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

NICOLE RENAUD

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

by

© Nicole Renaud

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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 traditional practices for the sake of modern approaches to water management and agricultural production. Yet the stress from these pressures can 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.

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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 and for human habitation. In fact, only 4.5% of Peru's Andes is arable (Hudson, 1992). The irregular availability of water has been one of the factors most hindering 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. 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 organizations promoting intensified water management and agricultural production compound these stressors. Water insecurity threatens to hinder a socio-ecological system's adaptive capacity. When the impacts of water-related stresses surpass a socio-ecological system's ability to cope, it may find itself unable of providing 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 (Newsham & 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. This thesis will explore these issues impacting local water security through a community case study of the Andean indigenous community of Mullak'as-Misminay.

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" (Bates et 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). To provide water security, water sources may also need protection from stresses deriving from human-induced events and processes such as 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 to 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, the author defines water security 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, their 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 changing, with rainfall projected to decline by 14% by 2050 in the Southern Andes, where Mullak'as-Misminay is located. 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 floods affecting this area negatively impact water quality and aggravate water pollution (Bates et al., 2008).

As temperatures increase and microclimates change, Andean flora and fauna species 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 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 may be precarious, particularly at the local level (Vuille et al., 2008).

1.3. Marginalization and the Rural Indigenous Poor

Historically, indigenous Andean communities have encountered multiple stressors that have created or exacerbated conditions of marginalization. Indigenous, rural Andean populations are disproportionately represented among the poor in Peru and systematically experience inadequate access to natural resources and land (Griffiths, 2002).

While poverty reduction itself is a goal universally agreed upon, conceptualizing poverty is a more contested area. Conventionally, monetary poverty is the approach most commonly acknowledged in poverty measurements, and in turn, poverty alleviation projects. However, this is beginning to be contested as an inadequate understanding of what it means to be poor. Poverty, after all, is deprivation of well-being, but not necessarily, exclusively, or universally the result of the deprivation of monetary wealth (Laderchi, Saith, & Stewart 2003). Alternative poverty conceptualizations may focus on different approaches to and indicators for well-being, while refuting the emphasis on maximizing utility or private and household income. These different approaches are discussed further in section 2.3.2.

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 overlapping 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; 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 divided into five community sectors, and these are: Pillahuara, Tayancayoc, Pucamachay, Santa Ana, and Misminay.

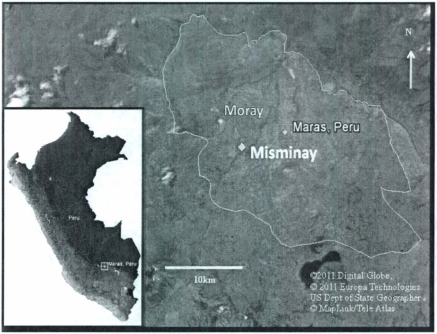
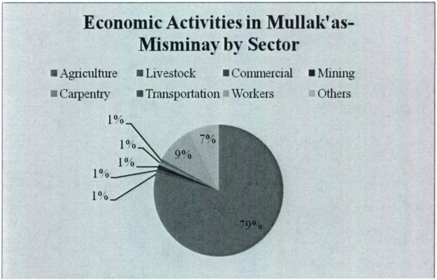


Figure 1.1. Map of Maras District with Inset of Peru

This community is populated primarily 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 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.). 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.).

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 1.2. Economic Activities in Mullak'as-Misminay by Sector.

Data from 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) (Cavero et al., 2005; Pulgar Vidal, 1979). 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, and community farmers coordinate their harvest around this seasonal division. Farmers store rain in their reservoirs for use in flood irrigation during the dry season. 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.; 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). 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 1.1 illustrates the different tasks in planting throughout a year in Mullak'as-Misminay, and provides an approximation of the times for each crop and task.

Table 1.1. Description of Misminay's Monthly Agricultural Duties

	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													

Adaptated from Gary Urton (1981).

1.5. Vertical Terraces

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 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 (Earls, 1998; Wright et al., 2011). Without the irrigation system formerly supporting this structure, crops are no longer regularly grown here, although attempts have been made using rainfed agricultural techniques (Personal communication, November 4, 2011). Moray currently serves as a major tourism attraction, drawing increasingly large numbers of tourists to the region (Cavero et al., 2005).

Vertical agricultural terraces are agronomically well-suited to mountain terrain and climates and are commonly used throughout the Andes (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.

The Inca had developed 700,000 ha of terraces in the Andes, which was accomplished with a large and highly-coordinated labour force (Alegria, 2007). Maintaining vertical terraces required not only an extensive amount of labour but also high levels of 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, and can involve labour such as working the fields, building a road, or developing irrigation. 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). 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. Multi-Level Relationships and the Pressure to Modernize

Andean communities have had a dynamic and shifting relationship with the state throughout history. The Inca Empire employed multi-level administration, and in the absence of a market system, the Inca economy promoted local self-sufficiency. When products were not locally available, social exchange through bartering or controlled trade were employed to secure extra-local products (McEwan, 2006). Empire citizens were generally provided for their basic needs. The Highland Economic Model, described by Rostworowski de Diez Canseco (1999), operated according to a subsistence pattern of usually rainfed agriculture. The relationship 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 eroded kinship alliances while facilitating exploitation (Andrien, 2011). The unstable, early colonial process was abetted by rampant epidemics that decimated indigenous populations as Spanish settlers flooded in, allowing indigenous lands to be seized with greater ease, while taxes and labour demands were imposed on surviving communities. These demands grew higher with the emergence of a competitive market economy, largely ushered in by Viceroy Francisco de Toledo's political economy reforms, which augmented food shortages and resource depletion for many Andean communities (Andrien, 2011; Larson, 1988). The extractive industries were rigorously pursued, and brought about new technology and approaches that modernized extractive practices, thus enabling more effective resource exploitation. The 19th century saw greater privatization of land and resources of Andean communities (Lange, Mahoney, vom Hau, 2006). Corrupt administration, oversight of kinship alliances, and local discontent served to unravel many colonial reforms (Larson, 1988).

This plethora of socio-political perturbations dealt a devastating blow to cultural and economic practices that drove traditional vertical agriculture and inter-community exchange. Later reforms saw large-scaled and mandatory resettlement of Andean communities by consolidating different Andean communities in the form of *reducciones*, serving to further disarticulate traditional Andean economies, kinships, and networks (Andrien, 2011). While discontent and restlessness brewed among indigenous peoples, strengthening control and snuffing out descent was facilitated by their weakened state.

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 (Childs & Williams, 1996). Precarious water supplies are often relegated to fuel agricultural modernization, and the discontent from indigenous populations manifest in response to competing interests.

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, for example, or the diversion of community water sources away from their own subsistence crops toward commercial-bound crops outside the community (Earls, 1998; 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.

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 pressurized irrigation (also referred to as "improved irrigation" by some agencies, and includes "drip" and "sprinkler" types) is largely oriented around concerns over efficiency, profit returns, and scale. Governments implement policy and legislation and propose incentives to adopt more modern and economic approaches to irrigation and other aspects of agricultural production (Gonzales, 2000).

Fujimori-era (from 1990-2000) neoliberal policies aimed to integrate Andean communities into cash markets through agricultural intensification for long-term growth and stability but have stretched smallholder farmers' local food systems thin, stressing water systems and resulting in heightened food insecurity and malnutrition (Marti & Pimbert, 2007; Slaughter-Holben, 1999). Former subsistence farmers have 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.

The external drive to modernize traditional and indigenous ways of life in rural agricultural communities is concretely rooted in profit incentives, focusing on water's market value and 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 & Leach, 1998). Inclusion in these schemes, however, usually requires profitable returns that may not be of benefit to the local populace, or even feasible (Kastelein, 1998; Vera Delgado & Zwarteveen, 2008). Avenues to modernity include standardized, top-down, market-oriented, Western scientific techniques and technology (Vera Delgado & Zwarteveen). The debate surrounding irrigation, discussed further in Chapter 4, is especially relevant, as currently practiced traditional methods employing gravity become displaced by pressurized irrigation schemes on the basis of higher efficiency (Embassy Brasilia, 2008).

1.7. Water Availability in Peru

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 & 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 (Gardner-Outlaw & Engelman; Gordon, 1998). 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 & Engelman). 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 most population and economic growth, such as the coast, may have the greatest access to water for uses that serve to further 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 with 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; 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; 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.

1.8. 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 & 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.

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 & 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.

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-level 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. In this thesis, multi-level governance also plays an important role and helps delineate actor relationships, networks, and interactions as they relate to Mullak'as-Misminay. Schmitter (2004) provides a good definition for this below.

