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Assessing the Determinants Facilitating Local Vulnerabilities and Adaptive Capacities to Climate Change Impacts in High Mountain Areas: A Case Study of Northern Ladakh, India

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ASSESSING THE DETERMINANTS FACILITATING LOCAL VULNERABILITIES AND ADAPTIVE CAPACITIES TO CLIMATE CHANGE IN HIGH MOUNTAIN ENVIRONMENTS: A CASE STUDY OF NORTHERN LADAKH, INDIA

By

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ABSTRACT

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Assessing the Determinants Facilitating Local Vulnerabilities and Adaptive Capacities to Climate Change Impacts in High Mountain Environments: A Case Study of Northern Ladakh, India

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Climate change is increasingly redefining the dialectic exchange between human systems and ecological processes. While the rhetoric of climate change is articulated within broad arenas of governance and policy, the realities of climate change are experienced at the local scale. Effective adaptation measures must therefore be commensurate with local resources, needs and objectives while remaining aligned with larger decision-making efforts.

The impacts of climate change are heterogeneous and vary with geographic context. Biophysical parameters interface with socioeconomic and political forces to greatly influence the outcome of climate-related risks at the local level. In the high mountains of the western Himalayas for example, climate change is tangibly influencing precipitation patterns, glacial movement and the occurrence of extreme weather events. Rather than work in isolation, these adverse effects exacerbate ongoing stresses related to chronic development and demographic issues. Assessing the nature of biophysical and social vulnerability to climate change, and the initial conditions that differently expose some groups of people over others to climate change impacts, can correspondingly aid in the identification of entry points for adaptation and response planning.

This research draws from theoretical traditions couched within geography, political ecology, natural hazards and risk management and climate ethics to assess the multi-scalar factors that aggregate at the local level to shape climate change outcomes. This unique conceptual background directly informs a mixed-methodological design that integrates surveys, climate trend modeling and geospatial mapping to evaluate how climate change is unfolding on-the-ground to influence local engagement around climate change response. In doing so, the key climatic and non-climatic drivers propelling initial conditions of vulnerability are identified as are the determinants facilitating opportunities for adaptation. Research findings suggest access and availability of future water resources will work in tandem with transformations in the wider political economy to significantly determine the long-term ability for many impacted mountain communities to live and thrive. Traditional assumptions of vulnerability are challenged and the need to consider cultural frameworks of social resilience, sense of place and community cohesion are advanced.

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Ultimately, none of this would have been possible without the incessant support and love from my family, especially my parents, brother and grandmother. From a young age, they instilled in me an unwavering love for the outdoors and natural landscapes, which continue to provide the backdrop to all my life endeavors. Lastly, I owe the completion of this project to my husband Bradley Barrett who has been my guide, traveling companion, best friend and continual ally, thank you.

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Introduction

Introduction

On the night of August 5th, 2010, residents in the town of Leh, Ladakh were violently awakened by a fury of storm and rain. A climatic microsystem known as a cloudburst had unleashed a torrent of rain, rock and debris onto the remote western Himalayan region. The rising waters quickly engulfed towns and settlements along the Indus River, with some areas reportedly receiving more than twice their average annual rainfall within one hour (Thayyen et al., 2013). In its devastating wake, the cloudburst affected over 50 mountain villages, damaged nearly 2,000 homes and blanketed more than 3,500 acres of prime agricultural lands in mud and sediment. By the time the waters receded, more than 250 people were dead with thousands displaced, harmed or otherwise impacted (IMD, 2010). Equally calamitous were the long-term losses in tourism revenue, cultural and religious artifacts and infrastructural support, as well as profound psychological distress and emotional trauma. Culminating into Ladakh's worst recorded natural disaster, the cloudburst event in the western Himalayas was an ill-boding harbinger of climate changes already underway and those yet to come.

Incidences like the cloudburst event in Ladakh are a vivid testament to the dangers posed by a changing and increasingly warming world. To be sure, the climate is changing and many of the earth's most intriguing and complex landscapes are being affected. Such is true of high mountain areas where climate change is redefining the ethos and interface between people and the land. For example, in the world's highest and most extensive concentration of mountains, the Himalayas, warming global air temperatures are altering the ability for these crucial headwaters to support and sustain life. In this vast stretch of peaks and valleys, communities are deeply attached to the mountains as a source of livelihood and wellbeing. Similar to other high mountain environments, changing climatic conditions in the Himalayas, including warming air temperatures, unpredictable precipitation patterns and the retreat of mountain glaciers are rapidly transforming essential ecosystem functionality and the human activities that depend on them. In addition and equally disconcerting, are the adverse implications climate change presents in the form of extreme weather events and associated natural hazards, such as flash floods, landslides and droughts. These conditions exacerbate existing stresses imposed by the economic, political and social marginalization of many Himalayan populations. How climate change impacts materialize at the local level to implicitly and explicitly affect households and communities thus operates as a process of biophysical circumstance and socioeconomic context. Identifying the key causal drivers accentuating vulnerability to climate change impacts can correspondingly yield valuable insight regarding potential entry points for adaptation and response planning to transpire.

The fundamental goal of this research is to evaluate community and household vulnerabilities and adaptive capacities to climate change impacts in terms of perceived risks, observed trends and existing livelihood conditions. Guiding the course of this research design are the following specific objectives: (1) elicit local interpretations and perceptions of climate change impacts, (2) compare and contrast local narratives of changes in climate to the meteorological record, climatic data and other empirical measurements, (3) examine household and community vulnerability and risks to climate change with respect to geographic context and, (4) identify the main structural drivers and multi-scalar phenomena that work to both enhance and inhibit adaptive capacity to climate change impacts at the local scale. In assessing the bioclimatic, socioeconomic and political parameters determining household and community vulnerability to climate change impacts, this research will inform theory and broader scales of decision-making on climate change response to more effectively reflect the realities and circumstance of local context.

Structure of Dissertation

This dissertation is divided into six chapters, with three chapters dedicated to data analysis and three supporting chapters. Following this first introductory chapter, the second chapter discusses the literature review and theoretical background for this research. The aim of this chapter is to establish the conceptual context and axiological framework applied in this study for examining local vulnerabilities and adaptive capacities in high mountain areas. In particular, the chapter draws heavily from antecedent traditions based in geography and the contributing role scale plays in reconfiguring the spatial and temporal arena where climate change impacts interact with human systems. Concepts of vulnerability, adaptation and adaptive capacity are explained as well as the theoretical toolkits commonly utilized to examine the interface between these three intervening processes. Literature within the natural hazards and disaster community is referenced as a field of scholarship specializing in vulnerability and human response to environmental risks. Studies within the natural hazards and disaster management discipline tend to emphasize aspects of both social and biophysical vulnerability in determining the outcome of environmental change at the local level. Also important in shaping climate change impacts at the household and community scale is the arrangement of power relations and the distribution of resources, capital, representation and knowledge. Theoretical themes within political ecology and social justice are consequently discussed as a way to highlight the uneven capacities and ethical implications involved when climate change impacts differentially affect the world's poorest and most marginalized populations. This conceptual background directly feeds into and legitimizes the methodological design applied in this research for assessing the nature of vulnerability and adaptation to climate change impacts in each of the study areas.

Chapter three is the first of the three data intensive chapters and interrogates the process with which climate change is contextualized, interpreted and communicated at the household scale. This chapter explicitly addresses the first of four guiding research questions and delves into the psychological, social, cultural and demographic dimensions of climate change. Using household surveys and statistical analysis, descriptive associations are identified that convey the degree that climate change is perceived, valued and prioritized at the household level. Individual results are then scaled-up to assess and characterize a community-wide portrayal of climate change impacts.

The fourth chapter is dedicated to the second research question and the identification of climatic trends in Ladakh over time. As such, this chapter employs the temporal definition of scale to closely examine changes in temperature, precipitation, land use patterns and crop yields. Linear regression modeling is used to quantify significant correlations between time and climate, as well as associations between time and agricultural livelihood practices. Findings from this chapter express the empirical observations of climatic change in Ladakh.

Chapter five is the final data analysis phase of this research and applies the spatial connotations of scale to examine the relationship between geographic context and climate change impacts. By integrating datasets and research findings discussed in the previous two sections, this chapter uses geographic information systems (GIS) to model the distribution and concentration of community values toward climate change impacts at spatially-explicit levels of analysis. This was an important part of the research process because it indicated the range of values regarding perceived levels of a risk environment and further, the strength and intensity with which community members engage with future climate change response. In doing so, the third research question was addressed and an evolving dialogue on climate change was established within the larger Domkhar and Leh watersheds.

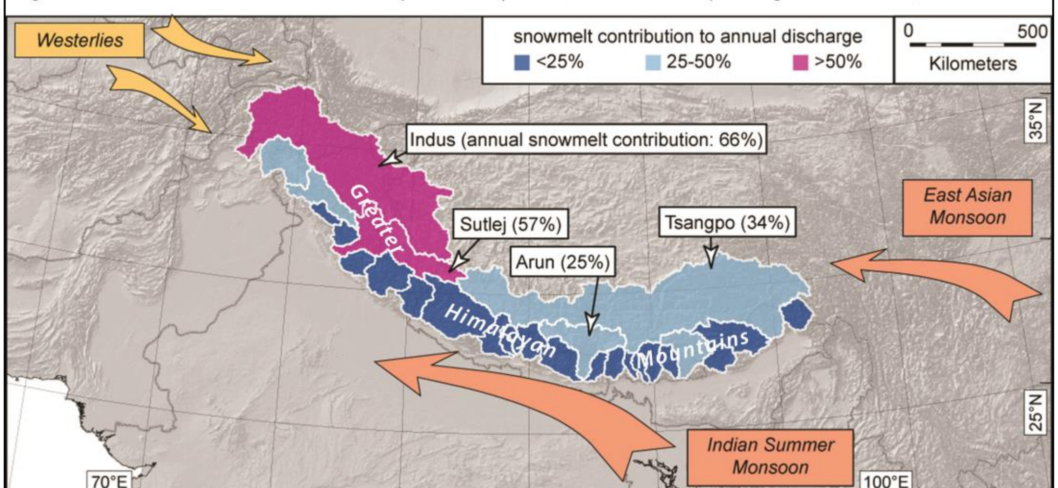
Chapter six is a synthesis of the preceding data analysis chapters and associated research questions. As the concluding chapter, this portion of the dissertation identifies key processes characterizing climate change vulnerability and adaptation in high mountain areas. In particular, this chapter isolates the underlying socioeconomic, political and environmental forces that encourage household and community vulnerability to climate-related impacts. In addition, this chapter proposes a set of potential recommendations to improve long-term community sustainability and reduce areas of vulnerability in the future. While summarizing the considerable challenges increasingly confronting the people and places of Ladakh, Chapter six similarly underscores the opportunities and adaptive mechanisms available to local communities in their emergent and ongoing efforts against climate change.

Research Setting: Climate Change in the Western Himalayas

The contrasting extremes of the Greater Himalayan region engender an inherent fascination and almost mesmerizing reverence for its sheer variability. The geomorphologic, cryospheric and physiographic properties of the Himalayas are a unique tribute to the powerful mechanics of the environment. Heavily glaciated, the Himalayan region contains the world's greatest concentration of high mountain peaks and is the largest repository of accumulated ice and snow outside the poles (Guneratne, 2010; Brower and Johnston, 2007). Accordingly, the Greater Himalayan arc, including the Hindu-Kush, Karakorum and Himalayan ranges, constitute vast reservoirs of water for much of Asia and parts of Europe. Originating at the base of Mount Kailash, the Indus and the Yarlungtsangpo-Brahmaputra rivers form the two principal Himalayan watersheds. Further supplemented by large downstream tributaries, including the Ganges, Sutlej, Yamuna, and Beas among others, these two rivers thread their way east and west out of the mountains, ultimately terminating at the Arabian Sea and the Bay of Bengal. Together, the Indus and Ganges river basins supply nearly a third of the world's population with water (Immerzeel et al., 2010).

In addition to hydrological processes, the altitudinal variability of the Himalayas is influential in shaping climate, in particular the seasonality of the Asiatic monsoons. Intense orographic lifting of warm and humid air during the summer generates a monsoon shift in the fall, bringing much needed rainfall to the many low-lying plains and deltas below. By contrast, lands situated within the northwestern rainshadow of the Tibetan Plateau are characterized by extreme aridity and lack of annual precipitation. In these areas, rainfall is minimal and communities primarily rely on winter snowpack and glacial runoff for their water source (Rautela, 2000; Zurick and Karan, 1999) (Fig.1.1). The wide variation in terrain, biodiversity and geologic tectonics truly make the Himalayas one of Earth's most formidable and provocative natural laboratories.

Figure 1.1: Contribution of snowmelt and major climatic patterns, Greater Himalayan range (Source: Bookhagen & Burbank, 2010)



Over time, human activities coupled with ecological processes have tacitly and overtly shaped the Himalayan setting. Subsistence practices of agriculture and animal husbandry have provided the primary means of food support for centuries. Livelihood strategies frequently consist of farming practices, such as swidden and terrace building, in addition to other activities like livestock rearing and transhumant agro-pastoralism. Historically, the Himalayas served as an important physical and economic land bridge linking the producing centers of the East with the colonial markets of the West. Therefore, the strategic value of the mountains as corridors of exchange made them important and contentious grounds since humans first settled there.

More recently, the Himalayas have been characterized as the geographical nexus where old customs meet and assimilate into new processes of modernity (Brower and Johnston, 2007; Zurick and Pacheco, 2006). This engagement in turn, is interconnected to the wider political economy and dictates the circulation and distribution of power, capital and resources at the local and regional level. Relevant issues of current and future concern on the Himalayas are correspondingly embedded within a larger theoretical canvas examining broad patterns of development and modernization. In particular, the rapacious rate of economic expansion and population growth in the adjacent countries of India and China strongly influence the livelihoods and environments within the Greater Himalayan region. As Brower and Johnston (2007) stated, "The ulcerating problems from past development, and fears over future development generate conditions and conflict that not only threaten the security of the state but at more fundamental levels, threaten the security of individual and group rights to culture, self-determination, livelihood, and life." Agencies of change often come in the form of infrastructural projects (e.g. Tehri Dam in India), national and transnational development schemes (e.g. Qinqhai-Tibet railway in Tibet Autonomous Region), commercial tourism (e.g. Mt. Everest) and, most recently large-scale environmental variability due to climate change (e.g. Tsho Rolpa glacial lake). The ways with which these variables coalesce within local and regional contexts will subsequently guide present and future interactions between mountain populations and the environment.

Indeed, climate change will undoubtedly meld with other issues stemming from both the domestic and global realm to substantially steer the shifting dichotomy between mountain livelihoods and ecological systems. For instance, in comparison to most other regions in the world, the temperature increase in the Himalayan range over the past 100 years has accelerated much faster than previously predicted (IPCC, 2013; 2007; Xu et al., 2009; Eriksson et al., 2008; Liu and Chen, 2000). Studies in Nepal and the Tibetan Plateau suggest that since 1961, average annual temperatures in the Himalayan range are increasing by up to 0.14°C per decade and could potentially rise by more than 5°C by 2080 (Shrestha and Aryal, 2011; Bhutiyani et al., 2009; Bajracharya et al., 2007). This continual warming trend has had significant effect on the region's water resources, most visibly with the retreat of glaciers and snowpack (Immerzeel et al., 2010; Eriksson et al., 2009; Dyurgerov and Meier, 2005). The recently published Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment report (2013; 2014) states that there is a very high measure of confidence that in the coming decades many glaciers in the Central Asian region will retreat, while smaller glaciers may disappear entirely. Further, current glacier extents are out of balance with current climatic conditions, indicating glaciers worldwide will continue to shrink in the future even without further temperature increase. Such significant changes in the global cryosphere are somber predictions for Asia's Himalayan water towers and the millions of people who depend on this vast hydrologic warehouse for sustenance, support and life.

Consequently, climate change is rapidly ushering many populations into an increasingly dangerous and precarious world. For communities in the Himalayas, effectively responding to the challenges from climate change is tantamount to their long-term survival. However, a diverse host of intervening processes rival climate change for political attention and social action and thus distract from an aggressive and mobilized climate change agenda. It is therefore crucial to integrate climate change response strategies into an iterative and multi-scalar framework that addresses ongoing development needs in concert with present and predicted environmental concerns.

Project Study Area

Figure 1.2: Location map, Ladakh, India

In the far northern reaches of the Indian Himalayas, geographically sandwiched between China's western border and Pakistan's eastern Kashmir, is the region of Ladakh (Figure 1.2). Constituting the eastern half of India's state of Jammu and Kashmir, Ladakh is the one of the county's largest yet most remote and least populated territories. Composed of nine different districts and with a total population of 117,232 people, Ladakh's capital is the town of Leh (Census of India, 2001). Leh is correspondingly the epicenter of government, tourism, commerce and education in Ladakh (Figure 1.3).

At elevations exceeding 11,000 feet, Ladakh is characterized by its arid and desert-like landscape. The region rests amidst the world's highest mountain ranges, including the Kashmiri Mountains to the west, the Karakorum and Hindu-Kush to the north, the central Indian Himalayas to the south, and the vast expanse of the Tibetan plateau to the east. Consequently, Ladakh falls within a rainshadow and receives minimal precipitation. Villages and homes predominantly rely on glacier-fed watering systems for domestic needs and irrigation purposes, which eventually feeds into the Indus River. Running from Tibet's western edge and into Pakistan's eastern Kashmir boundary, the Indus River basin is a lifeline for India's subcontinent and a considerable resource base for the Ladakhi people.

Figure 1.3: Photograph of Leh Town, Ladakh (Source: B.Barrett, 2012)

Like many rural areas across India, agriculture is the predominant livelihood for a majority of Ladakhis and approximately 95 percent of the region's population is engaged in some form of agriculture or cultivation (GERES, 2009). Alternative forms of employment in Ladakh include the government, border security forces and recently, a nascent tourism industry based out of Leh. In parallel with Ladakh's conservative water budget and harsh environment, local agricultural activities have adjusted to the region's extreme physiographic exigencies. As a result, strategically coordinated systems of irrigation, cropping patterns, harvesting times and livestock grazing are deeply instilled practices within Ladakhi agriculture. As such, sources of water, altitude, slope and aspect, solar radiation, soil content and proximity to the snowline are central ecological variables influencing the properties of local farming. However, historic dependency on the productivity of these food systems engenders a high degree of vulnerability to annual cropping yields and other agricultural outputs that can be affected by climatic variability (Bury et al., 2011; Jodha, 2005). Furthermore, the interconnectivity between social and ecological systems in mountain areas makes local communities acutely sensitive to the impacts of climate change, including variable weather patterns, climatic perturbations, biodiversity loss and natural hazards such as landslides, droughts and floods (IPCC, 2014; Orlove, 2009; Halvorson and Parker, 2007).

Previous studies suggest Ladakh has been transitioning into a new and increasingly more volatile environment due to climate change. Perhaps the most visible and tangible impact from rising global air temperatures has been the steady disappearance of regional glaciers. In the principle town of Leh for instance, where temperatures have increased by 1°C since 1973, the snow line has risen more than 490 feet (150 m) and the remaining glaciers have retreated by as much as 6.2 miles (10 km) in the past century (Vince, 2010; GERES, 2009). With no alternative water source, people are facing unprecedented threats to their traditional way of life. Already, two villages located in the Ladakh’s Zanskar and neighboring Spiti Valley have been relocated due to reduced water storage (GERES, 2009). Portending inauspicious implications for the future, the lack of water in Ladakh will likely compel a population of climate refugees to move elsewhere if present climatic scenarios remain unabated.

