Climate Change in the Peruvian Andes

A Case Study of Adverse Socioeconomic Impacts on Small-Scale Farmers in the Quillcay River Basin

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ABSTRACT

Climate anomalies have been observed in the tropical Andes in Peru resulting in hydrological changes that consequently threaten livelihoods and daily survival of the lowland residents. In this study, adverse socioeconomic impacts on small-scale farmers in the Quillcay River basin due to variation in precipitation patterns and enhanced glacier retreat are examined through a case study approach. Theories of vulnerability and resilience were applied as the basis of the study as well as analytical tools to evaluate influence of climatic and hydrological impacts on socio-ecological systems in the study site. The data gathering and analysis were implemented through an integrated qualitative-quantitative approach in order to achieve holistic research insight and trustworthy results. Semi-structured interviews were conducted to capture smallholders’ perceptions whilst statistical data was collected for robust physical evidence. The results that were achieved from the analysis using conceptual framework of vulnerability as well as correlation and ordinary linear regression showed partly conflicting results. On one hand, findings and interpretation of the interviews suggested high connection between climate proxies and worsened socioeconomic situation of the small-scale farmers. On the other hand, in the quantitative analysis enhanced glacier retreat was found to have influenced unfavorable socioeconomic changes in the study site to some extent whereas precipitation did not show significant impact. Altogether, the results of the study suggest that vulnerability of livelihoods and well-being of the small-scale farmers is an outcome of a complex cluster of economic, political, social and ecological factors rather than climatic and hydrological changes exclusively.

Keywords: Peru, climate change, hydrology, small-scale farming, vulnerability, resilience
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Abbreviations

ANA – Autoridad Nacional del Agua (National Water Authority)

ENSO – El Niño Southern Oscillation

EPS Chavin S.A. – La Entidad Prestadora de Servicios de Saneamiento de agua potable y alcantarillado Chavín S.A. (The Provider of Sanitation Services of potable water and sewerage Chavín S.A.)

INEI – Instituto Nacional de Estadistica e Informatica (National Institute of Statistics and Informatics)

IPCC – Intergovernmental Panel on Climate Change

MINAGRI – Ministerio de Agricultura (Ministry of Agriculture)

NGO – Non Governmental Organization

OECD – Organization for Economic Co-operation and Development

SENAMHI – Servicio Nacional de Meterología e Hidrología del Perú (National Meteorology and Hydrology service of Peru)

UNEP – United Nations Environmental Program

UNISDR – The United Nations Office for Disaster Risk Reduction

UGRH – Unidad de Glaciología y Recursos Hídricos (Unit of Glaciology and Hydrological Resources)
1. Introduction

Peru, hosting the largest share of the world’s tropical glaciers, has been ranked as one of the most vulnerable countries in the world to the impacts of climate change (UNEP, 2013). Previous studies show strong evidence of accelerated glacier recession in the tropical Andes due to increased global temperature during last decades (Painter, 2007:1; Vuille et al., 2008:79; Bradley et al., 2006:1755). Additionally, decreased precipitation with high variation between torrential rain and absence of rainfall have been monitored in the Andean region (Sanabria et al., 2014: 1534; Haylock et al., 2006: 1510).

Agriculture has traditionally been the most important livelihood in the Peruvian Andes. It is estimated that six million people living in the Andean highlands still predominantly rely on small-scale farming as their main subsistence (Painter 2007; Sanabria et al., 2014: 1533). Regular precipitation and glacier melt water play crucial roles in small-scale agriculture production in the Andes as the agriculture production to large extent is still rain-fed and during the dry season, water for irrigation is almost solely received from glacier melt water (Sanabria et al., 2014: 1533; Mark et al., 2010:796; Bradley et al., 2006:1756).

Throughout the Andean mountain ranges known as cordillera, rural populations already have a restricted access to potable water and water used for field irrigation. Poor rural communities often have weaker infrastructures, lack of adaptation capacity and less financial possibilities to respond to water scarcity and therefore, it is projected that they will be the first and the most affected by the shortages of water (Painter 2007:9,11).

Abundant amount of studies on glacier retreat and climatic change have been conducted in the Andean region by natural scientists. Despite the grave threat the consequences of climatic and hydrological changes have been estimated to pose for Andean societies, assessments on the socioeconomic impacts, particularly on rural poor, remain few. (Painter, 2007:2)

The previous climate and glacier retreat related research from the Andes present an unequivocal consensus that further monitoring of the geo-physiological patterns of glacier retreat, studies on future climate change scenarios and considerably, the interaction with human-ecological systems in the region is required (Perez et al., 2010:11; Vuille et al.,
In order to create adequate adaptation strategies for the impacts of climate change, the scholars have suggested that there is a high need for interdisciplinary collaboration between different research disciplines (Drenkahn et al., 2015: 727; Chevallier et al., 2011: 186). Additionally, to better evaluate socio-ecological changes on a regional level and to efficiently enhance resilience, intertwining scientific knowledge with perceptions of local residents has been emphasized (Vuille et al., 2008:94; Mark et al., 2010:803).

In my master thesis I aim to address this issue of high importance and contribute to existing research on vulnerability of coped socio-ecological systems in the Andean region. Applying a case study approach, the following research question will be answered in this study: To what extent have climate and hydrological changes enhanced adverse socioeconomic impacts on smallholders in the Quillcay River basin during the last decades (1972-2015)? Vulnerability to climatic and hydrological changes will be measured through exploring relation between accelerated glacier recession, changes in precipitation patterns and socioeconomic factors using mixed qualitative-quantitative methods. In this study, harvested area, farm gate prices and growth rate of rural population were chosen as measures for socioeconomic impacts. The research design has been constructed on the basis of the theoretical frameworks of vulnerability and resilience.

Similar assessments that include multiple climate change related threats in relation to vulnerability of local populations in the Quillcay River basin remain absent. Furthermore, intertwining small holders’ perceptions with statistical analysis, as a mixed method to the extent used in this thesis, has not yet been applied in the previous studies conducted in the Andean region. The findings of this research attempt to provide new scientific knowledge for the research field as well as assist policy makers in development of adequate adaption strategies for projected impacts of climate change in the study site.

1.1. Structure of the Thesis

This thesis is organized in seven sections. In the following section broader insight on the roots of climate change and its relation to adverse consequences in Peru will be given. In section 3 theoretical approaches of vulnerability and resilience will be defined and brief overview on previous research using these theoretical approaches will be provided. Description of the methodology used in this thesis will be given in section 4. Firstly, research design and the field study site will be introduced. Secondly, it will be described
what kind of data was used for both, quantitative and qualitative parts of the study, how it was collected and lastly, how the analysis was conducted. In section 5 the results of the analysis will be presented and in section 6 interpretations of the results will be discussed in-depth. Finally, in section 7 findings of the study will be concluded.

In Appendix, the interview guide that was used for the interviews with the smallholders will be provided both in English and Spanish.
2. Background

2.1 Climate Change

Climate change has been acknowledged as one of the most fundamental concerns of our era. The main cause of climate change is the increased concentration of gases and aerosols in the atmosphere that consequently, is affecting Earth’s energy balance. Interference in the energy balance system has led to soaring of global surface temperature. There is a robust evidence that global mean temperature has risen during the last 100 years and scientists predict that if the temperatures will climb over 2 °C consequences of climate change will be tremendous. (IPCC, 2013: 121,127)

Enhanced rise of global temperature has already caused variability in climate patterns in certain regions. Additionally, extreme weather events such as floods, heat waves and droughts, have become more frequent and intense. According to the Fifth Assessment Report of Intergovernmental Panel on Climate Change (IPCC) the research on climate change has shown that increase in global temperature highly correlates with occurrence of weather extremes (IPCC, 2014:11077).

2.2 Implications of Climate Change in the Tropical Andes

Impacts of climatic changes can be observed more prominently and rapidly in high elevations than elsewhere. Mountain regions represent one of the most unique and diverse ecosystems on Earth. Due to their topography and geographical location, mountain regions are highly sensitive to changes in climate patterns (Diaz et al., 2003:2). Mountains also provide important ecosystem services to societies situated in the vicinity of the mountain ranges, primarily as maintaining hydrological cycles and water supplies. (Benitson, 2003:5). Residents living in the mountain lowlands are often dependent on the fresh drinking water coming down from the mountains as the ice melts. Also, agricultural activities and the industrial sector are to large extent using water resources provided by the mountain watersheds (Diaz et al., 2003:2).

Temperature in mountain glaciers is often close to the 0 °C threshold and therefore, even tiny changes in the temperature or precipitation patterns will result as melting of the snowpack. (Benitson, 2003:6,10; Diaz et al., 2003:2) Changes in the climate and temperature regimes have a crucial impact on the natural hydrological cycle of the mountains. The
variations in the temperature disturb the glacier based river runoff, which may cause deficits of water or flooding. Such disturbances in the river flow cause severe impacts for the lowland socioeconomic systems in terms of water quality and availability. (Diaz et al., 2003:3; Benitson, 2003:7,14)

The tropical Andes form almost entirely the world’s tropical glaciers. Approximately 99% of tropical glaciers are found in South America, out of which 71% in Peru, 20% in Bolivia, 4% in Ecuador and 4% in Colombia and Venezuela. (Rabatel et al., 2013:82) The rest, 1% of tropical glaciers are situated in Africa and New Guinea (Chevallier et al., 2011:179). Specific characteristics of the tropical Andes make them particularly vulnerable to climatic variations. The tropical Andes are exposed to El Niño events, lack the winter precipitations and are sensitive to other weather related consequences caused by warming of the sea surface temperature of the Pacific Ocean (Rabatel et al., 2013:82; Francou et al., 2004:2; Chevallier et al., 2011:181). For example, augmented rainfall, cloudiness and higher humidity of the atmosphere are the principal causes of glacier retreat and these factors are strongly induced by intensified El Niño events (Rabatel et al., 2008:2.) Long-term monitoring of the Andean glaciers show strong evidence that there exists a relation between glacier retreat and the changes of the sea surface temperatures of the Pacific Ocean, especially during the El Niño Southern Oscillation (ENSO) events. Therefore, projected trends of more frequent and strong ENSO in the future may tremendously trigger enhanced glacier recession of the Andean glaciers. (Francou et al., 2004:16)

Glacier meltdown in Peru is a serious concern since the glaciers provide an important source of water for many sectors; irrigation, hydropower production and fresh drinking water for human use. In some regions, water for these purposes is almost entirely achieved from the glacier melt water (Vuille, 2015:2). It has been projected that in the arid and semiarid regions deficit in water supplies may even lead to violent conflicts as the competition over scarce water resources will intensify between agriculture, industrial sectors and local residents. (Benitson, 2003:14)

The region of the Peruvian Andes is characterized by seasonal precipitation patterns. The annual hydrological cycle is divided in a wet season from October to April and a dry season from May to September (Gurgiser et al., 2015:1864; Mark et al., 2010:795). The climate change projections in the tropical Andes predict weak increase in precipitation in northern Peru with augmented precipitation during the wet season and decline during the dry season.
(Vera et al., 2006: 4; Vuille et al., 2003:81). Significant changes in the regimes of total rainfall have not been discovered in the region, but by contrast, high year-to-year variability in precipitation patterns has been identified particularly in the Cordillera Blanca (the widest tropical glacier range in the world) of Peru (Gurgiser et al., 2015: 1884; USGS, 1999).