> Multi-level governance can be defined as an arrangement for making binding decisions that engages a multiplicity of politically independent but otherwise interdependent actors – private and public – at different levels of territorial aggregation in more-or-less continuous negotiation/deliberation/implementation, and that does not assign exclusive policy competence or assert a stable hierarchy of political authority to any of these levels (Schmitter 2004: 49).

The political interdependencies at play are particularly significant in the situation of local water security, where actors at multiple levels make decisions that influence water use and allocation (described further for the Peruvian context in Section 2.4 below). The study of multi-level relationships in this case encompasses multi-level governance relationships, and more broadly considers the scope of connections between numerous actors affecting Mullak'as-Misminay. Examining the historical context of water security for this case study community and the surrounding region will outline 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 manners in which marginalization and multi-level relationships, and in particular governance, influence water security in the rural Andes, while providing 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 (Cook & Bakker, 2010; Gleick, 2000). 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 & 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, such as economic priorities, over others. Furthermore, examining water security at the scale of a socio-ecological system 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 2.1 shows the duration and cause of dry land areas, divided by short and long-term periods, as well as by ecological or anthropogenic causation.

Table 2.1: Water Scarcity Type

	Cause of dry lands	
Duration of dry lands	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).

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 & Rockstrom, 2006).

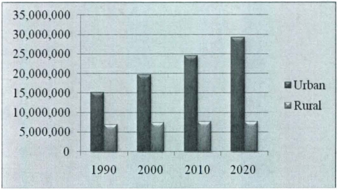
2.1.2. Water Stress

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, including increased demand for a finite resource (I Valls).

The population of Peru is steadily increasing, with large demographic and economic disparities between rural and urban regions. Table 2.2 indicates the demographic trends since 1990 and projections to 2020.

Table 2.2: Rural-Urban Population of Peru



(Adapted from McDevitt, 1999).

The demographic 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, 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 stress and 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, where water is drawn from either a reservoir or bore hole, are common in arid and semi-arid regions in developing countries. This makes for a particularly vulnerable situation, as single-point systems represent the primary water supplies in Mullak'as-Misminay and these are being affected by disruptions or shortages (Watson et al.). 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.).

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 (Servicio Nacional de Meteorología e Hidrología del Peru, 2011). These phenomena have stressed water availability, as droughts restrict water supply available for irrigation and in some instances reduce river flows (DuHamel, 2011; Ordinola, 1997).

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 (United Nations Framework Convention on Climate Change, 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). 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).

2.2. Adaptive Capacity and Water Management in Socio-Ecological Systems

Redman, Grove and Kuby (2004: 163) define a socio-ecological system as:

1. "A coherent system of biophysical and social factors that regularly interact in a resilient, sustained manner;

2. A system that is defined at several spatial, temporal, and organizational scales, which may be hierarchically linked;

3. A set of critical resources (natural, socioeconomic, and cultural) whose flow and use is regulated by a combination of ecological and social systems; and

4. A perpetually dynamic, complex system with continuous adaptation."

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 2.1, 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).

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 & 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 & 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 & Turner). 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 & Kolata, 2004). Experiencing such disturbances is part of the learning process involved in resiliency and allows societies the opportunity to develop and employ various short-term and long-term mechanisms and strategies in light of the water security problems they encounter.

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).

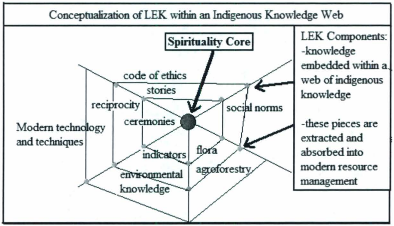


Figure 2.1: Local Ecological Knowledge Web
(Adapted from Casimirri, 2003).

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; 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 & 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; 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). 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).

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). The fragmentation of local ecological knowledge practices, such as vertical cultivation, was in part due to the intensified extraction of labour and resources from Andean communities used to fuel a growing New World export market economy, resulting in diminished local productive capacity (Andrien, 2011).

The application of distorted stereotypes of indigenous societies is detailed in Stephen Krech's The Ecological Indian: Myth and History (1999). In it, Krech describes how indigenous cultures have been portrayed as inherently environmentalist through the utopian projection of the "Noble Savage". This portrayal attributes a childlike innocence and victimhood to indigeneity. Conversely, they have also been portrayed as the incompetent, irrational, and even subhuman "Ignoble Savage". This version usually viewed the Ignoble Savages as incapable of self-governance, begging for the noble intervention to save them from themselves, which turns into "White Man's Burden" (Miller, 1982). Heider, Stack, and Betancourt (1990: 82) poignantly stated "as the Noble

Savage shows the innate goodness which is unspoiled by civilization, so the Ignoble Savage shows the innate evil which is uncontrolled by civilization."

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, both views deny the complex cultural processes involved in the development of indigenous societies and the local ecological knowledge they harbour.

The Inca's rule ended with the conquest, which prompted a lengthy Colonial period (1532-1821). Up until the 18^{th} 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).

2.2.2. Vulnerability

The adaptive capacity of a system is 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 shifting crop and field use; traditional agricultural mechanisms using irrigation strategies and structures; the balanced interaction of growing crops, rearing and herding animals; planting; and livelihood diversification (Earls, 2005). Many of these activities are oriented by reciprocity, which is embedded in the socio-cultural coordination and beliefs of Andean communities. In tandem, they help maintain resiliency despite vulnerabilities.

Table 2.3. 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 2.3 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.

Merino and Robson (2005) argue that there are numerous mechanisms by which communities develop conservation knowledge, including the gradual learning that comes with the natural progression of time. This model examines the prescriptive behaviour and productive outcomes of strife that directly compensate for resource depletion.

2.2.3. Adaptation and Resilience

Anthropologists and archaeologists had long believed irrigation systems in the Andes 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, and was experiencing punctuated droughts (Chepstow Lusty et al., 2003; Dillehay et al.).

In the Andean context we can emphasize not only practices conserving biodiversity and traditional management techniques, but also 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" (Brooks, 2003; Smit & Wandel, 2006: 282).

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 & 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 & 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. Hence, pathways to stability may not be returning to anything, but rather evolving into something new.

The three characteristics of socio-ecological system resilience are defined by Resilience Alliance (2011) as:

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

Capra (1996) has discussed the evolution of systems theory that has transitioned thinking from rationality towards intuition, analysis into synthesis, reductionism into holism, and linearity into non-linear forms of understanding. The shift in values has transitioned, at least to some extent, from expansionism to conservation, competition to cooperation, quantity to quality, and domination to partnership. These values are reflected in Peru's 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 depths of these transitions are argued, however, especially by critics of development politics such as Arturo Escobar, Paul Gelles, and Paul Trawick. 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 (Escobar, 1998; Gelles, 2005; Trawick, 2003).

2.2.4. Socio-ecological System Resiliency

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 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 may inform 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 (Gunderston & Holling, 2002). Gunderson and Holling 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.

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. Berkes et al. suggest that governing organizations should approach their sustainability goals as an ongoing, evolving, fluid process, building on system memory and enhancing multi-sector capital.

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 Intergovernmental Panel on Climate Change (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. Rights access 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.). 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.).

2.3.1. 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 has focused on the demand-side of development aims and the incompatibility of outside development concepts with Andean rural reality. This latter explanation sees the fault lying in the development discourse itself due to the foundational epistemologies and applications being unsuitable for indigenous Andean rural smallholder farmers (Zoomers). Zoomers 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.

2.3.2. Monetary Poverty and Social Exclusion in the Rural Peripheral Andes

Rural populations possess certain forms 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.

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 Juan Velasco Alvarado 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 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 has continued.

One fourth of the Peruvian population lives in extreme monetary poverty (Rural Poverty Portal, n.d.). 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). The majority of smallholder rural farmers live below Peru's national poverty line at $2 USD/day, with around 70% considered to be poor or extremely poor (Swiss Contact, 2011; World Bank, 2011).

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 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 (Gregory, 2009; Hayes, 1988; The Andean Observer, n.d.). Numerous authors (Chacaltana 2006; Tanaka & Travelli 2002; Yamada & 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.).

As discussed in section 1.3., there are alternative conceptualizations of poverty that are useful to consider when discussing material deprivation and well-being. Three approaches contrast the conventional view of monetary poverty and these are: the capability approach, the participatory approach, and the social exclusion approach (Laderchi, Saith, & Stewart, 2003). The capability approach refutes monetary poverty's emphasis, or overemphasis, on the maximization of utility and income, and is critical of monetary poverty as a means to well-being rather than focusing on the well-being end result or capability to function. This framework was crafted with the developing world in mind, as was the participatory approach. The participatory approach rejects externally developed and imposed poverty conceptualizations and centres around an internally-developed understanding of local poverty experiences. The social exclusion approach focuses on group dynamics and is useful in encapsulating the structural features of poverty. In essence it refers to members of a group who are effectively excluded from normal living practices, activities, and patterns (Townsend, 1979).

