: Myths, geology and engineering in the Peruvian Andes. In M. Kolbl-Ebert, Geology and religion: A history of harmony and hostility. Geological Society of London.

McDevitt, Thomas (1999). International Brief, Population Trends: Peru. U.S. Department of Commerce Economics and Statistics Administration, Bureau of the Census. Issued March 1999. Retrieved from http://www.census.gov/population/international/files/ib99-1.pdf

Merino, L., & Robson, J. (Eds). (2005). Managing the commons: Conservation of biodiversity. The Christensen Fund, Ford Foundation: Mexico. Retrieved from http://www2.ine.gob.mx/publicaciones/download/474.pdf#page=14

Minero, Ricardo Sandoval, (2007). Tracking governance – indicators and measurement for constructing learning water management systems. In World Water.

Ministerial Declaration of the Hague on Water Security in the 21st Century (Second World Water Forum, 2000)

Ministerio de Agricultura. Autoridad Nacional del Agua. Disponibilidad hidrica en el Peru. Retrieved from http://www.ana.gob.pe:8080/snirh/dsp_disphidrica.aspx

Ministerio de Transportes y Comunicaciones, 2009. In El Peruano. http://www.mtc.gob.pe/portal/transportes/asuntos/docs/Ley_29338.html

Mitchell, W. P. (1981). La agricultura de riego en la sierra central de los Andes: Implicaciones para el desarrollo del estado. In Lechtman and Soldi (comps). Retrieved at https://www.monmouth.edu/academics/history_and_anthropology/reprints/AGRICULTURADERIEGOENLASIERRACENTRALDELOSANDES.pdf.

Miyashita, A. (2009). Local discourses of poverty, well-being and social mobility. Chapter 3. In Killing the Snake of Local Poverty: local perceptions of poverty and well-being and people's capabilities to improve their lives in the Southern Andes of Peru. Amsterdam: Dutch University Press. http://dare.uva.nl/document/152251

Moss, T., IRS, Erkner, (2010). Managing water beyond IWRM – from paradigm to pragmatism. Presentation to 1st Water Research Horizon Conference, Berlin, 13-14 July 2010. IRS. Retrieved from http://www.water-research-horizon.ufz.de/data/Session4_Moss_WRHC201013414.pdf

Muller, E. N., Dietz, H. A., & Finkel, S. E. (1991). Discontent and the expected utility of rebellion: The case of Peru. In The American Political Science Review, 85:4, 1261-1282. Retrieved from http://www.pitt.edu/~finkel/download/discontent%20and%20the%20expected%20utility.pdf.

Murra, J. (1976) Los límites y las limitaciones del "Archipiélago Vertical" en los Andes. En *Homenaje al Dr. Gustavo Le Paige, SJ.,* editado por José María Casassas, pp. 141-146. Universidad del Norte, Antofagasta, Chile.

Natural Resources Conservation Service (NRCS). (N.d.) Factsheet. Native grasslands for wildlife, forage, and biomass. Environmental Quality Incentives Program. Wildlife Habitat Fact Sheet. Department of Agriculture, NRCS: Pennsylvania. Retrieved from http://www.pa.nrcs.usda.gov/programs/eqip/Documents/EQIPWILDLIFE.pdf

Newsham, A., & Thomas, R. (2009). Agricultural adaptation, local knowledge, and livelihoods diversification in North-Central Namibia. Tyndall Centre for Climate Change Research. Tyndall Working Paper 140. Retrieved from: http://www.the-eis.com/data/literature/Agricultural%20adaptation,%20local%20knowledge%20and%20livelihoods%20diversification%20in%20north-central%20Namibia.pdf

Oirdinolan., (1997), The consequences of cold events for Peru, Laboratorio de Física-Universidad de Piura Piura, Perú, d'après http://www.dir.ucar.edu, 2p.

Olson, D. (2007). Capitulo 18: Recursos hidricos. In Peru - La oportunidad de un país diferente: Próspero, equitativo y gobernable. *World Bank*. (pp. 409-411). http://siteresources.worldbank.org/INTPERUINSPANISH/Resources/Cap.18._Recursos_hidricos.pdf

Ore, M. T., Castillo, L., Van Orsel, S., & Vos, Jeroen. (2009). El agua, ante nuevos desafios. Actores e iniciativas en Ecuador, Peru, y Bolivia. Instituto de Estudios Peruanos.