Mark et al. (2010) and Gurgiser et al. (2015) have conducted two of the few studies that address the relationship between climatic and socioeconomic changes in the Peruvian Andes. Gurgiser et al. (2015) studied smallholders’ perceptions on precipitation changes compared to precipitation records in Callejón de Huayalas, Peru. They found that according to the peasants, rain-fed agriculture has been deteriorated since the last decades due to decreased rain during the dry period, earlier wet season and more volatile and unpredictable precipitation during both dry and wet seasons. In their quantitative study significant changes in the amount of precipitation were not discovered whereas it was found that during the last years there has been relatively high inter-annual variability in precipitation. Gurgiser et al. (2015) suggest that rather than changes in the amount of rain, volatility in precipitation have most probably caused challenges for small-scale farming in the case study region.

In the study of Mark et al. (2010) hydrologic changes and livelihood vulnerability in the Cordillera Blanca in Peru were evaluated. The perceptions of local residents were used in conjunction with quantitative study on hydrologic changes related to glacier mass balance loss, in order to assess vulnerability of local people to climatic change in the region. Their study revealed rather convergent results between perceptions of local population and quantitative measurements on decrease of watersheds due to glacier retreat. They suggest that further interdisciplinary research would facilitate to enhance efficient water management in the study area and thus, strengthen the adaptive capacity of the local communities (Mark et al., 2010:803).
3. Theoretical Framework

In this thesis the theoretical frameworks of vulnerability and resilience are applied to assess adverse socioeconomic impacts on small-scale farmers due to climate and water related changes in the Quillcay River basin, located in the Peruvian Andes. The theoretical frameworks have served as basis of the study, but have also been used to facilitate the empirical work and the analysis of the research material.

3.1. Vulnerability

Vulnerability to environmental changes was first theorized by disciplines of human geography and ecology (Adger, 2006:269). Later, the vulnerability concept has been widely adapted by different scientific communities, such as economy, anthropology and psychology. Currently, the publications of IPCC are considered as legitimate authority of the latest scientific knowledge of climate change related vulnerability. In the Fourth Assessment Report of IPCC (2007) the concept of vulnerability to climate change is defined as follows: “Vulnerability is the degree to which a system is susceptible to, and unable to cope with effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.”

Hence, vulnerability as a state refers to a situation in which socio-ecological1 system is exposed to external stresses and has low adaptive capacity. External stresses imply adverse human or environmental influence outside the system, such as climatic hazards2 or unequal distribution of resources in the society. The duration and frequency of external stresses play a key role when assessing the magnitude of system’s vulnerability. (Adger, 2006: 270; IPCC, 2014:1052)

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1 The concept of socio-ecological system (SES) implies the intertwist of nature and human subsystems that are scrutinized as solid entity in vulnerability assessments (Gallopín, 2006: 294).
2 Terms disaster, hazard, perturbation and stress are sometimes used overlappingly in climate change and vulnerability literature although the concepts are not synonyms to one another. Here, brief definitions of each term is given for clarification. "Perturbations are major spikes in pressure (e.g. a tidal wave or hurricane) beyond the normal range of variability in which the system operates, and commonly originates beyond the system operates." "Stress is continuous or slowly increasing pressure (e.g. soil degradation), commonly within the normal variability." "Hazards are threats to a system, comprised of perturbations and stress." (Gallopín: 2006: 294-5) "Disaster is a serious disruption of the functioning of a community or society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources."(UNISDR, 2007)
Diversity of different approaches to define and assess vulnerability can be found in vulnerability literature. Two different interpretations, however, can be indicated as the main orientations in the research on vulnerability to climate change depending on the aim of the study and its contextualization.

First interpretation views vulnerability as end point. Here, the consequences of climate or environmental change are in the center of analysis whereas human vulnerability is considered to be linked to their (vulnerable) physical environment. The pursue of biophysical vulnerability approach is primarily to measure level of vulnerability after the system has been exposed to perturbations and the adaption strategies have already been applied. (Kelly & Adger, 2000:326-328; O’Brien et al., 2005:1-3; Segnestam, 2014: 30)

Another approach sets vulnerability as starting point. The focus of the analysis is in present vulnerability, prior to external stresses, and finding strategies to strengthen adaptive capacity in front of future stresses caused by changed climatic conditions. Capacity to reduce vulnerability is seen as an outcome of multiple factors, including environmental, climatic, political and social conditions. Due to emphasis to identify human vulnerability in the first place, the stance has also been called as “social vulnerability”. In this thesis the emphasis is to assess the vulnerability of marginalized populations to climatic stresses and therefore, the approach of social vulnerability has been applied.

Despite the different focuses between the approaches of vulnerability, some terms are mutually accepted within both stances in conceptualization of vulnerability. Most commonly vulnerability is determined as an entity constituted of following elements: exposure and sensitivity to hazards or stresses, resilience and capacity to adapt. (Adger, 2006: 270; Gallopín, 2006: 294) Nonetheless, different interpretations for the components are often given across different scientific communities and hence, their distinction may remain rather vague. Incorporated definitions of the concepts from principal vulnerability literature will be given here in order to clarify their linkages and differences.

*Exposure* refers to the disposition, magnitude and duration that the system is subjected to environmental or human influenced stresses or perturbations. (Adger, 2006: 270; Gallopín, 2006: 296) *Sensitivity* on the other hand can be defined as the degree of external stresses the system encounters and the system’s potential to respond to the exposure of human or environmental originated forces. (Adger, 2006: 270; Luers, 2005:215) The concepts of *adaptive capacity* and *resilience* are easy to be confused with one another due to their close
resemblance. However, some fundamental distinctions between the two concepts can be
drawn. Adaptive capacity refers to the extent the system can adjust to the harms caused by
stresses and cope with the impacts or even improve its state. (IPCC, 2007:869; Gallopín,
2006:300) Resilience, on the other hand, applies to the amount of stress and perturbations
system can endure and still maintain relative stable state after the exposure to disturbances
(IPCC, 2007:880; Turner et al. 2003b: 8075). The concept of resilience is another theoretical
framework used in this study, and will be discussed more detailed in the following section.

3.2 Resilience

The theoretical approach of resilience is often favored in the research exploring socio-
ecological systems exposure to climate stresses and their adaption capacity to undesirable
changes (Nelson et al., 2007:395). The concept of resilience was first introduced within the
discipline of ecology by Holling (1973) and it has later been deployed in the research of
social sciences (IPCC, 2014:179). The concepts of vulnerability and resilience share
numerous common core interests as both research traditions aim to explain human-
environment interactions, considerably the response and adaptation capacity of human and
environmental systems to the external shocks (Adger, 2006:269). Vulnerability is also often
seen as a component within the theoretical framework of resilience, as vulnerability can also
be conceptualized as a poor state of resilience (Martin-Breen & Anderies, 2011:26).

Multiple definitions of resilience exist in the current literature. In the original literature
resilience was conceptualized as “the persistence of relationships within a system and a
measure of the ability of these systems to absorb changes of state variables, driving variables
and parameters, and still, persist” (Holling, 1973:17). The modern resilience theorists have
further developed the concept to: “the capacity of systems, communities, households or
individuals to prevent, mitigate or cope with risks, and recover from shocks” and suggest
that “a system is resilient when it is less vulnerable to shocks across time, and can recover
from them”. In order to strengthen resilience of a system, its exposure to biophysical,
economic and social risks should be tackled and thus, decrease vulnerability and build better

3.3 Previous Research on Vulnerability of Marginalized Populations to
Climatic Stresses

Vulnerability research has been previously used to expound food insecurity, civil conflicts
or other social disorders. These research traditions have focused on scrutinizing unfavorable consequences of environmental stresses on social systems through natural hazards solely, paying less attention to socioeconomic and political factors that later have been found to be crucial drivers of vulnerability. (Adger, 2006: 270) Recently, the multidimensional nature of vulnerability has been acknowledged and modern vulnerability literature is to an increasing extent attempting to explain vulnerability from the perspective of intertwined socio-ecological systems. (Adger, 2006: 272, Turner et al., 2003b:8077)

Current vulnerability studies present attestation that marginalized populations in developing countries are the most exposed to the consequences of adverse climatic variability due to their weak socioeconomic position that hinders their ability to adapt to the changes (Altieri et al., 2013:2; IPCC, 2007:720; Kelly & Adger, 2000:325). Adger (2006:270) states that “vulnerability of livelihoods to shocks occurs when people have insufficient real income and wealth, and when there is a breakdown in other previously held endowments”.

Kelly & Adger (2000:341) applied the theory of vulnerability in their study on assessing vulnerability to climate change and facilitating adaptation in coastal Vietnam. Using the approach of social vulnerability they found that poorer households whose income relied on unilateral resources, such as salt production, were more vulnerable to climate extremes, (mainly coastal flooding) than those who had access to more diverse resources. The methodology of multiple factor elaboration of vulnerability has been addressed by O’Brien et al. (2004) who studied vulnerability of Indian agriculture to climate change in conjunction with economic globalization. According to their findings, both decreased or volatile precipitation regimes and lack of institutional and governmental support were found to have a fundamental impact on vulnerability of agriculture sector. (O’Brien et al., 2004: 303, 309-10). The theoretical approach of vulnerability has also been favored in the studies evaluating the influence of climate hazards on other marginalized groups in the developing world. For example, Segnestam (2014) used a social vulnerability approach in her study on gender-differentiated vulnerability to drought in Nicaragua.

3.4 Previous Studies on Evaluating Potential to Strengthen Resilience to External Stresses

As concern for global warming has risen, the theoretical framework of resilience has increasingly been applied to address socio-ecological impacts of climate change. Adger et
al. (2005) used social-resilience approach to explore how to decrease vulnerability and hence, increase resilience of the systems that have been exposed to coastal disasters. They argue that the dimension and frequency of coastal hazards, such as flooding and hurricanes, have enhanced in recent decades by human made environmental change. According to their study, governmental initiatives are required in order to strengthen the adaptive capacity of the hazard sensitive coastal regions through introduction of norms that would improve sustainable use of coastal environment and thus, reduce vulnerability. (Adger et al., 2005: 1036-37) In their study, it was additionally revealed that advanced adaptation strategies, such as management of hurricane risk and strengthening the completeness for collaborative action of civil society and private sector facilitated in creating stronger resilience in the Cayman Islands during the Hurricane Ivan in 2004 (Adger et al., 2005: 1038).

Ickowicz et al. (2012) studied the role of public policies increasing resilience in the region of Sahel, West Africa. A large part of the population in the Sahelian lives in rural areas and depends on crop-livestock practices as their major subsistence that are currently threatened by stresses such as demographic growth, climate change and changes in global markets (Ickowicz et al., 2012:261-2). In their research, Ickowicz et al. (2012) show that appropriate policies, land management, regulation and investments in the infrastructure are evident actions to be taken in order to create resilience among rural populations to the intensified stresses they are facing (Ickowicz et al., 2012: 288).

3.5 Implementation of the Theoretical Frameworks

Karafakis et al., (2012:142) suggest that in the assessments of system’s exposures to hazards and their ability to cope with them, the use of both, vulnerability and resilience approaches allows to achieve more holistic picture on the situation than when considering theories of vulnerability and resilience as alternatives.