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 & Pimbert, 2007). Bartering-based market networks in Cuzco have strengthened as a response to 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.

Bartering has long existed in the Andes, possibly for 8,000 years, and pre-dating the Inca Empire (Beyers, 2001; 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 (Beyers; Custred). 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. This perspective is particularly similar to the social exclusion conceptualization of poverty.

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.

2.3.3. 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 & 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 adaptation 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).

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 remain important but can 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 participants are prepared to take (Shyamsundar, 2002). An example drawing from the Quechua context is the local conceptualization of poverty relating to disrupted social networks, which contrasts significantly to the state quantification of what it means to be poor (thought of primarily in monetary terms). 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.

2.3.4. Indigenous People, Marginalization and the Emerging Microfundia

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). One recurring challenge that indigenous 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, granted to smallholding indigenous and peasant farmers (Griffiths, 2002). As of 1994, 60% of Peruvian farmers owned less than five hectare plots of land (Escobal & Torero, 2006).

Smallholdings became even smaller as rural populations grew and these small plots of lands have been 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. 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 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. One of the main initiatives of Velasco's agrarian reform was to expropriate Andean estates larger than 15-55 hectares (Albertus, 2010; Long & Roberts, 1994). 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 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, who brought only violent political instability (Guran, 2008). These promises failed to manifest, 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 continues to be prevalent (Guardian News, 2010).

In a World Bank report (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, however, particularly in the instance of their unequal access to resources that would otherwise contribute to their adaptive capacity. Indigenous populations living in the Andes, for example, 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 & Hastorf, 1990). Macchi et al. (2008) project that food and water security for Andean traditional indigenous smallholder farming populations will be at risk by 2055.

2.3.5. The Green Revolution in Peru

Many Latin American countries, including Peru, implemented agrarian reforms in the 1950s and 1970s that included land redistribution with the intent of modernizing 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; Shiva, 1991).

Additional strategies included the pressure to implement crop specialization through monocultivation, feeding into 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).

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.

2.3.6. Water Politics in the Andes

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).

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.

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; 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 (Boelens & Gelles, 2005; Trawick, 2003). 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.

Pressurized 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. 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.

2.4. Peru's Water Governance System

Peru has recently adopted an Integrated Water Resource Management (IWRM) approach, and as such is synchronizing its legal framework, institutional framework, and national strategy to address the principles of IWRM. At the institutional level, Peru established the National Water Authority, known as Autoridad Nacional del Agua (ANA) in 2008, which organizes water management at the river basin-level (Andina, Agencia Peruana de Noticias, 2007). Its structure follows IWRM and it consolidates different ministries under its authority. The National Watershed Management and Conservation Soils Project (Programa Nacional de Manejo de Cuencas Hidrograficas y Conservacion del Suelo – PRONOMACHS) has an Andean-based IWRM river basin conservation focus. In addition to nationally-led projects, PRONOMACHS can work collaboratively with NGOs and international development funding institutions, such as the World Bank, in order to create profit-oriented water resource investments (e.g. pressurized irrigation projects in locations with market access) (Posner & Mujica, 1998). The World Bank and the Peruvian Government are jointly working on the National Water Resources Management Modernization Project that seeks to strengthen IWRM in three basin pilot regions across the country (World Bank, 2009b). At the District level, Maras reflects this water resource management direction in its Agricultural Economic Development objectives (Cavero et al., 2005). These include promoting pressurized irrigation in order to intensify agriculture with the support of international funders that do not require a profit return.

Legally, Peru's Constitution recognizes the state as the sole manager and entity ultimately responsible for water resource management. The General Water Law of 1969 had established water as an agricultural commodity, but in 1997 the Natural Resources Law enabled transferable water rights between users (Olson, 2007). The 2003 National Irrigation Strategy created a multi-level framework in order to facilitate irrigation projects, while the Technical Irrigation Program law was implemented in 2006 in order to promote pressurized irrigation systems throughout the country (Comisión Técnica Multisectorial, 2004).

2.4.1. 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 in Article 2 which explicitly stated that the administration of water resources will be not 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).

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). 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.

Peru's former General Water Law and the newly reformed LRH have mandated water management to be both "economical" and "efficient", thus enabling the country's legislative framework to couple with national policy and international funders to actively promote pressurized irrigation (Trawick, 2003).

2.4.2. Integrated Water Resource Management

Integrated Water Resource Management (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 (Connected Water, n.d; Engle et al., 2011).

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." (Global Water Partnership, 2000, 2008). 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). As socio-ecological systems are highly integrated and complex, actors acting independently of one another can lead to unexpected and unstable outcomes (Bouwen, 2004; Dongier et al., 2001).

It has been postulated within the executive summary of the Second World Water Assessment Report (World Water Assessment Programme, 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 sector reform must be accompanied with governance reform in order for IWRM and its principles to positively affect water security.

Peru's LRH 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. Hancco et al. (2006) argue that LRH embodying IWRM violates the principles and process of regional decentralization by maintaining decision-making powers in Lima.

2.5. Conclusion

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).

In conclusion, multi-level actors have created and built upon 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 of Andean Peru (Crabbé & Leroy, 2008). Baxter and Jack (2008) say "Qualitative case study methodology provides tools for researchers to study complex phenomena within their contexts." A nested case study helped in the investigation of the phenomenon of Andean water security, which is of contemporary importance, by drawing upon the local, socio-cultural context of a single community with a notable history on the subject.

3.2. 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, modified as Figure 3.1, 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 chosen socio-ecological system and relevance to the research. It also serves as a suitable guide to help navigate the research questions examining stresses, responses, marginalization, and multi-scale relationships.

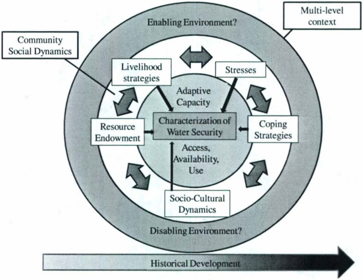


Figure 3.1. Conceptual Framework for the Characterization of Water Security (Adapted from Haan et al., 2001).

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.

3.3. Development of Socio-ecological System Case Study Criteria

Developing criteria for the socio-ecological system case study selection 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 socio-ecological system case study selection were to locate a system that possesses the characteristics of interest for this study (e.g. marginalization, adaptation, and water stress). 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. These adaptive responses have included long-term enduring strategies (e.g. native forestry, livelihood diversification, rotational agriculture) and more recent and short-term approaches (e.g. protest and civil disobedience).

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.

3.4. Community Case Study Selection

The first field work season took place in Ollantaytambo, Peru. The first two months were dedicated to community case study selection. The 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 having had conducted previous research in the community and felt it was suitable for the project. In part because 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 study. Further, previous research had been conducted in the area to build upon, such as Gary Urton's *At the Crossroads of Earth and the Sky: An Andean Cosmology* (1981), and John Earls's "Calendar and Coordination in High Mountain Terrain Systems" (2011) and Wright et al.'s *Moray: Inca engineering mystery* (2011).

3.4.1. Establishing Community Contact and Liaison

Ethics approval for this research project was obtained by the Interdisciplinary Committee on Ethics in Human Research on July 28, 2009. Following approval, contact with Mullak'as-Misminay was established.

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 as well as the community itself with relative ease, while offering sufficient amenities to assist 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.

3.5. 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 (CARE, n.d.). 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.

The role of the internship in the research process included working on a literature review on water security and climate change adaptation for smallholder farmers in the Andes, with a particular focus on Peru's national policy position regarding pressurized irrigation systems. This research helped contextualize the multi-level governance dynamics currently at play in Peru, and provided insight into the political and economic conditions that serve as barriers to local water security for the marginalized populations. Working at the national level helped the researcher delineate different roles and interactions between actors at varying levels. National policy research also accentuated the disparate power dynamics, which are manifested through highly uneven state-allocated water distribution.

Working with an NGO as a participant observer involved in meetings and discussions with project consultants and CARE's Climate Change Team also provided an understanding of the role of development aid in local water security and the coupling of poverty alleviation with climate change adaptation using dominant economic approaches to development. In this process, a key observation was that there was little to no space for debate regarding the inclusion of practices deriving from local ecological knowledge. Traditional irrigation systems were written off within this internship's project as inefficient and the modernization of water, and in particular irrigation, systems was lauded as the pathway out of poverty and solution to climate change adaptation.

