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Combining Qualitative and Quantitative tools for Enhancing Social Vulnerability Assessments: Peruvian Farmers’ Case Study

Author
Pardo-Rodriguez, Lumari

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Combining Qualitative and Quantitative tools for Enhancing Social Vulnerability Assessments: Peruvian Farmers' Case Study

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Geography

by

Lumari Pardo-Rodriguez

Committee in charge:

Professor Daniel R. Montello, Chair

Professor Krzysztof Janowicz

Professor Jeffrey Hoelle

DECEMBER 2018

The dissertation of Lumari Pardo-Rodriguez is approved.

Jeffrey Hoelle

Krzysztof Janowicz

Daniel R. Montello, Committee Chair

NOVEMBER 2018

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Nobody has been more important to me in the pursuit of this project than the members of my family. I want to thank my parents and younger sister; whose love and guidance are with me in whatever I pursue.

CURRICULUM VITAE OF LUMARI PARDO-RODRIGUEZ
NOVEMBER 2018

EDUCATION

Ph.D. in Geography Nov 2018
University of California-Santa Barbara, UCSB *Santa Barbara, CA*

MA in Climate and Society Oct 2009
Columbia University *New York, NY*

BSc. in Mathematics Magna Cum Laude Jun 2008
Universidad Interamericana de Puerto Rico *San Germán, PR*

QUALIFICATIONS

- Experience speaking to groups of assorted backgrounds, expertise, and sizes
- Extensive experience on higher education
- Experience with qualitative data collection through a fieldwork campaign
- Experience designing and conducted projects in both social and physical sciences
- Able to help others gain knowledge and skills through mentorship

EDUCATION AND TEACHING EXPERIENCE

Instructor/Lecturer Mar 2017- present
Geography Department, UCSB *Santa Barbara, CA*

- Lecturer for GEOG 5 People, Place, and Environment Fall 2018 (300 students and 4 Assistants)
- Lecturer for GEOG 5 People, Place, and Env Winter 2018 (300 students and 4 Assistants)
- Lecturer for GEOG 5 People, Place, and Environment Fall 2017
- Lecturer for GEOG 145 Hazard and Society Spring 2017

Department Lead Teaching Assistant Sept 2015 – Jun 2016
Geography Department, UCSB *Santa Barbara, CA*

- Gave support and guidance to all TAs in the department (new and experienced TAs).
- Provided training (pedagogy, resources, and conflict management among others) to new TAs
- Updated TA Manual for the Geography Department
- Helped in the instruction of the "Teaching Assistant Training" (GEOG 500).

Graduate Student Rep. for Curriculum Improvements Sept 2015-Jan 2016
Department of Geography. University of California Santa Barbara *Santa Barbara, CA*

- Develop and administrate a survey to gathered students' opinions
- Assist in the creation of a report summarizing changes to the curriculum

Teaching Assistant Sept 2011- Aug 2014
Geography Department, UCSB *Santa Barbara, CA*

- Instructed 13 undergraduate level courses as a teaching assistant (TA) which included three weekly discussion section per course (90 students per course for each TA)
- Create assessments and grade assignments
- Aid students with the understanding of the course material

Department Lead Teaching Assistant Jul 2013 - Jun 2014
Geography Department, UCSB *Santa Barbara, CA*

- Gave support and guidance to all TAs in the department (new and experienced TAs).
- Provided training (pedagogy, resources, and conflict management among others) to new TAs
- Updated TA Manual for the Geography Department

- Helped in the instruction of the "Teaching Assistant Training" (GEOG 500).
- Gave a workshop about “Conducting Discussion on Sensitive Topics” to new TAs for the campus
- Participated in a campus-wide expert panel to guide new TAs

HIGHER EDUCATION CERTIFICATIONS

Lead Teaching Assistant Institute Aug 2013
UCSB Instructional Development *Santa Barbara, CA*

- As expressed by Instructional Development, the Lead TA Institute it is designed to:
    - Assist Lead TAs in preparing for and (re) defining responsibilities.
    - Increase your knowledge of University policies relevant to TAs and their students.
    - Teach new strategies for student-centered teaching and learning.
    - Improve abilities to manage conflict through effective communication.
    - Cultivate a community of Lead TAs with whom to improve TA training programs.

Summer Teaching Institute for Associates July 2013
UCSB Instructional Development *Santa Barbara, CA*

- "Provides graduate student instructors (associates) with a flexible pre-summer program, that is based on principles of interactive, collaborative learning, and designed to assist Associates with the planning, conduct and assessment of summer undergraduate courses at UCSB" Granted by Instructional Development.

TECHNICAL AND RESEARCH EXPERIENCE

Graduate Student Researcher Sept 2011-present
Geography Department, UCSB *Santa Barbara, CA*

- Map social vulnerability (closely link to Sustainable Livelihoods Frameworks)
- Work with quantitative and qualitative approaches to assess social vulnerability
- Create research gaps analysis related to impacts, vulnerability, and adaptation topics

Project Manager Jan 2015- Mar 2017
Geography Department, UCSB *Puno, Peru* and *Santa Barbara, CA*

- Engaged in fieldwork independently for 14 months as well as prepped project support, timeline, goals, and research design
- Created and managed connections with local entities and community leaders to aid in finding participants
- Conducted ethnographic and ethnographic observations and semi-structured interviews
- Analyzed qualitative data about social vulnerability

Lab Manager Jan 2012 to Aug 2015
Human Environment Dynamics Lab, UCSB *Santa Barbara, CA*

- Provide technical, methodological and literature guidance about human-environment relations
- Helped any visiting scholar, post-doctoral or undergraduate students during their time at the lab
- Aid in any logistics related to projects and needs of the lab members

Research Assistant May 2014-Aug 2014
Department of Global Studies, UCSB *Santa Barbara, CA*

- Identified possible contacts and connections for collaboration in Bolivia, Argentina, and Chile
- Worked on fieldwork logistics about populations impacted by environmental changes due to booming of lithium extractions

Urban Climate Change Research Network (UCCRN) Intern Nov 2010-Aug 2011
Columbia University *New York, NY*

- Collaborated in logistics for the UCCRN first assessment report about climate change and cities
- Worked on a research gap analysis about impacts, vulnerability, and adaptation to climate change (used as the background material for the first meeting of PRO-VIA)

SOARS Protégé May 2007-Aug 2010
National Center for Atmospheric Research *Boulder, CO*

- Designed and conducted in three atmospheric science research projects
- Designed and conducted one education outreach research project

SERVICE AND MENTORSHIP

Elected Alumni Board Member: Climate and Society Program Nov 2017-present
Columbia University *Remotely*

- Serve as the link between the Alumni and the Climate and Society program
- Recommend curriculum changes and provided program evaluations
- Create content to enhance collaboration and communication among alumni

Graduate Student Representative at UCSB/SDSU Faculty Retreat Nov 2013

- Geography Department, UCSB *Santa Barbara, CA*
- Gave a presentation to the faculty about my research.
- Represented the graduate students from UCSB during the meeting.

Graduate Student Representative at Professor Hiring Committee Aug 2013 - Apr 2014

- Geography Department, UCSB *Santa Barbara, CA*
- Served as Graduate student's voice and vote on the hiring process
- Gathered graduate students' opinions about the final candidates while keeping confidentiality of key information

Guess Speaker Apr 2012
Upward Bound Program visiting UCSB *Santa Barbara, CA*

- Guide and motivate high school students from Hispanics family households to pursue a college degree.

Events committee member for the Geography Department Sept 2011-Aug 2013
Geography Department, UCSB *Santa Barbara, CA*

- Helped the Geography Department in planning and organizing all their events (for staff, post-doctoral, prospective students visits, faculty, and graduate students).

Guest Speaker Nov 2010
High School for Green Career *New York City, NY*

- Helped multicultural kids in a process of self-identification. Furthermore, motivated them to finish high school

Organizer 350 Climate Conference Apr 2009
Columbia University *New York City, NY*

- Helped organized a conference about how to minimize CO2 emissions.

Guest Speaker Nov 2008
Bronx High School *New York City, NY*

- Engaged students into conversations about the importance of bridging climate and society topics.

WORKSHOPS AND CERTIFICATIONS

Quantitative Methods in Demography Sept 2014
Pukyong National University *Busan, S. Korea*

Dynamic Population Modeling Aug 2014
Statistics Korea *Daejeon, S Korea.*

Lead Teaching Assistant Institute Aug 2013
UCSB Instructional Development *Santa Barbara, CA*

Summer Teaching Institute for Associates July 2013
UCSB Instructional Development *Santa Barbara, CA*

Atmospheric Processes: Observations, Analysis, and Impacts May 2013
PASI-NCAR *Cartagena, Colombia*

Emergency Management Institute at FEMA

- Leadership and Influence May 2011
- Emergency Planning Apr 2011
- Effective Communication Apr 2011
- Fundamentals of Emergency Management Oct 2010
- Anticipating Hazardous Weather & Community Risk Sept 2010

Atmospheric Science Workshop Oct 2008
COSMIC and NCAR *Taipei, Taiwan*

AWARDS, NOMINATIONS, FELLOWSHIPS AND GRANTS

Dissertation Block Grant, SPRING 2018 and SUMMER 2018

Dangermond Travel Award, WINTER 2018 and SPRING 2013

Special Fellowship in the STEM Disciplines for Academic Year 2015 – 2016
Nominations for the 2014-2015 UCSB Academic Senate Outstanding Teaching Assistant Award.

Graduate Opportunity Fellowship for Academic Year 2014 – 2015

Asia Pacific Population Institute and Statistics Korea - funding provided for demography training in the cities of Daejeon and Busan; both in South Korea. August and September 2014

Pan American Advanced Studies Institute (PASI) – funding for a three weeks workshop about climate variability and change in South America. June 2013

Nominations for the 2012-2013 UCSB Academic Senate Outstanding Teaching Assistant Award.

National Center for Atmospheric Research (NSF funded project) - funding towards a three weeks training program in atmospheric sciences in Taiwan. October 2008

Significant Opportunity in Atmospheric Research and Related Science Fellowship for 2008 – 2009

Leadership Award Inter-American University of Puerto Rico.2008

Academic Excellence Awards, Inter-American University of Puerto Rico.2008
UIPR Fellowship, Inter-American University of Puerto Rico. (4 years of full paid Tuition). August 2004 to May 2008.

PRESENTATIONS AT CONFERENCES AND PUBLICATIONS

Enhancing social vulnerability assessments: the optimal spatial scale. Presented at the IPCC Cities Conference in **Edmonton, Canada**. March 2018.

Pricope, N., Pardo-Rodriguez, L., López-Carr, D., Williams, E., & Zorich, L. (2018). Geographic Vulnerability to Climate Change. **Oxford Bibliographies** Online. DOI: 10.1093/OBO/9780199874002-0181

Ervin, D, Lopez-Carr, D and Pardo-Rodriguez, L. “An evaluation of serious games and computer based learning on student outcomes in university level geographic education." The European Association of Geographers Annual Meeting. **Malaga, Spain**. September 2016.

Understanding Adaptation to Climate Stimuli: Vulnerability Mapping, Threat Perception, and Subjective Adaptive Capacity among Farmers. Atmospheric Processes of Latin America and the Caribbean: Observations, Analysis, and Impacts. **Cartagena, Colombia**. June 2013.

Understanding Adaptation to Climate Stimuli: Vulnerability Mapping, Threat Perception, and Subjective Adaptive Capacity among Peruvian Farmers. Presented at the Association for American Geographers Annual Meeting, **Los Angeles: California**. April 2013.

Pardo-Rodriguez, L (May 2013) Make your Research Marketable!. Written as a guest author for **UCSB GradPost**.

Pricope, N., Pardo-Rodriguez, L., & López-Carr, D. (2013). Vulnerability to Climate Change. **Oxford Bibliographies** Online. doi: 10.1093/obo/9780199874002-0040

Science and Education Outreach: A case study of mutual learning between children and young scientists. Presented at the American Meteorological Society 90th Annual Meeting Conference, **Atlanta, Georgia USA.** January 2010.

Convective Transport of Chemical Constituents at Northern Alabama and Central Oklahoma: A,Numerical Analysis. Presented at Taipei FORMOSAT-3/COSMIC Workshop, 4th Asian Conference,**Taipei, Taiwan.** October 2008.

Improving Data Quality when Sampling Oxygen-18 Isotopes in Atmospheric Carbon Dioxide.Presented at the American Meteorological Society 88th Annual Meeting & 7th Annual Student Conference, **New Orleans: Louisiana, USA.** January 2008.

Improving Data Quality when Sampling Oxygen-18 Isotopes in Atmospheric Carbon Dioxide. Presented at the Society for Advancement of Chicanos and Native Americans in Science National Conference, **Kansas City: Missouri, USA**. October 2007.

LANGUAGES:

Spanish (Native); **English** (Fluent); **Portuguese** (Intermediate); **Korean** (Proficiency)

COMPUTER SKILLS

ArcGIS; R; STATA and SPSS; Microsoft Office (Excel, PowerPoint, Word, Outlook, and Access); Basic Knowledge of Matlab and Java.

ABSTRACT

Combining Qualitative and Quantitative tool for Enhancing Social Vulnerability Assessments: Peruvian Farmers' Case Study

by

Lumari Pardo-Rodriguez

The intensity, frequency, duration, and spatial extent of weather and climate extremes are projected to experience changes. However, the impacts of such hazards are not straightforward. This issue is challenging mainly because natural hazards by themselves do not wholly explain the experienced impacts. Furthermore, the latest assessment of the Intergovernmental Panel on Climate Change moves away from the idea of vulnerability in terms of a hazard's outcome and takes an approach in which vulnerability consists of pre-existing conditions that are exacerbated by climate variability and/or change. This framework is closer to that of the disaster risk reduction community and introduces approaches where the focus is on understanding those social vulnerabilities.

This dissertation aims to enhance assessment tools that support the identification of those most vulnerable to climate hazards. Peruvian farmers from Puno are used as a case study, examined with both quantitative and qualitative approaches. This dissertation presents three studies that aim to enhance social vulnerability assessments. The first study uses qualitative data: ethnographic observations, semi-structured interviews, and local agencies reports. The other two studies used 22 quantitative indicators extracted from a dataset of over 200,000 farmers. The first of these two creates a composite index to explore social vulnerability at the farm, census unit, and municipality levels. The second quantitative study uses geons to create homogenous areas of vulnerability that do not necessarily correspond to administrative boundaries.

Results point to a need to improve social capital among farmers as well as our need to increase our understanding of local social networks among farmers. The research revealed concerns people have with indoor thermal comfort as well as challenges in predicting and reporting droughts in the region. Social vulnerability maps and reported impacts were spatially associated, especially when weather hazards were not extreme. As expected, spatial patterns fluctuated by aggregation levels. The census unit level revealed patterns following specific topographic features in Puno. Furthermore, this dissertation showed how qualitative and quantitative methods can build on each other to create a more comprehensive assessment. Results from the dissertation have the potential to serve as scaffolding for future adaptation strategies in Puno and, eventually, in other areas where agriculture provides people's main livelihood.

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Chapter I. Introduction

Problem Statement

The intensity, frequency, duration, and spatial extent of weather and climate extremes are projected to experience changes (IPCC, 2014; SREX, 2012). Decision-makers need to be able to access reliable science-based information to evaluate adaptive opportunities for various human populations (Harrison et al., 2013; Turnpenny et al., 2004). Stakeholders are searching for efficient options that would reduce vulnerability or eliminate impacts, especially in highly climate-dependent economic sectors such as agriculture. Rural economies and their livelihoods predominantly depend on agriculture.

A significant fraction of the world's population, as large as 3.3 billion people, lives in rural areas, with 90% from developing countries. Rural environments, predominantly in developing countries, are particularly vulnerable to climate changes because their economies are highly dependent on natural resources, unlike their urban counterparts (Pricope et al., 2018). Furthermore, these populations live with higher levels of poverty, inequality, and social exclusion, exposing them to a higher level of vulnerability to weather-related and climate-sensitive events.

It is vital to address both weather-related disaster effects and vulnerabilities to aid the creation of adaptation opportunities (UNISDR, 2011). Interest in the connections between biophysical and social components of natural hazards started in 1942 with Gilbert White, who stated that floods are acts of God, but flood losses are largely acts of man (Montz and Tobin, 2013). Since then, researchers have focused on one of two approaches: a focus on the hazards and a focus on understanding vulnerability that encompasses economic, demographic, and social factors, regardless of the hazard (Montz and Tobin, 2013). The concept of vulnerability is a powerful analytical tool for "guiding normative analysis of actions to enhance well-being through reduction of risk" (Adger 2006, p. 268). Vulnerability to climate change and variability is unequally distributed across physical and cultural spaces and is often exacerbated by pre-existing inequalities (Adger, 2006). Such pre-existing conditions affect the ability of society to prepare and recover from weather events (Novelo-Cassanova, 2012).

The Intergovernmental Panel on Climate Change (IPCC) in their latest assessment (IPCC, 2014) takes a contextual approach, in which vulnerability is not the result of climate variability and/or change but rather is a pre-existing condition that is exacerbated by such changes. This framework brings the IPCC closer to the disaster risk reduction community and introduces approaches where the focus is on understanding those pre-existing vulnerabilities (vulnerabilities that exist regardless of the natural hazard). In a constantly changing world, it's imperative to identify and assess pre-existing vulnerabilities.

Spatial vulnerability assessments are often used as a synonym for vulnerability assessments in general, in part due to an understanding that vulnerability and its components possess high degrees of spatial and temporal heterogeneity (Preston et al., 2011). An array of problems commonly emerges in spatial vulnerability assessments, mainly due to the limitation of available data and various methodological issues (deSherbinin, 2014).

Vulnerability assessments are frequently mapped using variables that are spatially aggregated. However, this standard approach is highly problematic, insofar as we don't know the exact scale, spatial configuration, and boundary of the geographical area that exerts meaningful influence on the phenomenon under study (Kwan, 2012). Choices of geographical boundaries are frequently determined by data availability rather than by the system’s dynamics (Preston et al., 2011). We should be able to readily aggregate and disaggregate data used in vulnerability assessments from the household to the regional level (Frankenberger et al., 2005), in order to explore what is the appropriate analysis scale for these data (Montello, 2013). Access to the disaggregated data, rarely available, is imperative to determine the actual influence of the aggregated data as the analysis scale changes (Schmidtlein et al., 2008).

More detailed data could be found in household surveys; however, their spatial coverage is limited. Such surveys are commonly collected to be nationally representative; consequently, their sampling frames may not allow for finer resolution (Tatem et al., 2012). Some vulnerability assessments combine different household surveys dataset in order to obtain a rich variety of population attributes. When data at the household level is not available, researchers use other datasets.

Census data is another source available for performing vulnerability assessments and includes microdata that gives rich information for large areas with boundaries at a larger geographical scale. Nonetheless, census microdata is uncommon for developing countries and for specific climate-dependent sectors. Frequently, vulnerability assessments at larger analysis scales cannot be performed due to the limited availability of disaggregated data. Even if the data were available, their structure and pattern are not always well understood (especially for multidimensional datasets) and will not always directly improve the assessment. This highlights the key question of whether these assessments and maps satisfy their intended purpose.

The most common approach to quantifying vulnerability is to create multivariate indices based on various components and proxy measures. Creating composite indices is an empirical approach that has received significant attention, due to its potential for policy use (Beccari, 2016; OECD, 2008; Sonrexa and Moodie, 2013). Such indices allow areas of extremely high or low pre-existing vulnerability to emerge when the indices are mapped (deSherbinin, 2014). However, vulnerable populations could remain unnoticed if results are misinterpreted, misrepresented, or overstated.

A focus only on household assets presents an incomplete picture of vulnerability to hazards; it leaves gaps in identifying where in the system we could intervene. Assessments that involve asset-based methods are helpful in identifying the available resources that can aid in adapting and coping with changes in the environment. However, they mask processes and functions that are helpful for the stakeholder at the local level. Furthermore, assessments that are solely based on assets and quantitative methods are commonly criticized because they typically fail to capture local conditions that influence adaptation, as well as spatial and social variation in vulnerability (Adger, 2006). Ethnographic research offers an excellent opportunity to understand the external constraints that may be placed on assets (Kurlanska, 2011). Besides studying the availability of assets that an individual possesses, it is important to examine structural factors and uncertainty that individuals deal with (Rakodi, 2002).

Aim and Objectives

The concept of vulnerability used in this dissertation is what we know as social vulnerability or pre-existing vulnerability, which aims to understand pre-existing conditions in order to answer who is vulnerable and why. According to the chapter on rural areas from the latest IPCC assessment, more research is needed on identifying who is most vulnerable. Specifically, attention is needed to address, “research on methodological questions such as conceptualizations of vulnerability, assessment tools, spatial scales for analysis, and the relations between short-term support for adaptation, policy contexts and development trajectories, and long-term resilience or vulnerability" (IPCC 2014, p. 645).

This dissertation aims to enhance our understanding of the assessments tools and analysis scales that aid in the identification of the most vulnerable segments of the population. Farmers from the Peruvian department of Puno are examined as a case study, using a mix-method approach. The qualitative portion of the dissertation involves fieldwork data collected from January 2016 to March 2017. The quantitative portion of the study uses indicators from the latest agriculture census with information for over 200,000 farmers who are heads of their farms.

This dissertation comprises three studies that aim to improve our understanding of social vulnerability and contribute to developing better assessments. These studies have the following objectives:

1. To discover regional factors, internal or external to the farmer's agency, that constrain or enhance efforts to reduce vulnerability.
2. To identify social vulnerability indicators tailored to the local context.
3. To explore the effects that the analysis scale has on identifying the most vulnerable farmers (farm, census unit, and municipality levels) using a simple social vulnerability composite index.
4. To use a methodology that identifies the most vulnerable farmers but does not necessarily follow administrative boundaries.

Structure of the Dissertation

This dissertation comprises a total of eight chapters which include three studies. This current chapter, Chapter One, introduces and overviews the topics in the dissertation. Chapter

Two is dedicated to reviewing the main literature as a background for all the three studies, including a general view of the vulnerability concept and its operationalization. However, a literature review addressing specific research questions is included inside each respective study's chapter.

Chapter Three presents background information about the research location. The first study, Chapter Four, presents the results from the fieldwork campaign and addresses the importance of understanding the local context when creating a vulnerability assessment. Furthermore, this chapter explains the mix-method design. Study One uses data collected through the fieldwork, while both Studies Two and Three use the same indicators and dataset for their respective analyses. Because two studies use the same data and indicators, I provide one chapter with such information for both studies to avoid extensive repetition in the methodology sections of the individual studies. Chapter Five presents the data that the second and third studies used for answering their specific research questions. Furthermore, this chapter justifies the selected indicators that this dissertation uses to assess social vulnerability.

Chapter Six explores the influences that spatial aggregation and mapping technique can have on a spatial social vulnerability assessment. The last study is found in Chapter Seven, where techniques using integrated geons create areas of vulnerability that are not dependent on administrative boundaries. Finally, I proceed to summarize all three studies and draw conclusions in Chapter Eight. This chapter bridges together the findings from all three studies and considers future research that could be performed addressing questions arising from this dissertation.

Chapter II. Background Information

Vulnerability Assessments: Theoretical Approaches

Vulnerability is a dynamic concept produced by multiple stressors and operating simultaneously at different scales (Pricope et al., 2018). Some use the cognomen "Babylonian Confusion" when attempting to specifically define vulnerability, in recognition that its meaning varies across and within disciplines. The concept of vulnerability, in the scientific community, has its roots in geography, food security, and the natural hazards literature.

The concept of vulnerability involves two independent dimensions: *scale* and *disciplinary domain*. With respect to *scale* or scope, vulnerability involves *internal* and *external* factors influencing the system (e.g., human systems, natural system, ecological systems, and socio-ecological systems). *Internal* factors are endogenous to the system and can be controlled by the individuals; *external* factors are outside the scope of the vulnerability assessment and are not easily controlled by the individual (Füssel, 2006). With respect to *disciplinary domain*, vulnerability is divided into *biophysical* and *socioeconomic* factors that could affect the system. *Biophysical* factors are those usually studied by physical and life sciences; *socioeconomic* factors are studied in social sciences and humanities (Füssel, 2006).

The two dimensions can be combined to produce different meanings: *internal socioeconomic* factors relate to an individual's response capacity (e.g., social networks, income, and access to information), *internal biophysical* factors relate to a system's sensitivity (e.g., topography, environmental conditions, and type of soil); *external socioeconomic* factors relate to social factors exogenous to the system (e.g., national policies, economic globalization, and international aid); and *external biophysical* factors relate to hazards to which people are exposed (e.g., earthquakes, severe-storms, and droughts) (Füssel, 2006).