Orlove, B., Chiang, J. C. H., & Cane, M. A. (2002). Ethnoclimatology in the Andes: A cross-disciplinary study uncovers a scientific basis for the scheme Andean potato farmers traditionally use to predict the coming rains. *American Scientist*: 90:5, 428-435. http://chakana.nl/files/pub/Orlove_EthnoclimatologyInTheAndes_2002.pdf

Orlove, B. S., Chiang, J. C. H. & Cane, M. A. (2000). Forecasting Andean rainfall and crop yield from the influence of El Nino on Pleiades visibility. In Nature. Vol 403, 68-71.

Ortiz, O. (2006). Evolution of agricultural extension and information dissemination in Peru: An historical perspective focusing on potato-related pest control. In *Agriculture and Human Values*, 23:4, 477-489. Retrieved from http://www.springerlink.com/content/63485314l20j6984/

Parry, M. L., Canziani, O.F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Eds.) (2007). Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change 2007: Impacts, Adaptation and Vulnerability

Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

http://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch13s13-6.html

Peloquin, C. (2007). Variability, change and continuity in social-ecological systems: Insights from James Bay Cree cultural ecology. Manitoba: University of Manitoba. Retrieved from http://mspace.lib.umanitoba.ca/bitstream/1993/3019/1/Peloquin.2007.MNRM.Thesis.pdf

Pereira, Luis S., Cordery, Ian, and Iacovides, Iacovos. 2002. Coping with water scarcity. Technical Documents in Hydrology, No. 58. Paris: UNESCO.

Perez, C., Nicklin, C., Dangles, O., Vanek, S., Sherwood, S., Halloy, S., Garrett, K., & Forbes, G. (2010). Climate change in the high Andes: implications and adaptation strategies for smallscale farmers. *International Journal of Environmental, Cultural, Economic and Social Sustainability* 6, 1-16.

Retrieved from http://dangles.naturexpose.com/IMG/file/pdf%20peer-reviewed/2010_perez_et_al.pdf

Perez, C. A., Nicklin, C., & Paz, S. (2010). Food crisis, small-farmers and markets in the Andes. Special issue of: Global food-price shocks and poor people: themes and case studies. In Development in Practice, 21: 4-5, 566-577. Retrieved from http://www.ccrpleadershipteameeting2011.info/wikimcknight/images/c/cd/Perez-Food_crisis,_small_farmers_%26_markets_(2).pdf.

Peruvian Times, 2009. Peru farmers launch indefinite strike to protest water laws, Machu Picchu railway cut off and dozens of roads blocked. Retrieved from http://www.peruviantimes.com/16/peru-farmers-launch-indefinite-strike-to-protest-water-laws-machu-picchu-railway-cut-off-and-dozens-of-roads-blocked/1360/

Phocaides, A. (2000). Technical Handbook on Pressurized Irrigation Techniques. FAO: Rome.

Pimbert, M. (2005). Supporting locally determined food systems: the role of local organizations in farming, environment and people's access to food. In How to Make Poverty History The central role of local organizations in meeting the MDGs (2005) (pp.129-156). http://pubs.iied.org/pdfs/G00464.pdf

Poliak, L. (2007). Peru: Life of the Quechua: Up in the Andes, daily existence is a struggle for young people. In Junior Scholastic, 109:13. Thomson Gale. http://www2.scholastic.com/browse/article.jsp?id=11773.

Portillo, Z. (2008). Peru mountain glaciers 'receding rapidly'. Climate Change and Energy. Science and Development Network, 29 July 2008.

Posthumus, H. (2005). Adoption of terraces in the Peruvian Andes. Doctoral Thesis Wageningen University. Also published as Tropical Resource Management Papers, No. 72. Retrieved from http://library.wur.nl/wda/dissertations/dis3843.pdf.

Poveda, R. A, (2007). Natural resources and development. In M. Giugale, V. F. Cibils, and J. L. Newman. An opportunity for a different Peru: prosperous, equitable and governable.(pp. 363- 386). The International Bank for Reconstruction and Development. World Bank Publications: Washington, DC.