In-community research during the internship was much briefer due to limited time away from the office. Interview questions were increasingly tailored towards pressurized irrigation and multi-level governance and relationships based on research conducted during the internship. Participant observation included partaking in food preparation tasks, and reciprocity of offering food and receiving food in turn over conversation. The researcher stayed in a resident's home and one of the children introduced her around town, while interviewing people on their breaks from work. This form of research helped the researcher gain greater trust and inspired more comfortable conversation.

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 farmers who were also local water organization members.

3.6. 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.

3.6.1. Themes

The interviews were oriented around the following themes.

1. Ecological matters concerning water
2. Governance and marginalization
3. History of adaptation and stress
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.

3.6.2. Respondent Selection

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, as displayed in Table 3.1. 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 3.1. Interview Respondents

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	Ministry of Natural Resources and Environment	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.

3.6.3. 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 and marginalization

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 in Chapters Four and Five. 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.

3.7. Documents, Photographs and Archives

3.7.1. 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 Pontificia Universidad Católica del Perú 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.

3.7.2. 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.

3.7.3. 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.

4.1. 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" (Respondent 2, personal communication, August 5, 2009). These lagoons are visible in Figure 1.1 in Chapter 1, just south of the boundaries of Maras. 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 shows Moray's former water source to the left, which is fenced off and now supplies Maras's pressurized irrigation system. The image to the right of Figure 4.1 shows the main water source for drinking water in Mullak'as-Misminay.

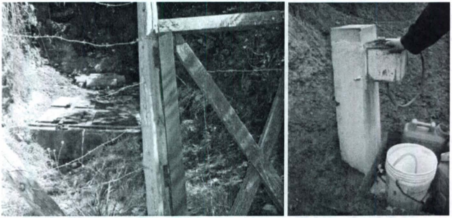


Figure 4.1. Water Supplies in Mullak'as-Misminay

Photo by Nicole Renaud, August, 3, 2009.

Mullak'as-Misminay's water sources include eight springs, and farmers largely rely on rainfed agriculture, although they would store water from the rainy season in reservoirs and use the water for flood irrigation during the dry season.

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 (personal communication, September 25, 2009), as he expressed concern for the state of the community's water supplies. This sentiment was shared by Respondent 2 (personal communication, 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; Respondent 13).

IMA has classified Maras as possessing low agricultural soil quality (Gobierno Regional Cusco, IMA, Grupo Tecnico de Coordinacion Interinstitucional, & Ministerio de Energia y Minas). 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). Natural grass coverage is precarious and poor as soil fertility is deemed low; a condition mitigated through fallow periods. It was noted that this practice of employing fallow periods has increasingly been lost due to decreasing agricultural land availability attributed to population growth.

The soil's shallowness and climate make the area unsuitable for intensive livestock rearing. "Agricultural production has diminished, agricultural terrain is not as fertile as before", stated Respondent 2 (personal communication, 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.

4.1.1. 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.; 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 (Earls, n.d.; World Bank, 2009a). Climate events are projected to deviate substantially from the long-term norm and communities will experience fluctuating atypical local weather variations (Earls, n.d.; 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 (Agrawal, 2008; Earls n.d.; Perez et al., 2010).

4.1.1.1. 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; World Bank, 2009a). 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, personal communication, September 25, 2009; Respondent 22, personal communication, 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 (personal communication, 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 (personal communication, August 10, 2009).

4.1.1.2.. 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, 2009a). Respondents 2 (personal communication, August 5, 2009), 6 (personal communication, August 10, 2009), 7 (personal communication, August 10, 2009), 8 (personal communication, August 10, 2009), and 12 (personal communication, 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-Misminay during the past ten years was also observed, and dry spells were said to be lasting longer than usual (Respondent 8, personal communication, August 10, 2009; Respondent 9, personal communication, August 10, 2009; Respondent 13, personal communication, September 25, 2009). Some respondents (Respondent 13; Respondent 21, personal communication, November 24, 2009; Respondent 22, personal communication, 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 (personal communication, 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, personal communication, August 13, 2009; Respondent 14, personal communication, September 25, 2009). Commenting on the diminishing water, Respondent 14 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."

4.1.1.3. Changing Precipitation Patterns

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 (personal communication, 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, November 24, 2009.

4.1.1.4. 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, personal communication, August 12, 2009; Respondent 12, personal communication, 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", said Respondent 10.

4.1.1.5. 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, 2009a). Frost is considered to be one of the most significant hindrances to agriculture (Perez et al.). 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, personal communication, August 5, 2009; Respondent 9, personal communication, August 10, 2009; Respondent 14, personal communication, September 25, 2009; Respondent 20, personal communication, November 23, 2009). "In May, June, and July there is more frost," said Respondent 20 (personal communication, 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). One respondent even deemed frost a significant environmental concern for the community alongside of water shortage, warming temperatures and increased hail (Respondent 9). More intense frosts were identified as a recent environmental change in Mullak'as-Misminay impacting agriculture (Respondent 9; Respondent 14).

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, personal communication, August 5, 2009; Respondent 10, personal communication, August 12, 2009; Respondent 23, personal communication, 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. 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 (personal communication, August 7, 2009). Respondent 4 (personal communication, 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; 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 (Cassinelli Del Sante, 2000; Respondent 2, personal communication, August 5, 2009; Respondent 10, personal communication, August 12, 2009; Respondent 11, personal communication, August 13, 2009). Respondent 2 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; Respondent 13, personal communication, 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). 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, 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; Respondent 2, personal communication, 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, personal communication, August 3, 2009; Respondent 3, personal communication, August 7, 2009; Respondent 21, personal communication, November 24, 2009). Some deforestation issues described include forest and tree zones being converted to agricultural lands and livestock ranches (Respondent 3). "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 (personal communication, 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, August 3, 2009.

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).

Mullak'as-Misminay employs rudimentary farming practices, including use of cattle for ploughing. Modified seeds are used to an extent in the Maras District, however for the most part crops grown in the community are beans, corn, different varieties of potato, quinoa, and wheat (Urton, 1981).

Diminishing ecological knowledge and traditional values have been linked to natural resource degradation (Respondent 2, personal communication, August 5, 2009; Respondent 3, personal communication, August 7, 2009). "In the past, during the time of the Incas people took better care of water resources and prevented soil erosion", stated Respondent 2. "Soils need the cover of trees, grass and shrubs", said Respondent 3, "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; 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 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; and Respondent 4, personal communication, August 8, 2009) saying it diminishes water supplies. "I think that we have to teach our kids not to burn grasses, shrubs, or trees. If not, we will not have water", said Respondent 4.

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 plant diseases, both of which are occasionally a problem in the Maras District (Cavero et al., 2005; FAO, 2010). Goland and Bauer 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, personal communication, 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, personal communication, August 7, 2009; Respondent 22, personal communication, November 24, 2009). "Yes there is a rotational system of agriculture – once a year corn is collected or beans or potatoes from different places. The earth has to rest to produce more", said Respondents 15, 16, and 17 (personal communication, September 25, 2009). The period of rest refers to the fallow period accompanying a low-intensity approach to their subsistence farming. While the community does practice rotational agriculture, however the District Strategic

Plan and respondents (Respondents 15, 16, and 17; 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, personal communication, 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). "The biggest water challenge in the area is water contamination", said Respondent 12 (personal communication, August 13, 2009).

Cavero et al. (2005) outline some of the main contaminants that are problematic for the District, which include plant agrochemicals. "I believe that due to climate change, more diseases in plants are appearing. On the other hand, insects and pests are moving quickly and we will reach a point where control will be very difficult", said Respondent 11 (personal communication, August 13, 2009). Pests and plant diseases, 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 create 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, et al., 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).

"We do not work with fertilizers, we use cattle manure, nothing more", said Respondent 23 (personal communication, November 24, 2009). Respondent 1 (personal communication, August 3, 2009) agreed, saying "organic resources are used, for example animal manure, and no pesticides are used in general, only when pests attack the crops." Respondent4 (personal communication, August 8, 2009) believed agrochemical use is concentrated in the lowlands. "Here in the upper Andean communities they work in an organic manner, although there have been more sprayings for pests and plant diseases", said Respondent 4. Agriculture in the community seems to be mostly organic. Some of the main sources of pollution described by interview respondents include the agrochemicals mentioned above, as well as waste (Respondent 1).

Figure 4.4. Open-Lined Canal Flood Irrigation in Mullak'as-Misminay.

Open canals leave water exposed to contaminants, as well as surrounding waste.

Photo by Nicole Renaud, August 3, 2009.

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, personal communication, 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 (Cavero et al., 2005; Respondent 2). "To avoid diseases, we chlorinate the water in Misminay", said Respondent 1.