For many decades, vulnerability research focused on the physical and technical causes of events. Subsequently, it evolved to incorporate a population's capacity to withstand such events and respond to them. Assessing vulnerability gained political importance when it was no longer just an academic exercise but necessary for policymaking (Hinkel, 2011). The conceptualization and operationalization of vulnerability was diverse as seen by various research traditions. The diverse traditions generated multiple approaches: risk-hazard approach, political economy approach, pressure-and-release approach, and hazard-of-place approach.

The risk-hazard approach conceptualizes vulnerability as how much damage results from a hazard of particular severity (Burton et al., 1978; White, 1973). This approach is suitable for evaluating the risk of the household unit based on its exposure to a specific hazard of a certain type and magnitude (Burton et al., 1978; Kates, 1985). The risk-hazard approach attributes vulnerability to being in the wrong place at the wrong time (Liverman, 1990) or to exposure to hazards (Hewitt, 1997). According to this framework, a hazard event is rare, known, and stationary (Downing et al., 1999).

Risk-hazard approaches are popular in assessments performed by engineers and economists. Vulnerability, in this approach, is not explanatory but focuses on describing vulnerability in relation to physical systems (Füssel, 2006). According to the risk-hazard framework, vulnerability is characterized as *internal biophysical vulnerability*. This denotation corresponds to the sensitivity of the system (Turner et al., 2003) and to the intervening conditions of danger (Hewitt, 1997). In other words, risk-hazard approaches classify the endogenous factors that relate to system properties investigated by physical scientists. However, critics of this approach emphasize the limitations of focusing only on the natural hazard with respect to understanding impacts and the systems' responses (Turner et al., 2003). Moreover, the approach has ignored the anthropological literature on human-environment relations (Torry, 1979).

Vulnerability conceptualization has moved from merely measuring impacts of hazards to understanding hazard linkages with human conditions (Parry and Carter, 1998). The political economy approach focusses on answering who is vulnerable and why. These approaches are popular among researchers interested in poverty and development. They focus on "the state of individuals, groups or communities in terms of their ability to cope with and adapt to any external stress placed on their livelihoods and well-being" (Adger and Kelly 1999, p. 254). Furthermore, they also consider "the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard" (Wisner et al. 2004, p. 11).

Building from the shortfalls found in the risk-hazard approach, Blaikie et al. (1994) developed the Pressure-and-Release (PAR) model, using the political economy framework. It successfully synthesizes both physical and human components of hazards and vulnerability. The PAR model recognizes that the intersection of two conditions are needed to create a disaster: physical exposure to a hazard and existing vulnerabilities (Awal, 2015). According to the model, risk to people that arises from combining their vulnerability with the severity of a hazard could be decreased by reducing the vulnerabilities. Determinants of vulnerability in the PAR model are organized into three groups: *Root causes* of the lack of access to resources and power structures; *dynamic pressures* including the lack of assets; and *unsafe conditions* such as fragile physical environments and fragile local economies (Blaikie et al., 1994). Some researchers have critiqued the model because it "fails to provide a systematic view of the mechanisms and processes of vulnerability" (Adger 2006, p.272). Others emphasize that the PAR model does not offer an analysis of interactions between the environment and society, or an analysis at the point at which disaster begins to present itself (Wisner et al., 2004).

Another approach to vulnerability is given by the hazard-of-place model. This conceptualization was presented by Cutter (1996) as an integrated and geographically centered approach. It combines the likelihood of a hazard event with measures of factors that reduce risk and impacts. Such a combination is filtered through an analysis of the geographic context (e.g., elevation, site, situation, and proximity) and the social fabric of the population (e.g., adaptive capacities, socioeconomic indicators, and perceptions). This method explicitly focusses on geographic location to create a typology for regional risk.

Vulnerability to Climate Change as Conceptualized by the IPCC

The leading international group for assessing climate change and its effects is the Intergovernmental Panel on Climate Change (IPCC). This body provides clear and complete scientific views on the current state of climate change research and is divided into three working groups: Working Group I that relates to physical science; Working Group II which relates to impacts, vulnerability, and adaptation; and Working Group III that relates to mitigation efforts. This dissertation focuses directly on the areas of concern to the IPCC Working Group II (IPCC WGII).

The IPCC's First Assessment Report (FAR), published in 1990, presented a description of the possible vulnerabilities experienced in different domains (e.g., agriculture, human settlements, natural terrestrial ecosystems, and costal zones among others); it provided no explicit definition of vulnerability. In 1995, the IPCC's Second Assessment Report (SAR) defined vulnerability as "the extent to which climate change may damage or harm a system. It depends not only on a system's sensitivity but also on its ability to adapt to new climatic conditions" (Watson et al. 1996, p. 23). Later, a special IPCC report titled *The Regional Impacts of Climate Change: An Assessment of Vulnerability* focused on presenting the current state of vulnerability for each of the world's geographical regions.

The first assessment to dedicate an entire chapter to the conceptualization and operationalization of vulnerability was the IPCC's Third Assessment Report (TAR), published in 2001. Topics mainly focused on impacts and offered only a limited incorporation of the full social-science perspective. TAR was also the first IPCC report to introduce vulnerability as a function of *exposure*, *sensitivity*, and *adaptive capacity*. These were part of the vulnerability framework used in the Fourth Assessment Report (AR4) in 2007. This vulnerability formulation defines *exposure* as the degree of climate variation to which a system is exposed. *Sensitivity* is the degree to which a system is affected by such climate variation. Lastly, *adaptive capacity* is the system's ability to adjust to climate variability and extreme weather events in order to moderate potential damages, and to take advantage of opportunities to cope with the consequences (IPCC 2007).

In 2012, the Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) introduced a framework that uses a vulnerability interpretation different from previous reports. Vulnerability, according to this framework, does not depend on climate events but is entirely based on pre-existing social vulnerability. Furthermore, exposure does not depend on the hazard but on the amount of population and wealth at risk. This approach became prevalent in disaster management literature, where hazards and exposure areas are well-defined. The IPCC has stated that the disaster risk-management community has helped highlight "the role of social factors in the constitution of risk, moving away from purely physical explanations and attributions of loss and damage" (SREX, 2012, p. 33). It is important to understand the various levels of social vulnerability because they lead to different levels of losses and damages under similar exposure to physical phenomenon (SREX, 2012). The existing capacity to respond to a hazard predominantly determines people's vulnerability to natural hazards rather than what may or may not happen in the future (Kelly and Adger, 2000). Following this vulnerability framework shift, in 2014, the IPCC's Fifth Assessment Report (AR5) reflected significant changes. The IPCC now sees vulnerability as shaped by human conditions; when combined with the hazard it is referred to as "climate risk." This report moves away from interpreting vulnerability in terms of outcome and toward interpreting it contextually. It is valuable to ask how these two main vulnerability interpretations are different.

Approaches to vulnerability assessment are shaped by the interpretations of both natural and social scientists. Natural scientists tend to focus on applying the concept descriptively, while social scientists search for a more contextual explanatory approach. These could be summarized in terms of the two primary interpretations of the vulnerability concept: end-point (*outcome vulnerability*) and starting-point (*contextual vulnerability*).

The end-point interpretation measures future vulnerability descriptively using a top-down approach for its assessment. Outcome vulnerability is seen as a residual of impacts minus adaptation. This interpretation expects a linear result wherein projected biophysical impacts on an exposed unit are counteracted by the socio-economic capacity of the unit to take adaptation measures. A commonly used example of an outcome vulnerability framework is the one in the TAR and AR4 reports. However, the latest report and the SREX special report favor a starting-point interpretation for vulnerability.

The starting-point interpretation has its origins in the desire to assess social vulnerability and identify changes and the distribution of vulnerability. This contextual vulnerability approach assumes that vulnerability is generated by a diversity of processes, but it is exacerbated by the biophysical impacts of interest (e.g., climate change). In terms of adaptive capacity, this interpretation assumes that vulnerability determines adaptive capacity. In addition, adaptive capacity is seen to be a part of present-day vulnerability. Contextual vulnerability is the existing system's inability to cope with changing biophysical conditions (such as climate change, sea-level rise, and climate variability among others) and, at the same time, be influenced by changes in other conditions (such as changes in trade, national policies, and political shifts, among others).

As seen in both interpretations, a chicken-or-egg dilemma of order is present with respect to adaptive capacity and vulnerability. Many underlying drivers of vulnerability often coincide with the determinants of adaptive capacity. In addition, the contextual interpretation tries to focus on the present, while an outcome interpretation concentrates on the future. O'Brien et al. (2007) emphasizes that these interpretations are complementary—they conceptualize vulnerability from different perspectives.

Social Vulnerability and The Sustainable Livelihoods Framework

Assessing all potential points of vulnerability is very difficult. But with the literature shifting away from a primary focus on the biophysical hazard event, stakeholders are increasingly accepting that managing a disaster goes well beyond the hazard agent itself (Quarentelli, 2005). A greater portion of the resulting disaster is shaped by vulnerability rather than by the hazard itself (Alexander, 2006). Human vulnerabilities need to be an integral concern in the development and assessment of disaster-related policies. Due to the "Babylonian Confusion" when defining vulnerability, this dissertation uses the term social vulnerability to express the vulnerability that encompasses the pre-existing conditions of a location. Since social vulnerability is partly a by-product of social inequalities, it can be defined as "the susceptibility of social groups to the impacts of hazards, as well as their resiliency, or ability to adequately recover from them" (Cutter and Emrich, 2006, p. 103). Social vulnerability encompasses an array of concepts, including susceptibility to harm and lack of adaptive capacity (IPCC, 2014). Furthermore, social vulnerability includes disturbances to livelihoods (Adger, 2003).

Rural populations, especially in developing countries, practice livelihoods that directly depend on natural resources (Rennie and Singh, 1996). A livelihood involves the assets and activities that combine to determine how an individual or group makes a living (Ellis, 2000). For a livelihood to be sustainable, it needs to be able to cope with and recover from shocks and maintain or enhance people's capabilities without undermining natural resources (Ashley and Carney, 1999). Early geographers and social anthropologists performed studies focusing on livelihoods and modes of life (Scoones, 2015). However, such perspectives on development did not dominate the literature until the late 1980s, when interests in livelihoods connected three concepts: sustainable, rural, and livelihoods.

Reflecting the complexities of relating these concepts, numerous frameworks that attempted to do so arose in the 1990s. The most popular became the Sustainable Livelihood Framework (SLF) that resulted from research by Scoones (1998). In the SLF, Scoones addressed issues regarding susceptibility and adaptive capacity to climate variability/change, to a limited extent (Hahn et al., 2009). It became common to use SLF to measure social vulnerability, especially with farmers and rural populations. The SLF ascended as a holistic tool that considers not only income but also gender relations, social institutions, and property rights necessary to support a standard of living (Ellis, 1998). It has been applied in various studies to examine the contextual and multi-dimensional nature of vulnerability (O'Brien et al., 2009; Reid and Vogel, 2006; Ziervogel and Calder, 2003). The framework has also proven beneficial for assessing the ability of households to withstand shocks (Chambers and Conway, 1992; Ellis, 2000). It highlighted that people need to possess basic tangible and intangible assets to successfully pursue different livelihood strategies (Scoones, 1998).

The possession and usability of assets, as described by the SLF, reveal differences in households' recovery from disasters that could result from adaptation and livelihood resilience (Cassidy and Barnes, 2012; Tewari and Bhowmick, 2014). The SLF looks at five types of "capitals," for which there are wide and, for some capitals, contested literature about their definition and measurement. The capitals included in this framework are: human, social, financial, physical, and natural (Scoones, 1998). The concept of capital implies the presence of usable productive resources. It is understood that all capitals are interdependent and interrelated (Slaus and Jacobs, 2011). Capitals are not merely possessions but take three distinctive roles: a vehicle to make a living, a way to give meaning to that living, and a challenge to the structures under which people make a living (Bebbington, 1999).

Human capital arises from the idea that nowadays humans are in charge of evolution (Huxley, 1957) and from the transformative effects of science and technology (Slaus and Jacobs, 2011). Personal abilities, including education and health status, are used to measure human capital. Such capital may be the most important component of the framework (Chivaura and Mararike, 1998), mainly because using some resources depends on an individual's depth of knowledge and level of cognitive skills (Odero, 2003).

Social capital comprises real-world links between groups or individuals that enhance networking. This capital contains features of social organization that can facilitate coordinated actions (Putnam, 1993). It provides the adhesive which smooths co-operation, exchange, and innovation. However, social networks can also be a barrier that members use to exclude others and reinforce dominance or privilege. According to its effects, social capital can be divided into three categories: bonding, bridging, or linking (World Bank, 2000). Social capital categorized as bonding comprises groups that tend to be homogeneous in terms of socioeconomic background. Due to the strong ties among the members, social capital in this sense can help the flow of information within the group, but it can also limit diversity (Hawkins and Maurer, 2010). Social capital that functions as a bridge provides weaker connections among members who possess similar social standing but different backgrounds (Hawkins and Maurer, 2010). However, this category provides a higher diversity of members. When ties between different economic and social classes exists, we can speak of linking social capital. This category aids poorer residents in obtaining information to which they did not have access within their own networks (Hawkins and Maurer, 2010).

Compared to these human and social capitals, the last three capitals discussed in the SLF are more concrete. Financial capital refers to those assets that can be used to purchase other capitals. Physical capital represents the basic infrastructure and production equipment such as transportation, water systems, and energy. Natural capital comprises goods and services such as the type of soil, available land, and plant genetics.

Operationalization of Vulnerability: Composite Index

A single measure of vulnerability is not possible; therefore, the common approach for its quantification is through the creation of composite indices or indicator-based assessments (Luers et al., 2003; Tonmoy et al., 2014). An indicator is an observed measure, qualitative or quantitative, that can help to simplify and explain a complex reality (Freudenberg, 2003). A composite index aggregates several individual indicators to provide a single value that measures the multidimensional, complex, and meaningful issue of vulnerability (deSherbinin, 2014).

Plagued with a lack of consensus, an ideal methodology for the creation of a composite vulnerability index does not exist (Tate, 2013). Methods for doing so encompass uncertainty, subjectivity, and assumptions that should be recognized and made clear throughout the analysis (Tate, 2012). Such uncertainties should not be presented as a shortcoming but rather an 'honest picture' that stimulates the creation of policies that are flexible and adaptable (Sullivan, 2011). Before creating an index, however, a clear and compelling conceptual and theoretical framework for vulnerability needs to be developed.

This first stage of this development should focus on exploring and evaluating approaches, fundamental concepts, and relevant theoretical frameworks for understanding vulnerability, as well as on conceptualizing the structure and composition of the complex system being analyzed (USAID, 2014). The vulnerable entity or system's boundaries are typically difficult to define accurately. In part, this difficulty arises from the desire to measure the vulnerability of entire countries or complex systems. But even when the vulnerability assessment is restricted to a local scale, the system/entity interacts with a vast array of institutional, economic, political, and social contexts, which creates uncertain boundaries (O'Brien et al., 2007).

After a conceptual framework is chosen, a well-defined spatial scale and scope of analysis is required. Applying an index to different spatial scales may result in different vulnerability patterns (Tate, 2012). Scale is related to the resolution that is available for the data. Although scale is important, however, selecting indicators to make up your index is a greater challenge in the vulnerability community.

Indicators are useful in simplifying a system's complexity, but as we have noted, they need to be used with caution when operationalizing vulnerability. Different approaches are taken to choosing indicators. Deductive arguments use a top-down approach to select indicators a-priori based on a theoretical framework. Inductive, bottom-up, approaches are data-based; they start with a larger set of indicators which are reduced by using either factor analysis or principal components analysis (PCA). This inductive approach is good for data reduction, but its subjectivity at critical stages contributes to uncertainty (Tate, 2013).

Averaging and additive approaches are the most popular way to combine indicators, due to their simplicity and transparency. However, raw data values present incommensurability in measurement units and need to be transformed to a consistent unitless scale. The standardization technique chosen should respect both the data properties and the theoretical framework. According to OECD (2008), the following standardization methodologies are commonly used:

- *Ranking*—this simple methodology rank orders cases on each input variable before combining them; it allows one to follow relative positions on the variables. However, detailed information about differences between cases and over time are lost. In ranking methods, the outcome is not affected by the presence of outliers.
- *Z-scores*—this methodology transforms each input variable by subtracting each from its mean and dividing by its standard deviation, producing transformed variables with means of zero and standard deviations of one. Outliers have some effect on the composite indicator.
- *Min-max*—this method rescales values to have a range from 0 to 1. The values of the input variables are subtracted from their minimum valued and divided by the range of that indicator. Outliers can greatly affect the outcome of this methodology. Furthermore, indicators with small range are widened, and their effect on the composite index is exaggerated.
- *Distance to a reference country*—this method is commonly used when the goal is to reach a target in a given timeframe. It standardizes by expressing each case on each variable in terms of its position relative to the value of a standardization country on that variable (e.g., a country considered to be "average"). Outliers have minimal effect.

- *Categorical scales*—a score is assigned to each indicator, grouping values into categories that reflect meaningful distinctions such as ‘poor’, ‘average’, ‘high.’ This method excludes much information about each indicator. Problems with this method arise when the variance of the data is small.

After input indicators are standardized, one must decide how to assign weights for their combination, starting with whether they should be equal or some form of unequal. Equal weighting is the most common approach in measuring social vulnerability; given a lack of specific knowledge about the relative importance of variables, equal weighting is seen as the simplest logical assumption. Unequal weights can be determined by various approaches, including those that are normative, data-driven, or hybrid (Decancq and Lugo, 2013). In many circumstances, unequal weights are assigned using expert knowledge to rank and assign the weights to each indicator.

Besides the simple approaches of averaging and adding to combine indicators, Reckien (2018) presented other approaches, including inductive, hierarchical, and fuzzy boundary. An inductive approach focusses on variable reduction using methodologies such as PCA and factor analysis. The hierarchical approach uses the likelihood of various sub-indices to create an overall vulnerability. The fuzzy boundaries approach joins important variables using fuzzy reasoning (logic). This allows one to handle uncertain and vague data using a series of decision-making steps.

The uncertainty and simplification involved in selecting, weighting, and aggregating indicators has been criticized for assessing vulnerability using indicator-based approaches. But in the end, aggregating indicators in these ways is the best option for quantifying and assessing vulnerability in most cases, because the creation of a complete and accurate mechanistic model for the causes of vulnerability is beyond our scope at this time in most situations (Tonmoy et al., 2014).

Chapter III. Research Location

Introduction

High mountainous regions are some of the most fragile and sensitive ecosystems in the world (Oliver-Smith, 2014). These areas, in many cases, are also home to the poorest populations and those most vulnerable to natural disasters. Under 'normal' circumstances, those living in South America's mountain range—the Andes—experience a wide range of environmental variability and high levels of uncertainty (Gobel, 2008). Andean communities, over the past centuries, have evolved practices that enable them to survive large environmental changes such as those involving climate variability. However, South America's mountain systems are not well understood in terms of climate change and the vulnerability and adaptive capacities of their people (Trigoso Rubio, 2007).

Peru ranks among the top thirty countries in the world in terms of risk from climate-related hazards (Trigoso Rubio, 2007). The Peruvian Andes, in the last quarter century, have experienced considerable environmental change; current assessments identify it as particularly vulnerable to climate change (Oliver-Smith, 2014). According to the World Bank (2013), the country's GDP has increased, but poverty and inequality persist, especially among farmers. Peru possesses a rich and relatively recent (2012) household-level dataset about farmers and about impacts from weather-related events. This richness of data is uncommon in developing countries, especially about farmers and at high resolutions.

During the past century, the Andean temperatures have increased, helping diseases and pests to reach crops at higher elevations and causing crop failure at lower elevations (Valdivia and Quiroz, 2003). In addition, factors such as the timing, type, and number of crops grown are also changing (Valdivia and Quiroz, 2003). These changes have had salient impacts on Andean livelihoods and landscapes alike. But the resources and capabilities of decision-makers are stretched thin, making it difficult to give proper attention to the effects of a changing climate.

The Peruvian Andes, bordering with Bolivia, ends with a high plateau named the Altiplano; it is home to the *Departamento* (Region) of Puno. This region has 68% of its territory within a zone characterized by pronounced daily temperature oscillations (Trigoso Rubio, 2007). Puno is frequently exposed to frost, droughts, and heavy precipitation; its climate is highly variable and semi-arid (Sietz et al., 2012). The Altiplano has a minimum altitude of 3,500 meters, which is close to what is considered the limit for most viable agriculture (Trigoso Rubio, 2007).

Characteristics of Puno

Puno is one of 24 *departamentos* (equivalent to US states, also called regions) in Peru and has an area of 72,000 km^2, the fifth largest *departamento*. The Altiplano, a high-elevation plateau, covers 70% (figure 1 left) of its territory, with an elevation that ranges between 3,812m and 5,500m. The natural regions of Suni (darker brown) and Puna (light grey) are considered to be altiplano areas. The light pumpkin color is known as quechua natural region, not part of the altiplano, and is undulated ranging at lower elevations from the other natural regions (2300m to 3500m). The patches of dark grey are similar to Puna but with higher elevations (4800m-6000m). The Altiplano has been inhabited since before the

Inca Empire and is the widest part of the Andes covering parts of Peru and western Bolivia and smallers areas in Argentina and Chile (also see figure 1 right).

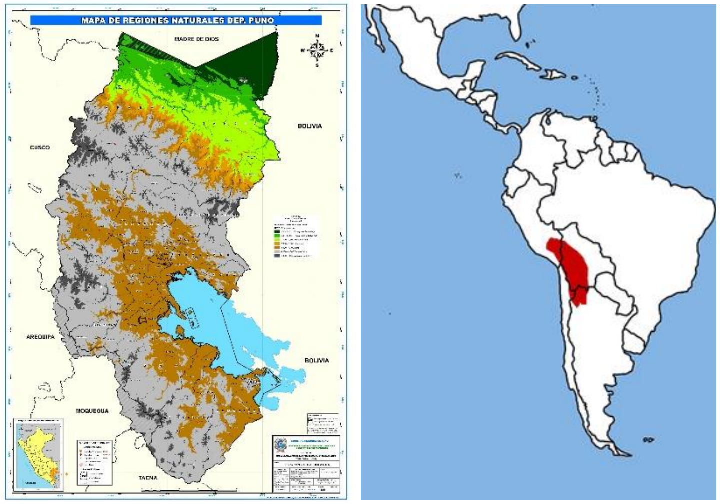

Figure 1: Natural Regions in Puno (left) and Altiplano in Latin America

The rest of Puno's territory has an elevation that ranges from 500m to 4,200m, mainly composed of higher altitude forest conditions. Furthermore, Puno is home to the highest navigable lake in the world, Lake Titicaca, which covers 7% of the region's territory. To the north, Puno borders the *Departamento* of Madre de Dios, to the east Bolivia and Lake Titicaca, to the south the *Departamento* of Tacna, to the southwest the *Departamento* of Moquegua, and to the west the *Departamentos* of Cuzco and Arequipa (see Figure 2). Puno's border with Bolivia contains 11% of Peru's national border. This region is divided into 109 municipalities and 13 provinces (equivalent to US counties).

According to INEI's dataset (for its Spanish name *Instituto Nacional de Estadisticas e Informatica-INEI*), the region has a total of 1,429,028 inhabitants, which is 5% of the nation's population, and has a population density of 20 inhabitants per km^2. The municipalities with the top five population densities are: Juliaca with 529 people per km^2 (282,417 inhabitants); Puno with 310 people per km^2 (142,863 inhabitants); Yunguyo with

159 people per km^2 (27,089 inhabitants); Ilave with 67 people per km^2 (58,210 inhabitants); and Huancane with 48 people per km^2 (18,398 inhabitants).

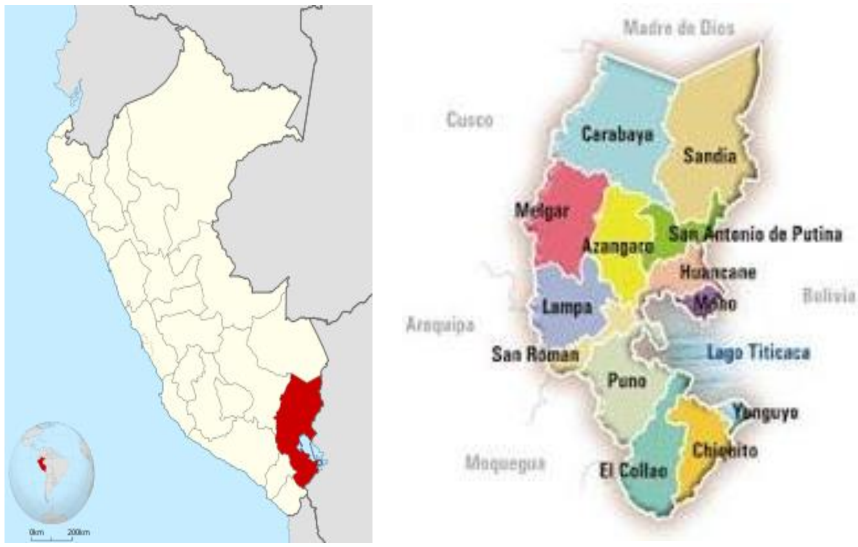

Figure 2: The Department of Puno, in relation to Peru (left) and its provinces (right).