In this thesis, on one hand, vulnerability approach is used to discover sensibility of small-scale farmers to the stresses caused by climatic and hydrological changes in the Quillcay River basin. This is implemented by firstly assessing the magnitude of climatic and hydrological stresses the smallholders in the study site are encountering, secondly, evaluating the impacts on well-being and livelihoods of the peasants due to exposure of stresses and thirdly, identifying their potential to adapt to the impacts. On the other hand, theory of resilience is applied to assess if the small-scale farmers have succeeded to create
adaption strategies to climatic and hydrological changes, which factors have facilitated successful adaption and what are the elements that should be addressed in order to strengthen resilience of the smallholders in the study site.
4. Methodology

4.1 Research Design

As discussed in the previous section, vulnerability of social-ecological systems is often a result of multiple external stress factors. In order to perform a profound vulnerability assessment, achieve a more diverse insight on the research and on other hand to receive trustworthy results, both quantitative and qualitative methods have been used in this thesis. According to Adger (2006:274) quantitative approach facilitates the assessment of vulnerability in certain places and contexts whereas qualitative measures complement them by capturing a broader picture of the personal experiences of the vulnerable populations.

Open-ended, semi-structured interviews were used in this study in order to capture a comprehensive picture of empirical reality of the small-scale farmers exposure to adverse hydrological and climatic changes in the case study area. Additionally, experts with relations to agriculture, climatology, glaciers and water management were interviewed to obtain the broadest possible overview on how climate and hydrology have changed in recent decades in Peru, what have been the consequences of the changes on small-scale farming and how the harmful implications should be tackled.

In total, 21 persons were interviewed, including eight key informants and 16 small-scale farmers. The key informants consisted of Peruvian authorities and experts from following institutions: National Service of Meteorology and Hydrology of Peru (Servicio Nacional de Meteorología e Hidrología del Perú, SENAMHI), Unit of Glaciology and Hydrological Resources (Unidad de Glaciología y Recursos Hídricos, UGRH), National Water Authority (Autoridad Nacional del Agua, ANA), Ministry of Agriculture (Ministerio de Agricultura, MINAGRI), National Institute of Statistics and Informatics (Instituto Nacional de Estadística e Informática, INEI) and The Provider of Sanitation Services of potable water and sewerage Chavín S.A (La Entidad Prestadora de Servicios de Saneamiento de agua potable y alcantarillado Chavín S.A., EPS Chavin S.A.).

The quantitative evidence used in this study was collected during the field study in Huaraz, Peru. All the statistical data was obtained from the databases of Peruvian water, glacier, agriculture and statistical institutions (ANA, UGRH, MINAGRI and INEI) that can be regarded as reliable sources of information.
4.2 Field Study Area

The case study was conducted in small communities (centros poblados) along the Quillcay River basin, situated in the community of Huaraz, belonging to the Department of Ancash, Peru. The Quillcay River basin pertains to the Cordillera Blanca, the world’s widest mountain range of tropical glaciers (Mark et al., 2010:797; Colonia & Torres, 2013:5) also representing the largest glacier cluster of Peru (Mark et al., 2005:2266; Portocarrero, 1995:218).

The altitude of the Quillcay River valley varies between 3,000 m for the lower part of the basin up to 6,295 m for the highest mountain slopes. The Quillcay River basin, with total surface of 249.92 km² consists of two main micro basins, the Auqui River and the Paría River. The micro rivers unite at downstream of the basin in the city of Huaraz and form the Quillcay River that ultimately falls into the Santa River (Colonia & Torres, 2013:5) The Auqui River and the Paría River micro basins form the main water supply for the district of Huaraz. Glacier melt water provides the main source of water, particularly in the upper stream of the basin. Precipitation contributes to the river watershed during the rainy season (October-April) along the whole stream. (Rivas et al., 2014:2,5; Gurgiser et al., 2015:1864-65).

Map 1. Location of the city of Huaraz and the field study area. The Quillcay River basin is indicated with the red line. Source: Rivas et al., 2014
Currently, there are approximately 50,000 inhabitants living in the Quillcay River basin that is nearly half of the total population of the municipality of Huaraz. (MINAGRI, 2015). Small-scale farming is still the most dominant subsistence in the area. According to Mark et al. (2010:796) 80 % of the population receives their main income from small-scale agriculture and livestock production. Most of the fields are still rain-fed (70%), and rely on precipitation for irrigation. Some peasants use irrigation systems (30%) fed by the glacier melt water. (Interview, Miguel Castro, MINAGRI) Smallholders of the region are, therefore, highly vulnerable to the disruptions in precipitation regimes or glacier originated river discharge (Mark et al., 2010: 795-796). Hence, future scenarios on accelerated glacier retreat and changes in the precipitation patterns are a serious concern for the livelihoods of the small-scale farmers in the Quillcay River basin.

Map 2. Map of the Quillcay River basin. The interview sites are circled with in red. Source: MINAGRI, 2008

The field study was conducted in small communities along the main rivers of the Quillcay River basin, the Auqui River and the Paría River. The interviews were carried out in the villages of Coyllur, Paquischa, Manzana, Jancu, Rivas, Cantú, Yaroshi, Llupa, Nueva Florida and Unchush (Map 2.). Due to differences in altitude and environment, slight differences exist in the favorability of circumstances for agriculture practices in different parts of the Quillcay River basin. The aim of the current study was, thus, to conduct the
interviews in different altitudes and locations of the basin in order to perceive a holistic insight of smallholders’ perceptions living in different parts of the Quillcay River basin.

4.3 Qualitative Methods

In total, 16 small-scale farmers living in the Quillcay River basin were interviewed. Both female and male smallholders were chosen to participate in the interviews. The majority of the respondents (11) were males and a smaller portion (5) females, since women were found to be less willing to participate in the study. Informants representing an older generation (49-79 years) were included in the study in order to obtain a longer historical trajectory on the observations on climate and water related changes and acquire an outlook on whether the changes have had an impact on their livelihood and well-being in the long run.

In addition, six key informants from distinct agriculture, climate, glacier, water and statistics institutions were interviewed in the city of Huaraz, one of the interviews was conducted in Lima, in the capital of Peru and one was performed through a Skype communication. The semi-structured interviews were lastly, analyzed using analytical vulnerability framework of the Research and Assessment Systems for Sustainability Program by Turner et al. (2003b).

4.4 Field Study

Before beginning the actual field study, I conducted a pilot study in Carhuaz, neighborhood community of Huaraz. For the pilot study, two small-scale farmers were interviewed in order to verify whether the themes and questions chosen for the interview guide were adequate. The interview guide was then revised and improvements were made accordingly.

An employee of a local Non Governmental Organization (NGO) CARE Perú, Alfredo Huaman, who also lives in the study area, accompanied me to meet small-scale farmers living in the Quillcay River basin. Visiting smallholders with a local person, who also personally knew most of the residents in the study area, was an enormous advantage when approaching the peasants and facilitated to achieve their agreement to participate in the study.
Most of the interviewees were fluent in Spanish, but some of them (mostly women) only spoke the indigenous Andean language, Kichwa. Therefore, a local English language student, Lidia Henostroza, who knew Spanish, Kicwha and English, participated in the fieldwork as a research assistant and interpreter. Although I was able to carry out most of the interviews in Spanish myself, I considered that a local interpreter accompanying me during all the interviews would help to avoid misunderstandings that later could cause biases in the data.

As I began to conduct the interviews I also noticed that the presence of a local, Peruvian person, facilitated to build trust with the interviewees. When interviewing monolingual Kichwa-speakers, the questions were first asked in English and then translated to Kichwa with the help of my research assistant. Conducting interviews through a third party may increase the possibility for errors in the data. Before and during the interviews, I attempted to explain to my research assistant how the questions should be presented in order to avoid leading the informants to give certain answers. However, the potential biases in data due to the interviewing set-up has been acknowledged and aimed to be minimized in the later analysis. All the interviews were also audio recorded and notes were taken.

At the end of the each day in the field, I went through my written notes and made a preliminary transcription of the records. When all the interviews had been conducted, more careful, in-depth transcription of the interviews was made. Once all the interviews were transcribed, I constructed initial matrices and summaries to have a preliminary perception of the data and also to facilitate the more profound analysis that was to be carried out later.

4.5 Ethical Considerations

The nature of social research requires careful consideration of ethical issues. Although some variation exists in the ethical stances among social scientist, there are some common principles that social researchers are expected to follow (Bryman, 2012: 130, 136). Bryman (2012:136-143) distinguishes four main ethical principles; no harm should be caused to participants, research participants should be sufficiently informed about the purpose of the

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3 The most common manner to spell the name of the language indigenous populations in the Peruvian Andes is Spanish version "Quechua". The Spanish spelling, originates from the time of Spanish conquests when "Kichwa" was adjusted to "Quechua" to facilitate pronunciation in Spanish. Nowadays, Kichwa-speakers aim to emphasize their independece from the oppression of Spanish language by spelling the language as "Kichwa" according to original Kichwan pronunciation and alphabet. (Davis, 2009)
study, the privacy of informants should not be harmed and the researcher should verify that the informants understand in what kind of study they are taking part in.

In my study I attempted to strictly follow the ethical guidelines. When I met the interviewees I always told them first who I was, what I was researching and asked if they would agree to participate in the study. Every informant was given an informant consent stating the background of the study, guaranteed confidentiality, the right of the informants not to answer questions they were not willing to answer and the right to withdraw from the study at any time if they felt so. During the interview sessions I aimed to ensure that the interviewees felt comfortable and avoided asking questions that would be obtrusive or would push the informants to give ‘wished answers’.

Photo 1. Interviewing a smallholder for the pilot study.

Throughout the field study I stored the contact information of the participants and the interview material in separate locations, so that no one except me could be able to recognize the identity of the interviewees. The nature of the current study is not to explore sensitive issues in a sense that participating in the research would cause any severe physical, mental, economical harm or alike for the informants. Nonetheless, I have wanted to ascertain the anonymity of the interviewees in order to minimize the risk that any inconveniences would be caused due to their participation in the study. Therefore, in this thesis I have decided to call all the interviewees as “informants” and distinction between participants has been made by numbering. The field study was also conducted in a relatively small area where people
know each other. Hence, for anonymity reasons it is not explicitly indicated where each of the interviews was conducted. Additionally, all the key informants that were interviewed for the study were asked for permission to publish the statements that were discussed during the personal communications.

### 4.6 Analytical Framework

Analytical frameworks of vulnerability have been acknowledged as advantageous tools in research on sociological and ecological systems’ exposure to hazards, weak resilience (to climate hazards) and marginal social conditions (Adger, 2006: 268). Numerous vulnerability frameworks have been developed for vulnerability and resilience assessments. In this study, however, the vulnerability framework of the Research and Assessment Systems for Sustainability Program by Turner et al. (2003b) is applied in the analysis of the semi-structured interviews.

Turner et al. (2003a) tested the applicability of the framework of vulnerability in four case studies of which two were conducted in Mexico and two in the Arctic regions. The findings of the studies that were performed in Mexico showed that vulnerability to environmental hazards was a consequence of multiple factors such as local farmers’ possibility to access both biophysical and social resources (Turner et al., 2003a: 8083). It was additionally showed that policies and land management practiced in the region had also contributed to the vulnerability of socio-ecological conditions of the region. The results of the study suggest, thus, that the whole complexity of factors should be included when conducting further vulnerability analysis in the concerned study region with the aim to develop sustainable coping strategies (Turner et al., 2003a: 8081-82).