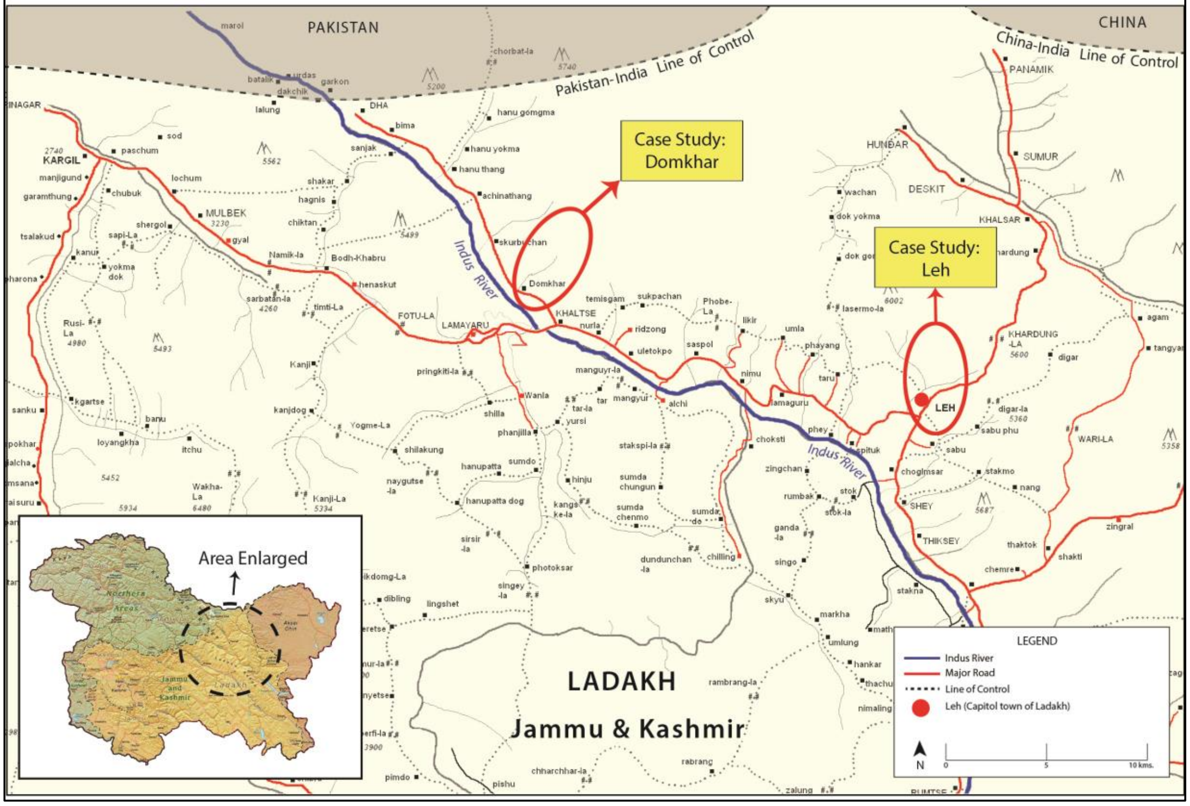
Ladakh is additionally experiencing other perturbations and anomalies in the hydrologic cycle at an increasing rate. For example, precipitation patterns in the region are becoming more variable and unpredictable compared to the past. While some areas in the Himalayas are receiving too little precipitation and glacial meltwater, resulting in the relocation of homes and settlements, other areas are experiencing too much precipitation and in shorter time periods (Xu et al., 2009). Moreover, a greater proportion of this precipitation is falling in the form of rain instead of snow (Gautam, 2010). In the western Himalayas, there has been a substantial upward trend in winter rainfall, concurring with projected Global Climate Change Models and assessments by the IPCC (IPCC, 2013; 2007; Archer and Fowler, 2004). It is estimated that in this part of the Himalayas, precipitation levels could increase as much as 30 percent by the end of the century (Kumar et al., 2007). Variations in precipitation trends reflects major changes in the strength and timing of the main weather systems driving Himalayan climatic patterns, including the Asian monsoon, inner Asian high pressure systems and winter westerlies (Erikkson et al., 2008). Alterations in weather systems have cascading effects down the ecosystem chain and influences river flow, groundwater renewal and surface discharge.

Changing climatic conditions in Ladakh are having immediate and reverberating effects across the landscape. Implications from climate change range from localized signatures, such as reduced stream levels and periodic heavy rainfall, to region-wide consequences like depleted glacial reserves and the latitudinal migration of plants and animals. As a region that has until recently, been largely overlooked by the modern political economy, Ladakh provides an exemplary case study to better examine the confluence between climate change and transitioning mountain livelihood patterns. Further, by identifying climate change impacts already taking place "on-the-ground," Ladakh serves as an indicative analog for future environmental scenarios likely to surface across the globe.

Comparative Case Study Selection

In order to more closely examine the role geographic context and locality plays in climate change response and engagement, two distinct research sites were selected in Ladakh. The two comparative study sites are representative case studies of a rural setting located in Domkhar Valley, and an urban environment located in Ladakh's capital of Leh (Figure 1.4). Households in both case studies were sampled to identify local observations, perceived risks and societal values regarding climatic variability in the area. Although this research is tangential to work

Figure 1.4: Project area with case study locations- Domkhar Valley and Leh District, Ladakh, India

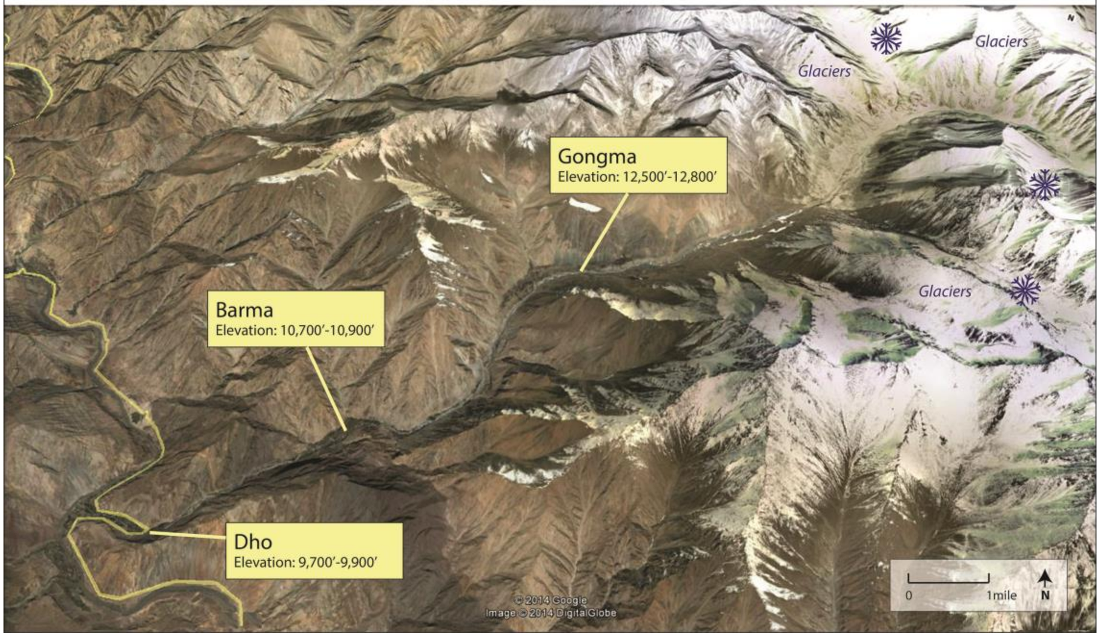


being conducted by private non-profit organizations in Leh, few studies have addressed climate change outside of Leh and no similar research has been conducted in Domkhar.

In focusing on Domkhar as an indicative rural mountain location and Leh as a more urbanized population center, this work aims to explore the different contexts where climate change impacts occur to shape community activities, societal outlooks and public engagement. In addition, both study sites were affected by the August 2010 cloudburst, which resulted in extensive damage to local properties, infrastructure and households. As a result, this extreme weather event has left a lasting impression in the Ladakhi social psyche and an ominous reminder of climate change potential. Accordingly, including impacted households in Domkhar and Leh provides important insight on the spatial and temporal relationship between locality, context and climate change impacts.

In the remote and rural setting of Domkhar, livelihoods are almost exclusively dependent on agriculture and surrounding natural resources. Situated along the upper Indus River Basin in a drainage stretching nearly 12.4 miles (20 km) long, Domkhar is illustrative of Ladakh's peripheral and more isolated villages. The Domkhar valley is located in the Khaltse district and borders Ladakh's northwestern edge with Pakistan and China. The valley is located approximately 78 miles (125 km) northwest of Leh. It is comprised of three separate villages including Domkhar Barma, Dho and Gongma, each situated respectively higher up the drainage than the next. With Dho located at the junction of the Domkhar Valley and the Indus River, Barma is situated approximately seven miles up the valley and Gongma is located an additional five miles past Barma, near upper cirque basin and head of the Domkhar watershed (Figure 1.5). The elevation ranges in Domkhar valley range from 9,700 feet at Dho to over 12,500 feet at Gongma. Collectively, the three communities in Domkhar have approximately 200 to 300 households and a population of around 500 to 800 people. Due to its proximity to the Pakistan border, an inner-line permit is required for all foreigners visiting this region. Data collection was

Figure 1.5: Mountain villages located in Domkhar Valley (Case Study)



thus limited to two week intervals and permits were regularly renewed at the District Magistrate Office in Leh.

Alternatively, Leh is the largest town in Ladakh and serves as the region's center of commerce, trade and government. Paralleling Leh's growth as a business and tourist hub has been a significant rise in population. In 1981, Leh's population was 27,423 people, including the surrounding area. By 2001, the population had risen to 46,740 people living within the incorporated limits of Leh, and in 2010 figure was estimated at 58,244 people (LAHDC, 2010). Leh is administered as one of nine government blocks in Ladakh and as the most populated, the town is relatively diverse in culture, religion and socioeconomic standing. While farming and agriculture remain dominant sources of income for many households, opportunities for supplemental forms of employment are more prevalent in Leh in comparison to the exterior rural villages. For example, the booming tourism industry in Leh supports jobs in the lodging and entertainment sector, food and restaurant businesses, commercial retail, trade, and manufacturing services, construction and recreational guiding. Farming and agricultural production therefore operate alongside, and at times is superseded, by tourism and other sectors of employment to drive and develop Leh's economy.

In short, the purpose of selecting two different study sites in the research area was to compare how different social, economic, infrastructural and biophysical contexts influence household and community vulnerability to climate change. Domkhar contrasts Leh with respect to land use practices, settlement patterns, political structuring, financial opportunities, sociocultural shifts, physiographic characteristics among other factors. Identifying how these dynamic characteristics aggregate to shape household and community response to climate change may provide useful details not only on the structural features propagating initial conditions of vulnerability but also the potential risks and opportunities generated through climate change.

Chapter 2:
Literature Review and Conceptual Background

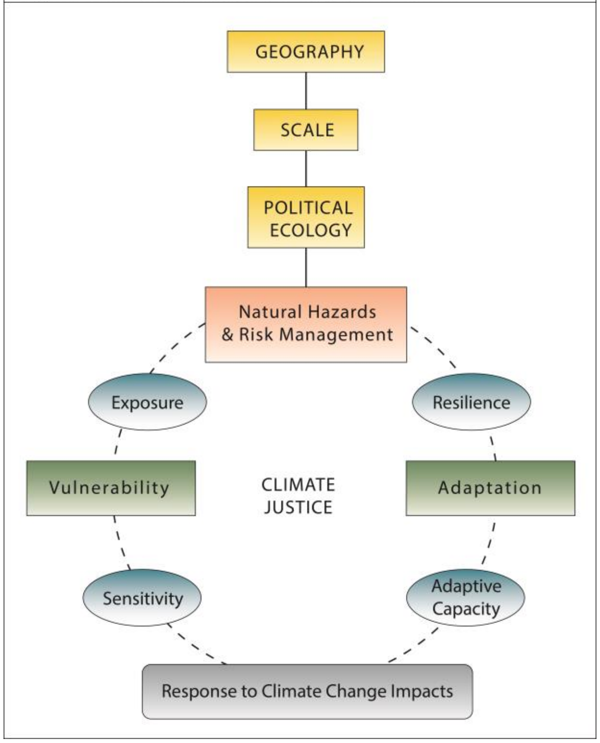
Introduction

Despite political platitudes, anthropogenic climate change is steadily transforming life and land everywhere. The implications of a warming world are having rapid and echoing affects, altering basic ecosystem functioning and associated human activities. In some places, the impacts are acute and mandate immediate decision-making efforts in order to maintain suitable livelihood conditions. For a growing number of impacted communities, making the requisite adjustments to climate change is not an option but a necessity. In Ladakh and other high mountain areas for example, climate change is reconfiguring the social-ecological landscape and influencing traditional ways of life. Rising global air temperatures are inducing an increasingly capricious climate, including unpredictable precipitation patterns, retreating snowlines and radical weather trends. As a result, the spatial and temporal dimensions of many human and environmental exchanges are being redefined and in many ways, presenting intransigent new challenges.

To effectively address the complexity of climate change and its related impacts in high mountain ecosystems like Ladakh, a vast and diverse field of scholarship must be interrogated. From biological and meteorological sciences to philosophical principals of morality and justice, the study of climate science reflects the multifaceted nature of the phenomenon itself. Indeed, the scientific undertaking of climate change is anything but discrete and is further complicated by the scope, depth and interdependency of the problem. As stated in the most recent Intergovernmental Panel on Climate Change (IPCC) report “The complexity of the climate system and the large range of processes involved bring particular challenges… because the Earth’s system is characterized by multiple spatial and temporal scales.” (2013: 138).

Yet in focusing in on one of the many iterations of climate change, such as impacts in high mountain ecosystems, several key concepts become particularly salient. To start, the larger conceptual canvas and theoretical architecture for this research is premised on geographical traditions of space and time. In particular, implications of scale and the spatial and temporal relationships characterizing human behavior and ecological environments is emphasized (Figure 2.1). While articulations from both physical and human geography guide the evolving narrative of this research, principals of political ecology further fine-tune the research dialogue into operational themes of adaptation, vulnerability and resilience. These ideological constructs effectively encapsulate the social-ecological dialectic defining climate change and draws attention to the root causes that propagate and influence differential abilities to respond to and plan for climate change impacts. As a result, ethical considerations of justice and intergenerational rights are unavoidably entrained into the larger climate change debate and highlight the uneven duality between cause and effect. Collectively, the above theoretical perspectives provide guidance and help to analytically unpack the myriad scientific explanations and academic paradigms on climate change into useful and tractable trajectories of thought.

Figure 2.1: Theoretical Model and Conceptual Framework



Social-Ecological Linkages within Scale and the Political Economy

Recent studies suggest a global warming trend of 2^{o}C to upwards of 4^{o}C by the end of the century will dangerously interfere with the climate system (IPCC, 2013; 2007; Hansen et al., 2012;). As a result, closely coupled social-ecological processes will be fundamentally altered and obligate societies to implement innovative strategies to respond to sudden and prolonged climate change scenarios. Yet, while the predominant drivers of climate change may operate within broad scales of the global political economy, the impacts of climate change aggregate and are most experienced at the household and community level. Understanding how the outcomes of climate change unfold at the local scale can in turn, provide valuable insight regarding the realities of global warming and identify appropriate mechanisms for response and planning.

Exercising effective decision-making that addresses climatic variability at the local scale while remaining consonant with broader policy goals is often hampered by operational and communicational discord. Until more recently, traditional approaches toward climate mitigation represented a formulaic solution and a prescribed "one-size-fits-all" approach for climate change response that repeatedly failed to capture the uniqueness and diversity of local context and the changes already taking place (Adger et al. 2009b; Tschakert and Dietrich, 2010). This in turn facilitates a dialogic, conceptual and scalar deficiency in how climate change is communicated at the national and state level and how response and managerial efforts materialize at the local scale. As such, the recognition of climatic processes, driving forces, and meaningful coping and adaptive strategies are insufficiently and incompatibly understood between researchers, community members and decision-makers (Leary et al., 2008; Twomlow et al., 2008). The theoretical integration of scale within the climate change discourse can therefore serve as a useful access point to decipher, refine and analyze the advancing climate change dialogue.

The Production of Space and Structuration of Scale

Examining the incongruence between climate change as a postulated theory and the practice of climate change response within site-specific settings is represented by the *scalar structuration* of different spaces of engagement, power and consumption. Scalar structuration implies a production of socio-spatial relationships that operate within the wider political economy, often dictating the circulation of goods, labor and capital (Harvey, 1996; Cox, 1998; Swyngedouw, 1997; Smith, 1984). Constituting a 'gestalt' of scales, this matrix of power relations is susceptible to manipulation and reprioritization and is thus viewed as a malleable and impermanent arrangement. Within this context, processes of *rescaling* can take place that can defy the fixed and bounded units of politicized space and challenge traditional power hierarchies. Rescaling allows for vertical and horizontal movement within the scalar structuration system and can catalyze transboundary opportunities for engagement between and within different levels of power and representation (Smith, 2008; Brenner, 2001).

Ontologically framing scale as in this way contradicts traditional definitions of scale as nested hierarchies of enclosed and contained spaces. For example local neighborhoods, urban landscapes, regional settings and global networks are connotations of scale that are best demonstrated with the cartographic descriptions evident in early surveillance and mapmaking procedures (Cosgrove, 2005; Delaney and Leitner, 1997; Harley, 1990; Jackson, 1989). Commonly expressed as a representative fraction, graphic or verbal unit demarcating determinate calculations on the map, this conventional definition of scale overlooked the concept's more abstract application as a theoretical lens to view and analyze outcomes of socially arranged power relations. Scale is thus not confined to measureable units of variability but more importantly, is composed and transformed by the suite of dynamic interrelations linked to changing social constructions, circulations of capital, political agendas and power configurations.

Arguing this perspective in his seminal work, *The Production of Space* (1974), Henri Lefebvre (1901-1991) observed how space, and by implication scale, is reprioritized and highly politicized by society's relations with capital thus embedding space with deeply seeded power arrangements. According to Lefebvre, modes of capital reshape and reinforce spatial and temporal spaces within society and through the process, space becomes conflicted, appropriated and alienated (Zieleniec, 2007). Modernity is therefore viewed as the preferred instrument of capitalist production and steers the control and centralization over knowledge, resources, information and most clearly, capital itself. Consumer behavior and commodity trends correspondingly direct the continued maintenance and orientation of capitalistic distribution, circulation and accumulation. In other words, capitalism facilitates the complete conquest, fetishism and integration of social space (Lefebvre, 1974).

It is only reasonable to assume that if space is socially constructed, the same must also be true for scale (McMaster and Sheppard, 2004: 15). As Marston (2004; 2000) notes, Lefebvre's conceptualizations about the production of space are a prerequisite for understanding the social production of scale and specifically identifying the historical and geographical contingent social processes by which scale constructions contribute to the production of space. Further, framing scale as a socially produced milieu theoretically linked processes of development and economic expansion into how contemporary western societies perceived and valued their progression into the twenty-first century (Said, 1978). Among other themes, evaluating the production of scale as a social process illuminated key understandings regarding uneven geographical development (Harvey, 2006; Swyngedouw, 1997; Smith, 1984), sociopolitical relations and latent power configurations (Leitner, 2004; Castells, 2002; Brenner, 1999; Cox, 1998; Agnew, 1997), organizational structures and social movements (Herod, 2001; Massey, 1994; Said, 1993) and the relationship between human society and the natural world (Escobar, 1996; Cronon, 1997; 1995; Smith, 1984).

Drawing heavily off the work of Lefebvre, a number of neo-Marxist inspired scholars emerged during the late twentieth century to further promulgate the sociospatial production of scale. For example, Neil Smith metaphorically addressed the reconceptualization of scale as a 'politics of scale,' in which he broadened his examination of scale production within the wider political economy by theorizing the role of geographical scales as frameworks for a continuum of social activities and struggles, including processes of capital accumulation, state regulation, social reproduction, gender relations, oppositional mobilization and subjective identities (Smith, 1995; Brenner, 2001). Framing the production of scale in this way conveys the mobility of scalar interactions between and within differentiated spatial arenas of power, positionality and engagement. Kevin Cox (1998) for instance, superimposes the politics of scale within the context of two separate spheres of sociospatial arrangements. While one domain constitutes the spaces of dependence or the spaces defined vis-à-vis localized social relations and the realization of essential interests, the other space consists of the networks and relations of engagements necessary for the security of dependence. Accordingly, it is the latter consideration of spaces of engagement that pertains to the empowering agency of sociospatial organizations and the processes of rescaling.

Closely paralleling Cox's spaces of engagement is the notion of rescaling opportunities that present themselves through the aggregation of multiple scales within the sociospatial composition of the political economy. In particular, processes of capitalism including the distribution and accumulation of capital, serve as avenues for interaction between a broad spectrum of actors and interests thus enabling the formation of cross-scaled interlinkages and connections to become established. In effect, the territorial requirements of capitalism articulate extensions of power while concomitantly providing openings to resist power through the manifold conglomeration of different scales (Smith, 1984). Referred to as 'jumping scales,' localized struggles and issues can become shadowed by an audience and network operating within a much larger spatial arena of power and representation. While still maintaining the 'nested' nature of scales, jumping scales rescripts, confronts and alters the hierarchical rigidity of scaled power relations.