Poverty (sociology)". *Poverty (sociology)*. britannica.com. Retrieved 2010-10-24
Pulgar Vidal, J. (1979). Pulgar Vidal, Javier: Geografía del Perú; Las Ocho Regiones Naturales del Perú. Edit. Universo S.A., Lima 1979. First Edition (his dissertation of 1940): Las ocho regiones naturales del Perú, Boletín del Museo de historia natural „Javier Prado", n° especial, Lima, 1941, 17, pp. 145-161.

Ramsay, P. M., Aucca, C. (n.d.). Biodiversity, conservation and sustainable management of the world's highest woodlands: Polylepis forest in the Andes of southern Peru. Terrestrial Ecology Research Group. Rainforest Concern and the Holly Hill Trust. http://www.perc.plymouth.ac.uk/terg/TERG%20projects/Polylepis%20in%20Peru.pdf.

Rao, D. B. (2007). Education for all: Adult education in a polarising world. In D. B. Rao Education for all: Issues and Trends. S.B. Nagia for APH Publishing Corporation: Delhi

Resilience dictionary. Stockholm Resilience Centre: Research for governance of social-ecological systems.
http://www.stockholmresilience.org/research/whatisresilience/resiliencedictionary.4.aeea46911a3127427980004355.html

Rockstrom, J., Barron, J., Fox, P. (2003). Water Productivity in Rain-fed Agriculture: Challenges and Opportunities for Smallholder Farmers in Drought-prone Tropical Agroecosystems. In: Kijne, W.J., Barker, R. And Molden, D. (eds) Water Productivity in Agriculture: Limits and Opportunities for Improvement. CAB International, Wallingford, UK (pp. 145-162). http://www.iwmi.cgiar.org/publications/CABI_Publications/CA_CABI_Series/Water_Productivity/Unprotected/0851996698ch9.pdf

Rural Development and Poverty Reduction in Peruvian Sierra and Selva, n.d. International Food Policy Research Institute. Retrieved from http://www.ifpri.org/book-52/ourwork/program/rural-development-and-poverty-reduction-peruvian-sierra-and-selva

Rural Poverty Portal. http://www.ruralpovertyportal.org/web/guest/country/statistics/tags/peru

Sandoval, R., 2007, “Tracking governance – indicators and measurement for constructing learning water management systems”. Extended abstract presented at the CAIWA Conference. Basel. Retrieved from http://www.newater.uos.de/caiwa/data/papers%20session/F4/multilevel%20water%20governance%20Sandoval.pdf

Schultz, B. & Uhlenbrook, S. (2007). Water security: What does it mean, what may it imply? Discussion Draft Paper for the session on Water Security. Netherlands: UNESCO Institute for Water Education.

Second World Water Assessment Report (2006)

Seltzer, G. O., Hastorf, C. A., (1990). Climatic Changes and its Effect on Prehispanic Agriculture in the Central Peruvian Andes. In Journal of Field Archaeology, Vol. 17, No. 4. Retrieved from http://www.ingentaconnect.com/content/maney/jfa/1990/00000017/00000004/art00002

Servicio Nacional de Meteorologia e hidrologia del Peru. (2005). Boletin meteorologico e hidrologico del Peru. Retrieved from http://www.wamis.org/countries/peru/PER200511.pdf.

Sherwood, S., & Bentley, J. (year). Katalysis: helping Andean farmers adapt to climate change.

Sherwood, S., Nelson, R., Thiele, G., & Ortiz, O. (2000). Farmer field schools for ecological potato production in the Andes. ILEIA Newsletter. Retrieved from http://www.share4dev.info/kb/documents/3232.pdf.

Shiva, V. (1991) The Violence of the Green revolution: Third World Agriculture, Ecology and Politics, London and New Jersey: Third World Network and ZED Books.

Shyamsundar, P. (2002). Poverty – Environment indicators. The World Bank Environment Department: Washington, D.C. Retrieved from http://www.unpei.org/PDF/PEMonitoring/Poverty-Environment-Indicators.pdf

Silverman, H. (2008). Rigidity and Poverty Traps. *People and Place: ideas that connect us*. 1(3).
http://www.peopleandplace.net/perspectives/2008/12/9/rigidity_and_poverty_traps
Simon, H. A. (1962). The architecture of complexity. Proceedings of the American Philosophical Society, 106(6), 467-482. Retrieved from http://ecoplexity.org/files/uploads/Simon.pdf

Smit and Wandel, 2005 Adaptation, adaptive capacity and vulnerability

Stadel, C. H. (2008). Vulnerability, Resilience and Adaptation: Rural Development in the Tropical Andes. In Pirineos, Vol. 163, (pp. 15-36), ISSN 0373-2568.