According to the case studies conducted in Ummannaq and Finnmark in the Arctic, Turner et al. (2003a) discovered that the ability to respond to the outside stresses, such as changes in the global markets and environmental pollution, of both regions is to a large extent affected by the government decisions. Therefore, Turner et al. (2003a) argue that in order to make broader vulnerability analysis and identify sustainable adaptation practices, it is necessary to include perceptions of indigenous populations of the regions in the vulnerability assessments. (Turner et al., 2003a: 8085)

Although the vulnerability framework of the Research and Assessment System of Sustainability program was originally designed to serve vulnerability evaluations within the
research of sustainability and global environmental change, it provides a multifaceted tool to analyze the myriad of elements of vulnerability and resilience. The framework allows broadly exploring interactions of coupled human-environment systems, how these systems respond to hazards and to what extent they are vulnerable to the outside stresses. In the analysis of the framework questions such as: who are vulnerable to the environmental changes, what are the consequences of the changes and how the vulnerability caused by the changes can be reduced, are addressed. (Turner et al., 2003b: 8074) Since similar questions are of interest to this thesis, the vulnerability framework of the Research and Assessment System of Sustainability program was considered appropriate to apply for analysis of vulnerability and resilience of the current study.

![Vulnerability framework of the Research and Assessment System for Sustainability Program developed by Turner et al. (2003b)](image)

Figure 1. Vulnerability framework of the Research and Assessment System for Sustainability Program developed by Turner et al. (2003b) applied in this study.

To better serve the current research, some contextual adjustments were made and some elements were left out from the original framework. The physical limits of this thesis set some restrictions to the width of analysis and therefore, the focus of the analysis was decided to be kept in the vulnerability and resilience related to climatic stresses, i.e. how
changes in precipitation regimes and enhanced glacier recession have affected well-being and livelihoods of the small-scale farmers in the Quillcay River basin. Although the primary stress of the framework is in vulnerability assessment, the dimension of resilience is included in the framework as a sub-component of vulnerability. Hence, in this thesis the framework will be as well applied to evaluate the extent of resilience the small-scale farmers hold to climatic and hydrological stressors.

4.7 Qualitative Analysis

I began the theory based in-depth analysis of the interviews by carefully re-listening all the interview records. Based on the interview transcription, I identified categories that were linked to the theoretical frameworks of vulnerability and resilience but also to the empirical reality discovered during the interviews. According to Dey (1993), the method of categorization is an advantageous tool to organize the data for the essential analysis. Once the data has been categorized, using both theoretical and empirical approaches facilitates the further exploration and interpretation of the data (Dey, 1993:135).

When creating the categories, I attempted to link the themes I had originally used in my interview guide and additionally, new themes that had arisen during the interviews and were linked to the theoretical frameworks of vulnerability and resilience. The livelihood assets concepts used in the sustainable livelihoods framework were adopted as a part of categories to facilitate identification and measurement of vulnerability, resilience and adaptive capacity of the smallholders. The capital concepts⁴ (natural, human, social, physical and financial) are used in the sustainable livelihoods framework to particularly evaluate the access of marginalized people to these capitals with an assumption that wider assortment of the assets can be determined as lower state of vulnerability (i.e. stronger livelihood outcome). (DFID, 2000:5; Jansen et al., 2006:23) As a result, categories and their sub-categories illustrated in Table 1. were identified.

Once the categorizing was accomplished, I defined what kind of data would be included in each category. Such a process in qualitative analysis is known as “coding”, i.e.

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⁴ According to Segnestam (2014: 38-39) and Jansen (2006:23) the five capitals are defined as follows: Natural capital is the amount and quality of resources such as farmland, climatic circumstances, soil and water. Physical capital refers to material and infrastructural assets. Social capital implies the strength of the networks and involvement in organizations that increases resilience and adaptive capacity. Financial capital includes all the savings, credit and income of the household. Lastly, human capital is constituted of skills, education, health, nutrition, labour force, ethnicity and household configuration.
conceptualization of the data. The codes chosen to each category should aim to answer the questions raised in each category but also act as links between the different categories. (Strauss, 1987:20-21) The coding process required a careful exploration of the interview transcriptions and weighing which data was relevant to be chosen under each category.

Table 1. Categories and sub-categories derived from the interviews. Source: Author

<table>
<thead>
<tr>
<th>CATEGORIES</th>
<th>SUB-CATEGORIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental stress outside the place</td>
<td>Climate change</td>
</tr>
<tr>
<td>Variability and Change in Environmental Conditions: Exposure to stresses</td>
<td>Variation in precipitation patterns</td>
</tr>
<tr>
<td></td>
<td>Enhanced glacier retreat</td>
</tr>
<tr>
<td>Sensitivity of biophysical systems and economic structures to climatic stresses (Natural &amp; Financial Capital)</td>
<td>Lower river discharge</td>
</tr>
<tr>
<td></td>
<td>Decreased yields due to less/volatile precipitation</td>
</tr>
<tr>
<td></td>
<td>Decreased market prices</td>
</tr>
<tr>
<td></td>
<td>Decreased income from agriculture</td>
</tr>
<tr>
<td>Impact</td>
<td>Less potable water/water for irrigation</td>
</tr>
<tr>
<td></td>
<td>Need to use agrochemicals</td>
</tr>
<tr>
<td></td>
<td>Deterioration of livelihoods</td>
</tr>
<tr>
<td>Adaptation (Financial, Human &amp; Social Capital)</td>
<td>Migration to cities</td>
</tr>
<tr>
<td></td>
<td>Complete shift to other subsistence than agriculture</td>
</tr>
<tr>
<td></td>
<td>Partial complementation of agriculture practices</td>
</tr>
<tr>
<td></td>
<td>Building canals, reservoirs and irrigation systems</td>
</tr>
<tr>
<td></td>
<td>Introducing new crops</td>
</tr>
<tr>
<td>Resilience (Financial &amp; Human Capital)</td>
<td>Good experience on agriculture practices</td>
</tr>
<tr>
<td></td>
<td>Efficient water management</td>
</tr>
<tr>
<td></td>
<td>Education</td>
</tr>
<tr>
<td></td>
<td>Experience in other professions than agriculture</td>
</tr>
<tr>
<td></td>
<td>Selling cattle</td>
</tr>
<tr>
<td>Institutional/governmental support (Social &amp; Physical Capital)</td>
<td>Facilitating in building canals, reservoirs and irrigation systems</td>
</tr>
<tr>
<td></td>
<td>Informing and educating small holders on modern agriculture practices</td>
</tr>
<tr>
<td></td>
<td>and water management</td>
</tr>
<tr>
<td></td>
<td>Investing on rural infrastructures</td>
</tr>
</tbody>
</table>

During the identification of the appropriate codes for the further analysis, new categories arose from the data and some tentatively identified categories had to be rearranged. When I
had finished the coding process, I wrote summaries of each category and chose relevant codes (quotes from the interviews) for the pervasive illustration of the results. Simultaneously with the coding, I created a table indicating the links between categories and testimonies from the interviews. Finally, I applied the summaries, the table representing the testimonies together with the basis of analytical framework of vulnerability to construct a diagram for the graphical illustration of the results (See Results, Figure 2.).

4.8 Quantitative Methods

A quantitative approach was used in this thesis in conjunction with qualitative methods to discover how perceptions of the small-scale farmers correspond to statistical evidence. Adger (2006: 276) states that vulnerability can be measured by objective, material measures of well-being, such as mortality, income, wealth and access to education. In this study, harvested area, farm gate prices\(^5\) and growth rate of rural population were applied to quantify the changes in the livelihoods and well-being of the smallholders in the study area.

Pearson’s correlation was used to explore whether correlation between climatic proxies (mass-balance and precipitation) and socioeconomic variables (harvested area, farm gate prices and growth rate of rural population) exists. Pearson’s correlation is a statistical tool that facilitates investigating relationship between two variables (Feinstein & Thomas, 2002:71). The closer value to 1 is achieved in Pearson’s correlation, the stronger positive correlation exists between the variables. Conversely, if the obtained value is on the verge of 0, the correlation between the variables is weak.

In order to discover the strength of relationships between the variables i.e. to what extent climatic factors explain the changes in economic and social well-being of the smallholders, ordinary linear regression was applied. The regression method is used to explore nature of the relationship between variables and how much the change in dependent variable can be explained by the independent variable (Feinstein & Thomas, 2002:95). The goodness of the fit between the variables can be answered by calculating the coefficient of determination ($r^2$) that tells “the proportion of the total variation that is explained by the regression line” (Feinstein & Thomas, 2002:95, 105).

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\(^5\) Farm gate price (precio en chacra) refers to "a basic price with the “farm gate” as the pricing point, that is, the price of the product available at the farm, excluding any separately billed transport or delivery charge.” Source: OECD (2005)
Another important value, when interpreting the results of the regression analysis, is significance level of the regression model, also known as p-value. P-value tells the probability of obtaining the null hypothesis (H0), i.e. what is the probability the research hypothesis does not stand. The lower the p-value (0=p<1) more significant is the regression line. (Feinstein & Thomas, 2002:162). The quantitative analysis was performed using SPSS statistical software.

4.9 Data

In this study, glacier mass-balance and precipitation were used as independent variables to indicate the climatic and hydrological changes in the study area. In the Quillcay River basin most water in the rivers originates from the glacier lakes formed by the glacier melt water (Rivas et al., 2014:2). This represents the strong interaction between the glaciers and the rivers in the basin. Variability in glacier mass-balance is therefore used as an indicator for the changes in volume of the river discharge.

According to the Peruvian Ministry of Agriculture, the most cultivated crops in the Department of Huaraz are corn, potato and wheat (Interview, Miguel Castro, MINAGRI). The harvested area of corn, potato and wheat respectively were, hence, chosen to measure changes in the agriculture livelihood activity. Farm gate prices of the three most cultivated crops were used as indicators for the income the peasants receive from agriculture. With these two dependent variables, the aim was to capture changes in the economic situation of the smallholders.

Change in the growth rate of rural population in the Department of Ancash was deployed to capture the relation between climatic and hydrological changes and changes in the small-scale farmers’ social conditions. Agesa & Kim, (2001) argue that rural areas often suffer from weak economic development compared to urban areas. As a result, in rural areas employment possibilities are narrower and infrastructure (such as education, healthcare and roads) is less developed giving incentives for rural residents to migrate to urban areas in order to raise their quality of living (Agesa & Kim, 2001:61-62). Therefore, using change in rural growth rate as the third dependent variable was considered to facilitate discovering the interaction between climatic changes and the social well-being of the smallholders.

4.9.1 Data Adjustments

In previous studies, the lack of data or incompleteness of historical data series has been acknowledged to pose restrictions for the research in the Andean region, considerably in
Peru (Drenkhan et al., 2015: 726, Salzman et al., 2013:104). While conducting the current study, similar challenges were confronted. Some data from the study region existed solely from recent years or had not been systematically monitored and included gaps. Therefore, some data adjustments and assumptions had to be made in order to overcome the problem of missing data.

Monitoring of the glaciers located in the proximity of the Quillcay River basin, such as Shallap, Palcaraju and Churup, has only begun recently and data on most of the glaciers does not exist before the beginning of the 21st century. Therefore, in this study mass-balance data from the most surveyed glacier of the Cordillera Blanca, glacier Yanamarey, has been used. Glacier mass-balance data from glacier Yanamarey exists from 1948. However, between 1948-1978 only average values of mass-balance changes are available due to lack of coherent monitoring of the glacier during the period.

In this thesis, it is presumed that the water related changes caused by mass-balance changes of glacier Yanamarey are comparable to those glaciers located within the hinterland of the Quillcay River basin. The assumption is based on the glacier Yanamarey’s close geographical location to the study area and therefore, it is presumed that climatic conditions are relatively equal in the two regions. Glacier Yanamarey is situated in the district of Ticapampa, province of Recuay in the Department of Ancash (Rosario & Cruz, 2014:45), approximately 70 kilometers from the Quillcay River basin.