Another commonly cited permutation of rescaling is the process of 'glocalization.' Discussed at length by geographer Erik Swyngedouw, glocalization encompasses the political economic forces driving globalization that are simultaneously making both the global scale and also subnational metropolitan regions more important spaces in the geography of economic change (Swyngedouw, 1997; McMaster and Sheppard, 2004). Following a similar conceptual vein as Cox, Harvey, Smith and other scholars allied with Marxist traditions, Swyngedouw (1992; 1997) posits that the historical geography of capitalism best demonstrates the process of territorial scalar construction of space and hence the corresponding production of scale. Scale thus exemplifies the sociospatial nexus where global forces meet individual forms of habits, routines, rules and norms that restructure and restrategize the flow of capital and with it, produce venues for control and domination as well as cooperation and compromise (Bourdieu, 1977; Swyngedouw, 1997).

In short, framing scale as a socio-spatial product within the wider political economy can add value to the advancing discourse on climate change because it stresses the role power and politicized space can play in shaping outcomes between society and nature. Further, theorizing scale as socially constructed, historically biased and politically contested (Neumann, 2009), provides insight into how aspects of scale transpire to privilege certain narratives and knowledge frameworks over others. Bringing synergy between multiple scales of interaction can therefore work to reorient hegemonic decision-making agendas to more closely reflect the conditions, resources and realities of local circumstance.

The Social Construction of Nature

In using scale as a theoretical tool to conceptualize the arrangement of power and capital within the broader political economy, the intrinsic linkages between society and nature become more discernible. As much as scale can be understood as a socially constructed process, many geographers and scholars similarly highlight the construction and commodification of nature as a socially generated product (Castree and Braun, 2001; Escobar 1996; Castree, 1995; Cronon, 1995; Haraway, 1989; Smith, 1984). To guide theoretical understanding of the human and nature dialectic are the advanced perspectives of political ecology. A political ecology lens stresses the role differential access and availability to resources, assets, capital and knowledge plays in shaping human behavior and their associated exchanges with ecological systems. Political ecology is the unique marriage between social scientific concerns, political economic processes and the natural environmental processes of ecology (Simon, 2008). In this holistic perspective, the constantly shifting interchange between society and land-based resources, and also within classes and groups within society itself are examined (Watts, 2000; Blaikie and Brookfield, 1987: 17).

In assessing the impacts of anthropogenic warming, political ecology provides an appropriate framework to examine the outcomes of climate change with regard to existing livelihood conditions, marginality, distribution and access to resources and political representation. Moreover, political ecology highlights the importance of integrating local knowledge, meanings and histories into discussions on climate change response and adaptation (Neumann, 2005; Wisner et al. 2004). To do so, political ecology applies themes of geographic scale to better examine the deep and inextricable links between human populations and ecological environments. Processes of development and conservation are correspondingly scrutinized and critically assessed in order to identify which groups of people gain at the expense of others and what the result implies for the control, management and allocation of nature.

Both political ecology and human geography focus on capitalism as the primary means through which nature is appropriated, commodified and governed. As Lefebvre (1991) argued, capitalistic modalities of production and consumption are premised on assumptions that nature is an alienated and distinctly separate abstraction therefore rationalizing the dominating and homogenizing behavior of capitalistic development. In fueling the engine of capitalism, nature is 'metabolized' in order to sustain societal trajectories of expansion and accumulation (Swyngedouw, 2010; 1996). As an endemic process of capitalism, the production of nature continually transforms, exploits and is 'creatively destroyed' by everyday societal mores and norms that perpetually reevaluates and applies new meanings to the material and non-material associations between society and nature (Harvey, 1996; Escobar, 1996; Smith, 1984).

Perhaps nowhere else is this metaphorical fusion between society and nature more conspicuous then with human-driven climate change. Indeed, in recognition of the irrevocable effect anthropogenic activities are having on biophysical systems, the present geologic era and one succeeding the Holocene period is known as the Anthropocene period (Crutzen, 2000). In this modern context, it is nearly impossible to extricate society from nature or de-politicize the socio-historical and political economic forces that constitute the dichotomous exchange between humans and environmental change. As a politically charged concept, climate change emblematically encapsulates the social production of nature because it highlights the uneven exchange between those who are impacted by the appropriation of nature against those who profit at the expense of capitalistic surplus. In this way, climate change expresses the excesses inscribed in the very normal functioning of the system while prophylactic qualities are assigned to the mobilization of the very inner dynamics and logic of the system that produced the problem to begin with (i.e. privatization, commoditization and market exchange) (Swyngedouw, 2011). Climate change is thus deeply imbued with political meanings, cultural semantics and social symbolism yet simultaneously emerges at the local level to physically alter the state of nature and the human activities that rely on it.

Response and Engagement with Climate Change Impacts

Under the conceptual auspices of geographic scale and political ecology, the social-ecological exchange underlying the climate change debate can be further extracted into specific ideological threads. In particular, processes of adaptation, vulnerability and resilience are highly germane to the climate change dialogue and focus on the theoretical crux between climate change impacts and the ability to respond to these outcomes at varying scales of interaction and engagement. In applying these theoretical tenets, the natural hazards and risk management approach is one dominant framework that seeks to identify how conditions of vulnerability are generated in the first place and further, how vulnerability enables or hinders processes of adaptation and resilience to evolve. The natural hazards and risk management perspective is useful because it emphasizes the wedded interplay between access to available resources, such as social, financial and political capital, and long-term livelihood security in the face of uncertain and in some cases abrupt, climate change.

Theoretical Climate Change Lexicon: Adaptation, Vulnerability and Resilience

In recognition of irreversible climate change, adaptation is now common vernacular within the climate policy and decision-making arena. In a new, deliberative and self-conscious way, climate change adaptation is part of the contemporary discourse about the politics and economics of global climate change (Adger et al., 2009a). In large part, this is in acknowledgement of the many climate change impacts already taking place (IPCC, 2014). The concept of adaptation was inaugurated into the policy debate through its appearance in Article 2 of the United Nations Framework Convention on Climate Change (UNFCCC), where the ultimate objective of the Convention concedes that adaptation to climate change in relation to food production, ecosystem health and economic development can and will occur (UNFCCC, 1992; 2007). The UNFCCC reaffirmed these ambitions in 2010 with the Cancun Convention, whereby it agreed,

> Adaptation is a challenge facing all Parties, and that enhanced action and international cooperation on adaptation is urgently required to enable and support the implementation of adaptation actions aimed at reducing vulnerability and building resilience in developing countries (UNFCCC 2010a, 4).

Closely aligned with the UNFCCC climate change goals are the responsibilities and recommendations of the Intergovernmental Panel on Climate Change (IPCC). Though the stated aim of the IPCC is to support national policy on climate change through offering scientific consensus, there is a high level of interaction between the IPCC and UNFCCC, with the former feeding into processes supported by the latter, which in turn helps to drive funding and political will for adaptive actions and research (Pelling, 2011). The IPCC's Fourth Assessment Report coincided with the UNFCCC declaration on vulnerability and adaptation in developing countries (IPCC, 2007). Unlike the previous three assessments, the Fourth Assessment Report specifically addressed adaptation as a necessary requisite in lieu of recent evidence supporting the inevitability of at least some degree of climate change (Solomon, et al. 2009). Accordingly, the IPCC concluded,

> Past emissions are estimated to involve some unavoidable warming even if atmospheric greenhouse gas concentrations remain at 2000 levels. There are some impacts for which adaptation is the only available and appropriate response. A wide array of adaptation options is available, but more extensive adaptation than is currently occurring is required to reduce vulnerability to future climate change (2007).

Adaptation rhetoric within the climate change debate has only become more pronounced in recent years and was reemphasized in IPCC's currently released Fifth Assessment Report (2014), *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. In the most up-to-date compilation of climate change science, the lead IPCC authors write, "Adaptation has emerged as a central area in climate change research, in country-level planning, and in implementation of climate change strategies." Moreover, the report notes a growing focus on the social and human dimensions of climate change, "The evolution of the IPCC assessments of impacts, adaptation, and vulnerability indicates an increasing emphasis on human beings, their role in managing resources and natural systems, and the societal impacts of climate change" (2014: 2).

The IPCC reports provide the scientific basis for nearly all climate change policy developed since, including the Bali Action Plan (2007), subsequent UNFCCC-COP gatherings in Copenhagen (2009), Cancun (2010), Durban (2011), Doha (2012) and Warsaw (2013), and most recently President Obama's Clean Power Plan (2014). Within each of these forums, adaptation has been identified as an essential pillar of the future climate change regime as envisaged under the UNFCCC. As a recent report stated, "recognizing and in many cases experiencing first-hand the adverse impacts of climate change on the natural environment and human society, policy makers, business leaders and civil society have now attached greater significance to the adaptation agenda" (UNFCCC, 2010b).

Yet the recipe for an adaptation agenda under a climate change framework remains vague and disputed. This is partly due to the intrinsic complexity of adaptation processes and partly due to its wide application within both the natural and human sciences (Orlove, 2009; Smithers and Smit, 2009; Füssel, 2007). With regard to climate change, the ecological principles of adaptation, including themes of stability, tolerance and resilience have been applied to human dimensions of coping, vulnerability and response (Burton, 2009; Smit and Wandel, 2006). In this way, *adaptation* refers to a process, action or outcome in a system in order for the system to better cope with, manage or adjust to some changing condition, stress, hazard, risk or opportunity (Smit and Wandel, 2006: 282; Adger et al., 2004). Adaptation implies the sustained viability or improvement of social and economic activities and the quality of human life (Gallopin, 2006). The IPCC further states adaptation involves specific responses in natural and human systems to actual or expected climatic stimuli or their effects and can be anticipatory, spontaneous or planned (2007; 2014).

There are a number of pertinent concepts that characterize the diversity of adaptive activities. In addition to being reactive, concurrent and anticipatory, adaptation can be short- or long-term and this has come to be associated with a distinction between actions aiming for short-term stability (coping) or longer term change (adaptation) (Pelling, 2011: 15). Adaptation has also been characterized according to the form of action, for example technological, financial, behavioral and institutional (Chhetri and Easterling, 2010; Smit and Pilifosova, 2001) as well as by sector, such as government, civil society or private (Ford et al., 2010; Ensor and Berger, 2009; Thomas and Twyman, 2005). Further, adaptation can take place within a broad range of scales from the international to the state and household level (Moser and Estrom, 2010; Blanco, 2006; Adger et al., 2005). In other words, adaptation is a multi-scalar process of multi-level governance, concerned with the interaction of individual and collective behaviors acting from the bottom-up and the top-down in response to changing circumstances (Adger et al., 2009b: 10).

Adaptation is highly dependent on *adaptive capacity*, or the ability for adjustments to be made as to better cope with existing or anticipated external stress (Gallopin, 2006). The development and deployment of adaptive capacity is context-specific and is influenced by the nature of the society-environment interactions taking place at specific scales. As many have pointed out, adaptive capacity is correspondingly uneven among different groups of people and varies from place to place (IPCC, 2014; UNDP, 2010; Paavola, 2008; Brooks et al., 2005; Smit and Pilifosova, 2001; Kates, 2000). Factors influencing adaptive capacity include tangible and intangible assets, such as access to financial resources, technology, information, social capital and infrastructure (Eakin et al., 2010; Cutter, 2009; 2006; Wisner et al., 2004). Together with other socioeconomic, institutional and ecological variables, these attributes determine who adapts to climate change, where adaptation takes place and how adaptive practices are developed (Pelling, 2011). Adaptive capacity therefore represents the potential for adaption to manifest, and is constrained by multiple internal and external stresses that work to shape the outcome of climate change within particular locales.

Adaptive capacity is a key component and underlying process of biophysical and social vulnerability. As adaptive capacity is enhanced, vulnerability to environmental change is decreased as individuals and groups of people are able to modify characteristics and behaviors in order to better cope with existing or anticipated stresses (Wilbanks and Kates, 2010; Adger, 2006). *Vulnerability* can be viewed in terms of both biophysical and social systems, and refers to the degree of susceptibility to adverse conditions imposed by climate change (IPCC, 2014; Brooks, 2003; Bohle et al., 1994; Downing, 1992). While biophysical vulnerability refers to the physical exposure and sensitivity to environmental hazards and impacts of climate change, social vulnerability encompasses the structural forces and human dimensions that situate some groups of people at unequal risk to injury and harm from climate change (Brooks et al., 2005; Adger and Kelly, 1999; Blaikie et al., 1994). Social vulnerability is determined by factors such as poverty, health, food entitlements and access and control over natural resources (Cutter, 2006; Sen, 1989). Thus, social vulnerability influences biophysical vulnerability and is linked to the nature and selection of livelihood options available to people when confronted with the challenges of climate change (Jodha, 2005).

With respect to climate change impacts and the purposes of this research, vulnerability is conceptualized as a combination of social conditions, including economic and political, and biophysical parameters that collectively influence the ability to respond to hazardous conditions and exposure to natural events. This view directs attention to both the human and environmental processes at different spatial and temporal scales that affect human-ecological interactions in specific regions or communities (Ford et al., 2006). Similar to other frameworks on vulnerability, this view emphasizes the social, political and economic determinants that result in disproportionately exposing certain communities and individuals over others to physically hazardous conditions (Moser et al., 2010).

Often embedded within the vulnerability framework is the concept of resilience. Similar to adaptation, *resilience* has its roots in the biological sciences and has been increasingly applied toward human processes and changes within social-ecological systems (Folke, 2006). Holling (1973) and others have defined resilience to mean “the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks” (Walker et al., 2004; Berkes et al., 2003; Berkes and Jolly, 2001). In relation to social change, Adger (2000) has described social resilience as the ability of human communities to withstand external shocks to their social infrastructure, such as environmental variability or social, economic and political upheaval. In both respects, resilience connotes the degree of regenerative ability against internal and external stresses or perturbations imposed upon the system.

In the context of climate change, resiliency is reduced when climatic disturbances, such as hurricanes and floods, undermine the capacity of social-ecological systems to restructure and regenerate. While in part, this involves the degree to which a complex social-ecological system is capable of self-organization it also suggests the degree to which the system can build capacity for learning and adaptation (Brown, 2014; Adger et al., 2004; Folke et al., 2002). This latter concept is particularly important given future climatic predictions and variability. As climate change increases, the occurrence of climatic shocks and pressures will not only rise but also produce new ecological arrangements that influence the ability of systems to respond in the future. As Peterson (2009) describes, when the resilience of a system is exceeded by external or internal pressures, a threshold is broken and the regime reorganizes itself, shifting from one set of mutually reinforcing processes to another. Regime shifts can be caused by abrupt climatic shocks such as extreme rainfall, or by incremental changes that cumulate into a 'tipping point' with long-term consequences. Research suggests that with climate change, regime shifts are occurring more abruptly and with more frequency thus reducing the response rate and reorganization period before the next regime shift takes place (Ford et al., 2010; Folke et al., 2004).

Inferences to ecological regime shifts and tipping points signify a temporal epoch in system response to climate change. Given the extreme variability of climate change, including natural disasters, weather events and potential mass extinctions, some have questioned if simply adapting to these challenges is enough (Kates et al. 2012; O'brien, 2012; Pelling, 2011). In some situations, incrementally transitioning to respond to climate change impacts or accommodating to changes will not adequately suffice when challenged with such considerable risks. As Kates et al. (2012) explains, for some systems, vulnerabilities and risks may be so sizeable that they can be reduced only by novel or dramatically enlarged adaptations, the reorganization of the system or changing locations entirely. These options are increasingly incorporated under the theoretical umbrella known as climate change *transformation*. In this context, transformation is a fundamental alteration of the nature of a system once the current ecological, social or economic conditions become untenable or are undesirable (Nelson et al., 2007: 397). Transformation of a system can be driven by tipping points and when the aggregated pressures culminate to breach a system's thresholds, the system must be entirely reorganized and reconstituted.

When proactively implemented, transformation can be viewed as a deliberate or directional process and attempts to reform components of a system in order to enable a more desirable future. Examples include a combination of technological innovations, institutional changes, behavioral and cultural shifts as well as questioning the values, assumptions, beliefs and identities of the entrenched system (O'brien, 2012). Accordingly, transformation is ancillary to adaptation and shares a creative tension with resilience because it endorses a complete overhaul of the system rather than an adjustment to the system. Yet in doing so, transformation like adaptation and resilience, implies a critical and deliberative assessment of the underlying social, political and economic root causes propelling system vulnerability in the first place.

The relationship between vulnerability, adaptation and resilience is fluid and there is overlap in how each contributes to the formation of the other. However, there are a number of consistencies in how the three concepts are used to articulate the climate change discursive framework. Gallopin (2006) and others for example, argue that while vulnerability does not appear to be the opposite of adaptive capacity and resilience there is broad interconnectivity between the degree of vulnerability and how capable a system is of responding to change (Flint, 2008; Smit and Wandel, 2006). In this respect, adaptive capacity and resilience provide the main conceptual pillars of vulnerability and collectively determine how the impacts of climate change are distributed and felt.

Although vulnerability is often positioned as an inverse of adaptive capacity and resilience, and hence an increase in one implies a decrease in the other, this is not always the case. As Brooks (2003) states, the relationship between the three concepts is context and temporally specific and varies according to hazard type. Therefore, the adaptation process and the nature of the relationship between the vulnerability, adaptive capacity and resilience of a system will be mediated by the nature of the hazard(s) faced by the system (Adger et al., 2004).

In addition, it is important to recognize how adaptive capacity, vulnerability and resilience do not work separate from larger political, socioeconomic and ecological influences

(Fields, 2005). The culmination of multiple stresses onto a landscape differentially determines the ability for people and regions to respond to environmental variability and change. As Kasperson and Kasperson (2001: 274) stated, the lesson from climate change is that risks and impacts do not register their effects abstractly; they occur in particular areas and to specific ecosystems and are the latest in a series of pressures and stresses that will add to and interact with what has come before, what is ongoing, and what will come in the future. Hence, a myriad of factors work to shape the nature and extent of vulnerabilities within social-ecological systems in turn determining the enhancement of adaptive capacity and resiliency.

Indeed, by contextualizing vulnerability as an outcome of convening forces, it is possible to better assess the precursory circumstances that lead to and perpetuate initial conditions of vulnerability. As Cutter (2006) further explains, response to climate change is primarily a factor of access to resources including, political power, representation, knowledge, information, financial capital, infrastructure and social capital such as social networks and connections. Other characteristics like age, gender, race, ethnicity and socioeconomic status can additionally influence vulnerability and the ability to adapt to change. O'brien et al. (2004) has explained the merging of these variables as a 'double exposure' of a society or an area to the impacts of climate change as well as to larger socioeconomic and political forces, like globalization. In an assessment of India (excluding Ladakh), O'brien et al. concluded double exposure poses simultaneous challenges of adapting to climate change while also enduring stresses emanating from adverse economic or political conditions. Thus while responding to climate change is difficult in and of itself, dually assessing the impacts of other variables that interact with climate change impacts is substantially more wicked and complex.

Recognizing and understanding the interlinkages between adaptive capacity, vulnerability and resilience can also present opportunities for mutual and integrated approaches. For example, Wilbanks and Kates (2010) and others agree, through the enhancement of adaptive capacity, resilience is similarly increased while at the same time reducing vulnerabilities to many other potential threats and stresses (Ayers and Forsyth, 2009; Flint, 2008; Adger, 2006). By framing adaptation as an element of community or regional resilience, climate change has become the catalyst for more incorporated attention to issues beyond climate change alone, such as sustainable development, risk reduction, poverty and environmental security and natural resource management (Erikson and Brown, 2010; Orlove, 2009; Helmer and Hilhorst, 2006; Wilbanks, 2003). Viewed holistically, climate change adaptation and its various processes are dimensions within one another rather than stand-alone issues. Accordingly, their interrelatedness suggests a multidisciplinary approach is needed that embeds adaptation as a response not only to climate change but also to the multiple threats and stresses presented by other environmental, socioeconomic and political factors.

Natural Hazards, Extreme Climatic Events and Risk Management

Significantly informing the vulnerability discourse and the role differential access and availability to resources plays in climate change response is the natural hazards and risk management paradigm. In particular, this field of scholarship heavily scrutinizes non-environmental factors, such as political, economic, technological, institutional and sociocultural variables, in generating conditions of vulnerability and making natural hazards into social-ecological disasters (Cutter, 2006; Bankoff et al., 2004; Wisner et al., 2004; Blaikie et al., 1994; White and Haas, 1975). In O'Keefe's et al.'s (1976) seminal paper for example, it is argued human and socioeconomic drivers are responsible for the underlying causes of vulnerability therefore explicitly faulting the role of human agency and pressures within the wider political economy for natural disaster response. Expanding on this, Hilhorst and Bankoff (2004) explain, social processes generate unequal exposure to risk by making some people more prone to disaster than others, and these inequalities are largely a function of the power relations operative in every society. By recognizing that the same social and cultural processes that give rise to vulnerability are also nested within wider national and global political-economic arenas sheds light on how natural hazards disproportionately result in disaster impacts and risks.