Stanchi et al. (2011). Properties, best management practices and conservation of terraced soils in Southern Europe (from Mediterranean areas to the Alps): a review. Quaternary International. Elsevier Ltd. In press.

Statesman. (2010). Peru water protests halt Cuzco flights. The Associated Press. Retrieved from http://www.statesman.com/news/nation/peru-water-protests-halt-cuzco-flights-935862.html.

Sumner, A., Mejia Acosta, A., Cabral, L., Kapur, R., Bahadur, A., Bobde, S., Hussein, K., Brouillet, A., (2008). Access to governance and policy processes: what enables the participation of the rural poor? Background paper for IFAD rural poverty report 2011. Retrieved from http://www.ifad.org/rpr2011/background/4.pdf

Suyo Flores, J. (N.d). Quemas e incendios. IMA & Gobierno regional Cuzco.

Symantha A. Slaughter-Holben (1999). Demand management and Peruvian highland irrigation systems. In *PoLAR: Political and Legal Anthropology Review* Volume 22, Issue 1, (pp. 14–23), May 1999. DOI: 10.1525/pol.1999.22.1.14
http://onlinelibrary.wiley.com/doi/10.1525/pol.1999.22.1.14/abstract

Swiss Contact. Entrepreneurial Smallholders Make up Ground
http://www.swisscontact.ch/english/pages/PR_Dn/PR_Dn_114_Img.php

Tahirkheli, H. (2010). An exploration of the impacts of climate change on health and well being among indigenous groups in the Andes region. Master of Arts thesis. Athabasca, Alberta: Athabasca University. Retrieved from http://library.athabascau.ca/drr/download.php?filename=mais/Athabasca_Final_Project-_MAIS_701.pdf

Tanaka & Travelli (2002). Las trampas de la focalizacion y la participacion: Pobreza y politicas socials en el Peru durante la decada de Fujimori. Documento de trabajo no. 121. Serie Sociologia y Politica 35. Lima Peru: Instituto de Estudios Peruanos.

The Andean Vision of Water (2003). Poverty and anti-poverty strategies in Peru. Retrieved from http://www.andean-observer.com/poverty-peru.html

The Sustainable Scale Project. Panarchy. (n.d.). Retrieved from http://www.sustainablescale.org/ConceptualFramework/UnderstandingScale/MeasuringScale/Panarchy.aspx.

Toland, J. D. (1983). Discrepencies and dissolution: Breakdown of the early Inca state. Studies in Human Society, vol. 2. (pp. 138- 153). In H. J. M. Claessen, Piet van de Velde (Eds.) Early state dynamics. Chiefly papers presented at the Conference on the Early State and After, held Aug. 17-19, 1983. University of Montreal.

Tompkins, E. L. & Adger, W. N. (2004). Does Adaptive Management of Natural Resources Enhance Resilience to Climate Change? , **Ecology and Society**, **9**.

Trawick, P. (2002). The Struggle for Water in Peru: Comedy and Tragedy in the Andean Commons. Palo Alto: Standford University Press.

Trawick, Paul (2003). Against the privatization of water: An indigenous model for improving existing laws and successfully governing the commons. In *World Development*, 31(6), 977-996. Great Britain: Elsevier Science Ltd. http://www.ag.unr.edu/saito/classes/nres400/readings/trawick.pdf

Treacy, J. M. (1987). Building and rebuilding agricultural terraces in the Colca Valley of Peru. Paper presented at the 1987 International Meeting, Conference of Latin Americanist Geographers (CLAG), Merida, Mexico, 5-10 January 1987. http://sites.maxwell.syr.edu/clag/Yearbook1987/treacy.htm.

UNESCO Institute for Water Education, n.d. Research Themes: Water Security. http://www.unesco-ihe.org/Research/Research-Themes/Water-security

UNESCO, (2000). International Consultative Forum on Education for All (EFA Forum), UNESCO, *Status and Trends*, 2000.