The data used for the analysis represents the annual retreat or accumulation of the glacier Yanamarey. The unit of glacier mass-balance changes is expressed in meters (m). Mass-balance of the glaciers expresses the changes in accumulation and ablation of the glacier ice cover, i.e. mass-balance (c) = accumulation (a) – ablation (b). The most common method to measure glacier mass-balance is to implant stakes, made of wood or plastic, across the glacier. (Antarctic Glaciers, 2015) Monitoring of the stakes is usually done twice a year, in the end of the rainy period (May) and in the beginning of the rainy period (December) (Rosario & Cruz, 2014:49).

Data on precipitation patterns in the region of Huaraz have been collected since 1972 until present at the weather station of Huaraz located at the altitude of 3,109 m, latitude 09°31'36.6" South, longitude: 77°31'16.2" West. Some incompleteness was found in data series since data was missing between 2000-2002 and in 2012. To overcome the lack of data
for these years, linear interpolation method\textsuperscript{6} was applied. Both data series, on glacier mass-balance changes and precipitation, were obtained from the databases of Unit of Glaciology and Hydrological Resources (UGRH) of Huaraz.

Agricultural data from the whole Department of Ancash was used in the study due to that agriculture data from the region of Huaraz was only available since 1997. In this thesis, it is assumed that the trends in harvested area and farm gate prices of Department of Ancash correspond to the trends of the study area. The assumption was based on the pilot analysis performed with data on harvested area and farm gate prices that was available from Huaraz for the time period from 1997 to 2013. The Peruvian Ministry of Agriculture maintains rather encompassing agriculture databases from the Department of Ancash since the 1950s. Data for the harvested area of potato and wheat exist since 1950 and for corn since 1952. Information on farm gate prices for all the crops has been collected since 1963.

The Peruvian National Institute of Statistics and Informatics sustains registers of changes in rural population growth rate from 1940. However, the data series were also found inadequate. Data on urban and rural growth rates from the Department of Ancash exists from the years 1940, 1961, 1972, 1981, 1993 and 2007. Missing data was interpolated in a manner that arithmetic mean of the last existing values (for example 1940 and 1961) was calculated and the achieved average was placed as an estimate between these years.

Time span, from which the most cohesive data sequences from all the variables could be obtained, was attempted to identify in order to conduct the most reliable analysis. After exploration and evaluation of the data, the time period from 1972 until 2015 was chosen for this study. The time pattern was also considered to cover a sufficiently long historical trajectory with minimized need to interpolate the missing data values. Although the method of interpolation is an advantageous tool when data is not available, the more estimated values are used instead of robust observations, the more it increases the occurrence of biases in the results.

\textsuperscript{6} Interpolation is a method that can be used to estimate missing values in a function or data series (Merriam-Webster, 2016). Numerous, more complex interpolation techniques are in use in mathematical analysis. In this thesis, however, interpolation was done by counting arithmetic means of the closest existing values for estimation of the missing data.
5. Results

5.1 Semi-Structured Interviews, Small-Scale Farmers

5.1.1 Variability and Change in Environmental Conditions: Exposure to Climatic Stresses

Diverse environmental stresses, such as heat and drought, were mentioned during the interviews. Due to the limitations of the study, however, only exposure to precipitation and glacier retreat related stresses are included in the essential analysis of this thesis.

*Climate Change*

According to the conducted interviews it can be deduced that there is a consensus on changed climatic conditions among the interviewed smallholders in the study region. Mostly mentioned changes were that the weather had become unpredictable and the weather events were more extreme. During the interviews, the small-scale farmers told that the heat had become so intense that “it was burning the skin” and on the other hand, sometimes it was so cold that the frost was damaging their cultivations.

When we were children it wasn’t so hot. And now we have noticed…when it is not raining…it is so hot…it burns us. Before it wasn’t like that. (Informant no. 4)

Rain was also reported to be either absent or torrential. Several interviewees told that hailstorms had become more frequent in the region. When it was asked since when the informants had first observed changes in climate, the received answers varied from “last year” (2015) to the 1960s. However, the most common perception was that climate had begun to change approximately 5-10 years ago.

*Precipitation*

Nearly all of the interviewees had observed changes in precipitation regimes in their living area. Nonetheless, the nature of the observed changes varied among the informants; some considered that the rain was more abundant now than before and as contrast, some perceived that nowadays the lack of rain was causing drought.

All the smallholders, however, mentioned during the interview sessions that the rainy period had become shorter. I was told that before it had been raining from August/September until April and that the rain had been “soft” and “continuous”. According to the notices of the
informants since last five years, the rain did not arrive before January or February and when it finally began to rain, the rain was unpredictable and fierce.

Before when it was raining, the rain was calm. But now when the rain arrives, it is torrential… and it washes away all the soils. (Informant no.2)

Most of the small-scale farmers reported that lack of rain had damaged the cultivations, the production had become less regular and the grass in the pastures was not growing as it used to. I was told that as a consequence, nowadays the cows were producing less milk. At the same time, some (presumably the peasants with better economic situation) told that due to the shortened rainy season they had decided to construct irrigation systems in the fields in order to ensure a successful harvest.

Glacier retreat
The respondents gave unequivocal answers that the glaciers around their living area were visibly disappearing. The average estimation among the peasants was that the glacier retreat had begun approximately two decades ago. As one of the interviewed smallholders described his observations:

For example in the time when I was a child the glaciers were pure white and now they are just pure rock. The ice is disappearing. (Informant no. 13)

Photo 2. A typical house of a smallholder in the case study site. Photo 3. Landscape of the case study area.
The informants also expressed a feeling of uncertainty how deglaciation would affect the future water supply and consequently, the agriculture practices. A cultural aspect of the glacier retreat was also discussed as the white glacier peaks have traditionally been considered as a landscape trademark of Huaraz.

5.1.2 Sensitivity of Biophysical Systems and Economic Structures to Climatic Stresses

Cultivations
All of the smallholders, except one, reported decline in agriculture production since the 1980s/1990s. As most of the farmers in the region rely on precipitation for irrigation, the most common reason for lessened or deteriorated yields was told to be that “rain arrives late”, lack of rain or that the rain comes down in the form of hail and destroys the crops. Both heat and frost were also mentioned to be causes for smaller or entirely lost harvests. Only one interviewee told that the production has remained the same when he was using an irrigation system.

Everything is normal, with the irrigation. Everything is normal, quinoa, corn, barley, wheat…everything is just normal. (Informant no. 9)

According to the smallholders, before the variety of crops they cultivated used to be wider than now. Peasants told that due to changed climatic conditions the traditional Andean crops such as oca, ollyco and kiwicha could not be grown any more in the region. Nearly all of the informants also mentioned that before they had succeeded achieving abundant yields “naturally” but nowadays they had to use fertilizers and pesticides in order to receive even decent harvests.

Before the production was better, now there is not that much anymore. Before chemicals were used less. Before no one used fertilizers. (Informant no. 1)

Income and Prices
The income received from the agriculture practices was reported to have fallen as a result of decline of the yields. The informants told that before they were descending to the city of Huaraz to sell their products in the market. Nowadays, most of the smallholders were mainly cultivating for self-consumption. Some of the informants, however, considered that the fields did not even produce enough crops to feed their families anymore. Many of the respondents had obtained either part-time or full-time work in Huaraz to compensate the income loss from the agriculture. One of the small-scale farmers describes his situation as follows:
When I was kid, the potato yields allowed me to go to school…the potatoes yes…but when I was about twenty years…since then there was no harvest anymore…also because when it is not raining, the potatoes don’t grow. --- No, it [agriculture] doesn’t give return anymore. Before I could always pay for the school of my kids with my field…but now it’s not giving anymore (ya no da)…so much work but the harvest is not giving so much anymore. (Informant no.11)

Another reason for decreased income from agriculture was told to be a growing need to use fertilizers. According to the peasants, fertilizers are costly and therefore, their use lowers the net income received from the crops. It was also argued that market price of agriculture products had fallen considerably during the last decades. Declined market prices had led to a situation where the smallholders did not find it worthwhile to make additional investments on agrochemicals and then descend to the city to sell the products because the prices did not cover their labor input and the increased production costs.

Because before…one kilo of potatoes was sold for a regular price. And now…you have to sell two or three kilos for one sol…and this doesn’t suit us. (Informant no. 8)

…the market price is very low now. And that is not convenient for us at all. – we are paying for the fertilizers and pesticides and it [agriculture] doesn’t pay back anymore. Therefore the agriculture production has lowered…who would harvest if it doesn’t pay back? And many people have left the countryside to work at the construction…to find other sources of income… (Informant no.7)

5.1.3 Impact of the Climatic Stresses

Water and Health

Most of the informants stated that in the last decade they have had access to less potable water and water for irrigation than before. Rivers had been observed to be less charged now than a couple of decades ago, especially during the dry season (May-September). Concern for lack of sufficient supplies of drinking water for everyone in the villages was also revealed during some interview sessions. I was told that due to restricted access to potable water people had to put more effort in order to obtain drinking water since it had to be carried in buckets from the wells of which some were situated far away from their homes.

For example, we have cultivated potatoes…and now there is almost nothing anymore…everything is lost…there hasn’t been production. Why? Because of the rain, it hasn’t rained! With what else could we irrigate? (Informant no.10)

In the interviews that were conducted on the side of the river Auqui, it was discovered that the water in the river was contaminated. The interviewees told that sometimes the colour of the water was yellow and that people who had been drinking the water had become ill. When interviewing the coordinator of Unit of Glaciology and Hydrological Resources,
Alejo Cochachín (ANA), I was told that the changes in the quality of the water were caused by natural contamination process:

The contamination of the river is caused by so called natural contamination. When the ice melts, the minerals that are encapsulated in the rock wall begin to extract. When the minerals end up to the river, the water gets contaminated. The water [in the Auqui river] has been contaminated since 2000 and it is not usable at the moment.

The residents who were living by the Auqui River were no longer using the water for drinking or irrigation and were acquiring water from springs and river Paría instead. Alejo Cochachín did not exclude the possibility that a similar contamination process could occur in the future in another main river in the basin of the Quillcay River basin, the Paría River.

Besides the lowered access to potable water and irrigation water, the interviewees considered that changes in the climate had also affected health of people and the domestic animals. For example, local residents were told to have more skin diseases due to the higher radiation and more frequent flues caused by high contrasts in the weather. Additionally, the domestic animals were reported to require medical treatments more often now than before. The smallholders did not know, however, what was the actual root cause of the more frequent illnesses of their livestock.

Photo 4. Small-scale farmers with their cattle in the field study region.
When it was asked how the peasants perceived the future water situation, rather unequivocal answers were received that since they had noted enhanced recessions of the glaciers near their living area, they consider that in the future there would be no more water if “the glaciers will finish” (*terminarán los glaciares*).

Well, we have to see what will happen…what will happen when the glacier lake will finish (*se terminará*). If the snow cover will disappear, the water will disappear as well then. (Informant no.8)

5.1.4 Resilience: Response and Adaptive Capacity to Climatic Stresses

*Shift to other subsistence*

In order to compensate the income lost in agriculture, many of the peasants were now working part-time in Huaraz, mainly at the constructions, besides agriculture activities. Some of the informants had moved to the city and were no longer practicing agriculture as their main livelihood. Willingness to move to Huaraz was expressed during some interviews, but many smallholders told that they could not afford to move because the living and apartments in the city are too expensive.