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; Respondent 12, personal communication, August 13, 2009). "Here the people are used to taking water from the canal, and do not know that it has parasites", said Respondent 4 (personal communication, August 8, 2009), speaking of water in the region. 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 (J. Earls, 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 in the province as it reduces available agricultural areas (Respondent 11, personal communication, August 13, 2009). "Areas are being reduced as there is growing urban expansion. There is an increase in population that is not sustainable therefore farmers cannot produce as much food as they have few hectares of land", said Respondent 11.

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, personal communication, August 10, 2009). "I have compiled stories my grandparents told me about the mountains", said

Respondent 4 (personal communication, August 8, 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, personal communication, August 3, 2009; 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.

People receive rewards for contributing to faenas. This includes giving "small prizes that can include corn beer [or] potatoes", says Respondent 1 (personal communication, August 3, 2009). If people do not contribute through labour, they need to pay instead, or have their water service cut (Respondent 1). 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, personal communication, November 24, 2009). The water organization in Mullak'as-Misminay is composed of faena works. "We work with 47 people and every three months we do faenas", said Respondent 21. 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, personal communication, August 8, 2009; Respondent 7, personal communication, August 10, 2009; Respondent 9, personal communication, August 10, 2009; Respondent 12, personal communication, August 13, 2009). When faenas are performed for the benefit of a family, this is called ayni or minka (Respondent 4).

A faena underway during the field work season was working to open up a community road (Respondent 7, personal communication, August 10, 2009; Respondent 9, personal communication, 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, personal communication, August 13, 2009). In discussing what the community does when there is a drought longer than normal, Respondent 21 (personal communication, November 24, 2009) said "we talk to the president of Maras. We organize ourselves, and we have organized assemblies."

Based on these traditional ways of organizing, during times of water scarcity neighbours will pull together to help one another out (Respondent 8, personal communication, 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

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. "When there aren't good harvests in general a farmer sells some cattle to survive", Respondent 4 (personal communication, August 8, 2009) said, when answering how they respond in times of insufficient water availability. This kind of livelihood diversification helps distribute risk during difficult dry spells.

The bartering system of the Andes was discussed by interview respondents, where produce is traded (personal communication, Respondent 1, August 3, 2009; Respondent 9, August 10, 2009; Respondent 18, personal communication, September 29, 2009). "We communicate with other regions, we use bartering, we exchange products with other communities", said Respondent 9. A farmer who grows potatoes can exchange their produce with a farmer who spins wool, for example (Respondent 18). Many farmers also consider a certain degree of market participation as an important livelihood strategy to distribute risk (Perez, Nicklin & Paz,

2010)http://www.ccrpleadershipteameeting2011.info/wikimcknight/images/c/cd/Perez-

Food_crisis,_small_farmers_%26_markets_(2).pdf). While providing another income source, the introduction of money is sometimes understood as contrary to the bartering system, incorporating farmers in the capitalist system (Respondent 18). 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 (Local residents, personal communication, September 25, 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.

4.3.3 Agricultural Strategies

The foundation of Andean crop cycles is especially grounded in the opportunities presented at various ecological levels (Golta, 1980; 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 continuously irrigated corn (J. Earls, 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, Respondent 23, personal communication, 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). "Up top we plant potatoes, one year on this side, another year on this side, another year on the other side", said Respondent 23 (personal communication, November 23, 2009). Beans, corn and potatoes were some of the crops mentioned that are part of the rotation (Respondents 16, 17 & 18, personal communication, September 25, 2009; 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. "When there's enough rain the [rotational system] produces enough, but when there's not enough rain it doesn't produce enough", said Respondent 23 (personal communication, November 24, 2009). It was observed that the schedule regarding the agricultural duties is greatly changing because crop cycles are oriented around seasonal rainfall, with crops planted after rainfall. "People start growing crops after rainfall…the problem is that rainfall occurs in other months, and sometimes is delayed and sometimes goes longer and this causes the agricultural schedule to be affected", said Respondent 10 (personal communication, 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, personal communication, August 10, 2009; Respondent 8, personal communication, August 10, 2009; personal communication, 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; 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 discuss traditional forecasting indicators for Andean communities based on abiotic and biotic indicators. 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 (personal communication, August 8, 2009) from Ollantaytambo states "there are people who predict climate change using stars, while others read fortunes." 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 4.5. Farmers in Mullak'as-Misminay Taking a Break from Working the Fields. Photo by Nicole Renaud, September 25, 2009.

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., 2010; Respondent 18, personal communication, September 29, 2009). 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.).

4.3.3.1. Vertical Terraces

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 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.

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.

Although 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; 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). Mullak'as-Misminay possesses some unmaintained vertical terraces that are overgrown with thick vegetation (Respondents 16, 17 & 18, personal communication, September 25, 2009). While there are some present, they did not appear to be very extensive.

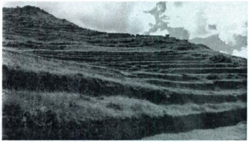


Figure 4.6. Abandoned Terraces in Cuzco Region.

Photo by Kelly Vodden, May 18, 2009.

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 4.7. One of Moray's Sinkhole.

Photo by Nicole Renaud, August 10, 2009.

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 (Cavero et al., 2005; Wright et al., 2011). The largest sinkhole 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 et al.).

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, personal communication, September 25, 2009). "The vertical terraces are not used now, the government used to work them but that was a long time ago", said Respondents 15, 16 and 17 (September 25, 2009). In conversations with locals, people merely commented that terraces are no longer used there as they once were.

4.3.3.2. Irrigation

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; 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 4.8. Flood Irrigation in Mullak'as-Misminay.

Photo by Nicole Renaud, August 3, 2009.

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).

Figure 4.9. Unpressurized lined and unlined irrigation canals in Mullak'as-Misminay. Photo by Nicole Renaud, August 3, 2009.

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, personal communication, August 7, 2009; Respondent 9, August 10, 2009; Respondent 13, personal communication, September 25, 2009;

Respondent 20, personal communication, November 23, 2009; Respondent 21, personal communication, November 24, 2009; Respondent 23, personal communication, 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. Respondent 20 (personal communication, November 23, 2009) 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 4.10. Cuzco Government Pressurized Irrigation Funding Sign for Maras

"Regional Government of Cuzco. Project: Maras Irrigation" – Photo by Nicole Renaud, August 1, 2009.

Four respondents stated they would like spray irrigation in the community, while two would like to see drip irrigation (Respondent 9, personal communication, August 10, 2009; Respondent 13, personal communication, September 25, 2009; Respondent 14, personal communication, September 25, 2009; Respondent 20, personal communication, November 23, 2009; Respondent 22, November 24, 2009; Respondent 23, personal communication, November 24, 2009). "The best would be drip but in Maras they irrigate by sprinkler. This system is used because it costs less than drip irrigation", said Respondent 20. Another did not believe drip irrigation provided sufficient water delivery, stating "it doesn't advance water, so sprinkler is better" (Respondent 22). Respondent 14 (September 25, 2009) stated "sprinkler irrigation would be a better system [than flood irrigation) because it's more efficient, [goes against gravity] and you could irrigate more land."

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, personal communication, November 24, 2009). Respondent 23 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. "We want water from a spring that is ten km away in Llanapolla (phonetic name provided)", said Respondent 21 (November 24, 2009). "What we want is to transport [the waters from glacier melts that have produced lagoons] to the zones in Maras where reservoirs are being built", said Respondent 2 (August 5, 2009), "this would help replenish the springs." It is possible that these two water sources referred to are the same, however this is unconfirmed.

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, personal communication, August 5, 2009; Respondent 12, personal communication, August 13, 2009; Respondent 14, personal communication, September 25, 2009; Respondent 19, personal communication, October 23, 2009; Respondent 22, personal communication, November 24, 2009; Respondent 23, personal communication, November 24, 2009). "If we had support we could build a reservoir to store water from the rains", said Respondent 14, "but we have no support, and the rainwater only goes to the river." Reservoirs were even attributed to improved erosion mitigation and water management during Inca times (Respondent 2). It was even suggested that reservoirs help improve water quality, and could diminish the incidence of parasitic intestinal worms in children (Respondent 12).

Figure 4.11. A reservoir in Mullak'as-Misminay.

Photo by Nicole Renaud, August 5, 2009.

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, personal communication, August 5, 2009). One Maras respondent brought up the administrative boards, and said "the organizations respond by water rationing. In this way each user receives potable water for hours, while the irrigators also leave areas without irrigation" (Respondent 1, personal communication, 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; Respondent 9, personal communication, August 10, 2009). Cavero et al. indicated research was currently underway in the District to investigate solutions for ways of tackling the lack of potable water. Improving water distribution was described as one of the biggest challenges facing the District, "because water does not reach higher places, you need bigger investments and technology. On the other side of the valley, water is wasted or disappears because it reaches the river and is not beneficial to farmers", said Respondent 1 (August 3, 2009).