The region is occupied by three linguistic groups: Quechua, Aymara, and Spanish-speaking *mestizos*. The present-day Quechuas are descendants of the Incas, and the present-day Aymaras are descendants of the various semi-independent groups which lived around Lake Titicaca during the Inca's expansion to the South (Primov, 1974). According to the latest census, 39% of Puno's population identifies Quechua as their native language, 34% Spanish, and 28% the Aymara language. However, rural populations are mainly divided into Quechuas and Aymaras. Three distinctive subregions can be observed in the region: Quechua areas (the northern provinces of Azangaro, Melgar, and Lampa; see Figure 2); Aymara areas (the southern provinces of Chucuito and Huancane; see Figure 2); and the rest of the provinces with a combination of both groups (Taylor, 1987). The *mestizos* are heavily concentrated in the city of Puno and in few of the province capitals. Puno was part of Bolivia until 1824, when it became part of Peru. Despite the relatively recent change, Aymara and Quechua groups in Peru identify themselves strongly as Peruvians and consider Bolivian-

Aymaras and Bolivian-Quechuas to be Bolivians and not fellow Aymaras and Quechuas (Primov, 1974). The topography of the region affects the division of Quechuas from the Cuzco region with those from the Puno region. *Kollas* is the name given to both Aymaras and Quechuas living in the Altiplano by Cuzco's Quechua groups. These groups have seen *Kollas* to be 'genotypically and phenotypically different,' mainly because of the effect on the skin of exposure to the intense sun and cold temperatures (Primov, 1974).

In terms of social indicators, the Puno region is in a generally dire situation. A total of 42% of residents have at least one unsatisfied basic need. Potable water is accessible to only 48% of the region's population; 87% have access to electricity. The region has an infant mortality rate of 28 per thousand live births; 59% of the infant morbidity is related to acute respiratory infections. Furthermore, the region has the highest percentage of childhood anemia with an occurrence of 76% in children under 3 years-old and 62% in children under 5 years old. Some municipalities in the region have above 90% of their children experiencing anemia.

In Puno, primary school enrollment is slightly higher than the national average, and illiteracy characterizes 12% of the population. In 2012, second-grade students in Peru took a learning achievement test for text comprehension and mathematics. At the national level, 30% passed the text comprehension and 13% the mathematics portion; however, in Puno, 19% and 8% passed, respectively. Rural areas in Puno obtained passing levels of 2% in both aspects of the test, while urban areas obtained 25% (text comprehension) and 10% (mathematics). Students in public schools passed at the rate of 14% in text comprehension and 6% in mathematics; students in private schools passed at rates of 42% and 14%, respectively.

Puno has an average income of approximately 300 USD per month. However, poverty has been reduced from 78% in 2004 to 34% in 2014. Income levels vary at the province level: Moho has the highest poverty level with 93%, most provinces are close to 80%, and Puno and San Roman Provinces are the lowest at close to 60% (Quispe and Rivas, 2015). Peru considers people to be under the poverty line if their income is lower than the cost of the minimum "basket of goods" (a fixed set of consumer products and services, such as food and clothing, the cost of which is tracked to establish the consumer price index). However, the government also identifies those poor populations whose income is less than the value of the food ingredients in the basket. These populations are under extreme poverty conditions. Extreme poverty was reduced from 44% in 2004 to 9% in 2014; however, extreme poverty in the provinces of San Roman and Puno is still 15% and 30%, respectively.

Peru created "macro regions" to promote decentralization by combining efforts from various *departamentos* that bridge political and economic strengths. Puno, one of seven *departamentos* that form the South Macro Region, has the highest growth rate in the area but has a Gross Domestic Product (GDP) that is inferior to the macro regional average. In terms of regional competitiveness, Puno is in the 23rd position out of 24 *departamentos*. Furthermore, the Gross Value Added (GVA)—an important component of the GDP—for Puno's region represents 3% of Peru's GVA. The most substantial economic sector is agriculture with a contribution of 16%, followed by mining with 13%, and manufacturing with 10% of the GVA. Puno has a population that is 63% in the working ages group, followed by 31% in the 14 years-old and younger group. With a clear majority of the population in the working age group, employment conditions in the region are an important component of the economy.

One of the biggest problems with employment, however, is that 89% of the jobs are in the informal economy. This is a set of economic activities that do not comply with regulation provided by the state for that specific activity (CEPLAN, 2016). Therefore, informal employment jobs do not have the benefits stipulated by law (CEPLAN, 2016), such as insurance or retirement. Microbusinesses—businesses with one to ten employees—are 99% of the economic units in Puno. All of these conditions present difficulties for the development of a stronger formal economy sector.

Agriculture in Puno

Farmers in the Andes and specially in Puno have experienced a history of social conflicts and uprisings. During colonial times, indigenous group rebelled against mistreatment from Spanish officials; neither side wanted to give quarter and much blood was shed (Tamayo, 1982). Peasant rebels demanding better treatment managed to control vast areas of the Puno for two years (Tamayo, 1982). Another widespread revolt happened between 1910 and 1925 due to economic changes that led rural populations to attack landlords and merchants. In 1969, the Velasco government introduced an agrarian reform that led to massive out-migration and more unequal land distribution (Brodsky and Oser, 1968). The reform was intended to destroy the landlord class; two million hectares were expropriated (Kay, 1982). However, the reform's poor implementation led to nine out of every ten hectares expropriated to be managed by co-operative managers from the Ministry of Agriculture. Membership and benefit from those co-operatives were not reaching peasants that worked on them. Furthermore, only 20% of rural families received land; those lands averaged 3.2 hectares per family (Taylor, 1987). Constraints stemming from these changes are still felt in today’s agriculture, and they are exacerbated by the challenges that mountainous regions bring to agriculture.

Peru can be divided into eight agroecological zones that are differentiated by variables that directly affect land use. Puno possesses six of these zones: Janca (>4,800m), Puna (4,001–4,800m), Suni (3,501–4000m), Quechua (2,301–3,500m), Yunga (1,000–2300m), and Forest (<1,000m). The most common agroecological zone for Puno is Suni, which encompasses 75% of the region’s farms. It is considered a land of frosts with a mild cold climate and a rocky and steep terrain. Suni land allows farmers to grow quinoa, potato, ollucos, bean, and barley, among other crops.

Agriculture productivity in mountain regions depends on factors such as slope, altitude, aspect, soil, moisture, and receipt of solar radiation (Goland, 1993). Unpredictability in mountainous environments increases the probability of production shortfalls, which lead to almost yearly unmet subsistence needs (Figueroa, 1984).

Despite a clear majority of the *departamento* having limitations due to its altitude, 51% of Puno’s population was engaged in agriculture in 2012 (INEI, 2012). Of these farmers, 83% are mainly dedicated to subsistence farming. The region’s productivity suffers from a lack of irrigation (INEI, 2012). According to GAV, the most common crops are potatoes (36.0%), oats to feed livestock (21.8%), alfalfa (10.5%), barley to feed livestock (5.6%), quinoa (5.4%), others (4.2%), and coffee (3.6%). However, the most important crops according to the number of hectares planted are potatoes (29.3%) and quinoa (23.7%). The agricultural calendar for Peru starts in August and goes until July of the following year. In the region of Puno, most of the planting occurs from September to November. Much of the harvesting occurs from April to June.

The potential agricultural landscape of the region covers 4,384,905 hectares, with grassland covering most of the land. Despite agriculture's poor potential for commercialization, this economic sector absorbs 44% of the employed population. The productivity per worker ranks 17 out of 24 *departamentos*. The conditions of the farms in this poor region are challenging for increasing productivity. Only 7% of the farms have irrigation, and 40% of the farming households are led by a woman, which create challenges in social networking since participation in the same networks as men is not always possible. Farmers that are above 60 years of age comprise 33% of the household heads; only 1% of farmers are teenagers. In terms of the household structure, 35% are parents with kids, 28% are single-person households, and 17% are married couples without children. Productivity of certain crops has decreased. For example, in 2001, Puno was responsible for 81% of the national production of quinoa, but by 2016, this share had fallen to 45.2% (Mercado and Ubillus, 2017).

Climate Variability and Change in the Peruvian Altiplano

Even though this dissertation focuses on pre-existing vulnerability, an understanding of past and present climate dynamics will help us comprehend some of the challenges that households experience. Peru's climate is affected by orography and controlled by water vapor transport and availability from/at the Amazon Basin, the Pacific Ocean's behavior, and the presence of Lake Titicaca (Garreaud, 2000). Peru has climates that depend on altitude and aspect stemming from the Andes, which rise abruptly from a very narrow Pacific coastal strip to the west of the country. Annual precipitation is highly variable over the Andes and Altiplano.

Among all high mountain ranges in the world, the Andes is the region that atmospheric science has studied the least (Garreaud, 2009). Furthermore, a detailed understanding of the characteristics that mountainous regional climate possesses is complicated. This is due to a scarcity in observations at the spatial and temporal resolution suitable for climate research in regions with a complex terrain; current Global Climate Models are also constrained in how they represent such topography (Beniston et al., 1997).

The Peruvian Andes starts at approximately 4.3° S latitude and runs south until 16.3° S. It is located between the Peruvian Amazon and the Pacific arid coast. Due to solar heating, the afternoon patterns over the Andes display high convergence at higher elevations, with divergence at the foothills. A reverse pattern is observed during nights and mornings (Romatschke and Houze, 2013). Precipitation varies on each of the Peruvian Andes slopes, with Pacific (western) slopes characterized by arid and dry conditions, while Eastern slopes are warm, moist, and rainy (Garreaud, 2009).

Altiplano's precipitation is highly sensitive to large-scale circulation anomalies. It has a pronounced annual cycle with more than 70% of its precipitation concentrated in the austral summer (Aceituno and Montecitos, 1993). During austral summer, water vapor from the Amazon basin is present in high concentrations in the boundary layer, which destabilizes the tropospheric column (Garreaud and Aceituno, 2001). Furthermore, rainfall happens in intense episodes that last one to two weeks, followed by dry spells of equal duration. Changes in the moisture transport over the eastern central Andean slopes produce moisture fluctuations over the Altiplano, which affects precipitation (Garreaud, 1999).

Climate variability in this region is influenced greatly by El Niño Southern Oscillations' (ENSO) modulation over the western Altiplano (Martinez et al., 2011). ENSO is characterized by irregular two to seven-year fluctuations between a warm phase (El Niño) and a cold phase (La Niña). It's worth emphasizing that this Altiplano region is markedly different than other areas of Peru. The ENSO warm phase shows an 88% increase in precipitation over the northern coastal region (Tapley and Waylen, 1990). However, a decrease of 18% in precipitation over the Southern highland and Altiplano area is experienced during the same warm phase (Tapley and Waylen, 1990). Exhibited impacts are opposite during ENSO cold phases but at different amplitudes than those displayed during the warm phases.

In terms of temperature, conditions can reach extremes. Frigid temperatures prevail at night due to loss of heat through low cloud coverage, atmospheric density, and vapor pressure. Throughout the year, especially at higher elevations, these temperatures drop below freezing (Thomas and Winterhalder, 1976). During the day, average air temperature ranges from −10°C to 23°C. Frost, hail, and cold temperature then persist in the region. These conditions, in combination with social conditions, create great impacts on agriculture and livelihoods.

Chapter IV. The Importance of Local Context (Study One)

Introduction

Asset-based vulnerability assessments are helpful in identifying the available resources that can aid human agency. However, structured survey methodologies cannot capture by themselves a contextual understanding of local realities (Shensul et al., 1999). Operationalizing social vulnerability requires an understanding of the structural factors involved, the uncertainties that individuals deal with (Rakodi, 2002), and the external constraints placed on assets (Kurlanska, 2011). These assessments must attend to context (Armitage and Plummer, 2010) and recognize that resources do not exist or are developed uniformly across groups (Adger et al., 2007). Approaches that might work in a particular location or with a particular socioeconomic group may not work elsewhere or with other groups (Smit and Pilifosova, 2001). Indicators that assess vulnerability do not necessarily generalize to other locations (Adger, 1999). Therefore, it is imperative to understand the local context and the environment in which the population deals with threats.

Selecting which indicators are essential for a specific location and understanding local context is possible by employing ethnographic and fieldwork methodologies. Exploring, unpacking, and describing the local perceptions and social meaning of a phenomenon are believed to be a starting point for qualitative research (Flick, 2002). It is essential to understand the importance of ethnographic fieldwork in gathering insights into the relationship between culture and climate. Engaging in daily life and social relationships through fieldwork and participant observation provide such contextual understanding (DeWalt and DeWalt, 2002). Eakin, a geographer, gathered ethnographic data on climate and economic change in rural Mexico. She expressed that “some of my greatest insights into the livelihoods of farmers in the Puebla-Tlaxcala Valley came from simply being there: helping with the harvest, chatting with mothers outside the primary school, attending a wedding celebration or school graduation. Alone, none of these methods and data sources would have been sufficient to understand the full complexity of the farmers' vulnerability" (Eakin, 2006, p. 213).

Qualitative evidence relating to people's perspectives and views aids in determining what interventions are appropriate in alleviating risks and reducing vulnerabilities. Furthermore, it allows discoveries to arise unexpectedly due to the slow accumulation of evidence and provides entry points for intervention (Roncoli et al., 2016). It can allow us to detect key barriers to change, identify local resources, aid in the selection of indicators, and create action plans. These types of studies aid in formulating relevant policies and guide assessments that used structured survey datasets. Before developing an asset-based assessment, it is imperative to understand the 'why,' 'how,' and 'under what circumstances' such assets influence social vulnerability.

Neither qualitative nor quantitative research approaches by themselves address the full picture. The complexity of assessing vulnerability requires using both approaches to build on each other. Qualitative approaches can be used to unpack the processes and contextual factors that have contributed to the failure or success of a certain practice. After such information is collected and processed, quantitative approaches can be used to build on the results.

Chapter's Objectives

This study intends to illuminate the importance of local context in aiding efforts to assess and reduce vulnerability. This issue arise due to the complexity in operationalizing vulnerability—especially when is exacerbated by weather and climate hazards—which has grown in importance in the light of the changes in interpretations made as part of assessments from the Intergovernmental Panel on Climate Change (IPCC). Although these changes are new in the climate change community, anthropologists and geographers have successfully used fieldwork methodologies to understand similar complex concepts. So far, however, vulnerability as an outcome has dominated discussions; incorporating social vulnerability has received insufficient attention in the climate change community. Also, research in high mountainous areas is limited. The population there has unique experiences that vulnerability models using generalized indicators tend to ignore. This study is designed to understand how local context can affect the selection of indicators and needs specific to the region of study. Furthermore, the findings from this study will directly inform the operationalization and mapping of social vulnerability in subsequent studies. Similar studies can be performed using the results of this study as a scaffolding.

This study aims to discover regional factors, internal or external to the farmer's agency, that constrain or enhance efforts to reduce vulnerability. The study presents the findings in themes that relate to social vulnerability in the region. These themes summarizing the information collected, including:

- Social Vulnerability, Weather Hazards, and Impacts
    - Temperature-related impacts and social vulnerability
    - The challenges of a drought: delimiting, assessing, and reacting
- Including Relative Distance, Network Structure, and Social Spaces
    - Relative distance and social vulnerability assessment
    - Social spaces and network structures

- Reducing Vulnerability: Proactive vs Reactive Approaches

Methodology

This study uses various qualitative methods of data collection: archival data (collected from January 2016 to March 2017); ethnographic observations (collected from January 2016 to March 2017); and semi-structured interviews (collected from September 2016 to February 2017).

Archival Data

During the fieldwork campaign, archival data were collected to complement the information obtained during ethnographic observations and semi-structured interviews. These secondary data include reports (NGOs and Government Agencies), publications, news articles, and documents concerning social vulnerability and weather events for the region. Information from INDECI related to weather emergencies was collected for a total of 415 reports. This information was collected from government ministries, local researchers, universities, and NGOs who have worked in the area. News articles and other documents were collected from internet sources and via library facilities. The majority of these data were not available in digital form or were only available in archives from the organizations.

Ethnographic Observation

Data collection through observation can provide information that highlights inaccuracies or distortions in descriptions provided by participants (Marshall and Rossman, 1995). Observation increases the validity of the interviews because they provide a better understanding of the phenomenon as well as add context (DeWalt and DeWalt, 2002). Schensul et al. (1999) provided a list of reasons for the importance of collecting data through participant observation:

- to guide relationships with informants
- to help understand how people relate to each other, how things are prioritized and organized, and what are the cultural constraints
- to see what is important for the population regarding leadership, social interaction, politics, manners, and taboos
- to facilitate the research process by getting known to the local population
- to provide a source of questions to be addressed by participants

These observations aid in understanding Puno's culture and social mechanisms. Moreover, they are imperative to understanding differences between Puno's department and the customs of neighboring geographical regions. This aids in understanding what behaviors are common in the region versus unique to Puno. Activities and interactions were observed in four nearby departments: Tacna, Moquegua, Arequipa, and Cuzco. Various visits to Bolivia aided in understanding Puno's uniqueness due to its connection with main geographical features, such as the Altiplano and Lake Titicaca, and similarities among linguistics groups (Quechua, Aymara, and Spanish mestizos).

Because of the extend timeframe of my observations, I was able to attend numerous important religious festivities and local activities. Experiencing these activities on more than one occasion and at more than one location helped me better understand situations that only happened once, versus recurring ones. Furthermore, experiencing the weather myself and comparing these experiences to those expressed by locals enhanced my understanding of local biases related to weather events.

Semi-structured Interviews

Structured interviews frequently produce quantitative information; therefore, the qualitative information that inform this study comes from semi-structured interviews. These interviews are somewhat like guided conversations. They are designed with open-ended questions and conducted in conjunction with observational data collection (DiCicco-Bloom and Crabtree, 2006).

In comparison to quantitative analysis, qualitative studies generally involve a smaller sample size than quantitative ones (Dworkin, 2012; Mason, 2010). However, a formula is not available for determining sample size in a qualitative analysis. A series of guidelines are present in the literature to aid in the selection of a sample size. Various approaches could be used to determine what is an optimal sample size. Literature about qualitative research has mentioned fifteen as the smallest acceptable sample size (Bertaux, 1981; Guest et al., 2006). Meanwhile, Ritchie et al. (2003) stated that sample sizes in qualitative studies regularly "lie under 50." Experienced qualitative researchers have stated that after around 20 interviews, little that is 'new' comes out of transcripts (Green and Thorogood 2009). I follow the concept of saturation here in order to stay faithful to qualitative research principles (Mason, 2010). Reaching saturation occurs when new data collected do not shed any further light on the issues covered by the study. Saturation can be reached by using maximum variation sampling and an educated guess. Maximum variation sampling involves selecting participants based on their specific characteristics, making sure to sample across the range of these characteristics.

Participants belong to one of the following two groups: administrative personnel and farmers. Administrative personnel include decision makers at regional, provincial, and municipality levels. Not all the participants are farmers themselves, but they have some decision-making power over the region of interest. Participants for this group included:

- scholars from the National University of the Altiplano;
- risk and disaster managers (regional and province level);
- politicians and policymakers (regional, provincial, and municipality levels);
- personnel from various ministries;
- and local NGOs.

The second group comprises farmers (over the age of 18). To ensure maximal variation of the sample, participants in this group represented various subgroups: male or female, different age groups, different primary languages, either subsistence or commercial farmers, and farmers with or without livestock. A final sample size was determined after achieving saturation and following maximum variation. This study consists of 55 participants consisting of 10 administrative personnel and 45 agricultural household heads.

Semi-structured interviews lasted approximately one hour with each of the participants. At the beginning of the interview verbal consent was obtained from the participants. The interviews were conducted in Spanish unless a participant felt more comfortable speaking a native language (Quechua or Aymara). I am fluent in Spanish, but a trusted translator was present if the interviewee preferred to talk in a native language.

Interviews with both administrative personnel and household heads were similar, except for their focus on either the administrative or individual level. The sections in my interviews were as follows (since they are semi-structured, interviewees usually gave more details than the specific questions asked):

- *Introduction*. In this section, I introduced myself, talked about the study and the purpose of the interview, and obtained verbal consent from the interviewee.
- *General questions*. Starting with personal questions is not optimal, so I asked general questions in this section to help relax interviewees and make them comfortable. Examples: How would you describe weather/climate in the area? Please tell me about any changes in the natural environment during your time here. How does weather influence your daily life? Is the weather we are experiencing these days common or uncommon, and why?
- *Impacts.* This section asks about weather-related events that could have produced impacts on their livelihoods, neighbors, or communities. Example questions: What type of impacts have you experienced? To what events? What impacts have you seen in your community? Are you experiencing the same impacts every year?
- *Vulnerability and Capacity to Respond*. In this section, I want to understand what is hindering their ability to reduce their vulnerability to an event. Example questions: Why are these impacts happening? Is there anything that you are missing in order to prevent them? Is one weather event causing more concern to you than another one? What actions have you performed in order to prevent such impacts?
- *Final question*. This was a free period allowing interviewees to add any other type of information they wanted to share. At this time, I allowed for other topics to arise in order to observe anything relevant I missed with my questions. I ended the interview by thanking them and again assuring them that their personal information such as name and address would be strictly confidential.

Data Analysis

The approach for the analysis starts close to the data and becomes more abstract. Creating categories and identifying patterns was essential to reduce the data into themes that could aid in understanding and provide input into future vulnerability assessments. Coding is the initial step of qualitative data analysis and is performed in several ways. In this study, I started by maintaining "openness"—the empirical research process should be open for unexpected information. Open coding allows finding distinct concepts and categories in the data that were not necessarily anticipated. These main categories could be:

- behaviors, specific acts;
- events, including short once-in-a-lifetime events or things people have done that are often told as a story;
- strategies, practices, or tactics;
- states—general conditions experienced by people or found in organizations;
- meanings—a wide range of semantic phenomena at the core of much qualitative analysis (we assume that meanings and interpretations are important parts of what directs participants' actions);
- participation—adaptation to a new setting or involvement;
- relationships or interactions;
- conditions or constraints; and
- consequences.

A category is an idea that is directly stated in the text (Hsieh and Shannon, 2005; Vaismoradi et al., 2016). However, a theme is more than a category; theme denotes a more implicit and abstract level, which entails interpretation (Sandelowski and Barroso, 2007; Vaismoradi et al., 2016). Therefore, the analysis needs to go beyond open coding.

Pattern coding aided in data reduction and theme creation using the categories initially defined. A pattern can be characterized by (Saldaña, 2009):

- similarity (situations happen the same way);
- difference (situations happen in predictably different ways);
- frequency (situations happen often or seldom);
- sequence (situations happen in a particular order);
- correspondence (situations happen concerning other events); and
- causation (one situation appears to cause another).

Once the multiple layers of coding were performed, I compared the resulting themes with the current vulnerability literature and previous studies about the subject and/or region of interest.

Social Vulnerability, Weather Hazards, and Impacts

The availability of resources and entitlements shapes social vulnerability. However, an awareness of the pressures external to social vulnerability is imperative to understand the local context in which these vulnerability conditions occur. This dissertation focuses on assessing social vulnerability; as mentioned before, that does not equate to undervaluing the effects of the weather hazard itself. The external factors in this section relate to the weather events and the resulting impacts experienced by multiple stakeholders during the fieldwork campaign, as well as the challenges that they encountered.

Agrometeorological reports from the Peruvian National Weather Service (SENAMHI) complement the observations, testimonies, and reports I obtained from stakeholders through ethnographic observations and semi-structured interviews. Here I also used written media sources—e.g., newspapers—to complement previous information.