Viewing vulnerability as a socioeconomic and political construct presupposes discriminatory conditions whereby the most marginal populations are the most impacted by environmental hazards. As Shaw et al. states (2010), disasters always have a social dimension and, whatever their cause, their effects are undoubtedly rooted in societal processes that render certain groups of individuals particularly vulnerable to their impacts. In the context of climate change, hazards and disasters present themselves in the form of extreme climatic events such as hurricanes, typhoons, heatwaves and floods. The impacts from these types of disturbances tend to be concentrated in areas where people have the least amount of social, financial and political capital to effectively deal with disaster. For example, Few (2003) and Mustafa (1998) both describe how the poor often occupy the more flood-prone environments and are geographically situated along low-lying sites, unstable riverbanks and highly erodible locations. Although caution must be used in immediately associating poverty with vulnerability, poor living conditions are frequently accompanied by a number of other adversities, such as lack of health, infrastructure support and livelihood opportunities, that facilitate uneven exposure to environmental threats. These deficiencies are described by Blaikie et al. (1994) as the underlying root causes, dynamic pressures and unsafe conditions that work to enhance vulnerability and reduce the ability to manage risk (Wisner et al., 2004). When flooding strikes, vulnerable areas have fewer resources and assets to counteract the impacts (Few, 2003; Chan and Parker, 1999; Mustafa, 1998). While this can lead to immediate deaths and injuries, long-term consequences jeopardize food security, financial assets, livelihood activities, governance support and social and cultural stability.

Differential vulnerability implies the same people at risk to natural disasters are correspondingly threatened by climatic hazards. Disaster risk reduction and climate change adaptation are hence closely linked and draw off the interdependent nature of local and global processes and the influence these factors have on social-ecological systems (Hilmer and Hilhorst 2006). Thomalla et al. (2006) elaborate on this point by explaining that the climate change discourse can reinforce a shift in disaster management away from response and recovery with a short-term view towards awareness, preparedness and risk reduction with a long-term, integrated outlook. Building adaptive capacities and enhancing resiliency will ultimately reduce risk to disasters caused by climate related and non-climate related hazards. Thus, recent work has called for more attention on the joint agenda of disaster management and climate change adaptation (UNFCC, 2011; Pelling, 2011; Shaw et al., 2010; CCDC, 2009; Schipper and Burton, 2009).

Joint Approaches: Vulnerability and Adaptation Assessments

One way for a conjuncture to develop between the disaster and risk management approach and the climate change adaptation framework is through vulnerability and adaptation assessments. Traditionally, vulnerability assessments have been cultivated over the years not only in the natural hazard field, but also in analyses on food security, poverty, sustainable development, resource management and other related issues (Schmidhumber and Tubiello, 2007; Sunderlin, 2006; Gunton, 2003; Murray and Frenk, 2000). In turn and paralleling the burgeoning body of research on climate change has been the wide application of vulnerability indices to assess climatic variability (Giupponi et al., 2013; Füssel, 2010; 2009; Hahn et al., 2009; Deressa et al., 2008; Brenkert and Malone, 2005; Sullivan and Meigh, 2005; Adger et al., 2004; O'brien et al., 2004; Vincent, 2004). Included in these analyses are indicators to measure health (i.e. life expectancy, mortality rate, food production), economy (i.e. GDP, debt), education (i.e. literacy rate), governance (i.e. refugees, conflict, law, stability), ecology (i.e. protected lands, forest coverage, water resources), and an assortment of other variables like technology, infrastructure, demography and agriculture.

Although assessments of climate change impacts and adaptive options have been both qualitative and quantitative in nature, there are inherent challenges with each approach. Pittock and Jones (2009) explain that many of these issues pertain to the uncertainties in climate change projections, including the extent of impact, scale of occurrence and duration of change. Add to this the complexities of human activities and response and it is easy to conclude that this 'explosion of uncertainty' (Henderson-Sellers, 1993) yields far too many potentialities and variables to predict a reliable outcome. Yet despite these concerns, such assessments have significantly contributed toward the development of policies and planning on climate change. For example, traditional climate change assessments have examined atmospheric emission mitigation and potential futures under various greenhouse gas scenarios (IPCC, 2007; Chandler et al., 2002; Metz et al., 2001). These evaluations examine the temporal and spatial shifts in weather patterns, precipitation trends and temperature ranges given estimated reductions in greenhouse gas emissions, and are a major contributing resource for decision-makers such as the IPCC and UNFCCC initiatives.

However, given the slow and lethargic action on mitigation, studies have increasingly redirected their attention to assessing climate change adaptation, including the reduction of risks and the identification of multiple stresses facilitating vulnerability and constraining adaptive capacities (IPCC, 2014; Schneiderbauer et al., 2013; Eriksen and Brown, 2011; Pearce et al., 2011; Eakin et al., 2010; Tompkins et al., 2010; GLCA, 2009; Füssel, 2007; Ford et al., 2006; Thomas and Twyman, 2005). Representing a departure from mitigation research, adaptation assessments focus on climate change impacts already taking place and the adaptive options available to respond these changes now rather than in the future. These reports do not negate the importance of mitigation, rather highlight the immediacy of the situation is some areas and the increasing relevance adaptation is playing within the international and national political arena.

For instance, in his examination of Inuit adaptive capacities in the Artic, Ford et al. (2010) argues mitigation is misplaced in policy and adaptation and should become a central feature in future planning. As an isolated population with limited resources and low consumption levels, the Inuit have contributed little to global greenhouse gas emissions, yet they are increasingly feeling the effects of warming temperatures. Mitigating carbon emissions in the Artic will have minimal impact in reducing the overall concentration of greenhouse gases and does nothing to enhance Inuit response to climatic variability. Adaptation assessments offer a tangible and more immediate way to better understand the vulnerable conditions communities are exposed to, identify initial policy entry points for strengthening adaptive planning and examine how adaptation can be mainstreamed into public perception.

Adaptation and vulnerability assessments often work in unison with one another. By recognizing those areas most vulnerable to climate change impact, adaptation ‘hotspots’ are identified and resources can be directed accordingly. In addition, assessments can provide comparative data across multiple scales that identify leverage points in reducing vulnerability and, by inference, the impacts of climate change while also addressing the underlying causes that merge to enhance or reduce adaptive capacity (Brooks et al., 2005). In this way, vulnerability can be used as a gauge and measurement of adaptive capacity and a synergistic analysis of the two can generate informative and robust results regarding individual and community response to climate change.

The Ethics and Justice of a Climate Change Framework

If conditions of vulnerability and adaptation function as outcomes of socioeconomic and political processes, as the above narrative implies, then exploring the formative causes which manufacture these initial driving forces additionally warrants consideration. Doing so unavoidably delves into the messy and contemplative musings of ethics and morality within the climate change framework. Indeed, the guiding principles and decisions steering the discourse and policy on climate change are inherently embedded within a broader philosophical framework of ethics and morality. Leading authorities within the climate change debate concede that decision-making and planning on climate change are latent with "value judgments determined through socio-political processes, taking into account considerations such as development, equity, and sustainability, as well as uncertainties and risk" (UNFCCC 1992) Incorporating these concerns into a united assault on climate change is thus fraught with challenging intricacies and ambiguities. Climate change policies themselves are subsumed within a larger theoretical scope that reflects how actors individually perceive, understand and conceptualize the role of ethics in shaping the course of humanity.

The sundry of approaches to climate change policy fundamentally contrast one another with respect to the recognition of particular principles. Invariably, any proposed political resolutions regarding the climate change problem inherently conjures up issues of value and power-brokering that work to explicitly and implicitly shape decision-making and governance efforts (Paavola, 2008). Most notably, notions of welfare, freedom and virtue inculcate diverse ideologies regarding the prioritization of certain issues and outcomes envisioned under a climate change framework. Accordingly, the manifestation of each of these ideas nurtures very different philosophical outlooks on how climate change and its impacts should be effectively managed, mitigated and adapted to. Whose value counts and at what expense to others is hence a primary concern when it comes to fashioning the international climate change regime (Dow et al., 2006; Kasperson and Kasperson, 2001).

Addressing the philosophical and ethical premises of the global warming debate is compounded by the multi-scalar and asymmetric nature of the climate change phenomenon. Although collectively manufactured at the industrial and national level, the percolating effects of climate change are most realized at much smaller and localized scales (Adger et al., 2009b; Dow et al., 2006; Kates, 2000). Those societies with the greatest access and availability to resources are correspondingly best equipped to deal with short- and long-term climatic hazards and stresses. Alternatively, socioeconomic and politically marginalized populations are not only differentially vulnerable to climate change impacts but also have the least capacity to absorb and prepare against future disruptions (Moser and Ekstrom, 2010; Paavola and Adger, 2006; O'brien and Leichenko, 2003). Broadly embodied within a 'climate justice' approach, issues of social equity and fairness in responding to climate change are associated with other general inequalities in wealth and wellbeing as well as dissociations between those who will benefit from and those who will bear the burdens and damage associated with global warming (Gardiner et al., Schneider et al., 2010).

In some ways the climate change debate is the most recent iteration of a widely-hyped world catastrophe. In the past, thematic tenets of marginalizaton, underrepresentation and economic inequality have been similarly inserted and adopted by various social movements from sustainable development to global poverty alleviation. Like climate change, each of these issues has sought to expose the garish inequalities that exist between and within different social groups. Analogous narratives on the causes and effects of global disparities subsequently highlight the underlying power configurations, structural components and undercurrent forces that steadily destabilize access and availability to social, financial, environmental, political and natural capital at multiple scales and between different groups of people (Pogge, 2011; 2002; Thomas and Twyman, 2005; Peet and Watts, 2004; Fairhead and Leach, 1998; Sen, 1984). Commonly constructed as uneven manifestations within a broader political economy, the differences in the global distribution and circulation of resources and capabilities often represent the theoretical bane of any equitable resolution toward climate change.

A number of scholars attribute the marked geographies of unequal global development to historical patterns of colonialism, imperialism, neo-liberal capitalism and most recently, globalization (Harvey 2010; 2006; 1996; O'brien et al. 2004; Said, 1993; Smith, 1984). Largely characterized as a bifurcation between the materialistic behaviors of the industrialized North and the natural resource dependent-users of the developing South, processes of uneven exchange between these two hemispheres has long invoked both wraith and fortune. According to Pogge (2002; 1992), in order to preserve great economic advantages favoring a minority of the world's affluent population (i.e. the developed North), a global economic order is universally imposed that leads to massive yet avoidable deprivations to the world's poor majority (i.e. the developing and undeveloped South). By holding marginalized populations under an acceptable baseline of livelihood at the expense of sustaining wealth and material accumulation, developed countries are committing grave acts against humanity (Shue, 2010; 1993).

With climate change, such ethical conundrums are exacerbated by the rate, frequency and magnitude with which climate change impacts are already occurring. Furthermore, the world's poorest populations are the most impacted by present and predicted climate variability while conversely, those societies causing climate change are favorably shielded from its worst effects. The lopsided and heavy reliance on fossil fuels and consumer-oriented activities of industrialized countries is generating irreversible effects within the global domain, including those impacts that have yet to come to fruition. Degradation of a 'common' atmosphere in turn reduces the global sink capacity to absorb present and future greenhouse gas emissions and increasingly nudges humanity into a more hazardous and unpredictable world. Populations already sensitive to social, political and economic vagaries are subsequently threatened by new risks and uncertainties imposed on them without their consent, representation or compensation. The tangible threats to livelihoods in places like low-lying island states (i.e. Maldives), arid regions (i.e. Sub-Saharan Africa), the poles (i.e. Artic), low-lying deltas (i.e. Bangladesh), coastal areas (i.e. Vietnam), and high mountain environments (i.e. Himalayas) among other vulnerable areas are testimony to the distorted global relationship between the causality and effect of climate change.

Climate change is a process that takes away the ability of individuals and their communities to fully function through the reverberated ill-effects to health, socioeconomic livelihoods, and the overall sustainability and security of environmental resources (Root and Goldsmith, 2010; Wronka, 2008; Scholsberg, 2007). The immediate and long-term implications of these changes strain individual's fundamental access and security to survival without their permission or reparation therefore violating key human rights. Applying a human rights perspective on climate change implies considerations of intergenerational inequities, the internalization of externalities, allowable emissions of subsistence living versus luxury materialism and moral thresholds of decency and respect of human life. In its most generic form, a human rights perspective articulates concepts of humanity, integrity, nondiscrimination, and social, political, economic and civil equality based on fundamental truisms that we are all entitled to by virtue of humanity itself. These basic rights override all other claims of actions and responsibilities and endorse a universal doctrine of moral threshold that no human being should be debased to. A rationality of human rights supports the intrinsic and inviolable prerogatives of all humans as autonomous functioning beings capable of reason and hence morally justified to essential liberties, freedoms and entitlements.

Human rights justifications in the context of climate change rest on the central presuppositions that emissions of greenhouse gases and the resulting differential distribution of the impacts, threaten the human right to survival. On an elemental level, this includes the causal claims that, (1) acts or policies that modify the atmosphere threaten to deprive human life, (2) every person has a human right not to be arbitrarily deprived of his life thus, (3) human activities that deprive a person of his human right to life are unjust (Caney, 2010; 2005; Harris, 2010; Beckman and Page, 2008). A closer examination of this sequential process requires a more stringent definition of what constitutes life-depriving acts. Henry Shue (1993) for example, positions the baseline of morally acceptable acts with respect to distinctions between subsistence emissions and luxury emissions. While the former activity involves emission allowances necessary to guarantee a minimum and decent standard of living the latter denotes the emissions that result from largely superfluous and expendable consumer preferences, mostly that of affluent individuals and nations. Accordingly, ethical deductions of fairness and just distribution infer that those persons and countries presently living in a state of impoverishment should be permitted a tolerable allocation of greenhouse gas emissions inasmuch as they can improve their standard of living to a level more equivalent to that of the more wealthy nations. As Shue states, those living in desperate poverty ought not to be required to restrain their emissions, thereby remaining in destitute conditions, in order that those living in luxury should not have to restrain their emissions (2010: 202; 1993).

Insofar as climate change denies people or entire communities the capacity to survive, it would follow from the basic human rights perspective that individuals who consume and pollute more than necessary have some obligation to stop doing so (Harris, 2010: 47). But how this obligation can be justified as a moral imperative or incentive to compel change is problematic due to the radical disparities between and within different social groups that encourages the continuation of the socioeconomic and political status quo. Consequently, the human rights approach must be refined and reembeded within a distilled lens that appeals to principles of common humanity. Reflecting Aristotelian and Kantian logics of social virtue, this principle considers the role of human actions and responsibilities relative to collective obligations shared by humanity as a whole. As we are all humans, this thread of commonality requires that we meet basic minimal commitments to ethical duties of equality and representation. Cosmopolitan morality further compels us to recognize that since we live in some sense, in one global society, we do have responsibilities to care in one way or another about what happens elsewhere in the world and to take action where appropriate (Dower, 2007: 11).

The impacts of climate change onto the most vulnerable populations like high mountain communities and other natural resource dependent-users are challenging livelihood securities on a scale never before realized. The moral impetus to moderate such stark injustices logically assumes that those with the most resources and capital are the most optimally placed to intervene. Although ethical incentives for humanitarian action have been justified as a way to ensure that "vulnerable people in the remotest outposts of the world do not become imprisoned in perennial cycles of destitution and impoverishment at the mercy of climate events' (Sokona and Dekton, 2001:120; Thomas and Twyman, 2005), the call for social justice solicits a much deeper recognition of cosmopolitan morality and respect for the individual. By scaling down the unit of analysis, a human-rights approach allows one to more definitively discern the fundamental implications and realities of climate change as they unfold on the ground. Such an ethical framework correspondingly sheds light on how we as a society, treat and interact with other human beings and equally important, elicits moral credibility because it has the potential to reveal profound limitations and opportunities in how societies value one another. Yet in recognizing these limitations, an inception point for a cohesive dialogue and enhanced understanding on the urgency and immediacy of climate change can take root.

Research and Methodological Design

The theoretical library described above frames the conceptual foundations of this research and in doing so, directly feeds into and substantiates the applied methodological design. Due to the multi-scalar nature of climate change, assessments that include both top-down evaluations of biophysical climate changes and bottom-up assessments of what makes the people and natural systems vulnerable to those changes will help deliver local solutions to globally-derived risks (IPCC, 2014). Therefore, the discursive and practical premises for effective climate change planning rests on the assumption that adaptive efforts ultimately reflect local circumstance, needs, assets and expectations.

Without a thorough investigation of the local setting, adaptation efforts may not be commensurate with geographic conditions or broad policy initiatives and may in fact, increase vulnerability in the long-run. Yet much ambiguity exists regarding how climate change response and adaptation manifests as a process of perceived risk, local environment and societal behaviors to the uncertainties of climatic variability. Consequently, there is a growing need for a clearer understanding of how climate change impacts unfold within community settings to influence perceptions, priorities and actions on climate change. Furthermore, societal engagement with climate change is contextually relevant and must be viewed in light of other pressing social, political and economic concerns, such as urbanization, tourism development and geopolitical relations. Hence, an integrative approach is required that synergistically explores the multifaceted and interdependent relationship between the realities of climate change at the local level and the underpinning forces that augment its negative outcomes.

The accompanying research design applies a four-tiered approach to flesh out the key contextual and environmental factors characterizing household vulnerability, climate variability and community adaptive responses in high mountain areas. Specifically, and aligned with the research objectives previously identified in the beginning of Chapter 1, four separate research questions steer the progression of the research outline. The purpose of these research questions is to hone in on the direct and indirect relationship between household and community vulnerability to climate change impacts. Vulnerability was subsequently operationalized with respect to perceived risks and observed trends, particularly within the context of weather variability, water and food security and impacts to livelihood conditions. The guiding research questions are as follows:

(1) In Ladakh, is there an association between geographical context and perceptions toward climate change?

(2) Is there a relationship between recent climatic trends in Ladakh and land use practices in rural and urban areas?

(3) In a mountainous setting such as Ladakh, how does the dialogue and interpretation of climate change shift down the valley (i.e. upstream to downstream)?

(4) What do local perceptions, observed climate trends and community values on climate change reveal about climatic and non-climatic drivers of vulnerability and risk to present and predicted climate change impacts?

Given both the idiographic and nomothetic quality of the research questions, a multi-methodological approach was used. Reasons for an interdisciplinary research design involved the recognition that multiple approaches yield a better comprehensive understanding and holistic foundation for data collection, analysis and research dissemination. By bridging humanistic perspectives with principles couched within both the physical and natural sciences, a multi-methodology broadened the epistemological research lens for this study. In this way, the explanatory motives behind quantitative techniques are complimented by the exploratory and human-social dimensions advocated by qualitative practices. Alternatively, theoretically housing this research exclusively within the human sciences (i.e. qualitative) or biological sciences (i.e. quantitative) would have limited the ability to make meaningful associations between and within different social-ecological systems. For example, through the analytical deduction of intricate processes, quantitative methods have a tendency to reduce particularities into generalizations and therefore often lack the intimate qualitative perspective required for examination of diverse and unique phenomena. In contrast, qualitative designs may lack the predictive modeling potential of numeric equations. Thus, a more synergistic methodological approach can utilize the advantages of both research preferences while still maintaining the integrity, validity and accuracy of the research objectives.