4.3.4. Forestry and native plants 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 (*Queuñoa de Altura*, *Polylepis tarapacana*), and saúco (*Sambucus Peruviana*).

Colle and Chachacomo were provided as good examples for focus (Respondent 23, personal communication, November 24, 2009; Cavero et al., 2005; 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). 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.). Chachacomo and polylepis now only exist in limited areas of the community around people's homes.

Figure 4.12. Trees and Shrubs in Mullak'as-Misminay.

Photo by Nicole Renaud, November 24, 2009.

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 (Respondent 1, personal communication, August 3, 2009; Respondent 4, personal communication, August 8, 2009; Respondent 10, personal communication, August 12, 2009; Respondent 11, personal communication, August 13, 2009; Respondent 13, personal communication, September 25, 2009). "They should plant near springs with sauco and aliso, because it brings more water. Aliso and sauco are very good, eucalyptus ruins the soil", said Respondent 4. It was lamented that some plant eucalyptus near springs which causes them to dry (Respondent 2, personal communication, August 5, 2009). One respondent stated that native plants should thus be the focus of local planting rather than non-native flora such as eucalyptus (Respondent 23, personal communication, November 24, 2009). "We need native plants to reforest, there's colle, chachacoma… there is eucalyptus but it's not good, it's bad for the earth. Colle is a good fertilizer and is used to dye sheep wool yellow", said Respondent 23.

"Now we are trying reforestation and bringing back native plants, there are irrigation projects and it depends on the authorities and the central government to see if they will give us a budget for a project to bring water", said Respondent 13 (personal communication, September 25, 2009). Another mentioned that the community does not receive any real support for forestry programs and that they are left to pay for planting initiatives themselves (Respondent 6, personal communication, August 8, 2009).

In conclusion, Mullak'as-Misminay and the surrounding region have experienced varying stresses of both ecological and anthropogenic origin impacting their water security. Climate change and weather taking place on the marginal lands of the Andes combine to deliver unpredictable rainfall, long dry spells, more frost days, and natural hazards. Stresses relating to social dynamics and local behaviours also impact local water security. Forestry and planting decisions relating to certain species, especially of eucalyptus, have shown to withdraw excess water from soils. Certain agricultural practices have also had negative impacts on water supplies and soils, including burning of grasslands, monocropping pressures in the region, pollution, and in particular agrochemicals contaminating water sources through surface runoff. The state of infrastructure and services was also identified as an issue. Local adaptations existing in the long-term as well as short-term strategies have helped Mullak'as-Misminay manage often scarce water sources using innovation and local ecological knowledge. Reciprocal community coordination such as through faenas, allow smallholder farmers to collectively pool efforts and enjoy the benefits of their labour. Livelihood diversification exists as well as a way to distribute risk and make ends meet when harvests fail. Local agricultural strategies have especially made good use of water supplies, and Moray in particular demonstrates a masterpiece of agricultural and water management innovation. Irrigation practices and goals showed to be of great interest to community respondents as they discussed several ideas in enhancing water security. Finally, planting native plants was frequently discussed as a way to conserve spring waters.

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

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.

One of the research questions addressed in this thesis is 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 (or disabling) environment component of the study's conceptual framework. It considers the influence of relationships with the community's environmental, political, economic, and social contexts. Environmental stresses, particularly climate change, have been previously discussed in Chapter 4. A brief overview of the multi-level socio-economic and political influences on the community's water security will be discussed further below. In reviewing these relationships links to the notion of marginalization are also considered.

5.1 Smallholder Farming, Modernity, and Water Security

Smallholder farmers have been challenged to maintain water security while navigating numerous political and economic changes to the rural Andean landscape. During the Colonial era, 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).

The uneven distribution of land, diminished freedom, and associated erosion of water rights were driving forces behind the arguments for the Agrarian Reform Decree Law 17716 of 1969. The agrarian reform was highly controversial and implemented after General Juan Velasco Alvarado led a coup and overthrew the previous president (Albertus, 2010). The reform, which lasted until 1980, claimed to promote poverty reduction and indigenous farming values through cooperative tenure systems. It is credited for liberating numerous indigenous people from providing unpaid and forced labour, but also for creating top-down policies that often excluded the indigenous rural poor while aiming to benefit commercial farms (Barraclough, S. L. & Eguren, F., 2001; Respondent 12, personal communication, August 13, 2009; Respondent 13, personal communication, September 25, 2009). In reflecting upon the reform, Respondent 12 said "I think the campesinos wanted to be free, not slaves anymore." "The agrarian reform saw the disappearance of large farms (haciendas) and the formation of rural communities," stated Respondent 11 (personal communication, August 13, 2009), "since then smallholder farming started to appear, so now the area of cultivation for each farmer is very small."

Prior to Velasco's reform, added Respondent 13, peasants were deprived of food and education, whereas now some youth can read and write (personal communication, September 25, 2009). "Water user organizations have existed since the time of the National Agrarian Reform", said Respondent 1 (personal communication, August 3, 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, personal communication, August 13, 2009). One respondent believes there has been progress for Andean farmers since the reform; however, the government still does not help rural people. "Now we are moving forward somewhat, but the government forgets about us", said Respondent 13 (personal communication, September 25, 2009).

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 (Albertus, 2010; Muller et al. 1991). 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, personal communication, August 13, 2009). "That's why Shining Path and MRTA existed. People from Lima did not respect people from the mountains. After the terrorist movement was initiated, people show more respect. But they didn't care for us, they were just afraid" said Respondent 12. 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). A sentiment of ongoing disrespect for Andean customs and rural people by the government was expressed (Respondent 9, personal communication, August 10, 2009).

5.1.1. Subsistence Farming with Microfundia Landholdings

Most indigenous highland land holdings continue to exist within the unevenly distributed agrarian system consisting of latifundia and minifundia, despite the agrarian reform's land redistribution (Griffiths, 2004). Increasingly, population growth has been transitioning minifundia into microfundia (less than 1 hectare of landholding), which is inadequate for subsistence farming. "There is an increase in population that is not sustainable, therefore farmers cannot produce as much food as they have few hectares of land (smallholdings)", said Respondent 11 (personal communication, August 13, 2009), and further "this area has tourism and this tourism generates construction of infrastructure works and therefore reduces crop areas." The combination of development and population growth stretches small cultivation areas thin.

The emergence of microfundia was described by a community farmer, and said that with this, smallholder farming has begun to disappear (Respondent 11, personal communication, August 13, 2009). "The production from one hectare doesn't feed an average family. Not even if you have a good policy in place, you can't develop agriculture when the cultivation areas are too small", said Respondent 11 (personal communication, August 13, 2009). 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 a cash income (Cavero et al., 2005). By feeding themselves with their own production and engaging in barter, however, little money is spent on food (J. Earls, personal communication, November 4, 2011). Nevertheless, reduced land availability results in pressures for intensified use of the lands smallholder farmers do have access to.

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 this 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 when residents return to the community (Respondent 13, personal communication, September 25, 2009). "The problem is that many [members of our community] are going to Lima to be educated and then come back, working in the region and are only worried about their own benefit. They forget about us," said Respondent 13.

5.1.2 Intensifying Agriculture and Crop Comercialization

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 have been 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).

In Maras, 90% of farmers use low to medium levels of fertilizers, and this use is principally for commercial varieties (Cavero et al., 2005). 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. 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. 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.; Halloy, et al., 2005). The less-intensive approach involved in rotational practices may result in lower yields, but 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, personal communication, August 3, 2009). "My biggest concern [for the future] is that everything will disappear, for example, the glaciers. We already are not going to be able to eat our natural products," said Respondent 1.

Genetically modified food was also discussed as an issue for Cuzco farmers, with respect to modernization of agriculture.

> The introduction of foreign elements such as GMO (Genetically Modified Organism) is a major threat to the environment and sovereignty, and the economy of communities. This will generate a transgenic deterioration because you can create crosses with native varieties and can make hybrids and can become sterile plants. God knows it can happen and we run out of diversity. Respondent 18, personal communication, September 29, 2009.

In November 2011, Peru's Congress 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 (J. Earls, personal communication, November 4, 2011). As discussed in Chapter 4, 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. "These native potatoes are …the reserves for future solutions to [plant] diseases, adaptation, and production" said Respondent 18, adding that economic and political systems threaten the Andean economy that maintains this plant diversity.