The fieldwork campaign started in January 2016 and finished in March 2017, and during this timeframe, Puno experienced numerous weather-related events: frosts, drought, flooding, strong winds, hail, snow, and thunderstorms. According to local reports from the *Instituto Nacional de Defensa Civil* (INDECI)—the institute in charge of disaster management and prevention—the region reported a total of 415 weather-related emergencies during those months. Each report includes a summary of all the damages experienced inside the municipality for a given weather event. The INDECI representative for each province (or, in some cases, other municipal and local authorities) creates and sends those reports to the regional office. However, these reports lack standardization of meteorological variables that make difficult the understanding of the impacts. These reports are per municipality and are not representative of the event's intensity or the spatial extent of the damage. Also, not every extreme weather condition appears in a report, since they only include emergencies.

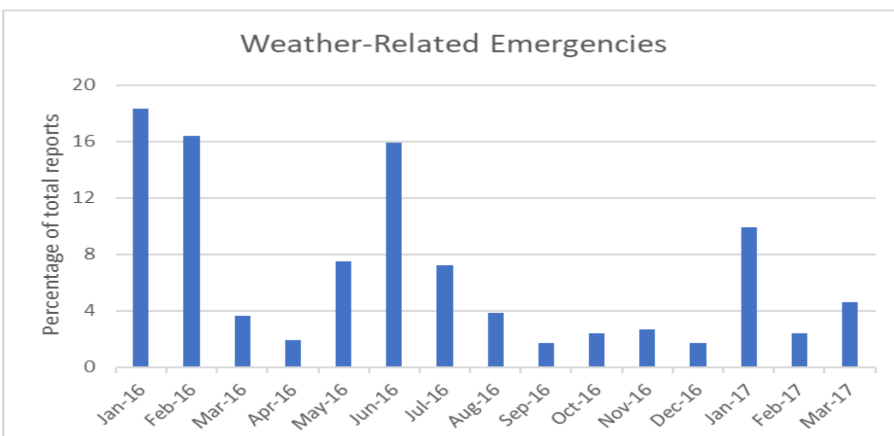

Figure 1: *The percentage of emergencies reported per month for the fieldwork campaign. The region reported a total of 415 weather-related emergencies during that timeframe.*

As seen in Figure 3, the first two months of the campaign, January and February 2016, were the most active regarding emergency reports—mainly due to the multiple types of hazards that occurred. These two months are part of the austral summer (summer in the Southern Hemisphere), but the number of reports in 2016 differs considerably from the second austral summer of the fieldwork campaign. Also, the number of reports and types of weather-related impacts varies throughout the year. Figure 4 presents the reports when divided by seasons—illustrating the difference between the two austral summers.

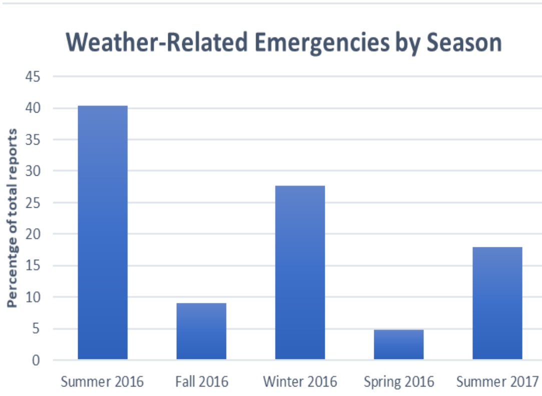

Figure 2: *The percentage of emergencies reported per season during fieldwork.*

On the other hand, June 2016—the middle of the austral winter—provides the second area of interest regarding the number of reports. Out-of-season frost events during January 2016 and early February 2016, combined with extreme drought conditions, led to declaring Puno's agriculture in a state of emergency by national and regional authorities. Consequently, reports related to frost conditions were the most common type of weather-related emergency during the fieldwork campaign. Figure 5 illustrates such variance, with 42% of the reports relating to frost conditions.

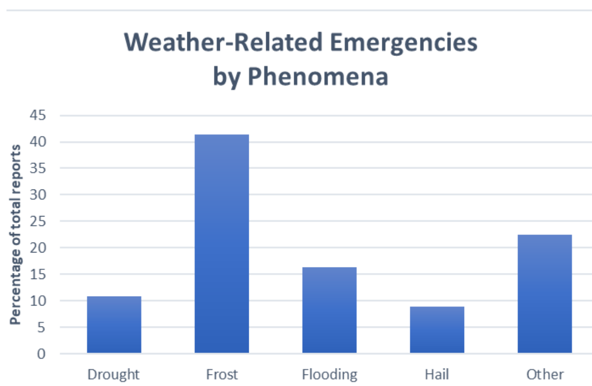

Figure 3: *The percentage of emergencies reported per phenomena during fieldwork.*

Due to the nature of reports and experiences during the fieldwork campaign, this section focuses on low-temperature events and drought conditions in Puno. The two types of weather hazards present different issues with respect to their relationship with human agency and social vulnerability. Therefore, this section has two subsections for each of the hazards and its relationship to vulnerability.

Low-temperature events are prevalent in the region, and their impacts are highly related to a lack of assets. A description of the relationship between low-temperature and its impacts gives specific examples of the problem going beyond just the experience of cold temperatures. On the other hand, drought conditions in Puno are challenging to predict and report. The section discussing drought will present the confusion that exists in information reported by meteorologists, newspapers, local agencies, and farmers. Both low-temperature and drought conditions significantly impacted farmers during the fieldwork campaign, and a better understanding of their impacts should help in assessing vulnerability to such events.

Temperature-Related Impacts and Social Vulnerability

Heat can take an enormous toll on human life, and most people are acutely conscious of its impacts, especially when in recent years the world has experienced heatwaves that have cost many human lives (e.g., the 2003 heatwave in Europe that resulted in 70,000 deaths). However, many people are surprised to find that deaths attributed to cold temperatures are higher in number than those caused by heatwaves.

Berko et al. (2014) performed a study of weather-related deaths that occurred in the United States from 2006 to 2010 and found that 91% of them were temperature-related. The study revealed that high temperatures caused 31% of the deaths, while low temperatures caused 63%. Furthermore, a study by Gasparrini et al. (2015) examined 74 million deaths in

13 countries—including high income countries such as Australia, Canada, Japan, South Korea, and the United Kingdom—and found that between 1985 and 2012, a total of 7.3% deaths were attributed to cold temperatures while 0.4% were related to heat. However, the relationship between deaths and temperature extremes is more complicated. Some studies have found a smaller difference between the number of deaths caused by cold temperatures versus hot temperatures (e.g., Hajat et al., 2007; Huynen et al., 2001). The recent focus on heatwaves is a valid approach to temperature-related impacts; however, stakeholders and public authorities should not underestimate cold-related impacts. Populations with high levels of social vulnerability possess fewer tools to protect themselves from cold temperatures, especially in high mountainous regions.

In the Andes, any region more than 3,200 meters above sea level experiences frosts and low temperature conditions. A frost occurs when the ambient temperature is equal to or less than zero degrees Celsius. In the department of Puno, the daily temperature can fluctuate 30ºC from day to night. Therefore, its population often experiences freezing temperatures at night, with a dangerously high level of ultraviolet rays during the day. The coldest

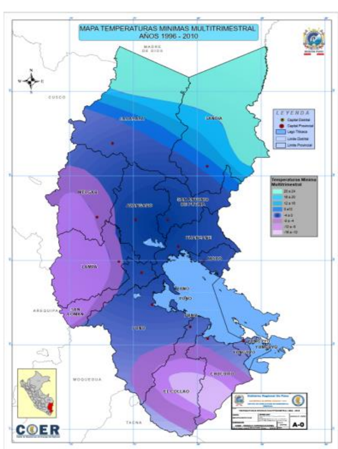

Figure 4: *Minimum multi-trimestral temperature. Source: COER Puno.*

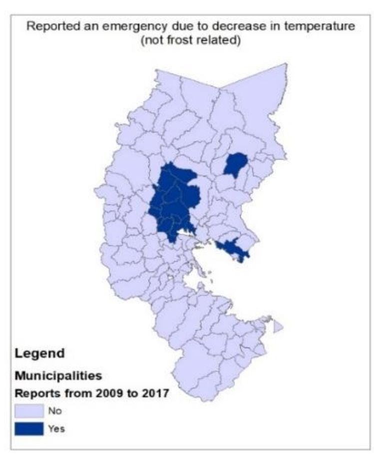

Figure 5: *Reported low temperature emergencies in INDECI's database.*

temperatures in Puno occur during the austral winter, with differing intensity throughout the region.

Figure 6 presents the minimum temperature typically experienced in Puno, which varies across the region. The areas reporting emergencies due to cold temperatures—not related to frosts—do not possess a spatial association with areas with similar minimum temperatures. Figure 7 presents the emergencies reported in Puno 2009–2017 due to decreases in temperature that were unrelated to frost events (frost is when temperature reaches zero or below zero degrees Celsius). This incompatibility might be an indication of a missing component when evaluating impacts and, as expected, a complexity in linking the actual hazard with its impacts. On the other hand, every municipality reported emergencies due to frost events during the same time.

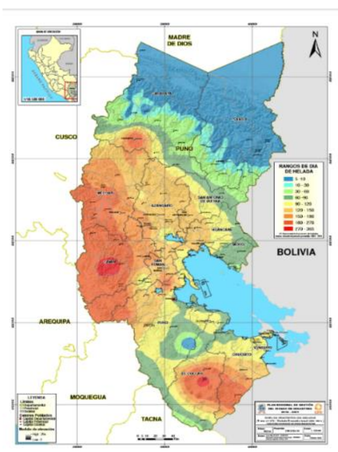

Figure 6: *Number of days in a year with frost conditions. Source: COEAR Puno.*

The months of May to September are known as frost season in Puno, with the highest occurrence of these events in June and July. Nevertheless, some areas might experience permanent frost conditions in the austral seasons of fall, winter, or spring. Figure 8 shows the number of days in a year an area might experience frost. Areas located beyond the end of the Altiplano experience five to ten days of frost conditions in a year. However, areas in the center of the west department's boundaries and at the south border with Bolivia experience more than 180 days of frost conditions a year.

The situation in Puno can be dire since the region has no heating systems, poor electricity coverage, and high poverty levels. Deaths and respiratory problems due to cold temperatures are of great concern. Every year, Puno suffers from adverse effects and damage caused by cold weather. From January 2003 until August 2016, Puno reported a total of 1,943,002 impacts related to a hazard. Figure 9 presents the number of registered impacts by hazard, and 63% of them are related to frost. The second highest number of report accounts for only 8% of total reports. However, are these impacts solely related to low temperatures, or does social vulnerability play a crucial role?

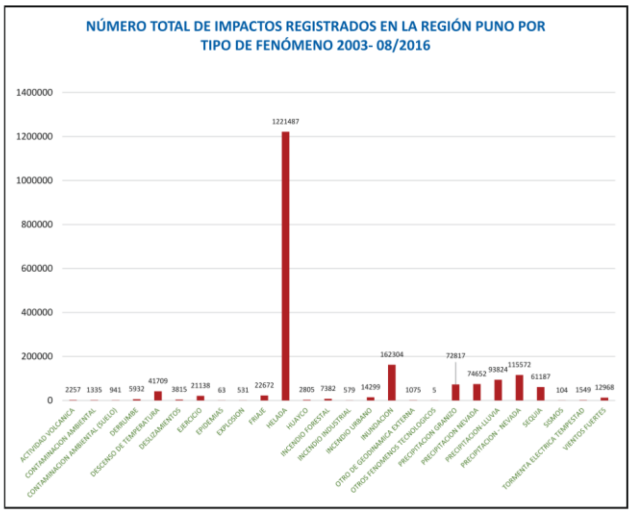

Figure 7: *Number of registered impacts by hazard.* Regional Government of Puno

Emergencies reported outside frost season happened in various municipalities during the 2015–2016 austral summer (seen in Figure 10). The region was experiencing months of below average precipitation, and a couple days with frost condition led to emergency alerts for many communities. I observed farmers burst into tears when expressing the recent impacts. They commented how unexpected the frost conditions were and how in combination with the drought now they lost the crops and livestock to feed their families. During this out-of-season frost, there were complaints mainly due to crops, notwithstanding both droughts and frost weather events. This combination was difficult to observed since the emergency reports were for one event and only by reading the document, I would see the combination of both hazards. However, during the rest of the year, reported emergencies led to numerous deaths (both human and livestocks). Figure 11 presents the location of the emergencies experienced during 2016 austral winter.

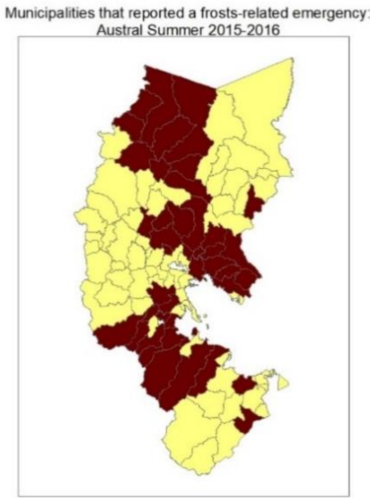

Figure 8: *Frost-related emergencies during austral summer 2015–2016.*

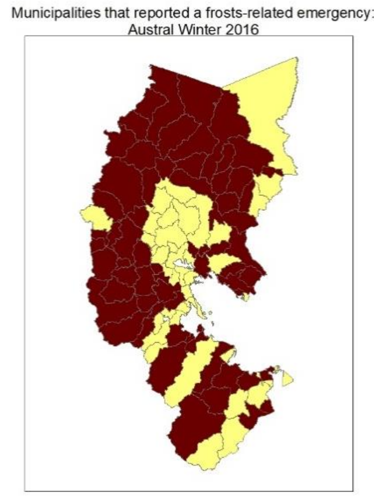

Figure 9: *Frost-related emergencies during austral winter 2016.*

The return of frost and its consequences is something that locals experience every year in Puno. According to the farmers and administrative personnel from the Ministry of Agriculture, animals that are thin or young do not survive this cold temperature. Furthermore, pregnant animals abort during the frost season, affecting the income and food supply for the local population. In the middle of the 2016 frost season, the regional government reported 61,000 animals died due to cold temperatures, and many other required medical interventions. However, animals are not the only ones suffering or dying from complications related to low-temperatures.

At the start of the frost season, I was informed that two kids (both five-years-old) died due to health complications related to cold temperatures. By the middle of the frost season, Puno’s regional goverment reported 47 deaths related to low temperatures, and 12 of those deaths were children. By then, humanitarian aid from numerous sources started to pour into the region, a yearly occurrence in the Peruvian Andes. This aid included food, blankets, and jackets delivered to affected areas. As the season progressed, the number of deaths, pneumonia cases, and complications kept rising. Toward the end of the frost season, the government declared 72 municipalities in Puno as emergency zones. Regardless of the impacts, farmers indicated that that season was not the coldest they experienced; such conditions are a battle re-experienced every year.

Every night, farmers and their families try to survive the cold temperatures; indoor temperatures are hardly warmer than outdoor. Nights are long, especially for mothers who indicate a constant fear of losing their kids. During the harshest days of winter, I observed many kids coughing, and living conditions that did not aid in health recovery. Even with the high UV rays in the morning, the interior of the house occasionally remains colder than the outside. I also experienced such difference in temperature which force me to relocate residence for a house that received more direct sunlight. I observed how many houses have no beds, forcing families to place blankets on the cold floor and sleep on top of them. As indoor temperatures reach -17ºC, people sleep with six alpaca blankets and up to seven thick jackets to protect themselves from the cold while they sleep. Some individuals' clothes have holes, or the layers used to keep warm are the entirety of their closet.

Indoor thermal comfort is rarely present in the region regardless of economic status. Thermal comfort is a subjective concept, defined as "that condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation" (ASHRAE 2010, p. 2). However, Puno's residents apply a simpler interpretation of the term. People want an optimal indoor temperature for a healthy life. Thermal comfort prevents contracting diseases within the home, and in case of illness, promotes a healthy space for recovery. Moreover, it allows people to carry out daily activities (e.g., sleeping, studying, meeting, and others) without the interference caused by excessive cold. For many residents outside the Andes, indoor heating is not considered to be a necessity; they underestimate the constraints imposed by such a lack.

Puno possesses various limitations that hinder the viability of indoor heating: inadequate infrastructure to support indoor heating, lack of an industry to manufacture and assemble the heating systems; and, among the most vulnerable, inability to pay the costs of energy services. Electrical heaters are available, but the energy cost of using them is extremely high. This cost depends on the plan for electricity that a family possesses—given that they can afford electricity or that it is available—which varies by peak hours and the voltage of the cables near the residence, among other variables. Therefore, many families rely on using their kitchens to heat themselves, which brings health problems.

Most farmers possess kitchens that do not evacuate combustion fumes outside the house efficiently. The typical kitchen in rural Puno generates combustion gases that are harmful to health, especially to the respiratory system and eyesight (Hadzich-Marin and Gonzales-Arcondo, 2009). Firewood is not accessible in the region, and many use manures, which is worst for health. Vulnerability studies sometimes overlook this, but in Puno, the use of an improved kitchen has substantial health benefits. This benefit is in part the result of not inhaling smoke. Farmers that recently obtained an improved kitchen commented to me about the surprising (to them) improvements in their daily energy and health. Many commented not realizing that such difference was possible or that the type of kitchen made a big difference.

The use of the kitchen for warming the house results from a lack of indoor thermal heating. Therefore, developing and encouraging a local heating industry adapted to this region is imperative, although outside the scope of this study. However, adequate infrastructure is an aspect of indoor thermal comfort that could be address by local stakeholders or the individual himself.

In a region where temperatures can change from 20ºC to -10ºC in just 12 hours, infrastructure is crucial in reducing people's vulnerability. In most cases, Puno's houses do not possess the minimum infrastructure to prevent the passage of cold air to the inside. I observed (and received numerous comments) about the high number of houses that possess deficient sealing in their doors, windows, and roof. Combining these poor housing characteristics with farmers that do not possess enough resources to buy proper clothing, blankets, beds, and nutritious foods aggravates the problem. Humanitarian aid consisting of food and blankets continually arrives in the region from various groups (NGOs, the government, private donations, and international organizations). Humanitarian aid is of great help; however, the problem of a lack of indoor thermal comfort will likely continue.

Even though most of Puno struggles with indoor thermal comfort, several projects and campaigns are searching to improve such comfort. The efforts started in 2007, but the problem persists. This study concentrates on changes happening in Puno; however, most of the efforts come from the national authorities. How this affects Puno? Why is indoor thermal comfort still a big problem causing deaths every year? Why with ten years of performing investigations and providing warmer houses the problem is still at alarming levels? What is the role of social vulnerability in these results?

During the fieldwork campaign, the data collected pointed to various projects related to warmer houses and one related to education facilities in the region. One of those projects is *K'ONICHUYAWASI Casa Caliente Limpia* proposed by the Pontifical Catholic University of Peru's Support Group for the Rural Sector (a University based in Lima, Peru) and implemented by Kusimayo (a Peruvian NGO). The name means Warm and Clean House in two languages: K'ONICHUYAWASI in Quechua and *Casa Caliente Limpia* in Spanish. The group started the project in 2008 and had modified over 100 houses and plans to modify 30 houses per year. In 2016, the project won the Inter-American Biennial Design award from the Madrid Design Foundation. This foundation collects money from donations and an annual activity in Lima.

K'ONICHUYAWASI improves rural houses by implementing a hot wall, an insulation system, and an improved kitchen. The hot wall is a structure of polycarbonate and wood located outside of the house. This wall increases the indoor temperature up to ten degrees Celsius using the heat of the sun. The insulation system, placed on the ceiling in order to conserve the heat generated by the hot wall, is a burlap type mesh covered with a layer of glue and plaster. It is coordinated with the arrangement of doors and windows, to avoid any heat leakage. The improved kitchen, as mentioned before, is implemented to reduce health-related effects.

Another project in the region, using the same technology described in the *K'ONICHUYAWASI* project, is named *Mi Abrigo* (a Spanish word meaning to wrap oneself up in something warm). This is a national project sponsored by the Ministry of Development and Social Inclusion (MIDIS) through their national program named the Cooperation Fund for Social Development (FONCODES). As a prevention effort for winter 2017, *Mi Abrigo* started building houses in December 2016 in three Peruvian departments: Apurimac, Cusco, and Puno. A total of 1,146 houses were modified in 33 communities from 12 districts. The program modified 400 houses in seven communities from four districts of Puno. However, the program is a national one, and the subsequent home modifications for the 2018 winter do not include Puno. The second stage of the program will modify 1,100 houses in 17 districts from four departments outside of Puno. Furthermore, the plans for the third stage that will modify houses for the 2019 winter does not include Puno either. This third stage will modify 980 homes in 14 districts of four departments outside of Puno.

The problem with regulating indoor heating is not only a concern for private housing. Education and health facilities also present poor levels of indoor thermal comfort. Many people in the area (both rural and urban inhabitants) express concern for the indoor thermal comfort inside hospitals. Their indoor thermal comfort is of greatest concern to the population experiencing childbirth. Education facilities also possess infrastructure and thermal insulation problems. These problems lead to an environment uncomfortable for learning, especially in the morning. Public education comprises 93% of Puno's educational facilities, and 65% of them are in rural areas. According to regional agencies, 75% of these facilities are mainly constructed with adobe and are considered to possess environments too cold for pedagogy. About 50% have very old-style constructions. The Ministry of Education has proposed to delay the time classes start every morning to aid in dealing with indoor thermal comfort. Furthermore, the national government has campaigned to educate teachers on how to properly close these facilities when they leave in order to maximize the indoor thermal comfort in the mornings.

So it is clearly imperative to prevent temperature-related deaths, but focusing only on heatwaves is not sufficient. Every year, farmers in the Peruvian Altiplano suffer and die due to cold temperatures in the region. Focusing only on heatwaves due to their increasing frequency and intensity around the world is similar to stakeholders forgetting about farmers in specific locations because the world is urbanizing. And temperature-related events do not result only in deaths, but in negative impacts on livelihoods, health, and comfort. People should not have to merely survive cold temperatures, and stakeholders should pay attention to improving indoor thermal comfort. Farmers with low human agency and low access to assets struggle to survive every cold night. Distributing blankets and food should not be the central response to such impacts. Long-term solutions are needed to avoid the repeated return of the harmful effects of cold temperatures in the region.

The Challenges of Drought: Delimiting, Assessing, and Reacting

Drought conditions entail a slow onset and combine multiple factors which make its prediction difficult. Some droughts are easy to predict and can be foreseen a month in advance, while others catch decision-makers by surprise. The prediction, report, and quantification of drought-related impacts remain a significant challenge. Unlike other weather phenomena, droughts are not a single distinct event; just a lack of rain does not equate to drought conditions.

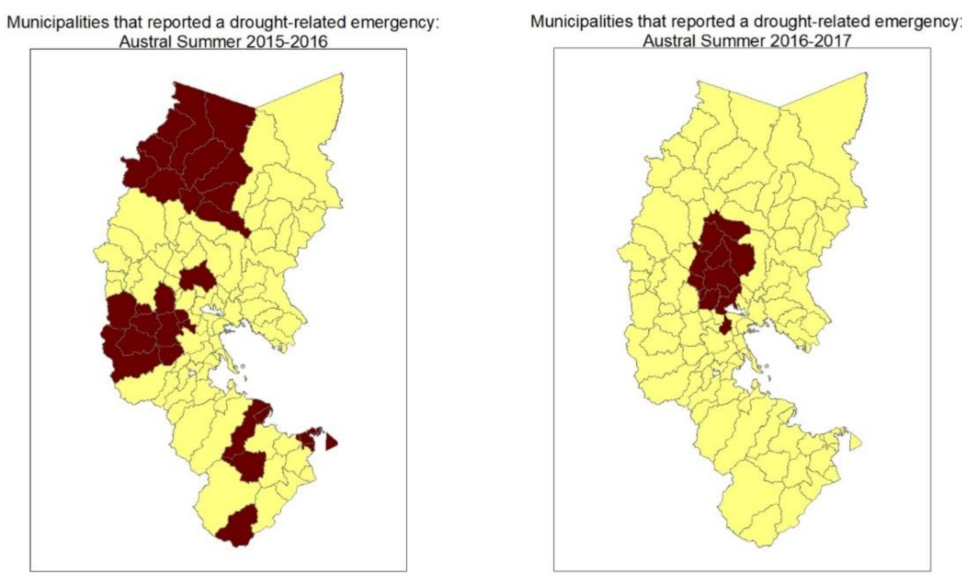

Figure 10: *Reported emergencies related to droughts during austral summer 2015–2016 (left) and austral summer 2016–2017 (right).*

During my fieldwork campaign, both austral summers reported drought conditions. However, they had different spatial coverage—as seen in Figure 12—regarding the emergencies reported. The first drought had a more widespread spatial coverage and presented a more significant challenge to both farmers and decision-makers. On the other hand, the second drought was more localized, and the difficulties experienced in many aspects of the emergency cycle were at a smaller scale than in the first drought.