Table 2.1: Research Questions and Corresponding Methodological Approach

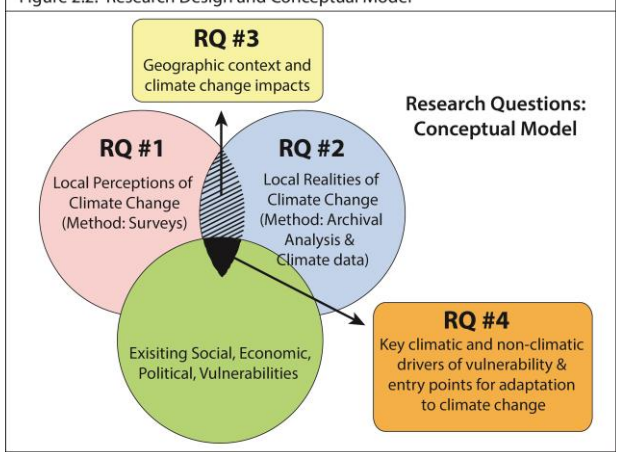
Research Question	Data Sets	Types of Data	Methodological Approach
RQ #1: In Ladakh, is there an association between geographical context and perceptions toward climate change?	• Household surveys • Key informant interviews	• Local observations • Identification of primary changes • Household values & attitudes	*Qualitative/Quantitative* - Sampled survey of households; t-test comparisons & Pearson Correlation testing
RQ #2: Is there a relationship between recent climatic trends in Ladakh and land use practices in rural and urban areas?	• Climatological and Meteorological data • Archived studies	• Agricultural yields • Cropping patterns • Irrigation trends • Temperature records • Precipitation patterns	*Quantitative* - Linear regression modeling; bivariate correlation
RQ #3: In a mountainous setting like Ladakh, how does the dialogue and interpretation of climate change shift down the valley (i.e. upstream to downstream)?	• GIS spatial layers • Climate records • Survey responses	• Elevation & terrain • Land cover • Household locations • Community perceptions	*Geospatial* - Integrated modeling analysis using Hot Spot and Density geoprocessing techniques
RQ #4: What do local perceptions, observed climate trends and community values on climate change reveal about climatic and non-climatic drivers of vulnerability and risk to present and predicted climate change impacts?			*Synthesis of previous data analysis and results*

To systematically respond to each of the above research questions, a methodology unique to each question was applied (Table 2.1). The first research question sought to tease out local perceptions and understandings of changing climatic conditions and therefore used household surveys and key informant interviews for data collection. Survey respondents were asked about their demographic background, source of income and observations about local changing climatic conditions, including the type, frequency and magnitude of various impacts. In particular, survey questions were designed to glean details about climate-induced impacts in the hydrologic cycle and associated affects these impacts may have on daily livelihood activities, such as agricultural yields, water supply and community planning priorities. Responses from key informant interviews provided supplemental background information to the surveys and enhanced background knowledge on local context and perceptions regarding changing socioeconomic and climatic conditions. Survey responses were processed and analyzed using

Statistical Package for the Social Sciences (SPSS V.21) software and statistically significant relationships were identified.

The second research question was based on the analysis of historic climatological data and involved ordinary least squares regression modeling and correlation testing. Trend lines and box plots were generated which indicated the degree of dispersion, variability and skewness in the climate data over a certain time period. Sources of climate and weather data included archival documents, government records, census reports and local non-governmental organizations. While the conducted surveys used to answer Research Question #1 were largely qualitative and descriptive, data acquired to answer Research Question #2 were quantitative and empirical in nature.

Figure 2.2: Research Design and Conceptual Model



Results and data from Research Questions #1 and #2 were subsequently combined into an aggregated database to identify the spatial and temporal associations between community observations of climate change impacts and geographical context therfore responding to Research Question #3 (Figure 2.2). To better understand how the dialogue and interpretation of climate variability shifts from upstream to downstream, survey responses, climate data and topographic reference features were integrated into geographic information systems (GIS) using ArcGIS 10.2 software. Using geoprocessing techniques and density analysis, community perceptions, opinions and attitudes toward climate change were modeled and areas of high and low value were identified. After performing this analysis within each community, it was possible to extract a larger narrative regarding local and regional climate change priorities. A synthesis of the results and discussions from the three previous research questions was subsequently applied to address the fourth and final research question. This four-tiered approach allowed for the identification, characterization and analysis of the predominant biophysical, social, economic and political determinants shaping the interface between mountain communities and climate change.

Contribution to the Literature

The theoretical foundation of this work is fundamentally inspired by geographic principles of space and time. Orientations of scale are the conceptual conduits through which the relationships shared between human societies and ecological systems can be better examined. As the most vexing and pervasive environmental issue to date, climate change subsequently presents itself as an ideal vehicle to more closely study social-ecological interdependencies. Assessing the full breadth of climate change impacts at multiple spatial and temporal scales unavoidably implicates processes within the wider political economy. Under the tutelage of political ecology therefore, and the related fields of natural hazards and risk management and climate ethics, a three-pronged approach for examining the multi-scalar dimensions of vulnerability and adaptation to climate change is afforded. This theoretical triumvirate was purposefully combined to produce a unique and specialized framework toward climate change research in the high Himalayas.

Presently, there is a dearth of data regarding how the biophysical effects of climate change translate into socioeconomic and political impacts at the local level and how these forces collectively converge to shape community engagement and response towards climate change impacts. In this context, spatial components of scale (i.e. biophysical and environmental variables) and temporal connotations of scale (i.e. socioeconomic and political factors) are complimentary, with each greatly influencing the maturation of the other. Although scale can be conceptually broken down into individual constructs of space and time, it is impossible to disentangle spatial configurations of movement and distribution from temporal references of power, resources and accumulation. It is thus impractical to explore local scenarios of vulnerability and adaptation to climate change without taking into full account the fundamental role biophysical settings plays in shaping the socioeconomic landscape, and vice versa.

In emphasizing the importance of locality and the socioeconomic milieu of a place in determining climate change response, this research framework applies a selective and critical approach towards the climate change discourse and adaptation paradigm. While broad institutional guidance may foster the operationalization and implementation of climate change response measures, adaptation practices must inherently emulate the surrounding natural and man-made environment. This is particularly true in the case of transformative adaptation adjustments and the possibility of significant climatic disruptions to vulnerable social-ecological systems (Kates et al., 2012). Should the worst-case scenarios of climate change come true, in some situations overwhelming even the most robust human-environment system, then responsive action will have to be immediate, aggressive and achievable.

To be effective, adapting to the severe and prolonged impacts from climate change will have to take root at the ground-level because the impacts from climate change will be diverse in outcome. Results from this study can therefore advance the climate change discourse and adaptation agenda by highlighting vital gaps in the deliberation and deployment of multi-scalar response strategies. In particular, this research suggests a need to more closely evaluate the role cultural frameworks contribute in the formulation of societal outlooks regarding climate change response. In doing so, findings from this work question categorical assumptions about the processes that contribute toward social vulnerability. Concepts of community cohesion and the meanings attached to particular localities can instill a deep sense of social resilience, even in the face of the most perilous climate change outcomes. Heightened social resilience can in turn moderate overall vulnerability to climate change impacts by motivating people to engage and act in defense of their community and home. In order to legitimize local adaptation scenarios therefore, it is essential that themes of place and community awareness are actively integrated into climate change planning efforts. At the same time, identifiable measures of viable adaptation options can be scaled-up or integrated into larger combinations of responsive actions to produce long-term strategies against climate change impacts.

Conclusion

In summary, adaptation to climate change is an evolving and multi-tiered process that involves a number of interrelated parts and players. A succession of physical, economic, cultural and institutional factors work throughout a gestalt of scales to enhance or limit the capacity for individuals and groups of people to respond to global environmental change. These variables often accentuate existing inequalities and stresses that propagate initial conditions of vulnerability to environmental risks, such as climate-induced hazards and weather events, as well as other intersecting challenges. Consequently, climate change impacts are altering biophysical systems and the ability for social systems to reorganize and adjust is highly dependent on the availability and access individuals have to resources like financial capital, institutional support, political representation and social assets. For marginalized areas, such as mountain communities, the capacity to effectively respond and recover from climate risks and related impacts is further constrained by their physical isolation, poor infrastructure and lack of alternative livelihood opportunities.

Yet mountain communities and other similar populations have long known how to deal with environmental change. It would be a fallacy to assert the need for adaptation and environmental response as a novel concept. However, what sets climate change apart from other wicked complexities is the scope and scale that responsive actions must take place. Given the speed and geographic reach of climate change, adaptation has now moved from the periphery of discussion to the forefront of policy making. Yet making the adjustments to these changes must ultimately materialize at the same scale where the impacts are most realized and experienced. Local histories and memories are therefore an invaluable database for knowledge on social-ecological processes and can provide compelling examples of practical adaptive practices to climate change. By incorporating these narratives into the broader climate change discussion, innovative ways for addressing the enormity of climate change threats, impacts and options may be achieved.

Engagement with climate change action must take place at multiple scales of organization and this truism invariably calls into question climate change values and the congruence of aspirations, aims, priorities and interests. Very often, the communities least responsible for generating atmospheric emissions leading to anthropogenic warming are among the most impacted populations. Consequently, attributing culpability to those who pollute while providing retribution to those who are harmed is a daunting ethical conundrum. A climate justice framework is therefore integrally linked with assessing the impacts of climate change and recognizes the initial conditions that generate and promulgate processes of vulnerability. Indeed, the ability for households and communities to respond to climate change impacts let alone engage in decision-making pathways, is predicated on differential degrees of exposure, sensitivity and access to various resources. Unequal geographies of vulnerability muddle the climate change debate and appeal to a deeper theoretical tradition of environmental ethics and principles of morality, values and intergenerational considerations. In doing so, the climate change problem is reduced to an issue of social justice and challenges the global political regime to implement an ambitious agenda of equitable and fair climate change governance across multiple scales.

Chapter 3:
Local Perceptions of Risk to Present and Predicted Climate Change Impacts

Introduction

Assessing the nature of household and community vulnerability to recent environmental change in Ladakh provides precursory insight into examining anthropogenic warming effects on livelihood conditions in similar settings around the world. In turn, valuable information can be elicited regarding the processes of adaptation and enhancing household and community resilience to climate change impacts as they materialize at the local scale. Moreover as a rapidly developing region, Ladakh provides a unique setting to explore the comparative impacts of climate change within diverse settings. In particular, the urban center of Leh and the peripheral rural community of Domkhar differ in geographic context and location and a contrasting analysis between the two study sites illuminates understandings on the relationship between locality, different demographic variables and community response to climate change. In evaluating urban and rural settings, a goal of this research seeks to intimately examine the role geographic context plays with regard to the convergence of site-specific impacts, social capital and household and community vulnerability.

Correspondingly, this chapter addresses how local residents in Domkhar and Leh perceive, value and interpret climate change and its present and predicted impacts in Ladakh. As the first of three chapters devoted to data analysis, this chapter explicitly responds to the first research question inquiring how climate change impacts are perceived, observed and prioritized at the household and community scale. Using qualitative and quantitative data collection from households surveys, and supported by details acquired during key informant interviews, interpretations of climate change are assessed with respect to immediate impacts, long-term planning perspectives and short-term community needs. The following two chapters subsequently respond to the second and third research question asking about the temporal and spatial observations of climate change as measured with archival, government and spatially-explicit meteorological sources of information.

Each of the three data analysis chapters are similarly structured and begin with an overview of the research statement and associated research question. An explanation of the accompanying methodological approach follows, including procedures related to data collection and analysis, followed by a discussion of the results. As a comparative study between two different study sites, research findings are discussed with reference to first, the rural area of Domkhar and second, the urbanized core of Leh. The two study sites are then collectively assessed to identify similar and divergent themes, concepts and variables between different demographic and environmental settings. Each chapter concludes with a section reflecting back on the research question and explains what the results may or may not suggest about the nature of household and community vulnerability to climate change in high mountain areas such as Ladakh.

Research Question #1 – Approach and Discussion

The first research question sought to reframe the larger dialogue on climate change into a clarified understanding of site-specific impacts as observed and experienced at the local scale. Correspondingly, the first research question asked:

> *RQ. #1: In Ladakh, is there an association between geographical context and perceptions toward climate change?*

The purpose of eliciting local perceptions of climate change impacts is to examine the meanings, semantics and vernacular of climate change at the household and community scale with respect to other ongoing socioeconomic and political concerns. More simply, without a thorough recognition of local perspectives, policy-making for climate change may not be compatible with local resources and goals and may worsen overall vulnerability in the long-run (Brody, 2012; Ireland, 2012). Such an oversight of local context can in turn facilitate maladaptation to climate change and the generation of unsustainable response strategies. Furthermore, embedding local perceptions of climate change into the scientific discourse can work to expose existing deficiencies between how climate change planning is articulated at broad regional and national scales versus how climate change impacts are acknowledged at the household and community scale.

Methodological Approach

In responding to the first research question, data from household surveys was analyzed to identify significant associations and relationships between livelihood characteristics and views regarding climate change. The survey was designed to solicit opinions of recent change within the hydrologic cycle and surrounding environmental conditions, and the potential risks posed to community sustainability by predicted climate change impacts. In addition, the survey design sought to contextualize how perceptions of risk to climate change are interpreted, responded to and prioritized within the community in light of emerging development and political concerns. In particular, the objectives of the survey were to (a) collect information on demographic data including household size, level of education, income sources, age and gender, (b) identify the key impacts observed with regard to changing climatic conditions, and (c) acquire an understanding of how community members perceive, value and engage with present and predicted climate change scenarios, including the planning and management of climate-induced impacts. Surveys were selected as the most appropriate method for data collection because surveys allow the researcher to generate analytical inferences about the larger population from a set sample of participants (Creswell, 2003). The household was chosen as the unit of analysis because in Ladakhi culture, the household is a more representative and discrete entity of measurement than the individual. In effect, household surveys provided a baseline of measurement regarding the internalization and interpretation of climate change impacts within the larger watershed.

Surveys were administered to households living within both Domkhar and Leh. Surveys were conducted in the Ladakhi dialect and involved a local graduate student translator. A pre-test of the survey was conducted on five Ladakhis before entering the field and questions were revised to improve respondent comprehension and understanding of the question. The same survey was administered in both study sites and the same translator was used throughout the data collection and translation period. In order to procure an accurate sampling of temporal change, all participants were over the age of 30 years and had lived in Domkhar or Leh for at least five years.

The first sampling frame involved a non-randomized and semi-randomized survey of households living within the three villages of Domkhar. During this period of data collection, the goal was to survey as many households as possible within each study area. Therefore, surveyed households were selected based on accessibility and availability. For instance, while the middle village of Domkhar Barma involved a blanketed survey, with all representative households accounted for, the other two villages of Dho and Gongma were non-randomly sampled. In the latter case, the village of Dho was a non-random sample of every other household situated along the main road. Similarly, in the village of Gongma, every other household proximal to the village's entry was approached to be sampled and if no one was available, then the neighboring household was surveyed. This resulted in approximately 70 households surveyed in Domkhar Barma and twenty households surveyed in each village of Dho and Gongma. In total, 110 households were surveyed in the Domkhar area. Alternatively, a second sampling frame involved 144 households living within Leh. The sampling procedure in Leh was semi-randomized and involved thirteen different wards within the inclusive perimeter of the town. Every third household within each ward was approached to be surveyed, starting with the first home on the street. Like Domkhar, if no one was available at the time of the sampling, then the next neighboring home was surveyed. In total, 255 surveys were conducted in both Domkhar and Leh.

Data Analysis

Analyzing the relationship between different variables was calculated using statistical comparisons and identifying levels of association. Qualitative and quantitative data was entered and organized first in a Microsoft Excel spreadsheet and later exported and transferred into a numeric database using a statistical software program. In particular, IBM Statistical Package for the Social Sciences (SPSS V.21) was used for comparing means and statistical significance differences. In order to identify significant relationships between different variables, a chi-square test of significance was used. Levels of significance between nominal, ordinal and interval variables were determined by conventional confidence levels of 95 percent and 99 percent ($p < .05$, $p < .001$). To measure the strength and direction of association between different variables, a Pearson Correlation test was performed. Lastly, to evaluate comparative differences between variables and the means of different groups, in this case Domkhar and Leh, an independent *t*-test was administered. High degrees of statistical significance emphasized the key relationships between group characteristics and identified interdependent associations.

Results by Study Site

Although climate change is increasingly influencing Ladakhi livelihood conditions, it is one of many issues challenging households and communities within the region. Comparisons within and between different site areas suggest climate change is a uniformly observed trend within Ladakh and its impacts are felt at both the local and regional level. Differences in geographical and socioeconomic context plays a role in how climate change is locally interpreted and socially valued relative to other continuing sociocultural, economic and political challenges. As such, climate change is often viewed in lieu of more pressing and immediate concerns facing households and communities in Ladakh.

Domkhar Study Site

Domkhar is a remote valley located approximately 125 kilometers (78 miles) northwest of Leh and adjacent to the Pakistan-Baltisan border. The three villages situated within the Domkhar valley, Dho, Barma and Gongma, are representative of Ladakh's peripheral and agriculturally-oriented communities. Local economies and livelihood practices within these mountain valley settlements are largely based on subsistence activities such as farming and livestock raising. Any extra produce and crops grown by farmers living in Domkhar and other outlying villages are transported and sold at markets in the commerce centers of Leh, Khaltse and Kargil. Consequently, the corridor between Domkhar and Leh is heavily traveled and many household members have extended family living in both communities.

Demographic Profile of Domkhar

The villages of Domkhar do not support a tourism infrastructure and alternative employment opportunities are lacking in the valley. Of the participants surveyed, a vast majority (81.8 percent) earned their primary form of income as farmers (M=1.6, SD=1.2) (Table 3.1). Further, women were nearly twenty percent more likely than men to work as farmers. While other common forms of employment for men in Domkhar included salaried positions, such as teaching or working with a government agency, women were less likely to participate in work outside of farming. For many men who did not consider farming their exclusive source of employment, working for the military and security forces was a popular alternative. Given Domkhar's strategic border location and proximity to India's Kashmir territory, it is common for

Table 3.1: Demographic and Community Characteristics for Households in Domkhar, Ladakh

CHARACTERISTIC	FULL SAMPLE (%)	MALE(%)	FEMALE(%)
What is your age?			
25-30 years	4.4	2.7	1.8
31-35 years	5.5	1.8	3.6
36-40 years	10.9	4.5	6.4
41-45 years	8.2	3.6	4.5
46-50 years	13.6	6.4	7.3
51-56 years	11.8	6.4	5.5
>56 years	45.6	16.4	29.1
How long have you lived in Domkhar?			
I was born here	87.3	41.8**	45.5
Under 5 years	0.9	0	0.9
5-10 years	0	0	0
10-20 years	3.6	0	3.6
20+ years	9.1	0	9.1
What level of education do you have?			
Primary school	9.1	6.4	2.7
Secondary school	13.6	4.5	9.1
Middle school	7.3	6.4	0.9
College/University	5.5	4.5	0.9
Never attended	65.5	20	44.5***
What is your main type of employment?			
Farmer	81.8*	29.1	52.7
Laborer	0	0	0
Employed (salaried)	11.8	6.4	5.5
Traditional (Housewife)	0	0	0
Tourist Guide	1.8	1.8	0
Military/Army	2.7	2.7	0
Other	1.8	1.8	0
Including yourself, how many people live in your household?			
1-3 members	9.9	4.5	5.4
4-5 members	26.3	10.9	15.4
6+ members	63.6	26.3	37.3
Sample Size	**110**	**46**	**64**

*Statistical significance levels are indicated as: *** = p <.001, ** = p < .01, * = p <.05* men to join the government border patrol. Subsequently the presence of men in the villages was smaller in comparison to women and this asymmetry was reflected in the survey. Of the total population surveyed in Domkhar, 64 percent were women and 46 percent were men. Results from the survey may therefore favor the female perspective regarding changing climatic conditions in Domkhar over the male viewpoint.

With respect to the level of education obtained, men in Domkhar were 50 percent more likely to receive formal schooling in comparison to their female counterpart. A majority of women surveyed in Domkhar (44.5 percent) never received any education ($x^2(4)$ =18.2, p <.001). By contrast, men were not only significantly more likely to enroll in primary school but also more likely to complete middle school or university. If women did attend school, it was customary for them to complete secondary school but not continue onto a higher level of education, such as middle school, college or university training. This trend is mirrored in Ladakh's average literacy rates which consistently reveals men outrank women when it comes to comprehensive reading and writing skills. For instance, in 1981, nearly 40 percent of Ladakhi men were literate in comparison to 12 percent of women. By 2011, the literacy rate in Ladakh had sharply increased to nearly 90 percent of men and 64 percent of women (LAHDC, 2012; Census of India, 2011). Despite a relatively high literacy rate for India, the number of literate women in Ladakh still trails behind the number of literate men by nearly a third.

Also like many of Ladakh's more rural and remote areas, a majority of Domkhar's community members are older and were born in one of the three villages within the valley. Of the participants surveyed nearly half were over the age of 56 years (M=6.38, SD=1.9) and a vast majority (87.3 percent) were born in Domkhar (M=1.45, SD=1.2). For instance, all of the men surveyed were unanimously from Domkhar while women were more likely to have moved to

Domkhar when they were younger. This is unsurprising given the high degree of intermarriage between different villages and the tradition of women moving to their husband's village after union. Despite not being originally from Domkhar however, many women had been living in the community for at least twenty years. It must be additionally noted that because the goal of the survey was to temporally reference recent environmental change in Ladakh and hence, only participants over 30 years of age were surveyed, this age bias was likely reflected in the survey results.

Like Leh and many communities in Ladakh, Domkhar families are large and frequently include six or more individuals. One household often supports multiple generations and includes extended family members. In Domkhar, it was likely for families to contain at least six members (63.8 percent) and much less likely to find a household with four or five individuals (26.3 percent). Few households surveyed included three individuals or less (9.9 percent). Having multiple family members working within each household allows for pooled resources, incomes and assisted hands in the fields. In addition, multiple generations living within one household provides more support for childcare and the exchange of oral knowledge and history from one generation to the next.