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 American Heritage Dictionary of the English Language, Fourth Edition, 2009)." This phenomenon was identified by one respondent as a concern in Cuzco. "The Regional Government of Cuzco has dedicated itself to preventing biopiracy [by issuing] an ordinance to protect biodiversity and ancestral knowledge of the region" said Respondent 10 (personal communication, August 12, 2009).

5.2 Privatization, Water Politics and Water Rights

Historically, local water traditions had 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 in Andean society, and this perception served to validate the ascribed stereotype of Ignoble Savages, 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). 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 (Strong, 1992).

Privatization in the colonial era 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 range. 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.

When Trawick (2003) wrote his critique of water privatization in the Peruvian Andes, he cautioned that a privatization law would "only turn the clock back, making the countryside a much less viable place for peasants to live in than it is (Trawick, 2003: 992-993." He added it would also lead to increased rural outmigration. Respondents described how privatization is also seen as conflicting with local Andean customs. "The government has privatized mining and land, and doesn't have the slightest respect for our customs", said Respondent 9 (personal communication, August 10, 2009). "The problem is security to the source of the water", said Respondent 19 (personal communication, October 23, 2009), "many communities have problems because the water sources are becoming private. Mining companies are buying lands and using water for their own purposes."

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, personal communication, August 8, 2009; Respondent 12, personal communication, August 13, 2009). "There are projects that want to privatize water and want to charge for irrigation water so people are angry", said Respondent 12. "State policy seeks to privatize water, supposedly to optimize the resource" lamented Respondent 18 (personal communication, September 29, 2009), "They say it's better for management and they deliver it to companies that seize the water. It's true that a better administration is needed, but the problem is who administers. I believe that communities should be the administrators."

5.2.1. Andean Water Rights and Politics

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, personal communication, August 7, 2009). "The government has recently released a comprehensive law of water resources, and it seems to me it's a very good law that creates watershed-level councils that are empowered to plan, manage, and administrate water resources", said Respondent 3, referencing the new water law. This contentious water law is part of the IWRM process, which Respondent 3 argues 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).

Contemporary water tension was also discussed by respondents. "Presently there are many fights, lawsuits, and it has even come to the point where people kill for water", said Respondent 2 (personal communication, August 5, 2009). Protests across Urubamba had been occurring in the months leading up to and during this research, with a general strike launched in January by the National Water Users Board and Irrigation Districts. "The villagers do not agree with the new water law issued by the government. They made a general strike in August to complain about this law to privatize water", said Respondent 4 (personal communication, August 8, 2009). 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 being 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 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; Respondent 10, August 12, 2009). "Due to this project, the province of Espinar is suing the central government and demanding that the regional government of Cuzco defend the water resources of the area", said Respondent 10.

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 seen as too general and coast-biased despite its decentralized basin-style management approach (Respondent 10).

> The use of water in agriculture is very different on the coast than in the Andes. The proposals of the new law favour the coast more because they use less water because their irrigation systems are the most effective. Obviously the implementation of these irrigation systems means a high investment. Here in the Andes, there is a totally different context, already that the irrigation systems by flooding are not efficient. Respondent 10, personal communication, August 12, 2009.

Interestingly, Respondent 3 (personal communication, August 7, 2009) commented that "on the coast the water is of productive input and in the Andes water is something of a divine deity, a god to be worshipped." These different valuations of water are thus reflected in which regions receive government backing. Alegria (2007) has argued that this coastal bias has resulted in Andean agriculture stagnating due to lack of government support.

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 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 and the National Water Law followed shortly after. Both the 2004 National Water Resources Management Strategy and 2009 Water Resources Law helped lay the foundation to implement integrated water resource management in Peru, combining sustainable and integrated water management with the conceptualization of water as an economic good (Comision Tecnica Multisectorial, 2004; Olson, 2007). "We didn't pay for water before, and now we pay for it since about five or six years ago", said one farmer in Mullak'as-Misminay (Respondent 14, personal communication, September 25, 2009), while another commented that "there were changes in [the government] that probably increased the water fees" (Respondent 1, personal communication, August 3, 2009).

IMA and its partners are involved in projects to bring water from other areas to supply drinking water to Maras (Respondent 3, personal communication, August 7, 2009). Organizations that the government collaborates with on water management include Plan Meriss Inka, IMA, Seda Cusco (public business that provides basic sanitary services), the water user boards, a committee of irrigators and regional watershed councils (Respondent 10, personal communication, August 12, 2009; Respondent 18, personal communication September 29, 2009). The regional government has created a platform for managing water resources (Respondent 10). "This platform is comprised of public, private, and the users of these water resources. Through this platform a strategy has been developed to administrate water resources… to improve water management in Cuzco", said Respondent 10.

As Boelens and 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 restrictions and water access among users. "In Misminay, before each person could be carrying water, but now they want to measure the water and that makes everyone take the same amount of water", said Respondent 13 (personal communication, September 25, 2009).

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). 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 Water Resources Law recognizes customary law governing water resources but only as long as it is not contrary to formal law.

The topic of water rights was explicitly addressed by Respondents 18 (personal communication, September 29, 2009) and 19 (personal communication, October 23, 2009) representing non-governmental organizations. "Water is a right that the people have, and on the side of the law, yes we have worked with the communities from a rights perspective", said Respondent 18, and emphasized "studies that optimize water use and management but that respect the rights of the people [are necessary to improve water security]." The willingness to fight for water was also expressed. "We are ready to fight to promote an irrigation project", said Respondent 9 (personal communication, August 10, 2009). "I want to, as [a] representative of my community, always fight for water", said Respondent 13 (personal communication, September 25, 2009), who saw education as a form of empowerment that supports this fight. This was seen as helping strengthen localized control over community needs (Respondent 13).

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 Andean water rights are expressed can be highly-localized and based on the needs of the specific context, such as that of Mullak'as-Misminay.

5.3. Financing, Support, and Development Aid

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 by respondents to be the state's policy and laws, with few supporting local water security (Respondent 18, personal communication, September 29, 2009; Respondent 23, November 24, 2009). The pressurized irrigation system provides sufficient water to Maras, but some believed Mullak'as-Misminay does not have enough (Respondent 5, personal communication, August 8, 2009). "At the parcel-level, the regional government helps us. If it was on a large scale, Mullak'as-Misminay could benefit. But there isn't enough water, only enough for Maras" said Respondent 20. "Here we need support for agriculture, but there's little water" said Respondent 23.

Access to financial resources to support irrigation was a key concern. 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, personal communication, November 23, 2009). "We are trying reforestation and bringing back native plants and there are irrigation projects, but it depends on the authorities and the central government to see if they will give us any budget for a project to bring water", said Respondent 13 (personal communication, September 25, 2009). When asking Respondent 20 whether government support is necessary to implement irrigation technology, he responded "yes it's necessary, [regional government support we get] is not sufficient." "We communicate with [the regional and national] governments… and they do nothing that benefits us", said Respondent 9 (personal communication, August 10, 2009). "The government should give us more support or seeds, to avoid using synthetic pesticides", said Maras Respondent 20. "The government doesn't support us. Few support us", said Respondent 23. Discussion directly mentioning international financial institutions did not arise frequently. Respondent 12 (personal communication, August 13, 2009) mentioned "There is a program to clean up water, as far as I know the World Bank gave money."

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, personal communication, September 25, 2009). "When we have a good harvest we keep the food and use it for a long time", said Respondent 13 (personal communication, September 25, 2009).

Several respondents discussed the need for community training, in particular with agricultural and water conservation capacity-building (Respondent 2, personal communication, August 5, 2009; Respondent 3, personal communication, August 7, 2009; Respondent 7, personal communication, August 10, 2009; Respondent 11, personal communication, August 13, 2009; Respondent 13, personal communication, September 25, 2009; Respondent 18, personal communication, September 29, 2009; Respondent 20, personal communication, November 23, 2009). "We want more water and don't have water as we had before. We want help and training on how we can conserve water," said Respondent 8 (August 10, 2009). Some provide training, as Respondent 11 stated "we contribute more than all in the organization and training of better technologies… [and] we sensitize farmers so they use less agrochemicals."

5.3.1 Enabling and Disabling Role of Development, Aid and Non-Government Organizations

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. The exclusion of the poorest from such adaptation opportunity was described as "unfortunate", but it was stated that the tools used to create the policy argument for the project simply could not accommodate the most marginalized (Climate Change Team, personal communication, 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 also face increasing water security challenges from current and future stresses.