The prediction of the drought in Summer 2015–2016, including the report of emergencies, was confusing and inconsistent. The national weather service agency provides monthly agrometeorological reports summarizing meteorology characteristics and providing information related to precipitation's probabilities for the next trimester. Three factors are essential to understand droughts in Puno and their impacts: the agricultural calendar starts in August, the rainy season covers from October to April, and the beginning of the austral summer presents a crucial stage for crop survival. Agrometeorological reports for the three months before the beginning of the fieldwork campaign in January 2016 aid in understanding the complexity of the drought in the region.

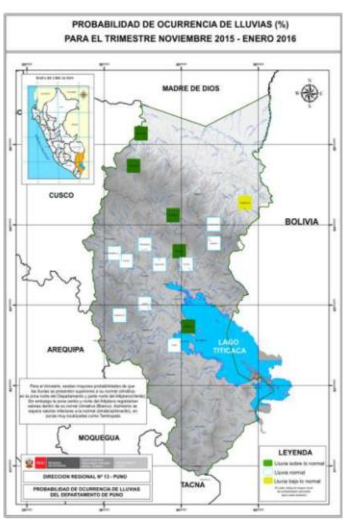

Figure 13: *Probability of rainfall Nov 2015–Jan 2016. Source: SENAMHI.*

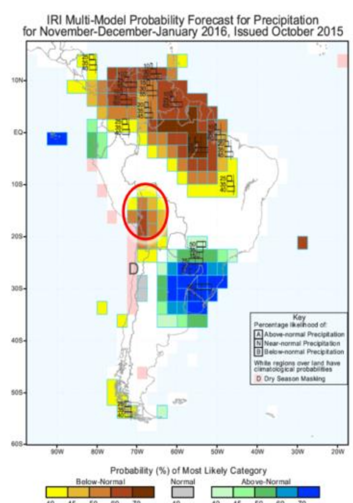

Figure 14: *Probability of rainfall Nov 2015–Jan 2016. Source: IRI-Columbia.*

Predictions in October for the November to January trimester had two scenarios that contradicted each other. Figure 13 presents a prediction with most of Puno experiencing normal precipitation and certain areas experiencing above normal precipitation conditions. However, the International Research Institute for Climate and Society (IRI) at Columbia University in New York had different probabilities for the region (Figure 14). These probabilities expressed areas with more than a 50% decrease in precipitation for Puno.

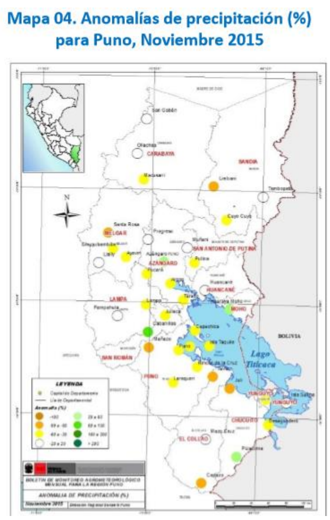

Figure 15: *Probability of rainfall Nov 2015. Source: SENAMHI.*

Local meteorology reports for November 2015 (Figure 15) and December 2015 (Figure 16) presented a rainfall deficit of -17% and -19% respectively for the entire department. Moreover, most of the stations were indicating between -20% and -100% of rainfall deficit. Station analysis performed by the regional SENAMHI office in Puno presented similar percentages of rainfall deficit from the start of the rainfall season in October. However, 2015 had only one report related to drought received toward the last week of December. This emergency report mentioned the lack of rainfall in the entire area of the municipality but reported only four hectares of crops affected by the drought. Also, it could be noted that the reported impacts during both austral summers were different from the areas identified to have a higher level of drought risk.

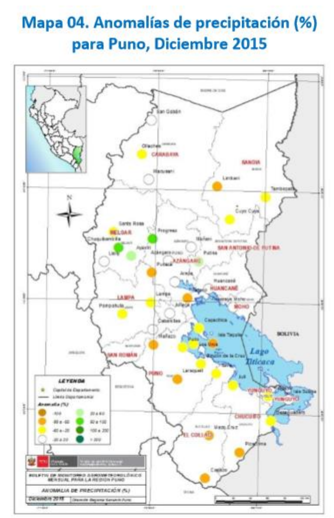

Figure 16: *Probability of rainfall Dec 2015. Source: SENAMHI.*

Let’s consider the difficulties of predicting the droughts, the conflicting information provided to farmers, the discrepancies in ground experiences in reports, and the farmers' perceptions. Aside from the discrepancy of the reports predicting normal precipitation conditions versus stations reporting deficits, the region was not expecting extreme drought conditions. The title of a local news article published on December 17 stated that the "drought would be mild in the Peruvian highlands." The article affirmed that the precipitation would be slightly less than in other years but "according to the experts it will not result disastrously for farmers in the region." An expert working for INDECI emphasized that if "it is true, according to the forecast of the climate entity, there would not be a drought scenario, the prevention of possible flooding of the rivers should be a priority." In the same article, other experts mentioned the changes in precipitation of -10% to -20% for individual municipalities.

Towards the end of December, the Laguna Colorada in Lampa (a municipality) utterly dried up. The Lagoon had been drying for three years due to high daily temperatures and lower precipitation in the area (even though emergency reports related to droughts were not present before December 2015 on INDECI's database). The representative of the Lagoon area mentioned that on multiple occasions, he presented projects to the provincial government to create a passage from the nearby river into the Lagoon. The provincial authorities emphasized that in November 2015, they brought the case to the Ministry of Agriculture and were expecting a response.

As the fieldwork campaign started, available information indicated that drought conditions were expected to be light, and the condition in the Lagoon resulted from a more extended timescale problem. However, the regional ministry of agriculture stated in early January that the drought conditions had affected up to 40% of the crops in the region. Furthermore, farmers pointed out that natural pastures were drying, and farming organizations were asking for oat bales for the animals. Toward the border with Bolivia, in the province of Chucuito, farmers told me stories about current drought conditions and their concerns that it was beyond “abnormal” drought. They showed dead birds and dead livestock. An elderly farmer cried as he explained to me what was happening: “We are all sad, it makes us want to cry, in June and July there will be nothing; then, this will be dry, and there will be no food for the animals.”

The display of farmers crying and showing me dead animals was repeated in various locations in the region. Farmers expressed concern with the availability of natural grassland. The grass available is not tall enough for their animals, and they recounted how it was supposed to be taller this time of the year. Many farmers were alarmed and often revisited stories from 1983. Many farmers did not mention a specific date, but those who did never mentioned anything other than the 1983 drought. Even the regional director of SENAMHI indicated the 1983 drought as a reference while talking about the drought in the area. Everyone admitted that conditions were getting drier every year. But how severe was the 1983 drought for farmers remembering its impacts more than 30 years after?

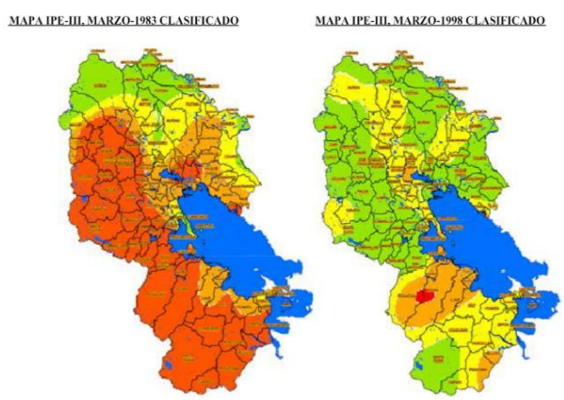

Tabla Nº 4.1-1 Categoría según Rangos del IPE

N°	CATEGORÍA	RANGO DEL IPE		FRECUENCIA DE OCURRENCIA TEÓRICA
1	EXTREMADAMENTE SECO (sequía extrema)	<-2	-2	1 en 50 años
2	MUY SECO (sequia severa)	-1.99	-1.5	1 en 20 años
3	MODERADAMENTE SECO (sequia moderada)	-1.49	-1	1 en 10 años
4	NORMAL	-0.99	0.99	1 en 3 años
5	MODERADAMENTE HÚMEDO (exceso moderado)	1	1.49	1 en 10 años
6	MUY HÚMEDO (exceso severo)	1.5	1.99	1 en 20 años
7	EXTREMADAMENTE HÚMEDO (exceso extremo)	2	>2	1 en 50 años

Figure 11: *Maps for drought condition conditions during El Niño of 1982–1983 (left) and El Niño of 1997–1998 (right). Source: SENAMHI.*

The austral summer of 2015–2016 was an El Niño year, which usually means less precipitation in Puno. But the relationship between El Niño and drought conditions in Puno is complicated, and the area needs more studies to evaluate the relationship. Maps produced by SENAMHI (Figure 17) show the Standardized Precipitation Index (SPI) for a severe drought during the El Niño of 1982–1983 and a more localized drought during the El Niño of 1997–1998. One of the strongest El Niño events worldwide was experienced during 1997–1998, but the extent of the drought was not severe in Puno. Furthermore, other years with El Niño conditions do not present drought conditions for the region. There is no doubt that the 1983 drought was real and caused numerous problems for the region. However, were the farmers correct in comparing the recent El Niño year with the 1983 drought conditions?

During my fieldwork in mid-January 2016, the National Water Authority (ANA, as a Spanish acronym) declared a state of emergency for Lake Titicaca for 90 days. The imminent danger of water deficit in four of the Lake sources of water prompted the decision, a decision praised by the director of the local meteorology agency. Furthermore, smaller towns in the provinces of Chucuito and Azángaro canceled activities that are usually celebrated all over the region. These cancellations, according to local officials, were due to the lack of water in their municipalities.

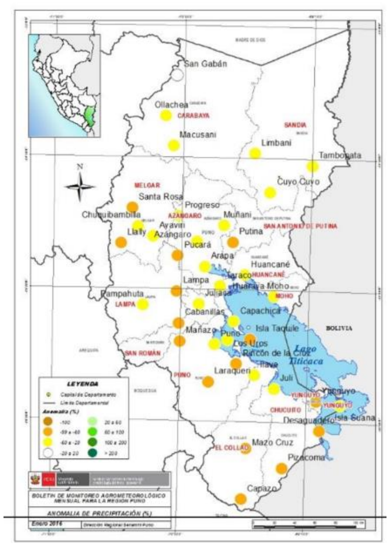

Figure 12: *Probability of rainfall Jan 2016. Source: SENAMHI.*

Towards the end of January, Puno's agricultural sector was declared an emergency zone by the regional agrarian authorities. This decision was necessary due to the loss of up to 60% of the essential crops in the region. The declaration was not only for droughts but included the out-of-season frost and hail that occurred in the region.

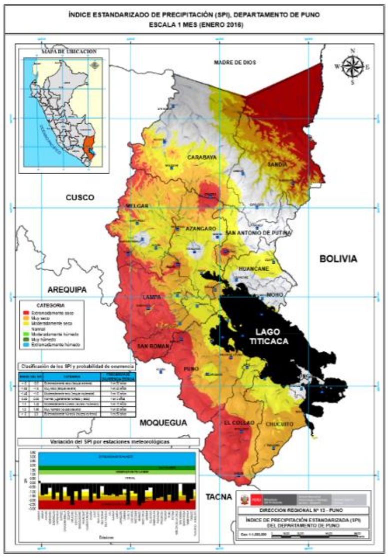

Figure 13: *Map of the Standardized Precipitation Index for Jan 2016. Source SENAMHI.*

The month of January ended with a deficit of -45% of the total monthly accumulated rainfall for the region. Figure 18 presents the anomalies in precipitation per weather station. One can see in yellow the stations reporting from -20% to -60% in precipitation for January 2016. While many stations, in orange, presented from -60% to -99% in precipitation. SENAMHI also provided a map with SPI to show the depth of the drought for January (Figure 19). Such SPI map patterns and water deficits do not completely explain the occurrence of reported emergencies, as seen in Figure 12.

The second drought experienced in the region during my fieldwork campaign had a smaller spatial coverage in terms of emergencies, but below normal precipitation happened in many municipalities outside that area. Farmers performed religious rituals to attract rainfall to the area. The level of emergency from the farmers and local authorities was lower than the previous season. The government did not declare a state of emergency, and farmers’ still suffered losses but to a lower degree. The government created and started to work on plans for water management and improvement of water wells in the region. The emergency reports related to drought still do not possess a standardized methodology for explaining impacts experienced on the ground. Many lacks crucial information, making it difficult to use those data for comparison with other social vulnerability indicators. When talking about impacts related to low temperatures, the primary concern is social vulnerability and a lack of resources. But drought impacts are complex and go beyond social vulnerability indicators.

Governance, access to water, and good quality wells and other methods of collecting water are of great importance.

Furthermore, the information provided by different agencies can be contradicting and confusing at times. Access to information does not necessarily allow leaders to understand what is happening on the ground nor farmers to adequately prepare for drought. Dealing with drought impacts would benefit from a stronger network of information and improved methods of transmitting a concise and less confusing message to stakeholders (not just information from government agencies to the people, but from people to the agencies).

Including Relative Distance, Network Structure, and Social Space

Frequently, social vulnerability assessments present their spatial unit of analysis (e.g., county, city, country, household) as an island. However, units interact with other units, influencing access to entitlements and resources. During my fieldwork campaign, three concepts outside the unit's agency seemed to influence social vulnerability. These concepts were relative distance, network structure, and social space.

Relative distance and social vulnerability assessments

The literature establishes the importance of access to health facilities, schools, markets, and town centers for reducing vulnerability and increasing agency. These locations possess resources that farmers and rural populations in general could not obtain on their own. However, resources availability does not guarantee accessibility. Long distances decrease access and increase vulnerability, especially in rural environments. Therefore, distance to resources has become an indicator in assessing vulnerability.

Access to resources that will reduce vulnerability reveal a relationship with distance that reflects what geographers know as distance decay. This concept states that an activity or function declines as distance increases from the point of origin. Physical distance is not necessarily the only relevant measurement of distance that relates to vulnerability. Physical distance (also known as absolute distance) is the spatial separation between points measured in standard units such as kilometers, miles, feet, or meters (Fellmann et. al., 2013). Geographers, until 1950, typically thought and hypothesized about distance in absolute terms (Gatrell, 1983). However, geographers now understand the importance of relative distance. Relative distance uses units often more directly relevant to spatial relationships (Fellmann et. al., 2013). Geographers see distance as any measure of what it takes to overcome the separation between places (e.g., effort, money, time, etc.).

Improvements in transportation and the availability of more efficient roads have shrunk the relative distances between places. For example, it now takes just two hours from Puno city to the most southern Peru-Bolivia border, due to cars, buses, and better roads. The concept of time-space convergence or compression describes how the relative distances between places effectively makes places "closer" (Warf, 2017). However, time-space convergence has been, and continues to be, very uneven (Dicken, 2011). For example, some farmers take 24 hours to cover just one-quarter of the absolute distance between Puno's city and the southern Peru-Bolivia border. In any case, other variables besides physical distance can affect accessibility to a resource.

Social vulnerability assessments that do not consider such unevenness of time-space converge or perform the assessment solely on the basis of absolute distance can be misleading. They can miss the problems some populations have in overcoming the separation between places or the fact that other populations have relatively short relative distances to goods and services. In the following section, I describe constraints I found during my fieldwork that highlight the dangers of measuring distance just in absolute terms when assessing social vulnerability. If these concerns are not addressed, they can mislead vulnerability assessments and efforts to reduce social vulnerability.

An understanding of the transportation system can partially explain challenges that Puno's residents face when moving from point A to B. The region has many types of transportation options: aerial, railway, lacustrine, and terrestrial. Here, I do not discuss aerial, railway, and lacustrine modes in detail. A one-way ticket at the local airport ranges from $50 to $250, in a region with an average monthly income of $233 for the entire population (with farmers earning considerably less). The railroad in the area, tailored for tourists, only goes to Cuzco and is not a mode of transportation used by locals in Puno. The lacustrine is the only mode of transportation for people living on the islands (Lake Titicaca) but is not widely used by others. Therefore, the mode of transportation available for our studied population is terrestrial.

Personal cars are available for transportation, but in many cases, people do not possess the income to own one. The most common mode of transportation outside urban centers is double deck buses or *combis*. A *combi* is a small white van that functions similarly to a bus; however, there are no established stops where people get on or off—stops are randomly dictated by passengers or drivers.

Outside of urban areas or when traveling to other towns, the transportation follows a hierarchical network pattern. Combis usually connect from one node of importance to another of equal importance, which is challenging for people at places in between. People that do not live at one of these nodes need to walk in the direction they want to head and hope that one of the combis has enough space. Double deck buses—mainly for moving to other departments—have a schedule and might have space for new people, if their policies allow for people on the way to get on the bus. However, *combis* do not have schedules and leave when they are full, which does not allow new people to get on unless a person gets off before the *combi*'s destination. Following this hierarchy, the popularity rather than the distance to a destination determines the effort it will take to reach it.

Consequently, many residents find themselves taking multiple *combis* to reach their towns. The arrival at a destination might depend on the time, day, and space availability. This problem is present for people traveling inside their municipalities as well as people traveling between municipalities. The role of mode of transportation is a clear example of the difference between relative and absolute distance, but there are other issues that are relevant as well.

Having a health facility in the vicinity is considered to lower vulnerability, since it indicates access to health service. Rural populations may be more habituated to travelling longer distance for health care since they travel similar distances for other goods and services. However, even after traveling longer distances than their urban counterparts, their needs are not always met. During my fieldwork campaign, many communities did not have access to health services even when a health facility was close in absolute terms.

According to local information, a community was physically near a health facility. This facility had hours of operation written on the door, but the locals mentioned that they had never seen it open. This situation was repeated in many remote communities in the area; sometimes the fact that the land or other resource was owned at other levels in the hierarchy was cited as the reason for not opening them. Farmers mentioned that they need to walk hours, in some cases almost nine hours, to reach the next available facility (remember that they are sick while doing these walks). Once they reach that facility, its office hours were changed, and therefore it was closed. In other instances, the facilities did not have the proper staff or even medicines to help them properly. Many farmers complained of how it felt to walk sick to reach the facility and not finding it available or having the needed resources. Furthermore, the community lost trust in the facility when this situation kept happening. The reasons and responsibilities for this lack of resources or change in hours is outside the scope of this research. However, it provides a good example to warn us about the use of physical distance to a health facility by itself as an indicator of social vulnerability in this area.

As with health facilities, proximity to an education facility is a proxy for access to education in many vulnerability assessments. However, several farmers pointed to the quality of the education in those facilities as a key concern. Many farmers—especially the women—expressed the view that education is more available in recent times, but that its quality is not good. They mentioned how its quality has even decreased in some instances. Schools that could provide better education are further away. Sometimes it does not help to encourage education because residents have seen that many with even higher levels of education struggle to find a job. Others mentioned that it does not provide useful information for their lives. The education, according to them, has no value since it does not provide any increase in income or any income at all.

Evaluating the quality of rural education is complicated for residents due to numerous constraints and challenges. Many rural primary schools combine grade levels without proper guidelines on how pedagogically to deal with these consolidations, which hurts the quality of the education. Challenges relating to distance to the school are present for the students, but also for the teacher that comes from far away. Many teachers live in the community only from Monday to Friday, and some respondents expressed concern that some teachers arrived late in the week and left early. And teachers that are eager to provide quality education encounter kids that haven't eaten proper meals or education facilities that are not optimal.

Furthermore, the system does not appear to offer a curriculum tailored to the needs of rural schools. Education above primary school is often found only in urban areas or areas far from the community where farmers reside. This further increases relative distance in terms of familiarity and security. Farmers mentioned unfamiliarity with the new school members as a reason for not wanting to travel the distance. Also, some students mentioned feeling unsafe walking to such schools. In some cases, this was due to unfamiliarity, but in other cases, it was due to strange males following them on the way to school. Therefore, although secondary school was reachable in terms of absolute distance, constraints added by fear and unfamiliarity made that distance relatively longer.

Social Spaces and Network Structure

A relationship defined on a set of individuals gives rise to a social network (Gatrell, 1983). Social networks act as channels for financial transfers, acquiring information about new technology, and enabling cooperation to overcome collective action dilemmas involving externalities (Deressa et al., 2008). They are a critical component of social capital, but social vulnerability assessments often reduce social networks to just an asset. These assessments rarely study how social networks help members to cope with a crisis or find alternative livelihood strategies. Furthermore, treating social networks in a binary way—either you have one or you don't—is problematic because the trust and access to resources they offer are unevenly distributed. A network can present benefits unequally to members, and different networks present different degrees of benefit.

Farmers’ associations are social networks that benefit their members in numerous ways. According to locals, membership in farmers’ associations provides supplies, access to markets, training, technical consulting services, credit, access to water resources; however, some reported no benefits at all. Answers revealed that gender plays a role in the type of benefit obtained by members.

During my fieldwork campaign, benefits were different for men and women in Puno. Men reported joining these types of associations mainly because of training and technical consulting services, followed by access to markets. In contrast, women reported joining them mainly to access water; after that, the most common response was that membership provided no benefits at all. It is intriguing that access to water is not among the top three benefits cited by men, but it was the top benefit for women. This raises questions, considering that both men and women cited water, followed by access to good seeds, as the primary barrier to increased crop production. Why do only women cite access to water as the association’s top benefit if water availability is of great concern to every farmer? I am unable to answer this question in this dissertation; however, the difference is an important example of how social networks have different effects as a function of gender. Other aspects of social vulnerability also show differences by gender.

Women farmers, especially older ones, experience a loss of voice when they are in leadership positions. Older women expressed that men do not listen to their opinions unless another male farmer repeats what they said. Therefore, women pass on their views with other women in a social network based on gender. Among younger generations, both females and male were able to express their opinions effectively to each other. Even then, voicing opinions and having leadership positions are not synonymous. Many women expressed their lack of access to leadership positions as a barrier. Even if leadership positions are available to women, many do not dare pursue them. Some farmers mentioned, which I later confirmed to be true, the case of the struggle in 2014 involving the first woman elected as community leader. They commented that on International Women's day, March 8th, almost 20 men locked her inside the office to demand her resignation. This outrage was provoked by the shame these men would feel in front of other communities if they let a woman be their boss. Numerous other examples provide insight into the leadership gender gap among rural populations in Puno. The level of social connectivity among rural women is considerably less than for their male counterparts. Therefore, gender plays a role in the number, type, and quality of connections available to rural populations.

Another aspect of social networks that assessments often ignore is that of ethnic networks. Assessments record native language spoken and membership in minority groups as social vulnerability indicators. These are decent indicators, but their effects on vulnerability are more complex than merely membership in such groups, especially for Puno. The results from the latest agricultural census divided producers mainly into Quechuas (47%) and Aymaras (45%). Three distinctive subregions can be observed in the region: Quechua areas (the northern provinces of Azangaro, Melgar, and Lampa); Aymara areas (the southern provinces of Chucuito and Huancane); and the rest of the provinces that combine both groups (Taylor, 1987). The existence of these three subregions makes the role of ethnic networks and interactions more complex.

A challenge with ethnic networks in Puno relates to their spatial dimensions. The connectedness of members at different places needs to be understood in a region divided, almost evenly, between two ethnic groups but simultaneously having neighbors that could be either Aymara (Bolivia) or Quechua (Cuzco). There is need to perform social network analysis concerning ethnicities and vulnerability. Does the location of the individual affect the strength of the ties with their ethnic networks? Do Quechuas received knowledge and assets from fellow Quechuas in Cuzco, or do they rely only on networks inside Puno? Do Aymaras exchange information and assets with fellow Aymaras across the Bolivian border, but only if they live near the border?

Furthermore, how does the quality of agricultural knowledge, innovation, and other assets vary by ethnicity? During my fieldwork campaign, I was not able to answer these questions, but numerous observations provided mixed indications of the nature and importance of ethnic networks in the region. Therefore, simply using language or membership in an ethnic group in the region might be an inadequate indicator, and such networks among farmers need to be analyzed further.