UNESCO (n.d.) International Hydrological Programme. Retrieved from http://www.unesco.org/en/moscow/natural-sciences/fresh-water/international-hydrological-programme/

UNFCCC (2007). Climate Change: Impacts, Vulnerabilities and Adaptation in Developing Countries. United Nations Framework Convention on Climate Change. Germany.http://unfccc.int/resource/docs/publications/impacts.pdf

United Nations, n.d. (millennium development goals)

United Nations. 1977. Report of the United Nations Water Conference, Mar del Plata, March 14- 25, 1977. New York: United Nations.

Urton, G. (1981). At the crossroads of the Earth and the sky: An Andean cosmology. Latin American Monographs, No. 55. University of Texas Press. Austin [1988 – Paperback edition of At the Crossroads... University of Texas Press.] Spanish edition: En el cruce de rumbos de la tierra y el cielo (2006). Cuzco: Centro Bartolomé de la Casas.

USAID Land Tenure and Property Rights Portal. (n.d.). Country profile: Peru. Retrieved from http://usaidlandtenure.net/usaidltprproducts/country-profiles/peru.

Valdivia, C., Gilles, J. L., Jetté, C., Quiroz, R., & Espejo, R. (2003). Coping and adapting to climate variability: The role of assets, networks, knowledge and institutions. In **Insights and Tools for Adaptation: Learning from Climate Variability**. 189-199. NOAA Office of Global Programs, Climate and Societal Interactions. Washington. DC. Retrieved from http://www.climateadaptation.net/docs/papers/Valdivia%20paper%20draft.pdf

Valdivia, C., Jetté, C., Quiroz, R., Gilles, J., & Materer, S. (2000). Peasant households strategies in the Andes and potential users of climate forecasts: El Nino of 1997-1998. Session on Natural Resources and Environmental Issues in Development. Selected Paper presented at the Meetings of the American Agricultural Economics Association, Tampa Florida, August 2000.

Van Cott, 1994, p23; see ILO Convention No 169

Vera Delgado, J., Zwarteveen, M. (2008). Modernity, exclusion and resistance: Water and indigenous struggles in Peru. In *Development*, Vol. 51, nº 1, (pp. 114-120). Palgrave Macmillan.
http://wur.academia.edu/MargreetZwarteveen/Papers/90482/Modernity_exclusion_and_resistance_water_and_indigenous_struggles_in_Peru

Vuille, M., Francou, B., Wagnon, P., Juen, I, Kaser, G., Mark, B. G., & Baradley, R. S. (2008). Climate change and tropical Andean glaciers: Past, present and future. Earth-Science Reviews, 89, 79-96. Elvsevier.

Wada, Y., van Beek, P. H., van Kempen, C. M., Reckman, J. W. T. M., Vasak, S., & Bierkens, M. F. P. (2010). Global depletion of groundwater resources. Geophysical Research Letters, 37(L20402), 1-5. Retrieved from http://igitur-archive.library.uu.nl/fysgeo/2011-0831-200526/2010GL044571.pdf

Water Security (n.d.). In UNESCO-IHE Research Themes. http://www.unesco-ihe.org/Research/Research-Themes/Water-security

Watson, Robert T., Zinyowera, Marufu C., Moss, Richard H., Dokken, David J. (1997). Summary for Policymakers. The Regional Impacts of Climate Change: An Assessment of Vulnerability. A special Report of IPCC Working Group II. IPCC. Retrieved from http://www.ipcc.ch/pdf/special-reports/spm/region-en.pdf

Wernke, S. A. (2007). Negotiating community and landscape in the Peruvian Andes: A transconquest view. In American Anthropologist. Vol. 109: 1, 130-152. http://www.vanderbilt.edu/wernke/wordpress/wp-content/uploads/2008/10/wernke_2007.pdf

Winpenny, J. T. (2000) Managing Water Scarcity for Water Security, FAO, Rome.

Wolf, Aaron T., (1998). Conflict and cooperation along international waterways. In *Water Policy*, Vol. 1, No. 2. (pp. 251-265). Retrieved from http://www.cawater-info.net/bk/water_law/pdf/wolf_e.pdf

World Bank. (2009). Climate change aspects in agriculture: Peru country note. http://siteresources.worldbank.org/INTLAC/Resources/257803-1235077152356/Country_Note_Peru.pdf.

World Economic Forum Water Initiative (2009). The bubble is close to bursting: A forecast of the main economic and geopolitical water issues likely to arise in the world during the next two decades. Draft for discussion at the world economic forum annual meeting. Davos.