Poverty and environmental degradation were mentioned together in one interview, as Respondent 3 (personal communication, August 7, 2009) said "poverty is great, and the farmer uses any land for cultivation and at the same time it destroys water sources." Respondent 3 has mentioned there is a lack of long-term support to address the root cause of poverty, with government focusing on short-term solutions. Instead of giving a small amount of money for food, Respondent 3 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, personal communication, August 5, 2009). Another respondent viewed the state as the one looking to earn money off of community water supplies. "There are NGOs that work with water [in Cuzco, and there is the] irrigation committee. The state and the irrigation committee have different positions. The state is only interested in making money," said Respondent 18 (personal communication, September 29, 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 (personal communication, Respondent 11, August 13, 2009). Plan Meriss Inka and IMA have done three large water projects throughout the Maras district (Respondent 10, personal communication, August 12, 2009).

Plan Meriss was also mentioned by Respondent 5 (August 8, 2009), who lives in Pucarrumi near the Ausangate glacier in Cuzco.

> Ausangate means: where there is much water. However, these glaciers are disappearing. There is a company that wants to buy this mountain. The villagers are not going to allow a company to buy the mountain. Plan Meriss is a business that is doing irrigation works, and the people think that it will buy the mountain. Respondent 5, personal communication, August 8, 2009.

Once again concerns surrounding the privatization of water sources, as these very sources continue to recede due to climate change, are noted as well as the emphasis of external agencies on "improving" local water management, particularly through irrigation systems.

Chapter 6: Discussion and Conclusion

This study examined numerous elements that have, and in some cases continue to, impact water security in the indigenous Andean 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, despite a history of resilience and adaptation. This chapter reviews the four research questions of this thesis. Each question is examined, summarizing results based on data collected through interviews, personal observations, and supporting literature. The thesis concludes by discussing the implications of this research for the realms of policy, practice, and research, and finally, arguing for further exploration of an indigenous Andean model for water rights.

6.1 Multiple Stresses to Water Security

The first question 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.

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 serves its original function due to water diversion but also the decline of terrace systems.

The main stresses relating to local behaviours 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 also a problem in the community, with water at risk of being contaminated by human waste, and lack of chlorination leaving some 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 barrier to the implementation of adequate sanitation services.

6.2. 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.

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.

Ayllus have historically orchestrated social labour in such a way as to meet the water needs of their population 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, flourishing during times of government failure.

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 or crops 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 remains engaged 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 interpretation of 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 of 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 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-technical-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.

6.3. 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.

6.4. 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 non-governmental actors 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 (Cavero et al., 2005). 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.). 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 Resources 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 program: that the communities be glacier-fed and have market access. The prevalence of glacier retreat in Andean-focused 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 new challenges 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. Further, communities such as Mullak'as-Misminay that are not glacier fed yet still facing increasing climate change-driven water security challenges 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 while conserving water, do not seem to be acknowledged in analyses promoting pressurized irrigation. Current water management strategies over-emphasize technological benefits and narrow definitions of efficiency. 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 and in ongoing disputes over water rights. As populations grow, the emergence of microfundia exacerbates the inequality experienced by indigenous farmers, while continuing to threaten water security.

6.5. Characterizing Water Security in Mullak'as-Misminay

The conceptual framework chosen to map the history and current conditions of water security in Mullak'as-Misminay provided an excellent avenue for analyzing and expressing the dynamic interactions and realizations over time of water security in this Peruvian Andes context. It proved a useful guide in connecting the water security concept to the interacting community dynamics through the consideration of water access, use, and availability. This framework has the potential to explore the linkages between water security, socio-ecological system dynamics and multi-level relationships and enables the user to explore less conventional conceptualizations of marginality, as discussed in Section 5.2.1. above.

As a participant in the field doing on the ground research, one of the most memorable observations during the time spent in the community and Maras District was that despite a general feeling of pessimism for the future in terms of local water security, there was a marked sense of confidence in their ability to meet the challenges ahead. While residents were aware of new and changing water-related difficulties, in particular those driven by climate change, many simply said "there has never been water here." The researcher attempted to get a deeper sense of adaptation and response strategies practiced, however this seemed to be something that could be communicated more implicitly through a longer and more involved field season.

Another prominent observation related to the researcher's interactions with the community. Conversation flowed much better when the researcher took part in communal activities of labour and learning, particularly in group settings, rather than apart as the role of interviewer speaking one-on-one with a respondent. The researcher took part in a small faena, engaged in reciprocity by offering and receiving food and drink, and was welcomed in the community. It was made clear in a matter of fact manner that those who do not engage in reciprocity do not have a place in the community, while those who did accept their generosity were immediately welcomed. Of note was that reciprocity often began with the outsider being offered food or drink from a community member, as an introduction to local customs. These interactions implicitly reflected the embedded sense of reciprocity and wealth manifesting in strong social alliances and kinships.

The persistent devaluation and distortion of local ecological knowledge emerged as a problematic issue compromising local water security. Based on the research conducted and participant observation noted above, the perseverance of reciprocity in the form of faenas and kinship alliances suggest that these are a large part of the foundation of local ecological knowledge and provide a platform upon which knowledge can be built upon once more. The resiliency of this socio-ecological system is not in its ability to reclaim or reflect the past, but to shape a sustainable future using the existing character of the community.

This is particularly important in facing the complex pressures from modernization and intensified use of water resources. The researcher did not want to give the impression that modernization was necessarily a negative or disabling element that is inherently in conflict with indigenous Andean communities. Rather, the author wished to emphasize the need to temper the uneven balance of power driving modernity. Water availability that is physically present is compromised through extra-local diversion to feed pressurized irrigation systems, water use is complicated by competing applications, such as to eucalyptus trees in addition to native tree species, and water access is threatened through changing legislation and in particular privatization.

The political discontent directly relating to water privatization in the form of civil disobedience served as a reminder of the postcolonial relationship patterns present. While the grounds for resistance remain, this past century's manifestations of rebellion claiming egalitarian goals have yielded failed results, with those who were supposed to be the beneficiaries suffering the most negative impacts. Watershed-level management using a socio-ecological system approach that intrinsically considers Andean water rights and developed through a participatory process offers an alternative to the existing system of water governance in Peru. Such a system could work towards evening the unequal power relationships experienced by communities such as Mullak'as-Misminay and recognize local rights to water for small-scale farmers. Particularly important is that accessing the full scope of these rights not require agricultural intensification using dwindling water resources. IWRM holds potential in facilitating localized water rights, however, this researcher is cautious in accepting the degree to which its participatory, decentralized structure translates in reality. Even with the implementation of water rights, it is difficult to say what can be done with those water resources already taken away. The community's water source being diverted to Maras, away from Moray, remains an unresolved conflict.

Finally, in asking if Mullak'as-Misminay could be considered water secure, the author chooses to abide by the participatory approach in poverty conceptualization and suggest that this is truly a question best answered, implicitly, from within the community. This research grazes the surface of a deep and rich history extending far beyond the scope of this study, involving people who share the belief that, come what may, they will meet the challenges ahead.

6.6. Implications for Policy, Research, and Practice

This research has implications for water management and agrarian policy in Peru. As policy evolves to adopt the internationally-guided principles of IWRM, the necessity to situate marginality within the power relationships influencing the interactions among multi-level actors is essential, as marginalized peoples often have a clearer awareness of society's unconscious underpinnings than do those who enjoy power and privilege. Stakeholder participation becomes meaningful when actors representing marginalized positions can present perspectives and access decision-making that translates into purposeful realizations enhancing local water security in their own political and personal realms.

Peru cannot afford to disregard or devalue the wealth of local ecological knowledge that has helped Andean communities such as Mullak'as Misminay to navigate stormy ecological and political conditions for centuries. Drawing upon this knowledge requires a departure from 'old habits' of extraction from the knowledge web and engaging with the myriad of stakeholders on a common platform.

This research also has broader implications for water security and climate change adaptation. As was stressed earlier, a disproportionate emphasis on physical water availability, quantitative efficiency measures, and modernizing infrastructure threatens to derail the success of water security and climate change adaptation projects. Power and politics are major determining factors in what diverts water from Andean aquifers to the coastal desert where physical water availability represents a mere 2% of country supplies. This study has begun to demonstrate the blend of factors influencing an agropastoral community's ongoing path towards water security and climate change adaptation. This research also has important implications for smallholder farmers facing climate change and water security challenges. The farmers of Mullak'as-Misminay have employed a range of strategies that offer lessons for other Andean communities, as does an increased understanding of how these challenges are framed in a multi-level context. Seriously addressing water security and climate change adaptation requires policymakers, politicians, government, non-governmental bodies and academics to confront the multiple, overlapping realities involved.

One consistent theme that emerges in the quest for water security in Mullak'as-Misminay is that of water rights. Indigenous Andean water rights models 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 offer much promise for amplifying water security. Additional research is needed to further explore these alternatives, and to more fully illustrate the evolution of community-water relationships in the Peruvian highlands.

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