Reducing vulnerability: Proactive vs Reactive Approaches

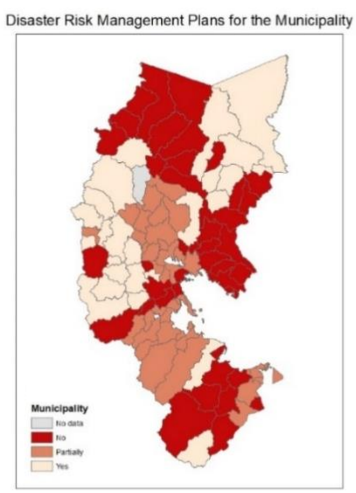

Figure 14: *Availability of disaster risk management plan per municipality.*

Reducing vulnerability is a challenge for decision-makers seeking to reduce social vulnerabilities in adapting to change. These efforts can take two approaches based on their timing: proactive or reactive. Proactive approaches, also known as anticipatory, are those actions taken in anticipation of the expected changes (Bosello et al., 2009). Reactive approaches, also called responsive, are those action taken once damage materializes (Bosello et al., 2009). The optimal approach involves including both approaches; however, many efforts are still only reactive and focused on short-term solutions. In this section, I present the efforts I found in the region and identify which are only reactive, only proactive, or a combination of both.

Reducing weather-related impacts by anticipating an emergency requires the availability of emergency personnel, disaster risk plans, and maps, among other things. The regional government created a summary in 2016 of the resources available per municipality in various disaster risk management categories. A municipality requires a disaster management plan to reduce its exclusive use of reactionary approaches when such events occurs; however, 38% of Puno’s municipalities do not possess such plan (Figure 20). Some municipalities possess only partial plans for emergency management. During my fieldwork campaign, decision makers commented on the possibility of suspending mayors from a number of months if they don’t provide such plans by a certain deadline every year.

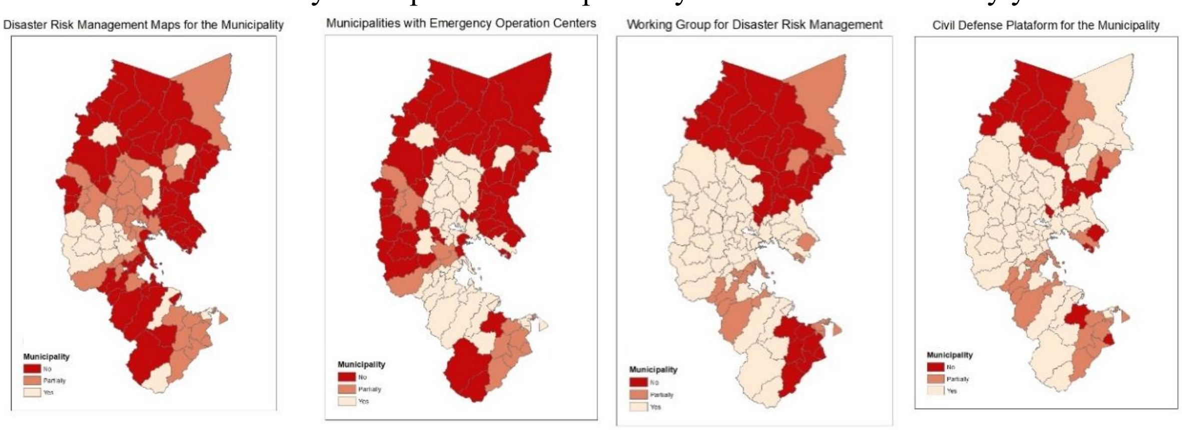

Figure 15: *Maps of disaster management related resources per municipality. Disaster risk management maps (left), emergency operation centers (center-left), working groups (center-right), and civil defense platforms (right).*

Encouraging local decision-makers to create emergency management plans is imperative, but the effects of such enforcements on other aspects of the community must be thought out.

Another resource to reduce vulnerability and manage a disaster is to make maps of such events available. However, 48% of the municipalities lack such maps for decision making. Figure 21 (left map) presents the locations of municipalities with complete or incomplete sets of maps. Other resources relating to disaster management and prevention involve the availability of working groups, civil defense platforms, and emergency operation centers. Almost half the municipalities do not possess an emergency operation center (Figure 21 center-left map). Furthermore, 27% of municipalities do not have a working group dedicated to disaster risk management. Figure 21 (center-right map) shows that most of these municipalities are in the northwestern and southeastern corners of the region. Many countries possess organizations with government support that aim to support populations living in vulnerable areas as they try to cope with disasters. In Peru, these are called *defensa civil* or civil defense. In Puno, 17% of the municipalities are without a civil defense platform, as shown in Figure 21 (right map), and many are in the same locations that lack working groups.

The Ministry of Economy allocates a budget for expenditures related to reducing vulnerability and attending to emergency disasters. This budget is aimed at reducing the vulnerability of the population in the face of hazard threats. Numerous government agencies can make use of the budget for their interventions, including the Ministry of Agriculture; Ministry of Housing, Construction and Sanitation; Ministry of Transportation; Ministry of Health; Ministry of Education; INDECI; and regional and local governments.

Budget for Reducing Vulnerability and Respond to Disaster's Emergencies by Provinces in Puno										
Provinces	**2013**		**2014**		**2015**		**2016 (as of Sept**		**2017 (as of July 2017)**	
	Budget (Soles)	***Used (%)***	***Budget (Soles)***	***Used (%)***	***Budget (Soles)***	***Used (%)***	***Budget (Soles)***	***Used (%)***	***Budget (Soles)***	***Used (%)***
Puno	16,000	90	1,656,501	79	739,046	62	624,732	43	640,519	25
Azangaro	1,070,339	92	97,120	62	1,505,202	78	1,793,631	36	1,269,718	36
Carabaya	815,076	76	1,027,790	96	254,527	90	341,040	50	1,091,482	40
Chucuito	328,066	62	1,036,978	60	2,256,279	85	411,005	55	492,571	27
El Collao	924,244	59	7,943	0	360,307	90	1,089,319	89	377,288	29
Huancane	93,474	19	342,278	6	590,473	40	1,334,210	91	359,676	25
Lampa	155,899	56	1,736,344	93	2,254,458	99	247,996	76	290,333	51
Melgar	255,580	49	896,020	8	2,116,636	87	662,989	28	1,578,874	11
Moho	43,049	74	26,632	100	139,972	88	96,784	62	93,562	21
S. Putina	237,363	63	209,745	22	611,751	39	744,772	37	543,034	13
San Roman	22,303	48	142,507	26	561,505	66	566,098	21	806,899	12
Sandia	255,237	77	965,492	97	3,808,497	50	2,332,304	83	2,318,960	90
Yunguyo	196,586	31	191,934	80	248,347	57	171,011	54	519,503	11

Figure 16: *Yearly budget dedicated to reducing vulnerability and responding to disasters for various provinces in the department of Puno. The table presents the allocated budget and the percentage of that budget that was used per province.*

This type of budget for the department of Puno starts with 7,371,945 nuevos soles ($2.2 million), but it changes every year according to national budget allocations. However, approaches are typically reactive when you look at how provinces use their hazard budget (Figure 22). During 2013, the province of Azangaro had the largest budget and used the highest percentage of its assigned budget (92%), while Huancane used the lowest (19%). During 2014, the province of Moho used its entire budget (its assigned budget was the second lowest) while the province of El Collao did not use any of its budget. During 2015, higher percentages were used; the province of Lampa used the highest percentage (99%) of the money allocated. Putina used the lowest percentage (39%) that year. For unknown reasons, the 2016 budget information is available only until September of that year. The use of these budgets suggests that a reactionary approach dominates the region.

Plans for managing risk and reducing vulnerability are increasingly common over the years; each year, reports about management of frost-related impacts involve a significant number of humanitarian aid and communication campaigns to educate the population.

Education campaigns are useful for those families that are not necessarily wealthy but possess the resources to follow what the campaigns suggest. However, many farmers do not possess the resources to take the precautionary methods suggested by the campaign. Furthermore, the struggle to create precautionary approaches to weather hazards is higher at certain levels of management. For example, as mentioned above, the regional authorities were thinking about suspending mayors that would not complete a disaster risk management plan. This approach would incentivize some mayors to comply but at the same time would hurt other administrative responsibilities in the municipality. While the region is improving its plans to prevent weather-related impacts, however, precautionary approaches—even inside the plans— heavily rely on reactionary approaches. Why is there such a heavy balance toward reacting, and what will Puno need to avoid the perennial return of frost hazards and decreasing water availability in the region?

Chapter V. Data Collection and Selection of Indicators for the Remaining Studies

This dissertation comprises three studies with diverse methodologies. However, the studies in chapters VI and VII use the same data for their analyses. In this chapter, I explain in detail the dataset used in these two studies. The first section provides a description of the data and its origins. The second justifies the selection of indicators to create maps and perform analyses in the two studies. I provide detailed information about the treatment of the data in the following two chapters of this dissertation.

Data

The second and third studies of this dissertation use quantitative data from two datasets to obtain 22 indicators measuring farmers' social vulnerability. Combining an array of datasets or indicators at different scales is a widespread practice; it is uncommon to obtain every indicator at the same scale or from the same dataset. Both datasets originate from the *Instituto Nacional de Estadistica* (INEI), which is the Peruvian agency in charge of the national statistical system. One dataset is available at the level of the farm and provided 91% of the indicators. The other dataset provided the indicators related to health at the municipality level.

The *Censo Nacional Agropecuario* (CENAGRO) is INEI's latest agricultural census (2012); it provides information to create 20 of the indicators. This census includes over 200,000 farmers from Puno but does not include interviewees with incomplete data. The data is geolocated only in Agricultural Enumeration Sectors (AES) to protect farmers' privacy—unique IDs are given to each farmer. CENAGRO defines an AES as the land surface entirely located inside a municipality and delimitated by INEI. These AESs were predetermined by natural or artificial boundaries that were easy to identify on the land as well as on blueprints. The department of Puno has 3,009 AESs; the number varies across each of the 109 municipalities.

The census only interviews farmers considered to be producers. According to CENAGRO, a producer is the person—regardless of legal status—that does the following for an agricultural unit: makes decisions about the use of resources; exercises control of administrative operations; has technical and economic responsibilities for the unit; and executes all these characteristics directly or through paid labor. In most of the cases, these producers are the head of their households and directly perform the needed agricultural activities. Therefore, the farmers interviewed by CENAGRO are the ones that can exercise control and make decisions about the agricultural unit. An agricultural unit, for CENAGRO, is the land or collection of lands that are used, total or partially, for agricultural purposes, including livestock. Only one farmer is considered the producer within an agricultural unit (hence the collection of land in the definition) to avoid duplicate interviews of farmers handling different parcels.

Justification for the Selected Social Vulnerability Indicators

This dissertation defines social vulnerability as the lack of available resources and the entitlements to call on those resources (Adger and Kelly, 1999). Therefore, the Sustainable Livelihood Framework (SLF) is the conceptual framework used to operationalize social vulnerability and guide the selection of indicators. The framework has proven beneficial for assessing the ability of households to withstand shocks (Chambers and Conway, 1992; Ellis, 2000).

People possess basic tangible and intangible assets to pursue different livelihood strategies (Scoones, 1998). The possession and accessibility of those assets, included in SLF, reveal differences among households in their recovery from disasters that could further lead to adaptation and livelihood resilience (Cassidy and Barnes, 2012; Madhuri et al., 2014). Indicators should measure all five "capitals" of the framework: human, social, physical, natural, and financial. Higher social vulnerability is associated with lower levels of a capital. Therefore, indicators will always have a positive functional relationship with vulnerability.

The following section describes how each capital is defined by specific indicators and my reasons for choosing those indicators to measure social vulnerability. The participant observation and semi-structured interviews described above guided the selection of some of the indicators (e.g., relative distance to town center and improved kitchens) as well as the decision not to use certain common indicators (e.g., native language, average years in school).

Human Capital

First, human capital includes the quality and quantity of available labor resources (Ashely and Carney, 1999). This capital is important, since using some resources depends on an individual's depth of knowledge and level of cognitive skill (Odero, 2003). Three components make up human capital, components which could enhance or constrain a household's ability to take advantage of their assets: education, health, and the demands of household maintenance (Rakodi, 1999). The following indicators were selected to measure these components of human capital:

- Illiteracy => Even though the effects of illiteracy can manifest themselves throughout the whole life cycle of an individual, illiteracy in adulthood increases current and future socioeconomic vulnerabilities (Martinez and Fernandez, 2010). Studies have found that illiteracy is negatively correlated with human agency and the individual's capacity to respond (Deressa et al., 2008).

- Education Attainment => Vulnerability indices typically use average years in school as a measure for educational attainment. Most farmers attain only low levels of education; the correlation of this indicator with literacy was 0.80 in my dataset. Due to this high correlation, I instead use as an indicator the lack of a high school diploma. This new indicator correlated only 0.24 with illiteracy, thus adding new information to the index.

  Farmers with higher levels of education are more likely to adopt new technology and apply methods that aid in reducing vulnerability (Ali and Erinstein, 2017). However, many farmers pointed out during my fieldwork campaign that the quality of education in many rural schools was not optimal and did not create opportunities for improving their lives. However, a high school (mainly located in urban areas) diploma provides more opportunities. Failing to complete high school brings problems that arise because adolescents without a diploma migrate alone to urban areas.

- Education Attainment of the Spouse => Farmers' education levels relate to their participation in non-farm activities (Barrett et al., 2001). However, education (as well as income diversification) is usually measured only for the head of the household. But level of education attained by the spouse could help to measure the household's access to resources that do not originate from farm activities (Zereyesus et al., 2017). Furthermore, females comprise 40% of farmers but many are not single. Therefore, the level of education attained by the spouse can indicate access to other sources of income, skills, and networks that can aid in reducing social vulnerability.

- Dependency Ratio => Life-cycle stage and the dependency ratio can help measure the time available to engage in income-earning activities (Rakodi, 1999). The dependency ratio reflects the household's age structure and indicates the household's support requirements. The ratio divides the number of people too old or young to work (thus requiring support) by the number of working age, who may be economically active (OECD, 2007). High dependency ratios constrain family assets. The formula used to calculate the dependency ratio is: $\frac{[(\text{Age } 0-14)+(\text{Age above } 65)]}{\text{Age } 15-65}$

- Health => The census does not ask direct questions about the farmer's health. Measuring children's health—especially when resources are limited—is a good proxy for family health, insofar as structural factors that affect the health of an entire population also affect children. The agency that collects census data provided assessments for two health variables: infant mortality and child malnutrition. This information is not measured at the farm level but only at the level of the municipality in which the farmer lives.

Infant mortality is an indicator used in many social inequality studies (Nabas-Ventura et al., 2008). It is a proxy for the population's health and the quality of health care (AMCHP, 2013). Infant mortality, as defined by INEI, is the total number of deaths recorded for children under one year of age in a given timeframe divided by the total number of live births in that same period.

Another health indicator uses the number of children under five years of age that are malnourished. Hunger and malnutrition are not synonyms, even though they frequently go together. Child malnutrition is a significant contributor to child mortality and morbidity, and it is widely used to determine an adult's poor socioeconomic status (Kien et al., 2016). Child malnutrition is a pathological state resulting from inadequate nutrition, including either undernourishment or over-nourishment (Ge and Chang, 2001). These variables were quantified following international standards that use various statistics of height and weight to infer levels of malnutrition.

Social Capital

Social capital consists of social networks that smooth co-operation, exchange, and innovation (OECD, 2001). This capital contains features of social organization that can facilitate coordinated actions (Putnam, 1993). However, social networks can also be a barrier that members use to exclude others and reinforce dominance or privilege. According to its effects, social capital can be divided into three categories: bonding, bridging, and linking (World Bank, 2000). Measuring social capital depends on the type, quality, and numbers of relationships that an individual possesses. The following indicators were selected to measure social capital:

- <u>Gender</u> => This indicator can contribute to measuring either social or human capital. Gender can be a human capital indicator because knowledge and the ability to take advantage of opportunities can be constrained in rural women. However, I use gender as a social capital indicator, because social networks diminish such awareness gaps in their members. Network associations allows women to use their agency to achieve more adaptive outcomes (Okali, 2006). However, the level of social connectivity for rural women, especially if they are head of the farm, is considerably less than for their male counterparts. Therefore, gender plays a role in the number, type, and quality of connections accessible for rural populations.

- Sources of Agricultural Information => Access to information is part of social capital; agricultural information is of especially great value to farmers. Farmers can adopt strategies to cope with climate risks if they have access to such information (Abid et al., 2016). Farmers that report not having any source of agricultural information are more vulnerable.
- Agricultural Consulting => Another indicator of social capital is acquiring information through networks. Accessing consultation is included within the Food and Agriculture Organization's (FAO) framework for good agricultural practices (FAO, 2002). Therefore, a farmer that has no access to consulting or has never used it is more vulnerable.
- Farm Association's Membership => Social capital increases through the enhancement of social networks, which is possible by participating in farmer-based organizations (Egyir et al., 2015). These types of memberships are a replacement for private social networks (Gbetibouo and Ringler, 2009). They act as channels for making financial transfers and acquiring information about new technology, and they enable the cooperation that helps overcome collective dilemmas involving externalities (Deressa et al., 2008).

Natural Capital

Natural capital is the collection of natural resources that support a long-term supply of agricultural inputs and services (Huai, 2016). It includes the productivity of the land and the actions to sustain such productivity (Williges et al., 2017). In comparison to their urban counterparts, rural populations value more the direct access and use of natural assets (Okali, 2006). I selected the following indicators to measure natural capital:

- Farm Size => Farmers with a significant amount of land are more likely to have diversified coping strategies (Defiesta and Rapera, 2014) and invest in strategies to reduce climate risk (Ali and Erenstein, 2017). Studies have reported a positive association between technology adoption and farm size (Abid et al., 2015; Bryan et al., 2013; Tiwari et al., 2009). Farm size in conjunction with land use intensity can give us an indication of a farm's capacity to respond to hazard risks (Reidsma et al., 2010).
- Agro-ecological Zone => Land is an indicator of wealth and a vital agricultural asset (Ali and Erenstein, 2017). However, this varies greatly according to the type of land that a person possesses. More intensive land use is linked to reduced vulnerability and a higher capacity to respond to hazards (Dixon et al., 2014). Peru possesses eight agro-ecological zones that are differentiated by variables directly affecting land use. Puno has six of those zones, with Suni being the most common zone in the region. The Suni agro-ecological zone encompasses 75% of the region's farms. It is considered a land of frosts with a mild cold climate, and a rocky and steep terrain. Suni land allows farmers to grow quinoa, potato, olluco, and barley, among others.
- Land Use => Due to Puno's orography and types of land, there is no option to profit from deforesting the land to obtain income or new cultivable land. Furthermore, a farmer might possess vast terrain, but the land might not be suitable for agricultural activities. Studies have used the amount of land dedicated to crops (Defiesta and

Rapera, 2014) as an indicator of the farm's vulnerability and capacity to respond to hazards.

- Certified Seeds => Many farmers, especially those without land tenure, invest in short-term benefits such as inorganic fertilizer and improved seeds (Asfaw et al., 2016). Certified seeds—following the provisions of law—have been verified as to their identity, production, packaging, and quality (INIA, 2018). Farmers using certified seeds produce crops with predictable yield and maturation schedules, disease resistance, and other desirable traits (CSGA, 2018). Also, some of these seeds are drought resistant (Akister, 2014).

Physical Capital

Physical capital involves needs for infrastructure, equipment, and tools. Obsolete technology, low access to a resource (primarily due to poor transportation), and poor infrastructure increase vulnerability (Smit and Pilifosova, 2003) and hurt productivity (Huai, 2016). I selected the following indicators to measure physical capital:

- Rainfed vs. Irrigated Agriculture => Access to irrigation increases the capacity of a farmer to respond to hazards and reduces their vulnerability (Aase et al., 2013; Eakin et al., 2011; Egyir et al., 2015). Furthermore, irrigation can indicate a farmer with higher social cohesion and wealth (Faures and Santini, 2008). Relying only on rainfed agriculture leads to a higher risk of crop failure, especially during droughts.
- Tractors => Physical capital also encompasses the equipment that a farmer possesses to make a living. Farm mechanization is synonymous with tractorization (Musa et al., 2012). A tractor is crucial for mechanical power (Ishola and Adeoti, 2004). In any

country, access to a tractor critical affects the level of agricultural development (NAERLS and NPFS, 2011).

- Distance to Town Center => Town centers possess resources that otherwise farmers and rural populations could not obtain. However, resources availability does not guarantee accessibility. Therefore, distance to these resources is relevant to vulnerability. Lengthy distances decrease access and increase vulnerability, especially in rural environments. This friction of distance is stated in the *First Law of Geography*, famously identified by Tobler in 1969: Everything is related to everything else, but near things are more related than distant things. As I discussed in the previous chapter, physical distance should not be used as the only measure of distance. For a geographer, distance is any measure of what it takes to overcome the separation between places. In this dissertation, I use the time (in minutes) that it takes to reach the town's center as an indicator of what it takes to overcome separation.
- Improved Kitchen => An improved kitchen allows the evacuation of combustion fumes outside the house efficiently, while granting comfort and saving fuel (Hadzich-Marin and Gonzales-Arcondo, 2009). As discussed in the previous chapter, the common style of kitchen in rural Puno generates combustion gases that are harmful to health, especially to the respiratory system and the eyesight (Hadzich-Marin and Gonzales-Arcondo, 2009). Firewood is not accessible in the region, so many families burn manure, which is worse for health. Other studies overlook this indicator, but in Puno, the use of an improved kitchen has substantial benefits.

Financial Capital

Finally, financial capital tends to be the least available livelihood assets for poor populations (Serrat, 2017). Financial capital incorporates indicators that reflect any form of access to financial services or money inflows. I selected the following indicators to measure financial capital:

- Sources of Income => Having diverse sources of income increase the capacity to respond to hazards and reduces farmer's vulnerability (Armah et al., 2010; Defiesta and Rapera et al., 2014). Reducing dependence on a specific resource of income, in this case agriculture, is beneficial. Including non-farm sources of income is an essential way to decrease local vulnerability (Ludena et al., 2015), since it can reduce a households' food insecurity and poverty (Zereyesus et al., 2017).
- Land Ownership => Land tenure influences a farmer's agricultural performance (Asfaw et al., 2016) and largely defines access to natural resources (Bugri, 2008). A farmer is more likely to adopt long-term strategies with the security that land ownership provides (Asfaw et al., 2016). Farmers that do not own their land tend to focus on short-term returns, especially when land is scarce (Kassie et al., 2008).
- Hired Labor => Farms that hire labor produce output to be sold at markets (Lokonon, 2017). Small farms employ family labor when they cannot afford to hire labor. This practice is common among subsistence farmers and limits the time family members have to acquire other sources of income.
- Self-Reported Income => Possessing enough income to buy basic necessities is an essential component of the financial capital of a household. Determining this through self-report is fast and easy, although I recognize that social desirability biases are present when an individual answer this type of question.

Chapter VI: Spatial Aggregation and Vulnerability Assessments (Study Two)

Introduction

Operationalizing vulnerability is considered a priority for supporting climate risk decision-making (PROVIA, 2013a). However, understanding vulnerability as a comparative metric diminishes without a visualization methodology (Cutter, 2009). The heterogeneity of variables and of goals in interpreting vulnerability have led to interest in visualizing vulnerability through mapping techniques. However, literature explicitly discussing vulnerability mapping (Cutter, 2009) and its influence on public policy (deSherbinin et al., 2017) is relatively scant.

Vulnerability maps potentially allow us to identify and locate vulnerable populations (Morrow, 1999). The technique's objective is to communicate 'vulnerability of place,' which aids spatial planning and helps educate the public about climate interactions with human/environment systems (Preston et al., 2011). Maps provide a common ground for discussion and communication among stakeholders (Preston et al., 2011).

Measuring and mapping vulnerability is challenging. An array of concerns commonly emerges, mainly related to limited data availability and various methodological issues (deSherbinin, 2014). There is an intrinsic trade-off between the wealth of information reflecting real-world complexity and the need to be able to communicate and use that information for policy-making and informing the public (Abson et al., 2012).

In the context of climate variability and change, vulnerability mapping has proliferated since the release of the IPCC AR4 (deSherbinin et al., 2017). This 4th assessment used the outcome vulnerability approach that is most popular for assessing vulnerability in the climate change community. However, more robust mapping techniques to assess social vulnerability emerged from the contextual vulnerability interpretation used in the IPCC AR5. Therefore, vulnerability maps increasingly focus on the spatial patterns of social-science constructs, such as the capitals I use in this research.

In recent decades, there has been a well-documented revival of interest in spatial social research (Entwisle, 2007; Logan, 2012; Voss, 2007). Spatial social science recognizes the crucial role that spatiality plays in human society and encourages the understanding of spatial patterns and processes (CSISS, 2004). In a sense, many social scientists have discovered geography. For geographers, scale is a key concept that aids in understanding spatial patterns and processes.

The scale concept involves the spatial units at which we observe and characterize patterns, entities, and processes. Literature, particularly in geography, discusses the importance of scale in both lay and scientific representations of the world. The concept of scale includes three domains: thematic, temporal, and spatial. Here, I focus on spatial scale.