Other multiple associations beyond gender were identified between different demographic variables for Domkhar households. For example, age was a significant determinant of education (r=.56, p <.01) suggesting individuals over the age of 46 years were significantly less likely to receive any formal schooling (Table 3.2). It was much more common for

Table 3.2 Correlations between Demographic Variables, Domkhar

VARIABLE	Age	Residency	Education
Residency	-.01		
Education	.56**	-.03	
Employment	-.31**	-.10	-.22*

Note: *p < .05 **p < .01

individuals between the age of 26 years and 36 years to have attended at least secondary school if not college. Correspondingly, age was frequently associated with the type of employment. Type of employment was operationalized in terms of sector, for example farming/agricultural labor, business/retail services, tourism industry, government and other areas of work. A majority of individuals who were over the age of 56 years and lived in Domkhar worked as farmers while younger adults, age 26 years to 46 years, were salaried employees or worked with the military. All of the Domkhar respondents who worked as salaried employees had received at least a secondary level of education if not a college degree. Individuals working in the military frequently had a middle school level of education and the few tourist guides living in Domkhar, but working in Leh, had all attended college. In comparison a significant majority (75.6 percent) of farmers had never attended school (M=1.55, SD=1.35).

The general socioeconomic profile of Domkhar reflects community characteristics for many rural communities peripherally situated to the urban center of Leh. Many residents are over the age of 56 years, have lived in the village for most of their life and come from a large household consisting of at least six family members. More women than men work in the fields as farmers and tend to be less educated and less literate than their male counterpart. Higher educated individuals frequently work in government or with the military security forces. Alternative forms of employment are limited in Domkhar and its population is aging. Many young people are increasingly moving to Leh and other urbanized areas for the education, employment, social activities and entertainment opportunities. Long-term community sustainability in Domkhar is therefore challenged by transitioning demographics and economics as much, and in some cases more, than it is by environment changes.

Perceived Impacts of Climate Change in Domkhar

People living in Domkhar unequivocally agree there has been a change in the climate over the course of their lifetime. Further, a majority of surveyed respondents (72.7 percent) believe these changes are strongly affecting their lives (*M*=1.33, *SD*=.64). In particular, community residents have observed changes in precipitation trends, an increase in the frequency of rainfall events and more extended droughts (Figure 3.1). Other perceived changes include an increase in the distribution and number of plant and animal species, more days in the annual cropping season and a rise in the amount of snow and glacier melt (Table 3.3). A slight to strong

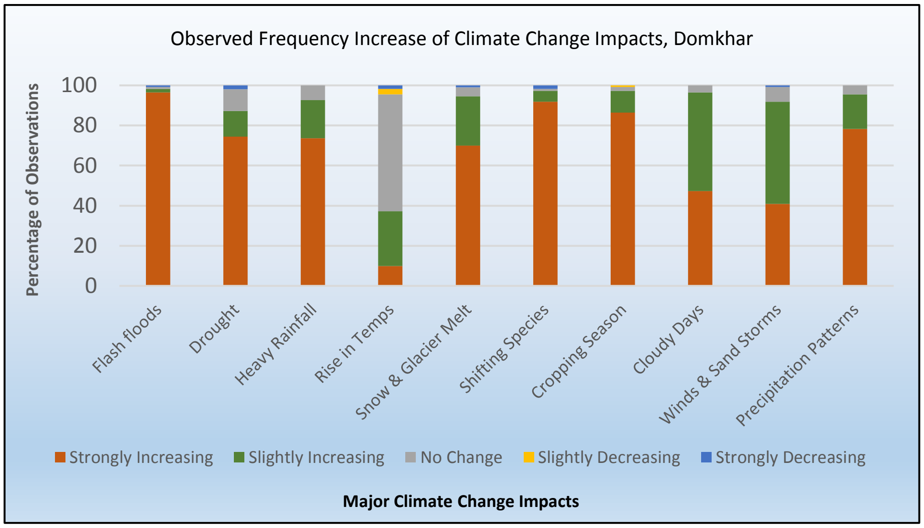


Figure 3.1: Frequency (%) distribution of perceived climate change impacts in Domkhar

Table 3.3: Statistical Distribution of Perceived Climate Change Impacts in Domkhar, Ladakh

CLIMATE VARIABLE	MEAN	S.D.	MEDIAN	MIN.	MAX.
Flash floods	1.07	0.44	1	1	5
Drought/Dry conditions	1.41	0.83	1	1	5
Heavy and untimely rainfall	1.34	0.61	1	1	3
Rise in air temperatures	2.59	0.78	3	1	5
Snow and glacier melt	1.37	0.66	1	1	5
New flora and fauna species	1.15	0.60	1	1	5
Timing of cropping season	1.17	0.49	1	1	4
Cloudy days	1.56	0.57	2	1	3
Winds and sand storms	1.69	0.69	2	1	5
Changing precipitation patterns	1.26	0.54	1	1	3

Note: Value based on Likert scale comparisons (1= very likely; 5 = not very likely; n = 110) increase in the number of cloudy days and wind/sand storm events was additionally reported. Lastly, and contrary to the scientific data suggesting otherwise, most Domkhar residents (62.7 percent) have not noticed a significant change in the ambient air temperatures (M=2.6, SD=.78). Climate change impacts in Domkhar therefore are commonly perceived with regard to changes in the hydrologic cycle, either too much or too little water, and the corresponding influence this may have on animal and plant species distribution.

Despite general agreement that climate change is impacting Domkhar households, particularly with respect to variability in precipitation patterns, glacier melt and flooding events, village respondents felt these impacts may not always yield negative outcomes. While nearly half (44.4 percent) of those surveyed felt neutral about the impacts of climate change or perceived climate change impacts to be very negative (20.9 percent), others (19.1 percent) thought potential climate change impacts could be positive. Respondents who believed in the latter outcome contextualized climate change as a benefit largely due to recent rises in agricultural yields. Indeed, a vast majority of Domkhar households (90.9 percent) observed an increase in annual agricultural output over the past two to three decades. While associations were made between climate change and the potential to prolong the cropping season, there are a myriad of extraneous variables that may also account for a rise in agricultural yields such as shifting market demands, new technologies and government-run agriculture food programs.

Although Domkhar residents indisputably believe there has been a change in climate over time, attributing this change to anthropogenic warming was less consistent. While a strong majority (77.3 percent) of individuals surveyed believed in the likelihood of climate change being caused by humans, many (15.5 percent) only slightly believed in the likelihood of climate change, felt neutral about it (3.6 percent) or didn’t believe in the likelihood of climate change at all (2.7 percent). In parallel, many respondents (33.6 percent) felt strongly about the importance of climate change yet nearly an equally large percentage (28.2 percent) of surveyed individuals felt climate change was unimportant in their lives. Many others felt neutral about the importance of climate change (21.8 percent). In other words, although many surveyed respondents believed in the likelihood of climate change as a process and outcome of changing environmental conditions, they did not necessarily associate this belief as an issue of high importance or as a result of human activities.

Nevertheless, the uncertainty of not knowing the full outcome of climate change is worrisome for most Domkhar residents and a majority of individuals (78.2 percent) believed planning for climate change should be a strong priority within the community. Yet many respondents (47.3 percent) felt strongly their community is able to effectively respond to predicted climate change impacts (M=1.87, SD= 1.02). Further, the more important respondents perceived climate change planning to be, the more strongly they felt their community was able to respond to climate change impacts ($\chi^2(12)$ =42.5, p <.000). When considering who would be involved with climate change response planning, respondents felt individual households could play a large role in enhancing overall community-wide preparedness. Correspondingly, the stronger a respondent felt about the importance of community planning for climate change the more interested they were in participating in such planning ($\chi^2(6)$ =30.2, p <.000). In addition, a majority of respondents (65.5 percent) felt the government should increase their presence and aid to villages in the case of future climate change response (M=1.46, SD=.73). Although more than half of the community members (56.4 percent) surveyed were satisfied with government relief and management of previous weather events, in particular the August 2010 flooding, many also believed the government could contribute needed resources and capital lacking in most villages.

At both the household and community scale, the impacts of climate change are increasingly shaping the lives of Domkhar residents. While there is wide consensus that the climate is changing and that these impacts are materializing most visibly in the form of altering precipitation patterns, heavy rainfall events, melting glaciers and extended droughts, many villagers also identify a positive trend in climate change. In particular, residents have observed an increase in annual agricultural yields which has been associated with a more productive and extended cropping season. In this way, climate change may not necessarily bode negative connotations for Domkhar residents, a vast majority who work as farmers and sell their crops at the market.

In anticipating future climate change, most community members believe their village is effectively able to manage climate change impacts and would like to be involved in planning for future climate change response. Additionally, government assistance is needed at the local level and should be increased in situations when villages are insufficiently resourced to manage climate change response on their own. Although Domkhar residents are worried about potential impacts from changing climatic conditions and consider it a priority within their community, they do not seem to emphasize its importance within the wider gamut of other chronic concerns. Rather, climate change is valued with respect to education, political relations with neighboring China and Pakistan, urbanization and village out-migration with no single issue out-competing the others. For Domkhar residents, climate change is a challenge alongside the community's aging population, lack of economic opportunities for young people, political underrepresentation and other substantial considerations. Like elsewhere in Ladakh, these adversities will increasingly strain community resources and exacerbate the ability for Domkhar residents to adequately respond to future climate change risks.

Leh Study Site

Since Ladakh was officially opened to foreign travelers in 1974, the town of Leh has become the region's booming urban core. Relative to other areas in Ladakh, Leh boasts a highly diversified economy and an expanding population. Leh is composed of over twenty minor villages, or wards, distributed as blocks within the city. Thirteen wards situated around the center of Leh were selected for data collection and approximately ten to twelve households within each ward were administered the survey. Accordingly, a total of 144 surveys were conducted in Leh.

Demographic Profile of Leh

Despite Leh hosting a wide variety of seasonal migrant workers and tourists, most of the town's permanent residents are local and were either born in Leh or in a nearby village. Of the individuals surveyed, a majority (51.4 percent) were native to Leh (M=2.27, SD=1.5) (Table 3.4). This is an important consideration in assessing local perspectives on climate change due to the range of impacts over time. Perhaps equally relevant, a large portion of the surveyed respondents (38.2 percent) were over the age of 56 years (M=5.62, SD=2.3) which similarly provides a longer timeframe to contextualize and observe changes in the local climate. The ratio of males to females surveyed was nearly equal, with 49.3 percent of surveyed individuals being male and 50.7 percent participants being female.

Results from the survey suggest people living in Leh have alternative employment opportunities beyond staple industries in farming and agriculture. For example, employment in local retail shops, tourism services and government has increasingly supplemented and sometimes replaced conventional sources of household income. While a majority (42.4 percent) of those surveyed still farm (M=3.15, SD=2.4), many other people living in Leh work as salaried employees or as shopkeepers. Further analysis indicated gender was significantly related to the type of employment ($x^2(6)$ = 34.3, p <.001). More than half of women (49.3 percent) work as farmers in comparison to men (35.2 percent) and women are not as involved with other means of employment as men. In addition to farming, many women stay at home as housewives or work as shopkeepers. In general, women were less educated than men with a majority (57.5 percent) having never attended any formal schooling. In contrast, men work as salaried employees, tour guides or in the military. Men were more likely to receive higher education and attend college or university after middle school.

The relationship between gender and employment implies women and men have segregated roles within the community. While most women are in the fields tending to crops,

Table 3.4: Demographic and Community Characteristics for Households in Leh, Ladakh

CHARACTERISTIC	FULL SAMPLE (%)	MALE(%)	FEMALE(%)
What is your age?			
25-30 years	12.5	2.8	9.7
31-35 years	13.2	7.6	5.6
36-40 years	13.9	4.2	9.7
41-45 years	5.6	3.5	2.1
46-50 years	8.3	4.9	3.5
51-56 years	8.3	4.9	3.5
>56 years	38.2	21.5	16.7
How long have you lived in Domkhar?			
I was born here	51.4	26.4	25.0
Under 5 years	11.1	5.6	5.6
5-10 years	6.3	2.8	3.5
10-20 years	20.8	8.3	12.5
20+ years	10.4	6.3	4.22
What level of education do you have?			
Primary school	9.7	5.6	4.2
Secondary school	24.3	11.1	13.2
Middle school	6.3	4.2	2.1
College/University	9.0	6.9	2.1
Never attended	50.7	21.5	29.2
What is your main type of employment?			
Farmer	42.4	17.4	25.0***
Laborer	5.6	4.2	1.4
Employed (salaried)	16.0	11.8	4.2
Traditional (Housewife)	10.4	0	10.4
Tourist Guide	1.4	1.4	0
Military/Army	5.6	5.6	0
Other	18.8	9.0	9.7
Including yourself, how many people live in your household?			
1-3 members	16.1	7.0	9.1
4-5 members	39.5	17.3	22.2
6+ members	44.5	25.0	19.5
Sample Size	**144**	**71**	**73**

*Statistical significance levels are indicated as: *** = p <.001, ** = p < .01, * = p <.05* harvesting yields and selling produce at the market, their husbands are working outside of the home. Ladakhi households are large and women are central figures in assuming responsibilities within the home. For instance, in Leh the average household supports seven or more people (*M*=5.1, *SD*=1.7) with few households containing less than four individuals. It is becoming increasingly customary therefore for men to pursue alternative forms of income beyond farming and agriculture while simultaneously supporting extended family members living within the same household.

Correlations between different demographic variables were relatively low and did not suggest statistical significance (Table 3.5). The exception was a strong association between the age of a person and the level of education they received (r = .47, p <.01). For instance, adults between the age of 26 years and 40 years commonly received a secondary level of education. Similarly, this age group was the most likely to attend college or university. As a whole, adults over the age of 56 years had never attended school or continued past the primary year.

Table 3.5: Correlations between Demographic Variables, Leh

VARIABLE	Age	Residency	Education
Residency	-.10		
Education	.47**	.12	
Employment	-.29**	.19	-.20*

Note: *p < .05 **p < .01

Like Domkhar, people living in Leh overwhelming agree there has been a change in the climate over the course of their lifetime. Of those surveyed, 95.8 percent have perceived a change in weather and climate conditions (*M*=1.04, *SD*=0.2). For most people, these changes have strongly affected their lives with men reportedly being more affected than women. Yet, many of the participants who reported being most affected by climate change also strongly agreed their community was prepared to respond to future climate change impacts ($x^2(16)$ = 29.7,

p <.02). Perhaps more interestingly, a majority of people surveyed in Leh (55.6 percent) considered climate change a very unimportant issue (M=3.78, SD=1.52). Despite many agreeing climate change impacts would have a negative impact on the community overall, most participants were equally concerned about issues related to education, foreign political relations with China, outmigration and ongoing development challenges. Planning for these issues as a whole was a significant priority within the community, with many participants wanting to be individually involved in this process.

No significant relationships existed between demographic variables, such as gender, age and education, and the degree that a participant was effected by climate change impacts. Nor did demographic background play a role in influencing views regarding community response and preparedness for future climate change impacts. The length of residency was a factor in shaping climate change perceptions with the participants born in Leh reporting the highest likelihood of climate change impacts occurring ($x^2(12) = 25.5$, $p < .01$). Nevertheless, participants born in Leh largely agreed climate change was not an important issue overall ($x^2(16) = 33.5$, $p < .005$). In the case of future climate change preparedness, this same group of people heavily supported assistance from the government in providing aid relief and disaster management services ($x^2(12) = 38.5$, $p < .001$).

In short, although many people living in Leh widely agree climate change is taking place, its hierarchy within the larger suite of persistent social, economic and political issues is relatively minimal. While most people range from being slightly worried to very worried about climate change impacts and agree the effects will largely be negative, they are similarly confident in the ability for their community and the central Indian government to respond to these challenges. With the exception of the length of residency, no other key demographic variables expressed statistically significant associations with respect to perceptions on climate change. Regardless, climate change impacts are overall, strongly affecting how people live in Leh and impacts are being ubiquitously felt at the community level.

Perceived Impacts of Climate Change in Leh

Among the various climate change impacts observed in Leh, many participants reported an increase in precipitation patterns and related extreme weather events, such as flash flooding and heavy rainfall (Figure 3.2). In addition, increasing shifts in flora and fauna distributions were noticed as well as an increase in the amount of snow and glacier melt. Opinions regarding an increase or decrease in average air temperatures were distributed between those who felt temperatures were strongly increasing and those who observed no change in recent temperature ranges (*M*=2.2, *SD*=1.1) (Table 3.6). The findings suggest many people in Leh observe the visible effects of climate change such as glacier melt, rainfall events and flash floods but disagree about ambient changes, such as a rise in air temperatures. Whereas the former impacts are material outcomes of climate change, air temperatures are less tangible of an outcome and thus there may be inconsistency in how temperatures are experienced and perceived.

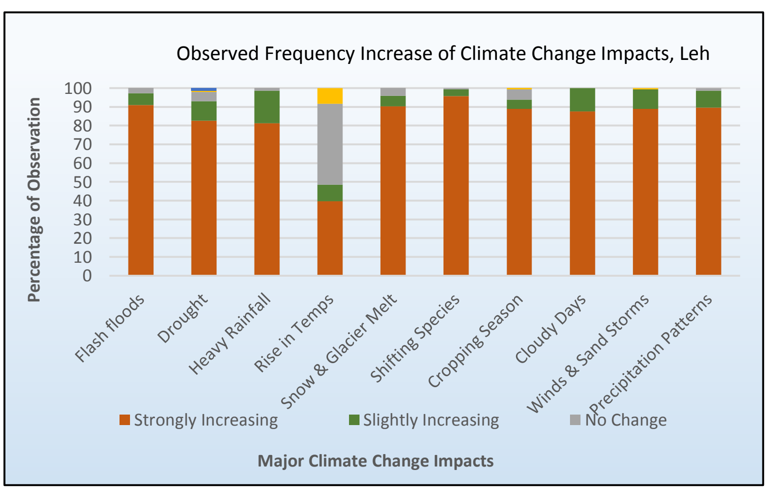


Figure 3.2: Frequency (%) distribution of perceived climate change impacts in Leh

Table 3.6: Statistical Distribution of Perceived Climate Change Impacts in Leh, Ladakh					
CLIMATE VARIABLE	MEAN	S.D.	MEDIAN	MIN.	MAX.
Flash floods	1.12	0.41	1	1	3
Drought/Dry conditions	1.27	0.71	1	1	5
Heavy and untimely rainfall	1.20	0.44	3	1	3
Rise in air temperatures	2.20	1.06	3	1	4
Snow and glacier melt	1.14	0.45	1	1	3
New flora and fauna species	1.05	0.25	1	1	3
Timing of cropping season	1.18	0.55	1	1	4
Cloudy days	1.13	0.33	1	1	2
Winds and sand storms	1.13	0.39	1	1	4
Changing precipitation patterns	1.12	0.36	1	1	3
Note: Value based on Likert scale comparisons (1= very likely; 5 = not very likely; n = 144)					

In terms of climate change impacts influencing livelihood conditions, more of the participants surveyed in Leh perceived an increase in agricultural yields in comparison to a decrease in annual yields (*M*=1.8, *SD*=1.2). While most men appeared to feel there has been a strong increase in agricultural yields, women were more likely to perceive a moderate rise in agricultural outputs. Additionally, the type of employment may contribute on views regarding agricultural production with an association significant at conventional 5 percent level ($x^2(24) = 36.5$, $p <.05$). Of those surveyed, participants who were laborers, housewives or served in the military perceived the greatest rise in agricultural yields while those professionally employed or worked as shopkeepers were more likely to perceive a slight to moderate change in agricultural yields. Alternatively, farmer's views regarding agricultural trends were more distributed between perceiving no change in yield production to a strong increase in production. Other demographic variables, including gender, age and length of residency did not seem to have a significant association with perceiving an increase or decrease in agricultural yields. Similarly, perceptions of the likelihood of climate change and the degree of being affected by climate change impacts did not associate with opinions related to agricultural production trends.

In contextualizing perceptions of change within the hydrologic cycle, a majority of participants surveyed overwhelming agreed there has been a decrease in water availability. However, this decrease was understood as a moderate decline in water supply rather than a substantial decrease (*M*=2.3, *SD*=.55). Respondents who perceived a decline in water availability were additionally most likely to strongly believe in climate change (r = .224, p <.01). Moreover, a decrease in water availability was significantly associated with concerns regarding potential impacts to the community with a majority of respondents feeling a decline in water supply was going to have a very negative effect on the community ($x^2(12)$ =48.2, p <.001). This relationship suggests future water availability is a growing concern for many who live in Leh. Hydrologic variability and the adverse consequences to water supply is correspondingly one of the more immediate and tangible manifestations of climate change impacts for many households living in the area.