Yes, I have thought about it [moving to Huaraz] but when you don’t have that economic situation…you just can’t. (Informant no.15)

*New crops*

Some of the respondents told that they were not educated, were illiterate or did not have any other work experience than agriculture, and therefore, they had to continue with agriculture as their principal subsistence. Only one of the informants told that he is trying to “figure out how to adjust to the changes”. He was attempting to find out how crops, fruits and vegetables that grow in higher temperatures and require less irrigation, survive in the changed climatic conditions in the highlands.

What I am doing is…hmm.. and experiment that in the future I could sustain myself with these products because before here…there weren’t any…almost any of these plants…to investigate and draw my conclusions if it is going to produce or not…and how in the future I could figure out how to sustain myself economically. (Informant no.10)

*Migration*

According to the interviewees, residents of the Quillcay River basin had begun to migrate to the cities approximately fifteen years ago. People from the highlands were mainly moving to Huaraz, but some had gone to the national capital, Lima, and other bigger coastal cities such
as Chimbote. Reasons for migration were diverse; young people had left for the better education possibilities or search for work, whole families had moved to look for better source of income and to live closer to the schools of their children. The most common reason for migration stated during the interviews was that the agriculture did not produce as it had done before.

Yes, about fifteen years ago [people began to leave]... little by little... we have come here...the field is not producing...it is not sustaining us anymore. (Informant no.14)

Therefore, those who had the opportunity had left to the cities to work as entrepreneurs or in the constructions. Some had moved to the cities and had opened small grocery stores. Two of the interviewees stated that they enjoyed life in the countryside, although they did not receive so much profit from agriculture anymore. According to them, life in the cities circulates around money and that they valued peace and calmness of the countryside higher than the hectic life in the city.

Here, I am living in freedom...more free than in the city. When you go down in the city...it is all about the money...I personally want to live more free in my fields and die here. Yes, that is my own decision. (Informant no.7)

**Institutional and governmental support**

One of the themes in the interview scheme was external aid, i.e. if the peasants had received any financial, informational or educational help in terms of climate change and water issues from government or other institutions. Most of the interviewees told that they had not received any kind of external aid for example to construct new canals and reservories for the potable water. Some had asked for help from the municipality of Huaraz, but according to the informants no help had been provided so far whilst some of the peasants told that the municipality of Huaraz had given them materials to construct canals and had also participated in the construction projects.

There is no help, no advices...There is nothing. (Informant no.2)

The representatives [of the municipality] came here once and they offered help to construct new canals, but then, they never fulfilled their promises. (Informant no.4)

Yes, the municipality has helped us. They brought the materials and then we ourselves worked to construct the canal. (Informant no. 16)

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7 The smallholders having school-aged children told that the public transportation between the highland countryside and Huaraz was not always working very well. According to the respondents, especially during the rainy season when the rain damages the mountain roads, the buses were not always able access the highlands at all.
Local NGOs were said to have helped to construct reservoirs for potable water in some
villages of the study area. The informants also brought up during the interviews that there is
a growing need for external aid to construct irrigation systems due to shortening rainy period
in order to avoid shortages in water supply in the future.

Soon we will need modern irrigation systems..not to waste water. (Informant no.10)

Some smallholders also raised the issue of their marginalized position compared to the urban
populations. The interviewees felt that the rural areas “had been forgotten” in terms of
development of the infrastructure and financial aid. The interviews were conducted under
the presidential election campaigns of 2016 and some of the peasants felt that at the moment
the politicians and the authorities came to visit them with amount of promises. I was told,
however, that their experience of the presidential elections campaigns from the previous
years was that the promises were not full filled later.

How could I say...now they are looking for votes and these people arrive with their hats and traditional
costumes. They want to show that they are as we are, rural [indigenous] people. But when they enter [to
parliament]…they don’t listen to us anymore.” (Informant no.14)

5.2 Semi-Structured Interviews, Key Informants

According to National Coordinator of Glaciers and Glacier Lakes of Peru, Nelson Santillán
Portilla (ANA), the glacier melt water with solid and liquid precipitation are the unique
sources of water in the Peruvian highlands. The results of glacier monitoring conducted by
ANA show that between 1970-2010 the glaciers in Peru have lost 42.2 % (870 km²) of the
glacier surface. Nelson Santillán Portilla also confirmed that decreased river discharge due
to accelerated glacier recession has been observed in the basins where the water originates
from the glaciers, particularly during the dry season (May-October).

In personal communication with Gilber Gonzales (UGRH), Specialist in Hydrology and
Glaciers, changes in precipitation patterns were discussed. Gilber Gonzales considered that
approximately until 1980s precipitation regimes had been regular during the rainy season
(November-April), but since recent years it has been observed that the precipitation was
varying between fifteen days patterns of torrential rain and rain being absent. According to
Gilber Gonzales, intensification of such precipitation phenomenon would have serious
impacts on the watersheds of the highland residents in the future.
Nelson Santillán Portilla acknowledged that decreased water resources in some glacier melt water based basins have already affected harvests adversely. Consequently, declined harvest together with other reasons, have triggered migration to the cities that in many cases has not lead to improved the situation of the rural migrants.

Many rural people are moving to the cities for many reasons such as that there is less water, worse harvests, worse prices for their products, challenges in transportation of products, adverse climatic impacts such as frosts and droughts among other things. As well, in other places, such as coastal valleys, the scale of potato production is much broader (however, the quality is not as good as of the Andean potato variety). This has lead to decline in the prices of potato and as a result, the Andean products can’t compete in the markets. The situation of migrants from the Andean region is not necessarily better in the cities, actually the opposite, the major part have serious problems to adapt and only few obtain good jobs. Many such cases are know, that rural people who have moved to the cities have confronted delinquency or have ended up to work within prostitution.

Agricultural engineer Miguel Castro (MINAGRI) stated that many peasants in the highlands had since recent years begun to cultivate “commercial potato” variety instead of the traditional Andean potato varieties with the aim to receive higher harvests. According to Miguel Castro, the commercial potato was successfully grown in warmer coastal regions, but does not suit to different climatic conditions of the highlands and therefore, inversely the peasants were now receiving smaller potato yields. Engineer Castro also argued that educational programs on modern agricultural practices would be highly needed to enhance sustainable small-scale farming in the region, but corruption is currently hindering further launch of such programs. Additionally, Miguel Castro argued that there is currently lack of new research on agriculture in Peru. He considers that one of the central reasons for decline of the harvests in the rural highlands is that no new scientific knowledge has been provided on how and which crops would succeed in the changed climatic conditions.

Coordinator of the Unit of Glaciology and Hydrological Resources, Alejo Cochachin (ANA) and Specialist on Glacier Monitoring César Salazar (UGRH) told both during personal communications that central adaptation strategies for adequacy of water resources would be to enhance efficient use of water through constructing water reservoirs that capture and store precipitation water. Additionally, Alejo Cochachin and César Salazar considered that in order to ensure continuity of small-scale farming, improvements in efficient use of water should be performed by constructing modern irrigation systems. César Salazar also argued that educating rural population on efficient water management and taking care of water resources is evident in order to advance sustainable use of water resources in the rural highlands.
We should educate [rural] people, especially the young generation. It is the only way to improve the understanding of the value of the water. The current ignorance to take care of water [in rural areas] is simply result of lack of consciousness.

Nelson Portilla highlighted similar strategies for tackling adverse impacts due to evanescence of water resources. In addition, the importance of adequate policies in vulnerability alleviation of smallholders was discussed:

The solutions [to prevent social dilemmas in rural areas due to changes in climate and hydrology] would go through educating both protagonists: specialists and farmers in order to improve the cultivating methods. And as well, we would need good state policies that would be capable and adequate to resolve these great problems with social sensibility and sustainable methods. For great problems, we need great solutions, and this would only be possible through good policies and good government. With the articulation of these components, these problems could be solved. And in Peru, the current situation is not quite like that.

Alejo Cochachín acknowledged that municipalities and government should share the responsibility in providing knowledge on modern irrigation technologies as well as financial entitlement for less developed rural areas. According to Alejo Cochachín, some initiatives had already been taken, however, during the interview it arose that peasants were often wary to receive information and help from the authorities and therefore, government led water management programs were not always very well received by rural residents.

In an interview with Evelyn Montensinos Rafael, Responsible for Sanitary Education at EPS Chavín S.A., I was told that currently the enterprise was driving an educational campaign on preserving water and good management of water. During the discussion, it came apparent that the campaign events were only held in urban primary and high schools and at the marketplaces in the cities. According to Evelyn Montesinos Rafael, none of the events had been held in the rural areas, neither to her knowledge any other water management programs had been organized in the highland peripheries.

5.3 Evaluation of the Semi-Structured Interviews through Vulnerability Framework

Precipitation anomalies and glacier retreat through changes in river discharge were found to be the major climatic stresses disturbing the biophysical and human systems of the Quillcay River basin. According to the interviewed smallholders, exposure to the climatic stresses was most visibly observed as scarcer water supply for irrigation and potable water. The
informants considered, that decline of the water supplies was a consequence of shortened rainy period and enhanced glacier retreat.

The peasants perceived that the changes in hydrology and climate are the causes of declined or damaged yields and that as a consequence they now received less income from agriculture. According to the analytical evaluation of the interviews, many smallholders were attempting to adapt to the changed circumstances for instance by moving to the cities and by obtaining additional sources of income to compensate the lost income from agriculture. Additionally, some of the peasants had constructed irrigation systems, had begun to use fertilizers or had introduced new crops that suit better for the changed climatic and hydrological conditions. The latter adaptation strategies, however, require sufficient economic assets that all the interviewees were discovered not to have.

The amount of financial capital and human capital were found to define the extent to which the small-scale farmers were able to respond to the changed climatic and hydrological conditions, i.e. how resilient they are to the external stresses. The peasants with stronger financial capital seemed to aim to respond to the diminished water supply by constructing new canals, water reservoirs and advanced irrigation systems. During many interviews it was also discovered that robust economic situation had facilitated finding additional sources of income such as selling livestock or migrating to the cities to look for new livelihoods, whereas peasants with weak financial capital lacked the opportunity for such adaptation mechanisms.

Smallholders with strong human capital, such as education, literacy, good knowledge of agriculture practices or experience in other professions than agriculture had higher capacity to adapt to the changes and were thus, less vulnerable to the hazards caused by hydrological and climatic changes. For example, the few peasants that were educated or otherwise had good experience in agriculture practices were attempting to cultivate new crops or alternative species of traditionally cultivated crops that were more resistant to the changed climatic circumstances than the currently cultivated crops.

Additionally, peasants who had stronger human capital had changed for alternative livelihoods, men mostly within construction or different affairs and women had opened small grocery stores. In contrast, it can be interpreted that the peasants who reported that they did not hold equivalent human capital, did not have the same adaptation opportunities
and continued practicing agriculture, although they now received less income from their subsistence compared to before.

Institutional and governmental support was found to have an impact on the level of resilience, especially in the case of smallholders with low financial, human and physical assets. The small-scale farmers who had received material or financial aid from the municipality or local NGOs, for instance to construct canals and reservoirs, reported that they had enough potable water and water for irrigation while those who had not received any kind of help told that they were suffering from lack of water.

While analyzing the results of the interviews, it was also explored that some peasants themselves perceived to be in a marginalized position in comparison to urban residents. The marginalization was felt as being neglected in terms of weak infrastructure development in the rural highlands, but also as discrimination due to their rural or indigenous background. Such marginalization can also be counted as one of the factors increasing vulnerability. However, due to restrictions of the current study the marginalization factor was left out from the vulnerability and resilience analysis.