Problems with scale and resolution are well-known in the geographic literature. The Modifiable Areal Unit Problem (MAUP) is a typical expression of this problem. MAUP is the "geographic manifestation of the ecological fallacy in which conclusions based on data aggregated to a particular set of districts may change if one aggregates the same underlying data to a different set of districts" (Waller and Gotway, 2004, p. 104). Scientific concern with MAUP can be traced back to the mid-1930s with a study by Gehlke and Biehl. This study of male juvenile delinquency in Cleveland, Ohio, showed that the correlation coefficient varied with the scale of aggregation. However, the MAUP term was not coined until 1979 when

Openshaw and Taylor worked with Iowa's electoral data. They coined the term MAUP to label the inconsistencies they found in their results with different spatial configurations.

MAUP entails two types of problems: scaling and zoning. The scaling problem, also called the aggregation problem, is that using data aggregated at different spatial scales can result in different spatial patterns of a variable. Spatial scale affects statistical analyses insofar as data aggregated more tend to inflate correlations as compared with less aggregated levels (Wong, 2009). The zoning or grouping problem is more difficult to understand than the scaling problem. The zoning problem concerns the effect of zone shape and location on spatial patterns of the data. The two MAUP components may present errors affecting the validity of the results. There is no generally straightforward solution to MAUP problems; they may not even be problems so much as they are an expression of the fact that geographic reality varies with different spatial units. It is imperative to recognize the threat of scaling and zoning problems when assessing and mapping vulnerability.

Chapter's Objectives

In this study, I intend to bring to light the effects that administrative boundaries and spatial scale exert on mapping social vulnerability. Although disaggregated datasets are increasing in availability, previous work on social vulnerability has mentioned the importance of MAUP issues but generally not specifically explored its effects. The present study uses a rich disaggregated farmers' dataset that is rarely available in developing countries and for specific sectors. Moreover, the region of Puno may represent the perfect "missing middle" scale often overlooked in studies.

This chapter's objective is to explore the effects that scale of analysis (farm, census unit, and municipality levels) may have on identifying the most vulnerable farmers using a social vulnerability composite index. To pursue this objective, I formulate the following hypothesis:

- A social vulnerability index at the middle scale of analysis—the census unit level—will reveal more information about vulnerability than will other spatial scales, while keeping irrelevant noise to a minimum.

Methodology

I quantify vulnerability by creating a composite index (Luers et al., 2003; Tonmoy et al., 2014), aggregating several individual indicators to provide a single value that measures a multidimensional and complex issue (deSherbinin, 2014). This study will create the composite index at three aggregation levels: farm, census unit, and municipality. Since there is no consensus on how this should be created (Tate, 2013), any attempt to do so involves uncertainty, subjectivity, and assumptions that should be recognized openly and considered throughout the analysis (Tate, 2012).

The first step to create the index consists of identifying a conceptual framework; as mentioned earlier, this dissertation uses the Sustainable Livelihood Framework (SLF), since that framework has proven beneficial for assessing the ability of households to withstand risk events (Chambers and Conway, 1992; Ellis, 2000). The second step involves selecting indicators; this dissertation selects 22 indicators for assessing social vulnerability, as described and justified in the previous chapter. These indicators are:

- Illiteracy
- Education Attainment
- Spouse's Education Attainment
- Dependency Ratio

- Infant Mortality Ratio
- Child Malnutrition
- Gender
- Sources of Agricultural Information
- Agricultural Consulting
- Farmers Association's Membership
- Farm Size
- Agro-ecological zone
- Land Use
- Certified Seeds
- Rainfed Agriculture
- Tractors
- Distance to Town's Center
- Improved Kitchen
- Sources of Income
- Land Ownership
- Hired Labor
- Self-Reported Income

The third step involves standardizing the indicators; raw data are incommensurable in measurement units and need to be transformed to an appropriate unit-less scale. To do this, I apply the z-score transform to each variable. Thus, each indicator variable will have a mean of zero and standard deviation of one. All indicators are oriented so that more vulnerable characteristics have a higher (more positive) value and less vulnerable characteristics receive a lower (more negative) value.

In the fourth step, I aggregate the indicators by summing them, weighting each equally. This produces the final social vulnerability index scores. Steps three and four are repeated for each set of indicators, to create the social vulnerability indices at the municipality, census unit, and farm levels.

I use spatial statistics to compare each of the patterns on the resulting maps. Specifically, I use two spatial statistical methods in this chapter: cluster and outlier analysis, and hotspot analysis. The cluster and outlier analysis, also known as Anselin's Local Moran's I, is a widely used test that identifies significant spatial clusters of high values and low values, as well as spatial outliers. The analysis looks for clusters by examining three quantities: Local Moran's I, z-scores, and pseudo-p-values. Local Moran's I is a ratio of the quadratic form commonly used in statistics that tests for spatial autocorrelation in univariate map patterns (Tiefelsdorf, 2002). The z-scores and p-values are standard measures of statistical magnitude and significance. The output is as follows: no statistically significant values (blank), clusters of statistically significant high values (HH), clusters of statistically significant low values (LL)high value surrounded by low values (HL), and low value surrounded by high values (LH). The hotspot analysis method is like the cluster and outlier's analysis but only uses z-scores and p-values to create the clusters. However, the results of the hotspot analysis give a percentage of confidence's level for the clusters. Like any statistical test, the results can help to identify relevant patterns, in this case, spatial patterns. However, they do not in themselves explain why these patterns occur.

Results and Discussion

The analysis performed presents three main issues: variation in results related to spatial scale; the relationship of social vulnerability indicators to topography; and the spatial association between clusters of high social vulnerability and locations of weather-related emergencies. The results suggest knowledge gaps that relate to the spatial assessment of social vulnerability.

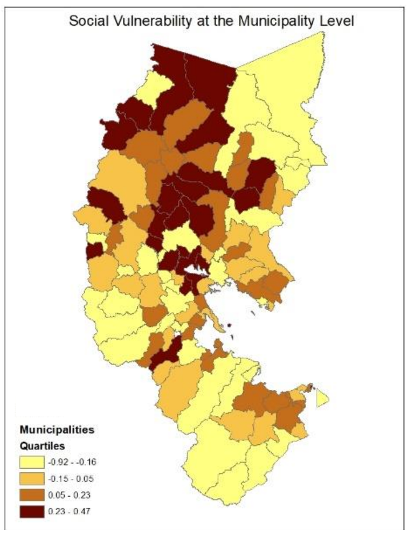

Figure 23: *Social Vulnerability Index at the municipality level.*

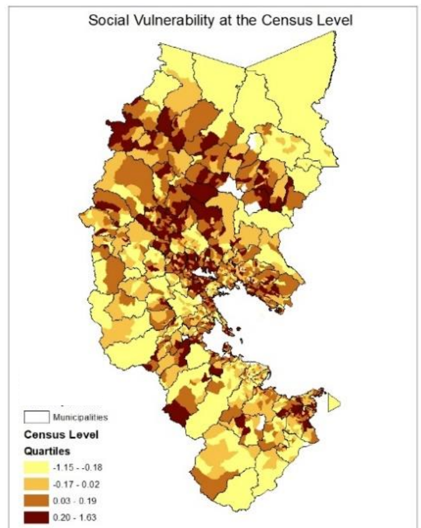

Figure 24: *Social Vulnerability Index at the census level.*

The highest level of generalization in the study happens at the municipality level, which possesses the highest level of data aggregation in the study. Figure 23 presents the composite index for social vulnerability with data aggregated at the municipality level. The northwestern area, as well as various municipalities surrounding Lake Titicaca, appear to have the highest levels of social vulnerability (dark colors). In developing countries, the municipality level is the most common spatial scale for mapping vulnerability due to data availability. However, while information at the municipality level might help national authorities, it is not optimal for decision-makers at more local levels. This level of aggregation does not allow decision-makers to find the right areas for intervention.

Assessments at the census unit and farm levels could aid in finding such sensitive populations. The index aggregated at the agricultural census unit level (Figure 24) presents a different image for social vulnerability. The southeastern area that borders with Bolivia and

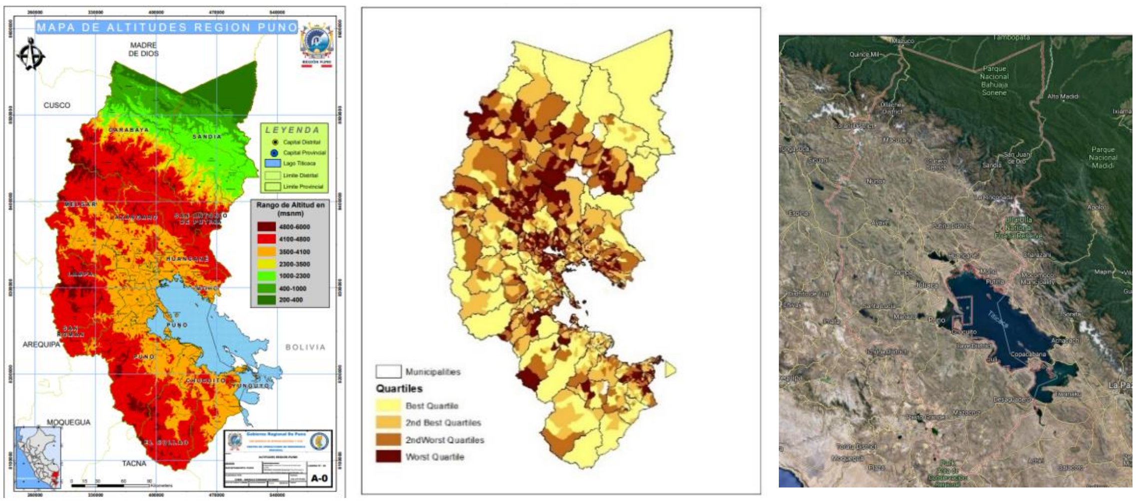

Figure 25: *A comparison with the topography. Elevation map provided by COER Puno (left), social vulnerability index (center), and Google's satellite image (right).*

the end of the Altiplano include some of the worst cases for social vulnerability. But most of the highly vulnerable cases are in the northern areas above Lake Titicaca.

Social vulnerability at the census unit level appears to be spatially associated with topography at the border of the Altiplano. The pattern around Altiplano's boundary is not evident at the municipality level. Figure 25 presents a comparison with the topography of the region. The end of the Altiplano is not the area with the highest elevation, and fluctuation in altitude is not found throughout the entire vulnerable area. Since only one of the 22 indicators involves topography in this study, the clear delineation of the Altiplano border raises a question. What conditions cause socio-economic indicators to reflect the topography of the region? We cannot answer this question in this study, but we can identify it as needing more investigation. Further research should explore the reason behind such spatial association. If the census unit level provided more information than the municipality level, can the farm level provide even more information?

Visualizing vulnerability at the farm levels is difficult since the coordinates overlap with each other in many cases. Therefore, I visualize the farm analysis with maps representing the percentage of farmers that are most vulnerable. Figure 26 presents the percentage of farmers inside the administrative region (municipality in the left and census units in the right) that are part of the worst quartile (the most vulnerable). Some census units show up to 100% of their farmers in this category. However, 80% is the highest proportion of most vulnerable farmers inside an administrative division at the municipality level.

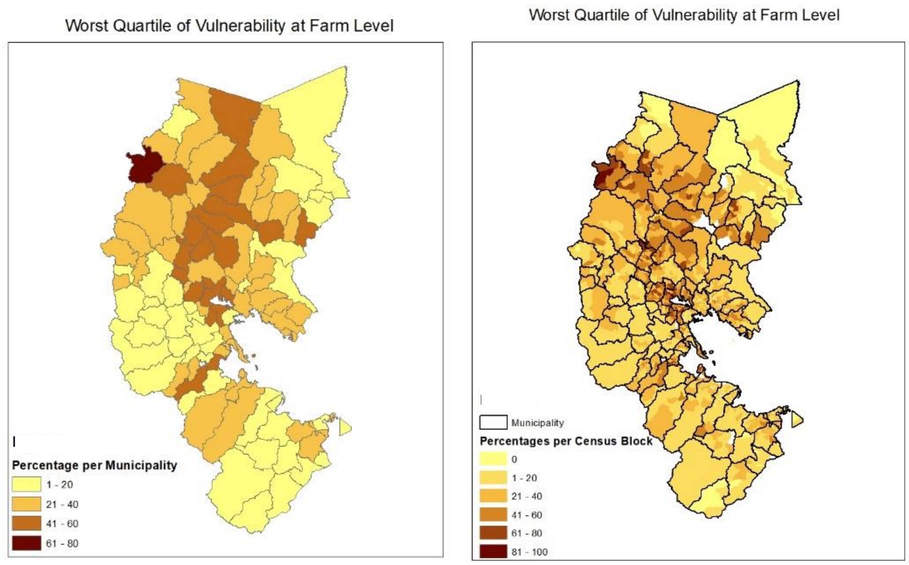

Figure 26: *Social vulnerability index at the farm level. Worst quantile mapped per municipality (left) and mapped per census unit (right).*

Spatial statistics aid in further understanding what is happening at the farm level. Spatial analysis at the farm level indicates (Figure 27) that the locations at the end of the Altiplano possess statistically significant clusters of highly vulnerable farms. The analysis reveals that 60%, and in many cases above 80%, of the farmers inside those census units are part of the vulnerable clusters. Contrary to other levels, the farm level index did not present visible patterns visible without performing spatial statistics analysis. Furthermore, the outliers in the data are minimal and dispersed through the region.

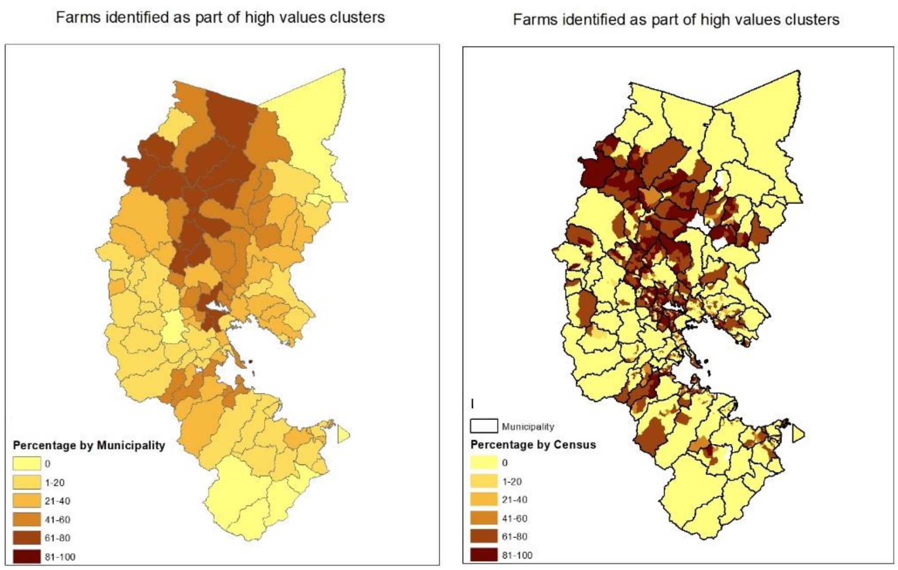

Figure 27: *Cluster and outlier analysis per farm. The map represents the farms found to be part of statistically significant clusters of high value per municipality (left) and per census unit (right).*

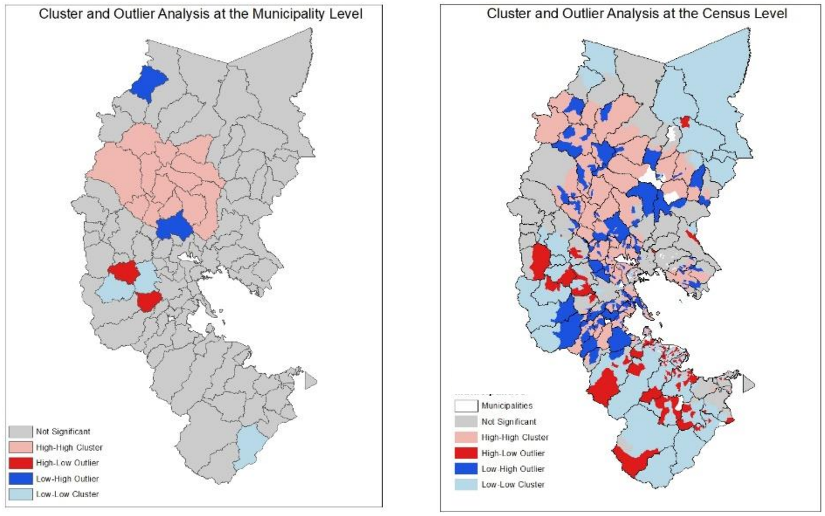

Figure 28: *Cluster and outlier analysis for municipalities (left) and for census units (right).*

Spatial analysis at the municipality and census unit levels present different spatial patterns. Figure 28 presents the cluster and outlier analysis for the municipality level (left) and for the census unit level (right). Such analyses present multiple census units as outliers of low value in the center and northern areas of the map. Southern areas present clusters of lower value with areas of concern at the census unit level. Also, the end of the Altiplano is visible with the cluster of high values at the census unit level. The municipality level has a greater proportion of nonsignificant results and a cluster of high values in the northern part of the map.

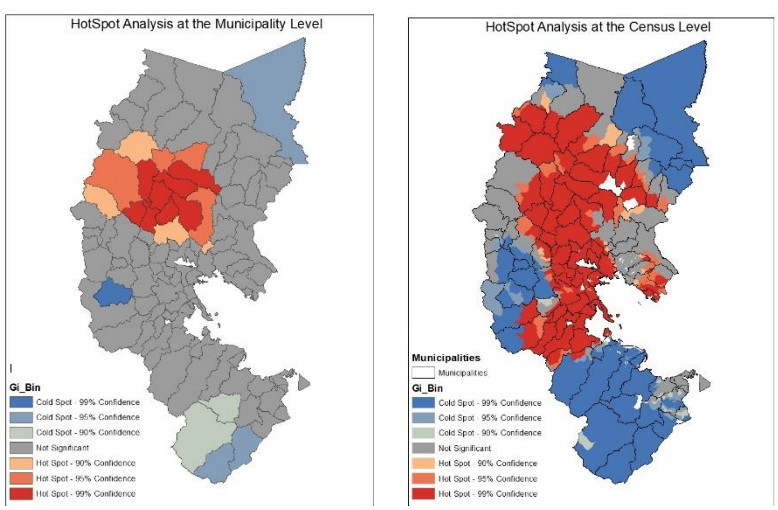

Figure 29: *Hotspot analysis for municipalities (left) and census units (right).*

Figure 29 presents the hotspot analysis for both the municipality level (left) and census units (right). The hot spot in the center-north of the map is similar to the cluster and outlier analysis but illustrates a center of worst cases inside the cluster. Areas with cold spots appear at the municipality level where they did not on the previous analysis. The hotspot analysis at the census unit level gives an interesting pattern of high values. Again, the end of the Altiplano is

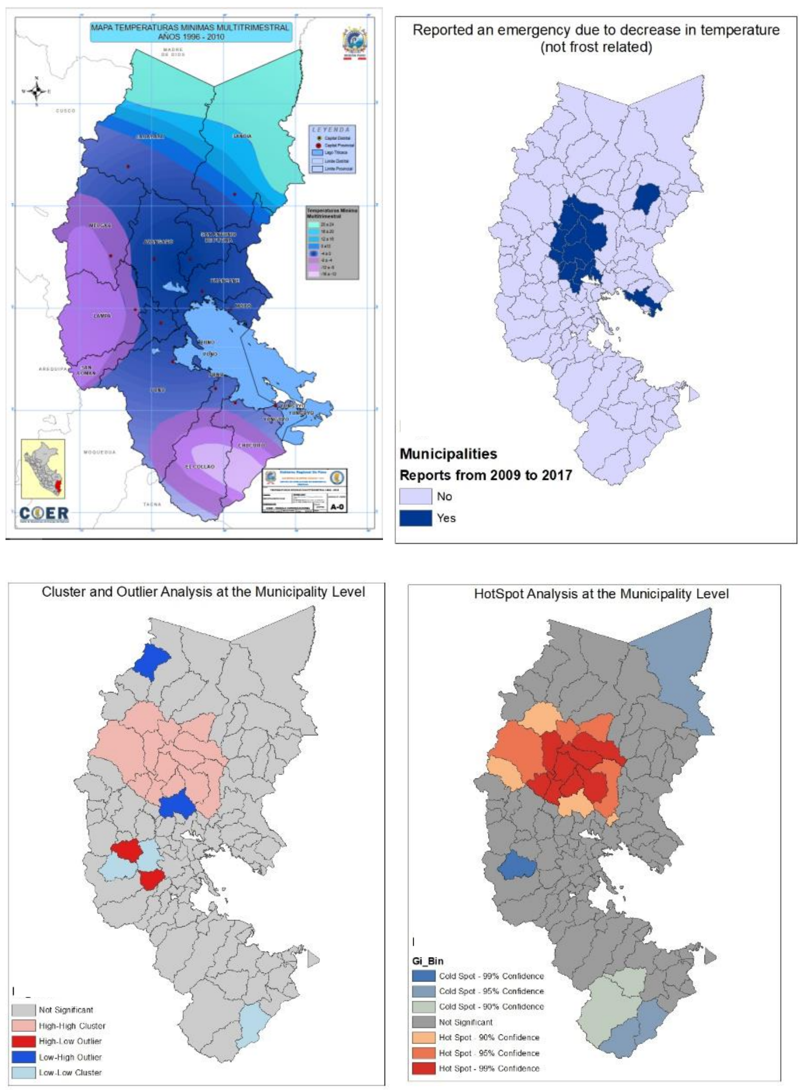

Figure 30: *Minimum temperatures in the region (top-left), reported emergencies related to low temperatures but not frost (top-right), cluster and outlier analysis for social vulnerability (bottom-left), and hotspot analysis for social vulnerability (bottom-right).*

visible at the census unit level; however, a larger area of concern appears at this level. As seen in the cluster and outlier analysis, areas with better conditions include outlier areas in need.

Another finding of interest is the similarity of the hotspot analysis at the municipality level with the impacts revealed in my first study (Figure 30). The actual temperatures of the region do not match the reported emergencies related to cold temperature (but not to frost). However, some spatial association is present between those impacts related to temperature that are not supposed to be extreme with hot spots of high social vulnerability. This raises the possibility that places with clusters of high social vulnerability might not require extreme weather conditions for impacts to occur.

The level of analysis optimal for decision-making might vary according to who the information is supposed to aid and for what purpose. Therefore, one cannot identify a single "correct" scale of analysis. Furthermore, the results of this study suggest the need for a more detailed look at impacts resulting from weather events of lesser intensity and duration. Social vulnerability might be strongly spatially associated with such impacts. Moreover, the reason that socio-economic indicators follow some patterns linked to topography is unknown; this pattern should be studied further.

Chapter VII: Integrated Geons and Social Vulnerability Assessments (Study Three)

Introduction

As seen in the previous chapter, spatial patterns of social vulnerability change somewhat with level of aggregation. Due to the complexity in the data and the modeling of individual behaviors, spatially aggregated units are necessary; however, such units are typically not meaningful regions but administrative divisions (King and Blackmore, 2013). An administrative boundary is an echo of governmental relations (Guoen and Yuanyuan, 2012), an abstract entity that defines the limits of administrative responsibility (Hamilton et al., 2005). These human-made borders are physically intangible in most cases but have tangible effects (Schonewald-Cox and Bayless, 1986). However, they rarely correspond to variations in vulnerability (Larmarange et al., 2011). In geographic research, spatial units are usually determined by data availability rather than by the dynamics of one's system of interest (Montello, 2013; Preston et al., 2011).

This standard approach to vulnerability mapping is highly problematic insofar as we do not know the exact spatial configuration and boundaries of the geographical area that encompasses the phenomenon under study (Kwan, 2012). Even though the goal of a sophisticated systems approach is to model at the individual level, sometimes it is optimal to aggregate data to units that offer a higher level of abstraction (Bonabeau, 2002). Research conclusions and administrative decisions based on information that does not consider the effects of spatial scales and geographical boundaries may be misled and can have undesirable impacts (Kienberger et al., 2009).