Many respondents surveyed in Leh largely concur there is a strong likelihood of climate change. Likewise, the impacts of climate change are increasingly being felt at the household and community scale. Among the suite of observed changes taking place, an increase in flash flooding events, shifts in precipitation patterns and new distributions of flora and fauna species were the most commonly reported impacts. Variability in the hydrologic cycle was perceived not only in the form of flooding, heavy and untimely rainfall events and melting snowpack but also as a decrease in overall water supply. Future shortages in the availability of water was a significant concern for people surveyed in Leh and did not appear to be associated with any particular demographic variable, such as gender, age, education or type of employment. Alternatively, type of employment was marginally associated with perceptions regarding trends in agricultural production with many people agreeing there has been an increase in crop yields and output over time.

Interpretations of climate change in Leh therefore are not necessarily related to demographic background and instead largely center on present and future variability within the hydrologic cycle. In particular, the long-term security of water supply was perceived to be closely associated with climate change and was a major concern for many Leh residents. As a whole, respondents in Leh observed a rise in agricultural production yet a decrease in glacier and snowmelt as well as an increasingly unreliable water resource. Rising demands for agriculture and food will likely increase as Leh's population and development continues to accelerate.

Case Study Comparisons

In order to better assess the relationship between geographic context and perceptions of climate change, survey responses were compared between Domkhar and Leh. In this case, Domkhar is representative of the average rural community situated peripheral to Leh's urban core. To test for statistical variation between Domkhar and Leh, an independent-samples *t*-test was performed. As such, the demographic profile for each community is first compared for similarities and differences in socioeconomic context followed by an analytical breakdown of climate change perceptions and the primary impacts observed within each community. In evaluating climate change perceptions between these two study areas, a better understanding of the role rural and urban setting plays with regard to individual and household interpretations of climate change may be generated.

Demographic Profile Comparisons

An assessment of demographic and socioeconomic characteristics between the two study sites revealed several significant associations. As the more rural and agriculturally-oriented community, Domkhar hosts an older, slightly less educated population who largely supports their family through traditional subsistence activities such as farming and livestock rearing. In contrast, Leh has a more diversified employment base that supports a younger, urban and higher educated population. In evaluating these two community profiles, key demographic and household traits such as gender, age, education and employment, were used to characterize and operationalize the similarities and differences between a representative rural community of Domkhar, and its urban counterpart, Leh.

Although gender comparisons were not determined to be significant between Domkhar and Leh, a gender gap was identified within the rural area of Domkhar. In particular, women outnumbered men in Domkhar by over 30 percent. By contrast, the number of men and women in Leh was more evenly distributed between the two genders. While this relationship was not statistically meaningful, it does indicate a slightly skewed gender profile for rural communities situated on the outskirts of Ladakh's urban areas. As with many other peripheral mountain villages, economic opportunities in general are limited in Domkhar and many men subsequently seek employment in the military security forces, government or in the larger towns. Conversely, many women remain in the village to provide as primary caregiver, manage the household and maintain the farm. As a result, women in Ladakh perform a majority of the agricultural work and labor involved with the cropping, tending and harvesting of fields. As a high mountain setting, Ladakh is especially susceptible to the impacts of climate change and the segregated role women play in agriculture places them at uneven risk to these changes.

This gender gap is analogous of India's agricultural sector where women largely outnumber men as farm workers, particularly in rural areas where 85 percent of women work in agriculture (Census of India, 2001). Such a distorted relationship implies more women than men will be unfavorably affected by present and future climate change as they are primarily the ones dealing with climate change impacts as they unfold at the local level (Denton, 2002; Arora-Jonsson, 2011). Gender specific roles and responsibilities require women to provision the household with water, food and supplies, much of which involves a heavy dependence on local natural resources (Mearns and Norton, 2010). Changing climatic conditions will make food security less reliable by effecting the timing of the cropping season and the onset of rainfall, snowmelt and extreme weather events. In turn, women will have to exert more time and energy procuring much needed food, water and resources to sustain their household. Although additional exigencies exist that further disadvantages women over men in responding to climate change, such as access to resources, differential pay and other social and political pressures, climate change will likely strain these inequities to differentially impact women, particularly in rural and remote communities like Domkhar.

In addition to gender, other demographic comparisons between Domkhar and Leh were identified. For instance, the average age of individuals living in Domkhar (M=6.38, SD=.18) was significantly higher than in Leh (M=5.62, SD=.19, $t(252)$= 2.83, p < .00). Similar to gender discrimination, age stratification in many rural mountain communities is largely a result of the lack of economic opportunities and alternative forms of employment that compel young people to migrate to larger towns for work. While many people living in Domkhar are 56 years or older, Leh hosts a relatively younger population averaging around 40 years to 45 years old. Like age, the average length of residency was significantly different between Domkhar and Leh. A vast majority of people living in Domkhar were born there or had lived there for multiple decades (*M*=1.45, *SD*=1.2). In contrast, many residents of Leh had lived in the town for less than twenty years (*M*=2.27, *SD*=1.5, $t(252) = -4.73$, $p < .00$). With respect to duration therefore, people living in Domkhar were not only older but had also lived in the same village for much longer in comparison to the younger urban population in Leh.

As mentioned above, the paucity of employment opportunities in rural and remote villages like Domkhar is partly responsible for driving the community's age and gender gap. Indeed, agriculture is the main economic staple supporting nearly all of Domkhar's households (*M*=1.55, *SD*=1.4). While teaching and government work provides occasional opportunities for employment, these options are minimal and highly competitive. Consequently, farming is a crucial component of life and society for rural villages situated outside of Leh. In comparison, the urban center of Leh, with its ever-increasing tourism industry and related services, accommodates an expanding employment base with jobs in the food, lodging, entertainment and retail sector. Other growing employment industries in Leh include government, education, health and construction. Correspondingly, people living in Leh were much more likely to farm only part-time and mostly to provide their household with immediate food provisions such as vegetables and fruit. For households in Domkhar therefore, farming is a means of livelihood subsistence and economic support whereas in Leh, farming is less restrictive and often supplements other forms of work.

In summarizing the socioeconomic and demographic comparisons between Domkhar and Leh, the role of geographic context becomes increasingly more lucid. Like many urban areas that are rapidly developing, Leh promotes economic growth and employment diversification. In doing so, young people opt for opportunity in the city over traditional village life, resulting in an aging of the rural community population. Similarly men also leave the village, at least temporarily, to seek work outside of agriculture. The outcome of this age and gender out-migration is that women are consequently left to care for the fields, animals and household, which places them at unequal exposure to the impacts of local climate change. In some ways therefore, Domkhar may be less insulated from the impacts of climate change relative to more urban areas like Leh because livelihoods in urban areas are less directly dependent on natural resources for income and subsistence. Furthermore, women in rural areas like Domkhar may be at acute risk to climate change impacts due to their conventional role in the production and procurement of food, water and resources for the household.

Comparing Perceived Impacts of Climate Change

The impacts of climate change are universally perceived throughout Ladakh. For many residents living in the region, changing climatic conditions are generating very real and tangible affects at both the community and regional scale. While variability within the hydrologic cycle, the timing of cropping seasons and increasing extreme weather events are some of the frequently observed changes in Ladakh, other impacts include stronger wind events, an increase in new plant and animal species and more cloud-covered days. Climate change is therefore a commonly accepted notion within the region and few dispute the uncertainty climate change poses to future livelihood conditions. However the degree with which this concern resonates within each community to fundamentally influence anticipatory response and household adaptation planning varies and must be considered in lieu of other pressing needs. In this respect, climate change is one of many considerable challenges facing both rural and urban mountain societies in Ladakh.

Regardless of geographic context, a majority of people living in Domkhar and Leh believed in the likelihood of climate change occurring as a result of human activities. A small minority (8 percent) did not believe in the likelihood of anthropogenic climate change or felt neutral about it (M=1.26, SD=.73). Nevertheless, a significant majority (94 percent) believed climate change was slightly to strongly affecting their lives particularly with regard to sudden rainfall events, like the August 2010 flash flooding, and similar extreme weather events (M=1.37, SD=.76). Most respondents surveyed in Domkhar and Leh reported experiencing two to three substantial rainfall events over the course of their lifetime (85 percent), (M=1.16, SD=.41). Other respondents observed up to six extreme precipitation events over time (13 percent). No significant differences were determined between perceptions of extreme weather events between Domkhar and Leh, rather nearly everyone agreed the frequency of these weather perturbations is increasing (93.3 percent), (M =1.1, SD=.42), particularly in the case of sudden rainfall events (78 percent), (M=1.26, SD=.52).

With regard to the material effects of these abrupt weather events, many respondents vividly recalled the August 2010 flash flooding that impacted much of Ladakh. According to the survey results, more damages to homes and property were incurred in Domkhkar compared to Leh ($t(252)=-6.7$, $p< .00$). In parallel, a larger number of Domkhar respondents (77 percent) reported having to temporarily relocate as a result of the flooding in contrast to Leh residents (42 percent), ($t(252)= -6.5$, $p < .00$). In Domkhar, one respondent reported being severely injured from the flooding and in Leh, one respondent reported the death of a family member due to the flooding. In eliciting community member's opinions on government response to the August 2010 incident, most respondents in both communities were slightly to strongly satisfied (83.9 percent) and believed the government adequately provided relief and resources to the affected communities (M=1.7, SD=1.0). Extreme weather events, often manifested in the form of flash floods, were consequently the most observed impact of changing climatic conditions reported in both Domkhar and Leh.

Among the other climate change impacts additionally perceived, many surveyed respondents in Domkhar and Leh observed an overall rise in general weather variability (Figure 3.3). For instance, the duration and severity of droughts was noted to increase as well as the pace with which the snowpack and nearby glaciers are melting. Although residents in Leh perceive the glacier melt to be slightly more severe than Domkhar residents, both communities have observed a sizeable decline in regional snowpack levels ($t(252)= 3.34$, $p < .00$). Respondents in both Domkhar and Leh additionally observed an increase in the number of new animal and plants species as well as a rise in the duration of the cropping season.

When asked about the number of cloudy days however, a significant difference was noted between respondents from Domkhar compared to Leh ($t(252)= 7.7$, $p < .00$). Whereas less than

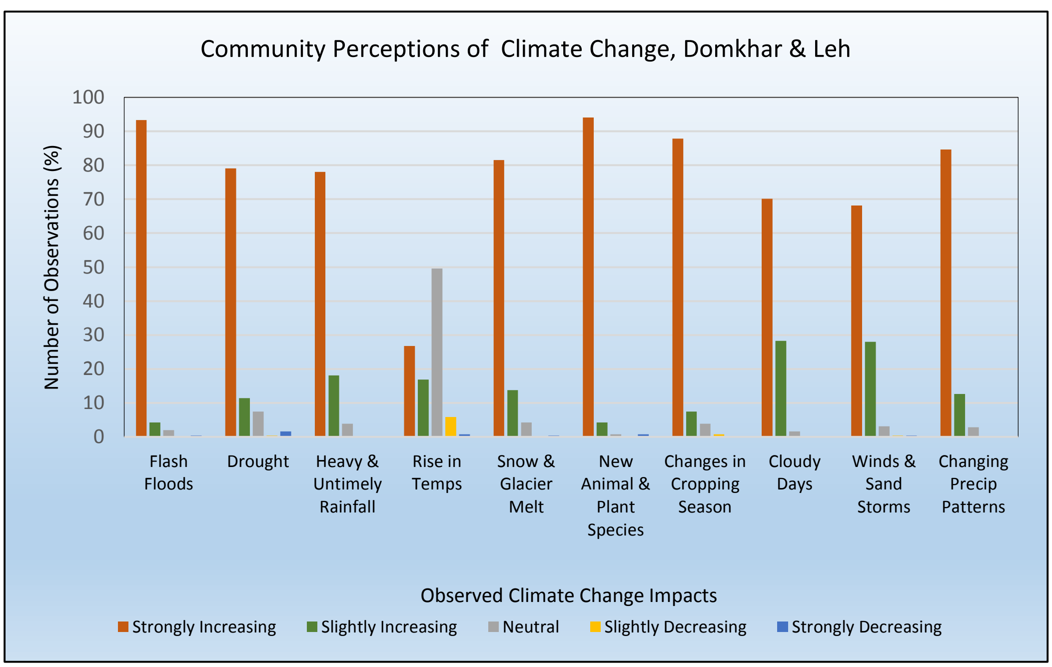


Fig. 3.3: Combined frequency (%) distribution of perceived climate change impacts in

half (47 percent) of Domkhar respondents identified a strong increase in the number of cloudy days (*M*=1.56, *SD*=.57), a large majority of Leh respondents (87.5 percent) have perceived an increase in cloudy days (*M*=1.13, *SD*=.33). Likewise, fewer Domkhar residents have noticed a rise in the number of severe wind storms in comparison to Leh residents ($t(252)= 8.3$, $p < .00$). A potential reason for this disparity is a likely a result of geographic topography. Domkhar is situated higher in elevation than Leh which implies a frequent temperature inversion and occasionally clearer skies. In addition, Domkhar's steep valley physiography minimizes wind shear in comparison to the broad, valley floor where Leh is located.

Respondents from Leh additionally reported higher average air temperatures compared to Domkhar respondents. While the former population observed a strong increase in the air temperatures (40 percent), respondents from the latter population perceived very little change or no change at all in temperature (85.5 percent), ($t(252)= 3.24$, $p < .00$). Again, Domkhar's higher elevation may account for the difference in perception and explain why Domkhar residents are not experiencing warming ambient air temperatures. Compared to their urban counterpart, Domkhar residents live 1,000 feet to 3,000 feet higher in altitude, which can significantly contribute to a colder climate. Regardless, there was no uniform agreement between the two communities and their respective opinions on recent temperature changes.

Domkhar and Leh also differed with regard to the perceived impacts of climate change on agriculture and local water resources. Whereas Domkhar respondents have largely observed an increase in recent crop production (96 percent), Leh respondents were less optimistic about rising agricultural yields (73 percent), ($t(252)= -4.8$, $p < .00$). Indeed, many surveyed households perceived a dramatic decline in crop production (18 percent), (*M*=1.7, *SD*=1.2). More residents living in Leh additionally noticed a decline in local water resources (78 percent) in contrast to residents in Domkhar (41.8 percent), ($t(252)= -.29$, $p < .00$). There are a host of potential factors influencing local water resource in each separate community setting. For example as a rapidly developing urban center, Leh's central water supply is heavily taxed by residential growth, tourism and other infrastructural and municipal demands. Water is an increasingly precious and precarious commodity in Leh and acquiring enough water supply to satiate future demands will be a crucial component of Leh's development outlook. By contrast, Domkhar supports a significantly smaller population and is proximal to several extensive glaciers and snow fields, all which feed into the Domkhar's main drainage. Although these sources of water are interpreted to be steadily declining, glacier melt provides Domkhar with an invaluable and at the moment, reliable resource for water. When compared to Leh residents therefore, Domkhar residents do not believe climate change is necessarily influencing the amount of water available to the community.

In light of the above climate change observations, most respondents in Domkhar and Leh believe these cumulative effects will have a negative impact on their individual communities. Respondents in Leh were particularly more perceptive about the negative impacts of climate change on their community (84 percent) in comparison to Domkhar respondents (31.8 percent), ($t(252)= -10.6$, $p < .00$). Correspondingly, Leh respondents are also significantly more worried about future climate change conditions (82.6 percent) in contrast to Domkhar residents (60 percent), ($t(252)= 4.7$, $p < .00$). Interestingly however, no significant differences were determined between the two communities regarding the degree of importance placed on climate change with respect to other social, political and economic issues. Although half of Domkhar respondents considered climate change to be somewhat to very important, a majority of Leh respondents did not perceive climate change to be important or felt neutral about it (81.9

percent), (M=3.8, SD=1.5). Irrespective of the level of concern and negative connotations associated with future climate change impacts, Leh respondents were overall much less likely to merit climate change as an issue of high value.

Despite the relatively neutral importance of climate change, both communities largely concurred that planning for climate change was essential. Yet planning for climate change apart from other considerable challenges facing the community, such as education, youth employment and political relations, was difficult to discern. Therefore, community planning for future scenarios involving climate change as well as other relevant issues was highly prioritized within Domkhar as well as Leh. When addressing the ability for communities to respond and plan for future change however, a significant difference was noted between rural and urban residents. Many Domkhar respondents felt their community and household were strongly capable of managing future planning of climate change and other problems (75.5 percent), (M=1.87, SD=1.0). Alternatively, fewer Leh respondents (58.3 percent) were confident in the ability for their community to effectively manage future response planning, ($t(252)= -3.2$, $p < .00$). Hence rural residents, who are accustomed to a self-reliant lifestyle and have a very tight-knit social fabric within their community, were more self-assured in the ability for their village to manage climate change compared to urban residents.

With regard to community planning, both Domkhar and Leh respondents strongly agreed increased government assistance could aid in response planning for future climate stresses and related issues. Respondents were predominantly satisfied with government action taken during the August 2010 floods and felt increased administrative and infrastructural support would greatly help with overall community preparedness. A majority of respondents additionally considered themselves as participants in community planning and wanted to be involved in future decisions regarding climate change response. The government therefore was perceived to play a contributing role in supplemental support and resource distribution for managing climate change impacts yet each community is ultimately responsible for the deliberation, decision-making and implementation of climate change planning.

In both Domkhar and Leh, climate change is a reality and its impacts are palpable at the community and household level. Residents from both communities agree climate change impacts are largely negative and will adversely affect community livelihoods in the future. Recent extreme weather events like the August 2010 flash floods, forewarn the grievous potential climate risks pose and suggest the need to anticipate future response measures. Coupled with other observed climate change impacts, such as melting glaciers, increased wind and sand storms, new animal and plant species and increased drought periods, extreme weather events and related climate variability are added pressures to an existing ambit of considerable concerns. Rural residents, many of whom are largely dependent on the community and household for support, express more confidence in being able to effectively manage these challenges. By contrast, urban residents are less certain of community adaptive capacity and are correspondingly more worried about future livelihood conditions in general. In this view, climate change is one of several imminent and problematic issues confronting Ladakhi communities and prioritizing it within the community is less important relative to other concerns, such as employment opportunities for young adults, education, out-migration and sharing a political border with China and Pakistan. Although regarded as a necessary requisite for future community development, planning for climate change in places like Domkhar and Leh must work in tandem with other aligning sociocultural, economic and political issues.

Discussion

Climate change is transforming the nature of social and ecological systems in Ladakh. For many mountain communities like Domkhar and Leh, the impacts of climate change will amplify existing insecurities such as food production, water reliability and the occurrence of natural hazards and disasters. Conventional roles in society and gender inequities suggest women will be particularly vulnerable to these impacts. This is especially evidenced in places like Domkhar and other rural mountain populations, where women perform a majority of the domestic chores as well as supervise crop production. Climate change is predicted to exacerbate variability in weather patterns in turn generating a more uncertain and unpredictable environment for agriculture, water resource and other livelihood sustenance activities. This creates undue stress for women and further burdens the ability to secure needed resources and materials for the household.

Moreover, a majority of the women in Domkhar were less educated than their male equivalent with many having never received any formal schooling. A lack of education renders alternative forms of employment outside farming difficult and further drives the gender divide characterizing rural mountain settings. While in Leh, the number of educated men was still higher than the number of educated women, the gender disparity was not as substantial in comparison to Domkhar. In general and consistent with demographic profiles in many rural areas throughout India and other developing countries, more Ladakhi women than men are involved in agriculture, live in rural areas and have never received any education. As a result women residing in Ladakh's rural villages are dually exposed to future risks, not only from those imposed by climate change but also the multiple stresses associated with maintaining and providing for a household.

Rapidly developing areas like Leh are similarly facing a suite of unique though equally complicated challenges. For instance, the converging pressures from urban growth, climate change and future infrastructural needs will continue to exhaust local and regional resources and influence the ability to permenantly support an expanding populace. The long-term implications of this increasingly stressed landscape has not been overlooked by local Leh residents yet for many, prioritizing climate change over other emerging and perpetual issues is one of the same concern. For many Leh residents, climate change is not an isolated phenomenon but aligns with population growth, rising development demands and other processes to collectively influence present livelihood conditions. Underscoring climate change as a distinctive stand-alone issue from the larger continuum of challenges facing Ladakh is subsequently complicated by the diverse range of other interfacing concerns.

As a result, many Ladakhis are conflicted when it comes to a planning decision-making framework. While most Ladakhis agree climate change will negatively affect local communities and anticipating these changes is essential to effectively respond to future impacts and risks, climate change is not valued as an important issue within most communities. Although changing climatic conditions are perceptibly influencing the physical environment including variability in the hydrologic cycle, decreasing snow melt, new distributions of plant and animal species and shifting the timing of cropping seasons, these impacts must be weighed against other potentially more immediate issues.