The authorities that were interviewed for this study agreed upon that changes in precipitation regimes and accelerated glacier recession have already affected the highland watersheds and consequently, posed challenges for small-scale farming. Hence, the key informants brought forward additional factors, such as low education of rural residents, weak knowledge on efficient use of water and appropriate agriculture practices and lack of political entitlement in rural areas that are lying behind the socioeconomic problems of the rural highland regions. The authorities, thus, emphasized the importance of education, providing novel research on agriculture and governmental involvement as efficient adaption methods for alleviation of adverse socioeconomic impacts triggered by climatic and hydrological changes in the study region.

As a summary of the analyzed results of the interviews are illustrated in the adjusted conceptual framework of vulnerability (Figure 3.). The framework presents relations between changes in hydrological and climatic conditions and vulnerability of small-scale farmers. It can be seen that enhanced glacier retreat and changes in precipitation regimes affect agriculture practices through diminished water supply in the rivers and unstable source of water for rain-fed irrigation. Scarcer access to water and consequently,
deteriorated livelihoods have pushed smallholders to develop coping strategies such as migration to the cities, looking for alternative livelihoods, using agrochemicals and building irrigation systems. Strong financial capital, human capital and physical capital were found to be prerequisites to create stronger resilience for the climatic and hydrologic stresses.

Figure 2. A conceptual framework illustrating results of the interviews. Source: Author, based on vulnerability framework of Turner et al., (2003b).
5.4 Statistical Analysis

Pearson’s correlation and ordinary linear regression analysis were conducted on one hand to test correctness of the research hypothesis (H1): climatic and hydrological changes have harmed the subsistence and well-being of the small-scale farmers in the Quillcay River basin and on the other hand inaccuracy of null hypothesis (H0): the adverse socioeconomic impacts that the smallholders in the Quillcay River basin have not been caused by climatic and hydrological changes. In order to test the hypotheses, the strength and nature between climatic variables (mass-balance and precipitation) and socioeconomic variables (harvested area, farm gate prices and growth rate of rural population) were measured.

Before performing correlation and regressions analysis on SPSS statistical software, trend lines of each variable were drawn in Excel. The purpose was to capture an initial perception if there had been significant changes in the trends of the variables during the time interval under review. The trend line drawn based on data on the mass-balance changes on glacier Yanamarrey confirmed the findings of previous studies with substantial decline of the mass-balance since 1972 (Painter, 2007:1; Rabatel et al., 2013:89; Rosario & Cruz, 2014:65). According to the trend line that was drawn on precipitation it was found that total precipitation in Huaraz had remained rather constant, with a slight increase and more volatility in recent years.

Harvested areas of all three crops (corn, potato and wheat) were found to have decreased approximately since the mid-1980s. The farm gate prices of corn, potato and wheat had all risen and at an accelerated pace since the 1990s. The 1980s was a turbulent decade in Peru’s economic history. Throughout the decade, the country confronted several hyperinflations; between 1979 and 1989 the prices were rising and falling heavily as a consequence of various economic crisis and climatic disasters caused by El Niño in 1983 (Webb, 1988:169, 171; Cermeño & De la Cruz, 1991:178). In this study, in order to offset the impact of the inflations, farm gate prices were converted from nuevos soles to U.S. dollars. Lastly, the growth rate of rural population in the Department of Ancash was found positive from 1961 until 1981 and had begun to decline since.
5.5 Pearson’s Correlation

According to the achieved results from Pearson’s correlation analysis, relatively strong correlations were found between glacier retreat and harvest of corn (0.495), harvest of potato (0.466) and harvest of wheat (0.524). The harvested area for all three crops correlated rather weakly with precipitation: corn (0.077), potato (0.042) and wheat (0.205).

Weak positive correlations were found between the farm gate prices and the climate proxies. The strongest correlations were found between farm gate price of corn and precipitation (0.210) and farm gate price of potato and precipitation (0.280). The correlation between farm gate price of potato and glacier retreat was weak and negative (-0.012). Growth rate of rural population showed negative correlation with both precipitation (-0.164) and glacier retreat (-0.257).

Correlation should not be interpreted as a direct causal effect between different variables. It is merely evidence that strengthens the research hypothesis, but does not ultimately validate it (Feinstein & Thomas, 2002:72). The results from Pearson’s correlation thus, give an indication that accelerated glacier retreat has had an impact on the decline of the harvested
land. Precipitation, however, cannot be proved as a unique cause of decline in harvested area. Detailed results of Pearson’s correlation are illustrated in Table 2.

Table 2. Correlations between climate proxies and socioeconomic factors. Upper value indicates the correlation (r) and value in parenthesis one-tailed significance level (p). Source: Author, based on the data obtained from MINAGRI, INEI and ANA

<table>
<thead>
<tr>
<th></th>
<th>Harvest Corn</th>
<th>Harvest Potato</th>
<th>Harvest Wheat</th>
<th>Price Corn</th>
<th>Price Potato</th>
<th>Price Wheat</th>
<th>Rural Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retreat</td>
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<td>0.466</td>
<td>0.524</td>
<td>0.011</td>
<td>-0.012</td>
<td>0.028</td>
<td>-0.257</td>
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<td></td>
<td>(0.000)</td>
<td>(0.001)</td>
<td>(0.000)</td>
<td>(0.473)</td>
<td>(0.496)</td>
<td>(0.428)</td>
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<td>Precipitation</td>
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<td>0.042</td>
<td>0.205</td>
<td>0.210</td>
<td>0.208</td>
<td>0.185</td>
<td>-0.164</td>
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<td>(0.310)</td>
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<td>(0.091)</td>
<td>(0.086)</td>
<td>(0.088)</td>
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5.6 Regression Analysis

Ordinary linear regression analysis was performed in order to discover how much the change in dependent variables, harvested area of corn, potato and wheat, farm gate prices of corn, potato and wheat and lastly, growth rate of rural population could be explained by independent variables, glacier retreat and precipitation. Results of the regressions are presented as whole in Table 3.

Modest coefficient of determination values ($r^2$) were discovered between all of the independent variables (glacier retreat and precipitation) and on the other hand the dependent variables (harvested area of corn, potato and wheat, farm gate prices of corn, potato and wheat and growth rate of rural population). Glacier retreat was found to explain well the changes in the harvested areas, especially the decline in the harvested land of wheat ($p=0.000$). On the other hand, precipitation was not found to be significant in explaining changes in the harvested areas. Modest significance was discovered, however, in explaining changes in harvested area of wheat ($p=0.217$).

Farm gate prices of corn, potato and wheat all received low $r^2$-values in relation to precipitation and retreat. The p-values for the farm gate prices of the three crops were found high for glacier retreat and low for precipitation, indicating that glacier recession is not significant explaining the changes in the prices. In contrast, precipitation was found to be significant to some extent to explain growth in farm gate prices. The price of corn ($p=0.178$) showed the highest significance in relation to precipitation. Lastly, according to the results, precipitation and glacier retreat explain only weakly the changes in growth rate of rural...
population. Precipitation, however, was discovered to have higher level of significance (p=0.108) than glacier retreat (p= 0.342).

Table 3. Results of linear regressions analysis. Coefficient of determination ($r^2$) presented above and statistical significance (p) below in parenthesis. Source: Author, based on the data obtained from MINAGRI, INEI and ANA

<table>
<thead>
<tr>
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<th>Harvest Corn</th>
<th>Harvest Potato</th>
<th>Harvest Wheat</th>
<th>Price Corn</th>
<th>Price Potato</th>
<th>Price Wheat</th>
<th>Rural Population</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Retreat</strong></td>
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<td>0.217</td>
<td>0.301</td>
<td>0.044</td>
<td>0.044</td>
<td>0.034</td>
<td>0.087</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.002)</td>
<td>(0.000)</td>
<td>(0.969)</td>
<td>(0.852)</td>
<td>(0.931)</td>
<td>(0.108)</td>
</tr>
<tr>
<td><strong>Precipitation</strong></td>
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<td>0.217</td>
<td>0.301</td>
<td>0.044</td>
<td>0.044</td>
<td>0.034</td>
<td>0.087</td>
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<tr>
<td></td>
<td>(0.782)</td>
<td>(0.972)</td>
<td>(0.217)</td>
<td>(0.178)</td>
<td>(0.177)</td>
<td>(0.238)</td>
<td>(0.342)</td>
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6. Discussion

Various scholars have recognized the pernicious impacts of climate change on marginalized populations in the global South (Altieri et al., 2013:2; IPCC, 2007:720; Kelly & Adger, 2000:325). The region of tropical Andes is highly sensitive to climatic variability, with projections of serious implications for the lowland populations particularly due to the transformation of hydrological cycles (Painter 2007:9,11; Rabatel et al., 2013:82). In this light, through a case study approach it was examined to what extent changes in climate and hydrology have harmfully affected livelihoods and well-being of the smallholders in the Quillcay River basin.

Findings of the current study, using mixed qualitative-quantitative methods, suggest that there are some discrepancies between how small-scale farmers perceive their vulnerability to climatic changes compared to what statistical evidence demonstrates. In line with the perceptions of informants, quantitative analysis confirmed that glacier retreat has had influence on the agriculture activities in terms of decline in harvested area of corn, potato and wheat. Mark et al. (2010) achieved equivalent results in their interdisciplinary evaluation of livelihood vulnerability in the case study of three watersheds (Llanganuco, Quillcay and Querecocha) in the Cordillera Blanca. They argue that decrease of water supplies due to recent glacier recession can be confirmed by both physical measurements as well by perceptions of local residents. (Mark et al. 2010: 803)

On the other hand, monitored data on precipitation did not show significant changes in long-term precipitation patterns in the study region. Neither was it found to have had a strong effect on decline in the harvested areas. The respondents, hence, reported that lack of rain was the major cause to deteriorated cultvations. Although statistical evidence did not demonstrate strong changes in total amount of precipitation, it revealed high inter-annual volatility in precipitation patterns during recent years. The smallholders’ perceptions on shortened rainy period and rain being either torrential or absent, seem to respond to the statistics. Therefore, it is suggested that extreme and irregular rain events of recent decades have posed challenges for agriculture practices rather than decreased precipitation. Similar interpretations were reported in the study of Gurgiser et al. (2015) on peasants’ perceptions on precipitation changes compared to precipitation records in Callejón de Huayalas, Peru.
Despite that the informants argued that changes in climate and hydrology have had an impact on income they received from agriculture, the statistical measurements did not endorse smallholders’ perceptions. Firstly, after correcting the impact of inflation, the data series showed an increase in farm gate prices of all three crops, considerably since 1990s. Data on farm gate prices, thus, suggest that the income from agriculture should have increased. Hence, the statistics did not confirm the statements of the small-scale farmers of diminished income from agriculture practices. Secondly, according to the regression analysis precipitation was found to explain only modestly growth in the farm gate prices whereas glacier retreat did not have almost any significance in explaining changes in the farm gate prices. Informants reported, however, that nowadays there was an increased need to use expensive agrochemicals in the fields that most probably have resulted that peasants now receive less profit when selling their products. In addition, one of the key informants mentioned the challenge of transportation of agri-products from the highlands to the cities that is also causes an additional cost for the smallholders.