Wright, R. (2011). Moray walking tour. In K. R. Wright, *Moray: Inca Engineering Mystery*. Universidad Nacional de Ingeneria, Department of Culture, Lima, Peru.

Yamada, Gustavo and Castro, Juan Francisco (2007). “Poverty, inequality and social policies in Peru: As poor as it gets”. Lima: Centro de Investigación, Universidad del Pacifico. Chapter for CAF-Harvard project, “The Peruvian Growth Puzzle”

Young, K.R., & Lipton, J. K. (2006). Adaptive governance and climate change in the tropical highlands of western South America. Climatic Change 78, 63-102.

Zimmerer, K. S. (1995). The origins of Andean irrigation. Letters to Nature 378, (pp. 481-483). Nature Publishing Group. Retrieved from http://www.nature.com/nature/journal/v378/n6556/abs/378481a0.html

Zimmerer, K. S. (1996). Changing fortunes: Biodiversity and peasant livelihood in the Peruvian Andes. Los Angeles: University of California Press.

Zoomers, A., (1999). Livelihood Strategies and Development Interventions in the Southern Andes of Bolivia: Contrasting Views on Development. Amsterdam: Centro de Estudio y Documentacion Latinoamericanos.

Zurlini, G., Riiters, K., Zaccarelli, N., Petrosillo, I., Jones, K.B., & Rossi, L. (2006). Disturbance patterns in a socio-ecological system at multiple scales. Ecological Complexity, 3, 119-128. http://www.srs.fs.usda.gov/pubs/ja/ja_zurlini001.pdf
Foster, S., & Garduño, H. (2006). Integrated approaches to groundwater resource conservation in the Mendoza aquifers of Argentina. Sustainable groundwater management: Lessons from practice. Case profile collection: Number 6. The World Bank: Washington DC. Retrieved from: http://water.worldbank.org/water/sites/worldbank.org.water/files/GWMATE_CP06_Argentina2006_0.pdf

Crabbé, A., & Leroy, P. (2008). The handbook of environmental policy evaluation. UK: Cromwell Press. http://books.google.ca/books?id=rHUN_LSf-fYC&pg=PA59&lpg=PA59&dq=%22nested+case+study%22&source=bl&ots=88JNcUsqY1&sig=9WGUFkdgyRLYgEFf7rKJzjphKvk&hl=en&ei=A2e3Tt3tCMjy0gG92_jQBA&sa=X&oi=book_result&ct=result&resnum=4&ved=0CDIQ6AEwAw#v=onepage&q=%22nested%20case%20study%22&f=false

Stanish, C. (1989). Household archeology: Testing models of zonal complementarity in the South Central Andes. In American Anthropologist, New Series, 91: 1, 7-24. American Anthropological Association.

http://www.sscnet.ucla.edu/ioa/stanish/pubs/stanish_1989.pdf

Rubio, E. T. (2007). Climate change impacts and adaptation in Peru: The case of Puno and Piura. http://hdr.undp.org/en/reports/global/hdr2007-8/papers/Trigoso%20Rubio_Erika.pdf

Goland, C., & Bauer, S. (2004).
http://www.ediblestrategies.com/fsd/2004_local_diversity.pdf

Isbell, William H.
1997 Mummies and Mortuary Monuments: A Postprocessual Prehistory of Central Andean Social Organization. Austin: University of Texas Press.

http://www.capitalfm.co.ke/news/2011/11/perus-congress-approves-10-year-gmo-ban/

The Free Dictionary – biopiracy, 2009

Gobierno Regional Cusco (Climatico map from IMA), 2005.

Hawkes, J. G. (2000). Introduction to the revised impression. In R. N. Salaman The history and social influence of the potato. UK: Cambridge University Press. http://books.google.ca/books?hl=en&lr=&id=EV4YE_0RsywC&oi=fnd&pg=PR9&dq=+Andes+%228,000+years%22+bartering+exchange&ots=U3Xsy_hUJc&sig=BMavobxMQlGVN3XqA9VuUMD74VI#v=onepage&q&f=false

McEwan, G. F. (2006). The Incas: New perspectives.

Rostworowski de Diez Canseco (1999). History of the Inca realm. Cambridge University Press.

Andrien, K. J. (2011). The invention of colonial Andean worlds.
http://lasa.international.pitt.edu/LARR/prot/fulltext/vol46no1/Andrien_217-225_46-1.pdf