An approach that is independent of administrative boundaries was developed by Lang et al. (2008). This relatively new approach to aggregation and regionalization is called the *geon* approach (deSherbinin, 2014) (not to be confused with the use of the word "geon" by Biederman [1987] in his recognition-by-components theory of object perception.) Geons, in the context of social vulnerability assessment, are similar to the "geo-atoms" proposed by Goodchild et al. (2007): a "representational primitive [that] has the capability to serve as the foundation for both object-based views through aggregation as well as field based views through a convolution operation using some discretization" (Ahlqvist, 2007, p. 1). Geons are not the smallest or most atomic unit, as is the case with topons (space units) or chronons (time units) discussed by Couclelis (2010). As such, geons do not claim to be undividable (Lang et al., 2014). A geon is designed to be as small as needed so it is maximally applicable in a given context (Lang et al., 2014). Nor should geons be confused with the Elementary_geoParticle concept proposed by Voudouris (2010). Geons are basic building blocks with no predefined substructure; Elementary_geoParticles possess the fixed definition of a cell (Lang et al., 2014).

Geons are homogenous spatial objects generated by a scale-specific spatial regionalization of a complex and multidimensional geographical reality (Lang et al., 2014). Two types of geons appear in the literature: composite geons (for functional land use classes) and integrated geons (for abstract concepts). Due to the abstractness of social vulnerability assessments, I use integrated geons. I aim to create homogeneous and integrative spatial regions independent from administrative units (Kienberger and Hagenlocher, 2014).

Studies have used integrated geons to measure social vulnerability (Bizamana et al., 2016; Hagenlocher et al., 2014; Kienberger et al., 2009; Kienberger, 2012; Kienberger and

Hagenlocher, 2014), in order to address this abstract, yet policy-relevant, phenomenon (Kienberger and Hagenlocher, 2014). Three of these studies involve malaria in Africa, two involve floods in Austria and Rwanda, and one is about droughts in Africa. The geographical scale for this approach goes from relatively small scale (e.g., river catchment in Kienberger [2009] and a district in Kienberger [2012]) to large scale (e.g., multiple countries in Hagenlocher et al. [2014] and national level in Bizamana et al. [2016]). These studies all focused on Africa, except for one done Austria. There is a "missing middle" between local and cross-country assessments in these integrated geon studies, although a middle level of analysis is usually misisng in vulnerability assessments (Lobao et al., 2008).

Chapter's Objectives

In this study, I intend to explore a methodology that maps social vulnerability according to the homogeneity of its indicators rather than according to administrative boundaries. Vulnerability assessments are frequently mapped using variables that are spatially aggregated. However, this standard approach is highly problematic, insofar as we don't know the exact spatial configuration and boundary of the geographical area that meaningfully expresses the phenomenon under study. Standard approaches do not explore the appropriate boundary for mapping such assessments. Here, I explore this issue by implementing homogenous regionalization techniques for the multivariate index of vulnerability as well for each vulnerability domain (capital). Also, this study represents the first application of these techniques in vulnerability assessment outside of Africa or Europe.

In this chapter, I explore the use of a methodology that identifies the most vulnerable farmers but does not necessarily follow administrative boundaries. This exploration is organized with respect to the following hypothesis:

- Integrated geons will be more helpful than traditional regionalization methods in identifying and presenting the locations of the most vulnerable farmers in the region.

Methodology

The integrated geon methodology used here is also designed around the Sustainable Livelihood Framework (SLF), given that the framework has proven beneficial for assessing the ability of households to withstand shocks (Chambers and Conway, 1992; Ellis, 2000). To recap, 22 indicators were selected for assessing social vulnerability, as described and justified in Chapter 4. As a reminder, the indicators are:

- Illiteracy
- Education Attainment
- Spouse's Education Attainment
- Dependency Ratio
- Infant Mortality Ratio
- Child Malnutrition
- Gender
- Sources of Agricultural Information
- Agricultural Consulting
- Farmers Association's Membership
- Farm Size
- Agro-ecological zone
- Land Use
- Certified Seeds
- Rainfed Agriculture

- Tractors
- Distance to Town's Center
- Improved Kitchen
- Sources of Incomes
- Land Ownership
- Hired Labor
- Self-Reported Income

Next, I standardized the indicators using the equation found in Kienberger and Hagenlocher (2014): $V_i' = \frac{(v_i - v_{min})}{(v_{max} - v_{min})} * 255$. After standardization, each indicator is rasterized by transforming polygons of data into an image made of pixels.

After rasterization, I delineated homogenous vulnerability regions using a multi-resolution segmentation procedure carried out with the eCognition software. The multi-resolution segmentation procedure is a region aggregation technique that merges similar neighboring pixels—using local homogeneity criteria—as additional layers are added (Baatz and Schape, 2000). The criterion for homogeneity is based on the degree to which two pixels fit together and applies an assigned scale parameter establishing the minimum degree of fit required to treat neighboring pixels as appropriate for merging (Baatz and Schape, 2000). If the least degree of fitting is not reached, merging stops and gives the resulting segmentation that satisfies homogeneity. Choosing the appropriate minimum value for the scale parameter is a trial and error process in which the minimal rate of change between the different parameters is desired.

In the final stage, a liner combination of all indicators was used to obtain the final social vulnerability score. Resulting values are then rescaled to fall within zero to one for visualization. The integrated geon maps were overlaid with municipality boundaries for comparison.

Results and Discussion

The results present a variation of homogeneity that in some cases completely disregarded the municipality boundaries present in the region. In other instances, relation to those municipality boundaries is present. Figure 31 presents a set of maps using integrated geons for each capital as well as for the overall social vulnerability index. Mapping indices based on geons significantly fewer units than the original census units. The integrated geon methodology created at least 80% fewer zones than the census units. In the overall social vulnerability map, the methodology combines the 3,009 original census units into 500 geons.

Figure 31: *Maps representing assessments using integrated geons. Lack of social capital (top-left), lack of social capital (top-center), lack of natural capital (top-right), lack of physical capital (bottom-left), lack of financial capital (bottom-center), and overall social vulnerability (bottom-right).*

Homogeneity differs by domain—the maximum is 591 geons of financial capital, and the minimum is 331 geons of natural capital. As expected, neighboring farmers possess more homogenous levels of natural capital than of other capitals. A higher heterogeneity in financial capital is to be expected, given the diversities of income among individuals. In the next section, I discuss in detail each map and overlay municipality boundaries on them in order to examine heterogeneities inside municipality divisions.

Figure 32 presents the lack of human capital for Puno using integrated geons, with and without municipality borders. The lack of human capital is high on the northwestern side of the region. This is exacerbated in areas closer to the end of the Altiplano, where elevation begins to fluctuate. In contrast, northeastern and southeastern areas present better levels of human capital. Municipalities with areas that have very low levels of human capital tend to

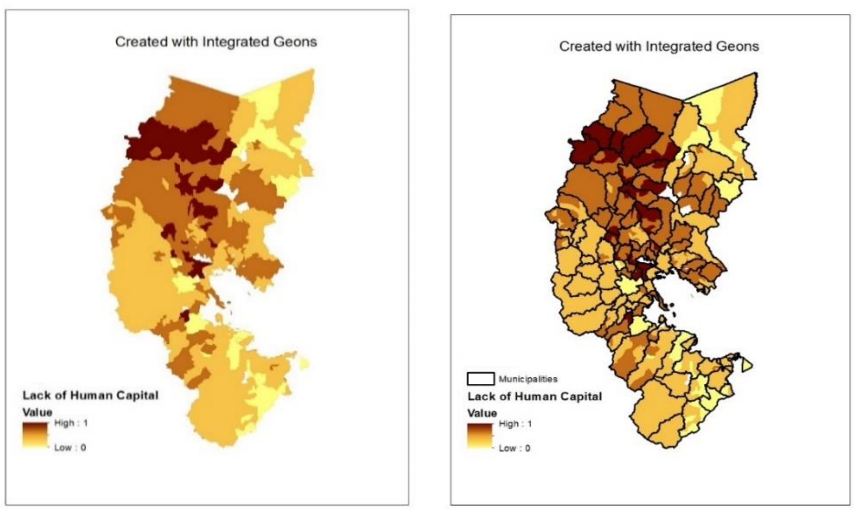

Figure 32: *Lack of human capital using integrated geons (left) and with overlaid municipality boundaries (right).*

be low throughout and could be of concern to relevant authorities. Few municipalities present extreme values of human capital.

Figure 33 presents the lack of social capital in Puno, with and without municipality borders. Most of the department of Puno has poor social capital with very few areas displaying better social capital levels. Compared to other capitals, social capital presents the most homogeneity in values across the entire department, and the values are fairly poor. An area of better social capital in the center west of the map is part of two neighboring municipalities. An interesting situation was the boundary between the extremes coincides with their municipality boundary.

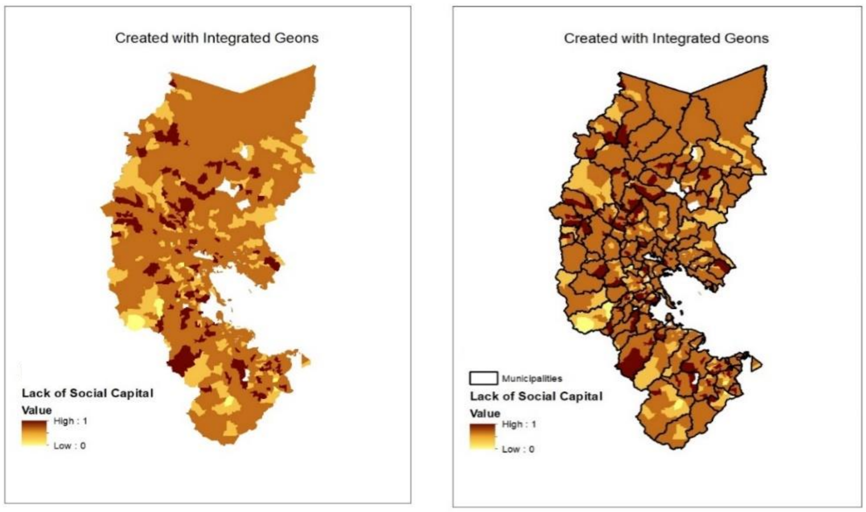

Figure33: *Lack of social capital using integrated geons (left) and with overlaid municipality boundaries (right).*

Figure 34 presents Puno's lack of natural capital, with and without municipality borders. The lack of natural capital is strongest surrounding Lake Titicaca, mainly because

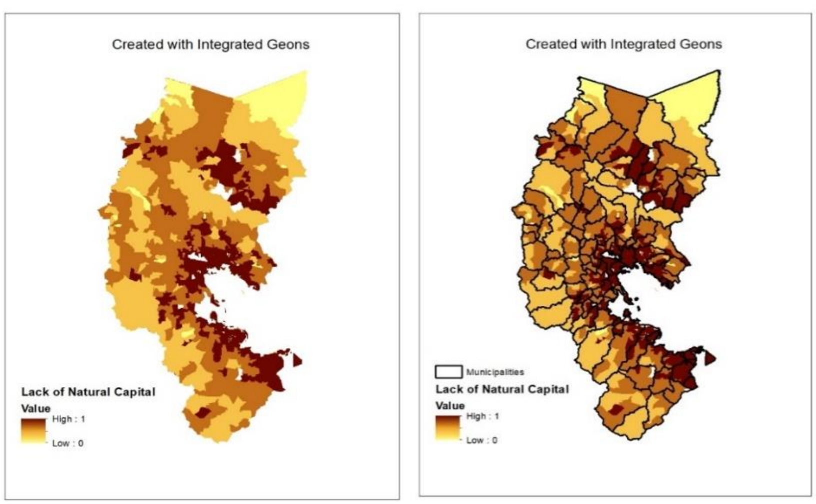

Figure 34: *Lack of natural capital using integrated geons (left) and overlaying municipality boundaries to the results (right).*

numerous farms are less than five hectares. Only the municipalities surrounding Lake Titicaca have 100% of their territories with the lowest level of natural capital. The western

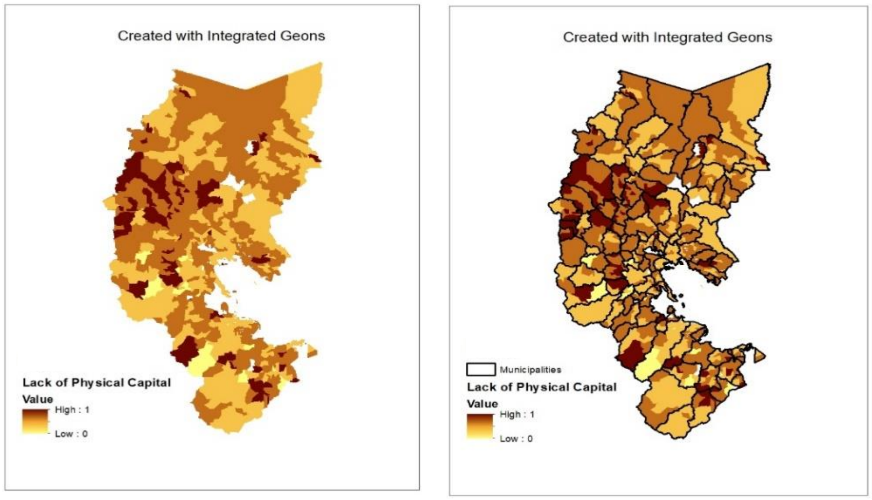

Figure 35: *Lack of physical capital using integrated geons (left) and with overlaid municipality boundaries (right).*

outskirts of the region present middle levels of natural capital because the land there available for crops is limited. There is also low natural capital at the end of the Altiplano but only on the eastern side. It is intriguing to consider why natural capital shows this pattern, but we cannot tell from the maps presented here.

Figure 35 presents the lack of physical capital in Puno, with and without municipality borders. The lowest levels of this capital can be seen in the center and western areas of Puno, a pattern of great importance for decision-makers. In the southwestern outskirts, two neighboring municipalities have contrasting extreme values, the same pattern we observed with social capital. What explains these extremes in both physical and social capital across the municipality boundaries?

Figure 36 presents Puno's lack of financial capital, with and without municipality borders. Low levels of the financial capital are present in southeastern areas near the Bolivian border as well as northern areas toward Cuzco. Certain locations display better levels of

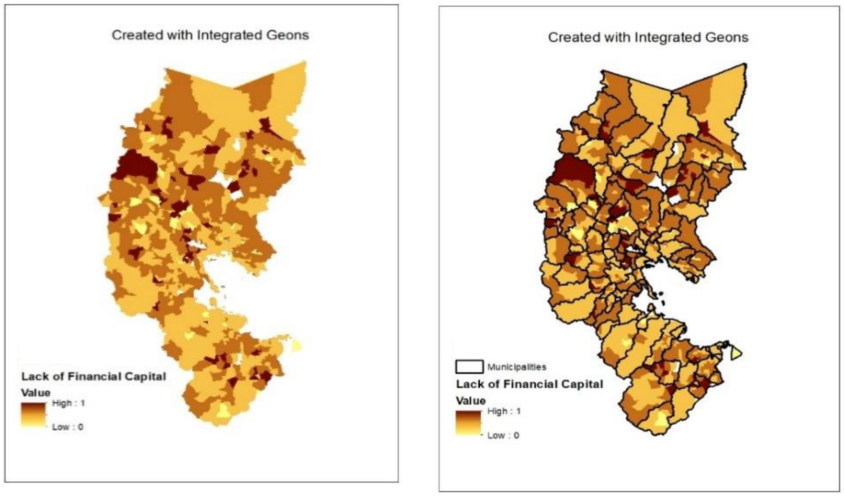

Figure 36: *Lack of financial capital using integrated geons (left) and with overlaid municipality boundaries (right).*

financial capital, an important fact in a region dominated by poverty. Overlaying municipality boundaries on this map allows us to see which municipalities possess heterogeneous vs. homogenous levels of vulnerability. Most of the municipalities are heterogeneous inside their boundaries; however, municipalities with the worst values tend to

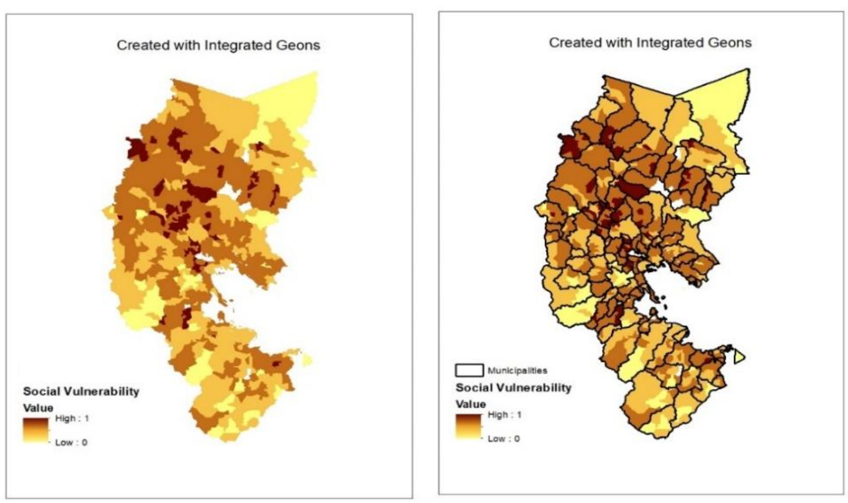

Figure 37: *Social vulnerability index using integrated geons (left) and with overlaid municipality boundaries (right).*

be more homogeneous.

Finally, Figure 37 presents the multivariate index of Puno's overall social vulnerability, with and without municipality borders. The worst scores concentrate in the north with better values in the northeast and south. Overlaying municipalities reveals variation within municipalities, but extreme contrasts are not evident inside them.

Geons often do not follow municipality divisions, but patterns following those boundaries was present in the maps. For example, both physical and social capital presented two neighboring geons displaying extremes of the index values. The boundary separating the geons coincides with the municipality boundary.

This study cannot cover the specific reasons or how significant is that certain vulnerabilities follow municipality boundaries. However, the delineation of the boundaries could be an indication that local policies and resources are either hindering or aiding these areas. The population on the dataset are farmers and raises questions related to the entire population: are this difference only with farmers? Or the composition of the population affects the resources since one could be entirely farmers and the other a minority in the community? A study on why certain vulnerability patterns follow administrative regions would be imperative to implement similar policies on their neighboring areas. Furthermore, could provide information on what characteristics are causing the heterogeneity.

Perhaps municipalities can work with their neighbors to address similar concerns. Furthermore, regional officials can use these maps to address concerns at the level of the phenomena and not just according to imposed administrative boundaries. However, the methodology is not easy to replicate due to its cost and required software. The methodology uses a software that its licensing could be costly to many universities and organizations. Future efforts should develop affordable ways for regional and national agencies in developing countries to apply this approach.

Chapter VIII: Conclusion

Assessing all potential aspects of vulnerability is difficult. However, the literature is increasingly recognizing the role that social inequality plays in creating vulnerabilities. Human vulnerabilities must be a fundamental concern in developing and accessing disaster-related policies. Therefore, a better understanding of the components that lead to vulnerability—understood within its local context—is imperative to reducing the negative consequences of hazard events, including those related to climate. This dissertation explored the importance of local context in shaping the indicators selected for vulnerability indices and the quantitative patterns of its spatial distribution.

Using a mix-method approach combines the strength of both qualitative and quantitative methodologies while lessening its weaknesses. The popular purpose of triangulation, corroboration of the results with different methodologies, is not the only purpose for conducting mix-methodologies. This dissertation used a qualitative methodology to inform quantitative methodologies (e.g., aiding in the selection of social vulnerability indicators). The qualitative portion of this dissertation takes an inductive approach that it allows discoveries to arise unexpectedly due to the slow accumulation of evidence and provides entry points for intervention. Humans do not follow rational behaviors and understanding the local context allow us to observe where are those entry points. Furthermore, adding context to an asset-based assessment aids in understanding the information behind an indicator thus making interpretation meaningful.

Ethnicity and native language reveal a complicated relationship to social vulnerability in this region, specifically among a population made up of farmers, 92% who identify as Quechuas or Aymaras. My results raise questions about using physical distance to health facilities, schools, and downtown areas as indicators of vulnerability. Education attainment is essential, and whether a farmer completes high school or not significantly influences levels of social vulnerability for his or her future. Years in school had different meanings for many farmers as a function of differences in the quality of education, differences that are understood to affect what knowledge is acquired in school. Another important component of social vulnerability and local context are the weather-related events and impacts a farmer has experienced.

Every year farmers in the Peruvian Altiplano suffer and die due to cold temperatures in the region. Focusing only on heatwaves because of their increasing frequency and intensity around the world is analogous to ignoring farmers in rural locations because the world is urbanizing. Moreover, temperature-related events not only result in death but negatively impact livelihoods, health, and comfort. People should be able to do more than merely survive cold temperatures. Furthermore, stakeholders should pay attention to improving indoor thermal comfort, not just outdoor. The lack of indoor thermal comfort brings farmers to use their kitchen for warmth, and the lack of well-designed kitchens in the region creates health complications for many farmers and their families.

Farmers with low human agency and low access to assets struggle to survive every cold night. Distributing blankets and food should not be the sole response to such conditions. Long-term solutions are needed to abolish the never-ending cycle of the harmful effects of cold temperatures in the region. The optimal solution would continue using reactive approaches, such as humanitarian aid when needed, but add to those a focus on creating robust long-term proactive approaches to improving indoor thermal comfort in the region.

When talking about impacts related to low temperatures, the primary concerns are due to social vulnerability and a lack of resources. However, impacts related to drought are complex and go beyond social vulnerability. Governance, access to water, good quality of wells, and other methods of collecting water are of great importance.

The information provided by different agencies can be contradicting and confusing at times. Access to certain kinds of information alone does not provide everything that leaders need to understand what is happening on the ground and everything farmers need to adequately prepare for drought. Dealing with drought-related impacts would benefit from a stronger network of information and improved methods of transmitting a concise and less confusing message to stakeholders (not just information from government agencies to the people but from the people to the agencies).

Both qualitative and quantitative analyses point to concerns about social capital in the region and indicate the need for a stronger understanding of the role of social networks in vulnerability. Social networks are a critical component of the social capital that protects against vulnerability, but vulnerability assessments often reduce social networks to an asset. These assessments rarely study how social networks can aid members to cope with a crisis, including finding alternative livelihood strategies. Furthermore, a binary approach to social network (have it or not) is problematic, because while membership bolsters trust and access to resources, the distribution of such benefits are uneven across specific networks and specific positions within a network. A network does not benefit all its members equally, nor does each network benefit its members equally. These variations raise questions about how to measure network interactions in vulnerability assessments. Should social networks even be included as part of social capital? Should social networks be treated as a new component of vulnerability that connects entities (individual farmers, families, administrative divisions, agencies) forming such networks? I included social networks only as an asset in this dissertation, but the qualitative results suggest that more effort should be focused on how best to include social network structures and connectivity in spatial vulnerability assessments.

Mapping social vulnerability indices allows areas of extremely high or low vulnerability to emerge. However, vulnerable populations remain unseen at certain levels of aggregation. The level of analysis optimal for decision-making likely varies according to who the information is aiding and the purpose of the analysis. Therefore, a single correct scale of analysis cannot be suggested. This brings interest to the uses of an interactive interface to study vulnerability at multiple scales rather than the typical static map for assessing vulnerability.

The results of the present research suggest the value of a more detailed look into the impacts that result from weather-events of less intensity and duration. Social vulnerability might be strongly spatially associated with such impacts. Also, the reason that socio-economic vulnerability indicators are spatially associated with some aspects of topography is unknown, and this association clearly deserves further study.

The geon methodology creates homogenous areas that do not necessarily follow administrative divisions. Region officials can use these maps to address concerns at the level of phenomena and not just according to imposed administrative boundaries. Many cases showed homogeneity in vulnerability indicators across neighboring municipality boundaries. In such cases, municipalities can work together with neighbors to address similar concerns.

However, patterns linked to administrative boundaries are present in some of the geon maps. For example, physical and social capital present two neighboring geons at both extremes of the index values. When municipality boundaries are added to the map, it is revealed that the boundary separating the geons coincides with the municipality boundary. Therefore, while it is quite valuable to map vulnerability according to the boundaries of phenomena instead of administrative boundaries, in some circumstances, the boundary patterns do coincide.

In su, this dissertation demonstrates how qualitative and quantitative research methods can build on each other to create a more comprehensive assessment. With the increase in the uncertainty due to weather and climate hazards, using ethnographic approaches to understand the local context is imperative. Such methodologies could act as a bridge that connects local understandings with a multitude of stakeholders and scales.

Results from this dissertation have the potential to serve as scaffolding for future adaptation strategies in Puno and, eventually, in other areas less developed parts of the world where agriculture provides the main livelihood. Ethnographic components of these research provide an in-depth understanding of the location; however, they possess transferability. The results from this dissertation could be transferable to the study of social vulnerability in other high mountainous regions or rural environments.

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