Changes in climatic conditions were perceived as one of the major reasons people had begun to migrate from highlands to the cities. In the statistical analysis, however, the climatic variables explained the negative trend in growth rate of rural population only to a certain degree. In addition, during the interviews both peasants and key informants mentioned diverse reasons for migration besides changes in climate and hydrology, unfavorable market set-up for smallholders due to augmented large scale production, families abandoning farming for more stable income and young generation moving to look for better education and work opportunities. Hence, it is suggested that climatic factors do not exclusively explain movement from the rural to urban areas, but can be considered as one of the multiple factors enhancing migration.

There are several reasons why partly reverse results of the integrated study might have been obtained. Firstly, long-term monitoring of climate of the tropical Andes provides robust evidence of abnormal change in climate that cannot be disregarded. Nevertheless, historical climate records have shown year-to-year variability in climate patterns since the ice ages until present. In the geologic history, such variations have been to large extent caused by natural processes of the atmosphere and the oceans (Lamb, 1972:1) thus indicating that all inter-annual changes in the weather should not be interpreted as enhanced climate change.
When evaluating qualitative data based on people’s memories and views on changes in climate, one should also be aware of the fallibility of the human mind. For example, exceptional weather of current or recent years can lead to reasoning that climate has changed even though the phenomenon might be a part of natural climatic variation.

Secondly, informants’ awareness to be participating in the study measuring impacts of climatic changes may also lead to unconscious ‘biased remembrance’ and consequently, expressing arguments on climate change being culprit for all the experienced adverse socioeconomic changes. This does not necessarily mean that the data based on human perceptions is biased, but the researcher should bear in mind its subjective nature.

Thirdly, due to limitations of this thesis, numerous variables that may have had an impact on unfavorable socioeconomic on impacts on well-being and livelihoods of the smallholders had to be excluded. For example, when interviewing distinct authorities it became apparent that some peasants were suffering from lack of water for irrigation due to weak knowledge how to create and maintain more efficient irrigation systems. Statements of the key informants indicate that weak knowledge on good water management practices may be one reason hindering small-scale farmers’ capability to adjust the livelihoods to transformed climatic and hydrological conditions and consequently, leading to higher vulnerability.

In addition, the key informants emphasized the influence of larger political and economic structures on the struggles in rural areas. In personal communications with authorities it was discussed that markets for agri-products had shifted towards favoring large-scale production resulting as unprofitability of small-scale farming. Additionally, concern for lack of novel scientific knowledge on sustainable agriculture practices in changed climatic conditions was expressed. In line with the feelings of the smallholders being marginalized over the urban residents, the statements of key informants suggest that the rural areas are currently omitted in terms of adequate political engagement for enhancing education, financing infrastructure development and addressing social issues due to challenges in livelihoods caused by changes in climate and markets.
7. Conclusions

The findings of the study show that the adverse impact of climatic and hydrological changes on the livelihoods and well-being of the smallholders in the Quillcay River basin during the last decades cannot be neglected. Accelerated glacier recession has already had implications by deteriorating hydrological cycles in the study region and hence, presents a threat for sufficiency of future water supplies that should be addressed with high concern. Considerable influence of precipitation on the livelihoods of the small-scale farmers could not be verified by the statistical analysis in this study. However, perceptions of respondents as well as physical measurements on precipitation regimes refer to an intensification of extreme rain events that have complicated practicing small-scale agriculture in the study site and consequently, to some extent triggered migration from the rural highlands.

In accordance with the theoretical approaches of vulnerability and resilience, the results of this thesis confirm that vulnerability of marginal populations cannot solely be determined as a consequence of climatic and hydrological changes, but rather as an outcome of a complex integrity of social, ecological, economic and political factors. In the modern vulnerability literature the need to capture multiple dimensions of stressors causing vulnerability has been acknowledged and addressed to increasing extent. The analytical framework of Turner et al. (2003b) in its original form was found to be a commendable attempt to include a wide range of distinct variables in the vulnerability evaluation. Unfortunately, the limits of the current study did not allow performing a pervasive use of the framework.

In this study, it was showed that respondents with weak financial, social and physical assets were the most vulnerable to climatic and hydrological variability and were less capable to adapt to the changes. Studies on vulnerability and resilience have denoted that weak political structures and lack of government entitlement are often central causes of the systems’ increased vulnerability and low resilience when exposed to climatic stresses. The results of this study, in line with findings of previous research, suggest that poverty, low level of education and lack of political engagement in the case study area have increased climate vulnerability of the smallholders Therefore, in further evaluations on adverse influences of climatic and hydrological changes on certain populations, it is necessary to identify their backgrounds and the root causes that have primarily led to vulnerability.
In order to develop adequate adaptation strategies in the case study region, it is suggested that stronger governmental engagement in rural areas is required in terms of educating and informing rural residents on how to adjust the livelihoods in front of changes in climate and hydrology. In addition, governmental involvement in facilitating building and financing sustainable water management infrastructures for both potable water and irrigation would be recommended.

Diversity of factors affecting lowered socioeconomic situation of small-scale farmers in the case study area that could not be analyzed more in-depth within the frames of this thesis, became apparent during the research process. It is hence, recommended that in subsequent studies issues such as changes in market economy, corruption, weak policies and other climatic factors increasing vulnerability of rural populations in the Andean region, should be addressed. In addition, a hint of evidence was found that migration to the cities, that was one of the adaptation strategies the peasants used with the aim to improve their socioeconomic conditions, was in some cases indeed leading to even higher social vulnerability. Thus, attention should be paid to social problems rural migrants are encountering in the cities and in which manner they should be tackled. Lastly, during the field study it also came apparent that the Auqui River in the Quillcay River basin is contaminated due to a process caused by glacier recession. The potential impacts of the phenomenon in the future would certainly require more accurate exploration from both human and environmental perspectives.
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Key Informants
Castro, M. (2016.) Agricultural Engineer, MINAGRI, Direccion de Recursos Naturales y Ambiente de Agricultura [Interview] (Personal communication March 28, 2016) A. Heikkinen, Huaraz
Cochachín, A. (2016.) Coordinator of Unit of Glaciology and Hydrological Resources, ANA [Interview] (Personal communication March 18, 2016) A. Heikkinen, Huaraz

**Interviewees**

Informant 1. (2016.) Male, Small-scale farmer, 58 years
Informant 2. (2016.) Male, Small-scale farmer, 67 years
Informant 4. (2016.) Male, Small-scale farmer, 62 years
Informant 7. (2016.) Male, Small-scale farmer, 52 years
Informant 8. (2016.) Male, Small-scale farmer, 79 years
Informant 9. (2016.) Male, Small-scale farmer, 62 years
Informant 10. (2016.) Male, Small-scale farmer, 65 years
Informant 11. (2016.) Male, Small-scale farmer, 62 years
Informant 13. (2016.) Male, Small-scale farmer, 66 years
Informant 14. (2016.) Female, Small-scale farmer, 66 years
Informant 15. (2016) Female, Small-scale farmer, 51 years
Informant 16. (2016) Female, Small-scale farmer, 50 years

**APPENDIX**

Following questions were used as the base of the interview guide and its different themes. Additional questions were, however, asked depending on what the informants answered or if the interviewees showed willingness to discuss issues that were not included in the original interview guide. Here, first the translated of interview guide in English is given, followed by the original Spanish version.

**Interview guide, small-scale farmers**

Date and time of the interview (duration):
Place:
Personal information:
First name and surname:
Age (Year of birth):
Marital status:
General

For how long have you been living here?
What do you do for living? (Have you always done that for living?)
Do you think that life here is different now compared to before? (How life has changed? Since when?)

Water

Where do you obtain potable water and water for irrigation?
Have you noticed any changes in the quantity of water in the rivers? (Since when have you noticed that there is less/more water? Has it affected your life? How? How about agriculture?)
Have you noticed any changes in the quality of water?
What do you think, how the water situation will be in the future?

Glaciers

Have you noticed changes in the glaciers? (What kind of changes? Since when have you noticed the changes? How were the glaciers before?)

Climate

Have you noticed changes in the climate? (How has the climate changed? Since when? Have these changes affected your life? How?)

Agriculture

Have the harvests changed? (How have the harvests changed? Are there some crops that cannot be cultivated anymore? Why?)
Are there changes in income that comes from agriculture? (Since when? What do you think is the reason for the changes in income?)
Have you had to find some other sources of income besides agriculture? (What other sources? Since when?)
Have farmers/other persons of this village moved to the cities? (Since when? Do you know what are they doing for living in the cities? Have you considered to move to the city?)
On your opinion, is the life better in the countryside or in the city? Why?
Do you think that it will be possible to continue agriculture practices in the future in this region?

External aid

Have you received any information about climate change, glacier retreat or water management?
Have any authorities come here to help you with agriculture, constructing reservories and canals or to give any advice concerning adaptation to climatic changes? (Ask only if the informant has mentioned changes in climate or difficulties in accessing water) (Who? When? Did it help the situation?)

Would you have something more you would like to tell me or ask me?
Guía de entrevista, agricultores a pequeña escala

Fecha y hora de entrevista (duración):
Ubicación:
Datos personales
Nombres y apellidos:
Edad (Año de nacimiento):
Estado civil:

General
¿Cuánto tiempo hace que usted vive aquí?
¿En qué se dedica? (¿Siempre se ha dedicado en eso?)
¿Usted piensa que la vida es diferente aquí ahora que antes? (¿Cómo ha cambiado la vida? ¿Desde cuándo?)

Agua
¿De dónde sacan el agua potable y agua para el riego?
¿Hay cambios en la cantidad del agua en los ríos? (¿Desde cuándo se puede notar que hay menos/más agua?; ¿Cómo ha afectado su vida?; ¿Y agricultura? ¿Cómo?)
¿Hay cambios en la calidad del agua?
¿Qué le parece, cómo será la situación del agua en el futuro?

Glaciares
¿Usted ha notado cambios en los glaciares? (¿Qué tipo de cambios?; ¿Desde cuando usted ha notado los cambios? ¿Cómo los glaciares eran antes?)

Clima
¿Usted ha notado cambios en el clima? (¿Cómo ha cambiado el clima?; ¿Desde cuándo?; ¿Cómo afectó su vida los cambios en el clima? ¿Cómo?)

Agricultura
¿Han cambiado los rendimientos? (¿Cómo han cambiado los rendimientos?; ¿Hay algunos cultivos que ya no se puede sembrar?; ¿Por qué?)
¿Han cambiado los ingresos que vienen de agricultura? (¿Desde cuándo?; ¿Por qué usted piensa que han cambiado los ingresos? ¿Han tenido que encontrar otros fuentes de ingresos incluso agricultura? (¿Cuáles? ¿Desde cuándo?)
¿Se han mudado los agricultores/ las personas de esto pueblo a las ciudades? (¿Desde cuándo?; ¿Sabe usted en que cosas se dedican en las ciudades?; ¿Usted ha considerado a mudarse en la ciudad?)
¿Qué le parece, donde la vida está mejor en el campo o en las ciudades? Por qué?
¿Usted cree que será posible continuar con la agricultura en esta región en el futuro?

El apoyo externo
¿Usted ha recibido algún información sobre cambio climático, retroceso de glaciares o gestión del agua?
¿Han venido los autoridades para ayudarles con agricultura, construir los reservorios y canales o para dar los consejos sobre la adaptación al cambio climático? (Pregunta
solamente si han mencionado que el clima ha cambiado o que han tenido dificultades con acceso al agua) (¿Quién? ¿Cuándo? ¿Le parece que eso ha ayudado la situación? )

¿Tiene usted algo más que le gustaría contarme o preguntarme?