Conclusion

The temporal diffusion of climate change impacts materializes over the course of decades and centuries. Despite the spatial proximity and visible manifestation of climate change impacts in Ladakh, contextualizing these changes with regard to a long-term adaptation outlook is not perceived as a relevant issue. Rather, many community members were more concerned about the absence of young people, educational opportunities and political tensions between India, China and Pakistan than they were with changing climatic conditions. When valued against the impacts of climate change therefore, the above issues and other social, economic and political pressures trumped climate change planning as a subject of importance.

Noting the degree of relative value placed on climate change within Ladakhi communities is significant because it begs the question, how important is climate change within different societies? Furthermore, given the unabated trajectory of climate change and its subsequent impacts to life and land, what does this mean for global climate change action? As discussed by Mertz et al. (2009: 815), conceptually linking climate change as a distinct parameter of household and community adaptation planning is complex given its inextricable relation to other socioeconomic, political and environmental processes. Although households may be aware of climate variability, contextualizing climate change as an issue of community importance is often superimposed by other development needs and political prerogatives. Community anticipatory adaptation to climate change is consequently driven by a range of interrelated factors, of which climate change may not explicitly be considered as the most crucial.

Chapter 4:
Local Livelihood Practices and Climate Change

Introduction

Climate change poses a suite of unique and immediate challenges for high mountain populations. Of particular concern are the effects of warming global air temperatures and the associated impacts on long-term water security. Understanding the sensitivity of certain mountain land use practices, such as crop yields, agricultural trends and irrigation patterns to these outcomes and other climate-related changes is a crucial component of community sustainability. The theoretical underpinnings of community sustainability in places like Ladakh and other high mountain environments is often characterized by the social-ecological nexus shared between mountain livelihood activities and surrounding bioclimatic parameters. This intimate union correspondingly places certain livelihood activities at heightened risk to the vagaries of climate change including extreme weather events, heat waves, droughts, pest and pathogenic invasions and other associated impacts (Traore et al., 2013; IPCC, 2011). In turn, mountain livelihood systems of food production, land management, water collection and other household practices are exposed to a host of additional complexities that need to be considered in light of community vulnerabilities to present and projected climate change risks.

Agriculture is generally recognized as one of the socioeconomic sectors especially prone to the impacts of global warming (Brown, 2013; Easterling et al., 2007). Despite vast improvements in technology and crop yield potential, crop production remains highly dependent on climate input factors such as solar radiation, temperature, precipitation and soil nutrient content that together determine crop growth, flowering maturation and spread of plant pathogenic diseases and pest infestations (Murugan et al., 2012.). The unpredictability of climate change thus presents a significant dilemma in the production, management and durability of agricultural systems and in many ways, adversely affects both the quantity and quality of agricultural outputs (Altieri and Koohafkan, 2008; Sivakumar and Motha, 2007). Throughout the world and particularly within developing countries, agriculture is a main industry and is crucial to the sociocultural and economic backbone supporting many rural communities. Coupled with other externalities imposed by land use development, population growth and technological changes, agriculture is undergoing substantial and in some cases severe shifts. Changing climatic conditions will subsequently influence the costs, yields and overall commodity value of agriculture at the local, regional and global scale.

Similar to many other rural mountainous areas, climate change is affecting agriculture and other livelihood activities in Ladakh by altering the performance of basic ecosystem processes. Previous studies suggest the western Himalayas are experiencing rising mean air temperatures, variations in the intensity and frequency of flash floods, droughts, winds, sand storms and other disturbances, and increased variability in monsoonal weather patterns (IPCC, 2014; 2007; Gautam et al., 2013; Immerzeel et al., 2010; Akhtar et al., 2008; Archer and Fowler, 2004). These impacts are aggregating at the local and regional scale to influence the timing of the growing season, distribution of rainfall and availability of water from snowmelt (Shekhar et al., 2010; Bhutiyani et al. 2009; Vedwan and Rhoades, 2001). However, the heterogeneous distribution, proximity and magnitude of these impacts across Ladakh substantially varies. While some communities have been affected to the point of relocation, like Kumik in the Zanskar valley, other villages are seemingly less impacted such as areas in western Kashmir. It is therefore valuable to elicit a better understanding of site-specific variations in climate conditions in order to identify the explicit and implicit effects to Ladakhi household activities.

Often referred to as the Third Pole, most climate change research in the Himalayas addresses regional geologic morphologies and large-scale cryospheric processes. As the world's largest collection of glaciers, ice and snow, recent climate change research has principally examined physiographic shifts in the frozen landscape of the Himalayas (IPCC 2013; Shrestha and Aryal, 2011; Bishop et al., 2010; Xu et al., 2009; Berthier et al. 2007). Warming air temperatures suggest not only are many glaciers in the Himalayas retreating, but there is also the increased potential for glacial lake outburst floods to occur (GLOF) (Hewitt, 2013; Ashraf et al., 2012; Bajracharya et al., 2007). This is disconcerting because it unfavorably places downstream populations at adverse risk to flooding, water insecurities and other natural hazards resulting from hydrologic disturbances and other climate-induced events. Studies suggest a need to establish long-term monitoring assessments of regional mountain watersheds as well as prioritize and integrate local response measures and existing community resources into future planning efforts (Gardner and Dekens, 2007; Dekens, 2006; Jianchu et al., 2006).

As previously stated, climate change research indicates anthropogenic warming in concert with other human activities such as land development, urbanization and population pressures is increasingly generating a more hazardous and uncertain environment. In the Himalayas, many of these themes resonate with antecedent theories first articulated during the Himalayan degradation debates of the 1970s and 1980s (Eckholm, 1975; 1976; Ives and Messerli, 1989). However with climate change, many argue the scope, scale and magnitude with which impacts are taking place is distinguishing climate change as a particularly wicked dilemma (Gardiner et al., 2010; Schneider, S. and Mastrandrea, M. 2009; O'brien et al., 2004). Further, the spatial and temporal spread of climate change impacts demands unprecedented action from the local to global level to effectively mitigate and manage such effects (Moser, 2010; Adger et al., 2005). Accordingly, there is a need to identify both the immediate and protracted implications of climate change outcomes in places like the Himalayas, as well as ascertain the degree that resilience and adaptation plays in facilitating household and community response.

In comparison to other areas in the Himalayas, specific expressions of climate change in Ladakh are less understood. Similar to elsewhere in the Himalayan region, the few published studies on climate change in Ladakh have predominantly focused on glacial movement and ice mass recession (Schmidt and Nüsser, 2010; Fowler and Archer, 2006; Hewitt, 2005). One study by Brazel and Marcus (1991) used Ladakh as a case study to assess the accuracy of general climate circulation model simulations in contrast to observed records and datasets. Another study by Kumar et al. (2009) examined the carbon sequestration potential of Ladakhi agroforestry practices in dry desert landscapes. Only one organization, Groupe Energies Renouvelables (GERES), a French-based non-profit group, has publicly disseminated reports detailing overall climate change in Leh and the surrounding area. In their report, the GERES authors profile potential strategies and technologies available for Ladakhis to utilize in order to more effectively combat severe future environmental challenges (Daultrey and Gergan, 2011). Yet, limited studies have provided a region-wide assessment of current and past climatic trends in Ladakh and no research has produced an in-depth scientific study examining potential associations between climate change impacts and Ladakhi household livelihood practices.

The overarching aim of this chapter consequently seeks to characterize recent climatic trends and environmental conditions in Ladakh based on empirically measured observations. Whereas the previous chapter profiled local perceptions and observations of climate change as contextualized at the household level, this chapter integrates historical climate records, meteorological data and archived studies to chronicle variability in temperature and precipitation in Ladakh over time. In addition, measurements on land use patterns and cropping yields were collected and compared to identify possible associations between recent climate patterns and agricultural cropping outputs and behavior. Research data was collected from a variety of sources, including government census reports, meteorological records, previous scientific publications and Ladakhi academic archives. Climate data was analyzed using linear regression modelling and correlations were used to measure the strength and direction of associations between multiple variables. An overview of methods, data analysis and a discussion of the results follows.

Research Question #2 – Approach and Discussion

As an arid and high altitude landscape, climate change presents particularly troublesome scenarios for mountain communities in Ladakh. Shifting mean air temperatures implies increasing variability in the hydrologic cycle and less reliability and renewal of local and regional water resources. This has percolating implications at the community and household level including influencing the amount of water available for drinking, irrigation and other domestic uses. In addition, variation in precipitation patterns is further influencing and in some ways disrupting Ladakhi livelihood practices and their ability to thrive in high mountain settings. The August 2010 flash flooding in Ladakh for instance, which killed over 250 people and left thousands injured and displaced, has left a lasting impression on the region's land and people and portends an increasingly unpredictable existence. The associated links between temperature, precipitation and agricultural yields therefore underscores the importance of climate change in mountain areas and may provide insight regarding the complex interplay between climate change, local livelihoods and a sustainable future.

The second research question is in response to the need to better examine the convergence between theory and practice within the context of climate change impacts and local livelihood activities in Ladakh. Accordingly, the second analytical component of this research asks:

> *RQ#2: Is there a relationship between recent climatic trends in Ladakh and land use practices in rural and urban areas?*

Climate variability and related impacts from anthropogenic warming are unevenly manifested across Ladakh and vary with altitude, aspect and slope. Geographic location plays a central role in determining the outcome and degree of impact climate change imposes on mountain village life. Hence it is likely that for some areas, climate change will lead to an improvement in overall agricultural yields while alternatively other areas will likely experience a reduction in annual crop yields (Lobell and Field, 2007). Assessments examining the interface between human activities and climate change impacts must therefore note the asymmetric nature and multi-scalar matrix where this relationship unfolds. Identifying site-specific indicators of climate change, including both measured and perceived observations, is a preliminary step in distilling the larger discourse on climate change into the actualites playing out "on-the-ground." Doing so will help inform the scientific and decision-making community about key areas of household vulnerability and risk to climate change while also emphasizing local capacities to respond and actively address anticipated climate change impacts.

Methodological Approach

Climate change trends and livelihood practices in Ladakh were evaluated using meteorological records and agricultural census data. Independent variables for climate change included minimum and maximum annual temperature measurements and precipitation amounts. Weather stations for both of these indicators were located in Leh and cover a time period from 1973 to 2008. Validation of these records was based on similar analyses and methods identified in previous studies, (Daultrey and Gergan, 2011; Bhutiyani et al., 2007; Archer and Fowler, 2004). Often, and as explained by Bhutiyani et al. (2007: 161), gaps in temperature and precipitation data in the western Himalayas were estimated by using temporal interpolation approaches and computing monthly values based on mean trends for the same month within a two year span. Interpolations were further validated using double mass curves and simple linear regression modeling to reveal consistency in both temperature and precipitation values.

Proxy indicators for livelihood patterns were ascertained from agricultural records and land use trends. For example, independent variables analyzed for irrigation practices included the source of transport, relative discharge yields, village distribution and allocation for agricultural activities. In operationalizing agricultural activities, variables included the types of crops planted, area sown for crop cultivation, crop irrigation patterns and annual yields by district and state. Supplemental datasets, including tourism receipts, water consumption rates and population demographics were used to enhance contextual knowledge and baseline information regarding other socioeconomic trends in Ladakh. Due to the relatively large infrastructure in Leh, collected datasets and research assumptions are most relevant for the town of Leh and surrounding vicinity. Explicit sources of data are listed in Table 4.1 below.

Table 4.1: Sources for Climatological Records and Supporting Data for Ladakh, India.		
CLASSIFICATION	TYPE OF DATA COLLECTED	DATA SOURCE
Land Use	Areas of cultivated and non-cultivated land (ha)	Government of Jammu and Kashmir, Leh District Statistical and Evaluation Agency (2010); National Indian Census (2001, 2011)
Irrigation Practices	By type of transport/soure (i.e. canal, tank, watering truck, etc.), discharge amounts, consumption rates	Deputy Commissioner's Office, Leh, Ladakh Agricultural Department, Ladakh Autonomous Hill Development Council (LAHDC); Sudhalkar (2010).
Agricultural Yields	Yearly totals for food and non-food items	Agricultural Census, Department of Agriculture, Ladakh Agricultural Department, LAHDC
Average Air Temperatures	Monthly average air temperatures for Leh District	GERES (2009); Government of Jammu and Kashmir, Leh District Statistical and Evaluation Agency (2010)
Precipitation Trends	Seasonal total precipitation for Leh District	Indian Meteorological Department, Leh District Statistical and Evaluation Agency (2010)
Population & Tourism Demographics	Population census and tourism receipts	Tourism Department, LAHDC (2011); National Indian Census (2001, 2011)

Climate and land use data was largely acquired from the District Statistical and Evaluation Agency in Leh. This administrative branch is supervised by the Government of Jammu and Kashmir and is part of the Ladakh Autonomous Hill Development Council (LAHDC). Data regarding agriculture yields and land use is supplied to the LAHDC's Deputy Commissioner's Office and is annually reported by specific administrative departments, including the Ladakh Agriculture Department, Forestry Department, Horticulture Department, Husbandry and Livestock Department and the Flood Department. Irrigation records were similarly obtained through the Deputy Commissioner's Office in Leh as well as the National Indian Census of 2001 and 2011. Other temperature records were provided and corroborated by a study conducted by the non-government organization GERES (2009). Additionally, the LAHDC Population Census (2010), the National Indian Population Census (2011) and a Master's Thesis by Sudhalkar (2007) provided supplemental information regarding population blocks, household data and local water resources.

Data Analysis

Data was statistically analyzed using linear regression modeling and correlation testing. Monthly annual mean, maximum and minimum temperatures were calculated to provide a descriptive assessment of climate trends over time. To identify changes relative to time series, data was analyzed by fitting an ordinary least squares regression trend line to the annual deviation from the mean. A linear regression model was used to evaluate the effect of time period on regional agricultural yields as well as crop type, temperature mean and seasonal precipitation. In applying a trend line, slope was quantified and significance was tested using a 2-tailed *t*-test at a 95 percent confidence interval. Although information was acquired and normalized for the years 2000 to 2011, significant discrepancies between pre-2000 and post-2000 crop data suggest variation in census acquisition methods. Consequently, only crop records from 1964 through 1999 are analyzed for potential associations.

To evaluate relationships between crop yields and climate variables, a Pearson correlation coefficient test was used. Significance was similarly tested using post-hoc comparisons and 2-tailed *t*-test. This method was selected because correlation analysis provides a framework in which the time series analysis can be viewed and compared for temporal variation. Outliers were removed and the LOESS procedure was used to graphically assess variation over time at a 50 percent default value. Bivariate correlation analysis was additionally used to assess for associations between cropping region and annual yields as well as irrigated crop patterns over time. For precipitation analysis, a box plot was generated for visual reference and to identify the degree of dispersion and skewness in the data with respect to mean and quartile ranges. By statistically comparing measured climatic trends and meteorological records with data on annual land use and cropping patterns, possible associations between increasing climate variability and Ladakhi livelihood practices were identified.

Results

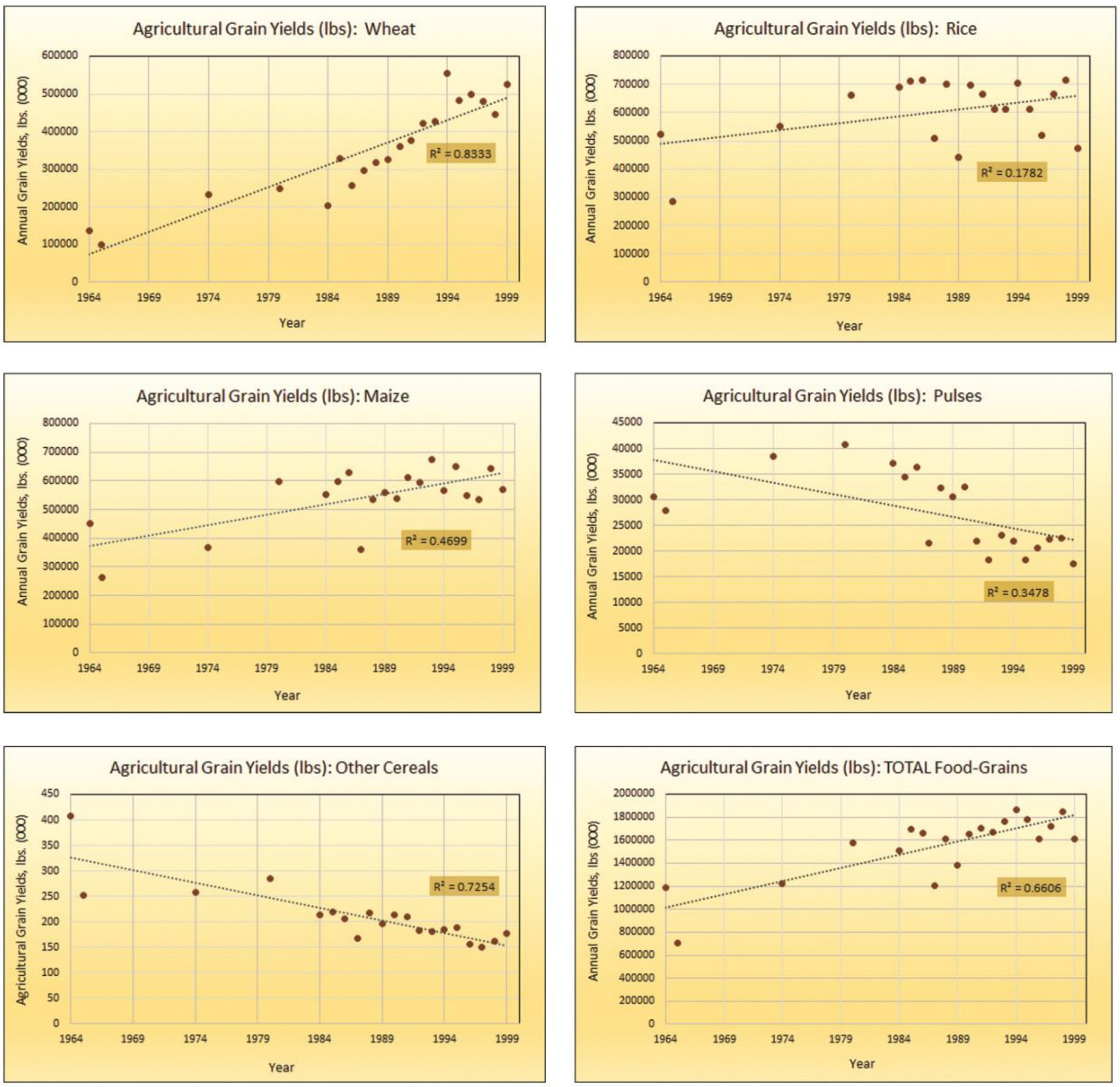
Time series comparisons between different cropping yields indicate an overall rise in agricultural production across Ladakh. For certain crops, both the land area sown for crop growing as well as total annual yields have increased since 1955. Specifically, average yields for wheat, rice and maize production has paralleled a rise in the amount of land annually planted for each crop, respectively. Alternatively, agricultural production of barley and pulses (i.e. legumes such as peas and lentils) has decreased with time. Land cultivation for fruit and vegetable production has increased over recent decades, particularly with respect to apricots, apples and potatoes. Other crop yield increases include oilseeds and fodder species for livestock and winter provisions. In short, while some agricultural yields have decreased such as barley and pulses, others have shown a moderate to strong gain in crop production, like wheat and fruits.

Grain Production and Cropping Patterns in Ladakh

Of all the crops documented in Ladakh, wheat production and cultivation has experienced the sharpest rise, a pattern consistent with neighboring district trends in Jammu and Kashmir (Figure 4.1 and Figure 4.2). A significant relationship was inferred with the amount of land sown for wheat ($r^2 = 0.91$, $p < .001$) as well as annual wheat yields ($r^2 = 0.83$, $p < .001$). In comparison, trends for annual rice yields ($r^2 = 0.18$, $p < .05$) and maize yields ($r^2 = 0.\ 47$, $p < .001$) were less considerable. Although the amount of land used for rice production ($r^2 = 0.80$, $p < .001$) and maize production ($r^2 = .82$, $p < .001$) has increased with time across the state, annual cropping yields do not reflect this expanded effort. On the contrary, the amount of land area dedicated to rice and maize production exceeds annual cropping yields. Farmers in Jammu and Kashmir are subsequently planting more rice and maize seed then they are receiving in harvested returns. Wheat on the other hand, with its high yield capacity and a steady rise in demand, has consistently shown an increase both in the amount of land sown each year as well as total annual yields.

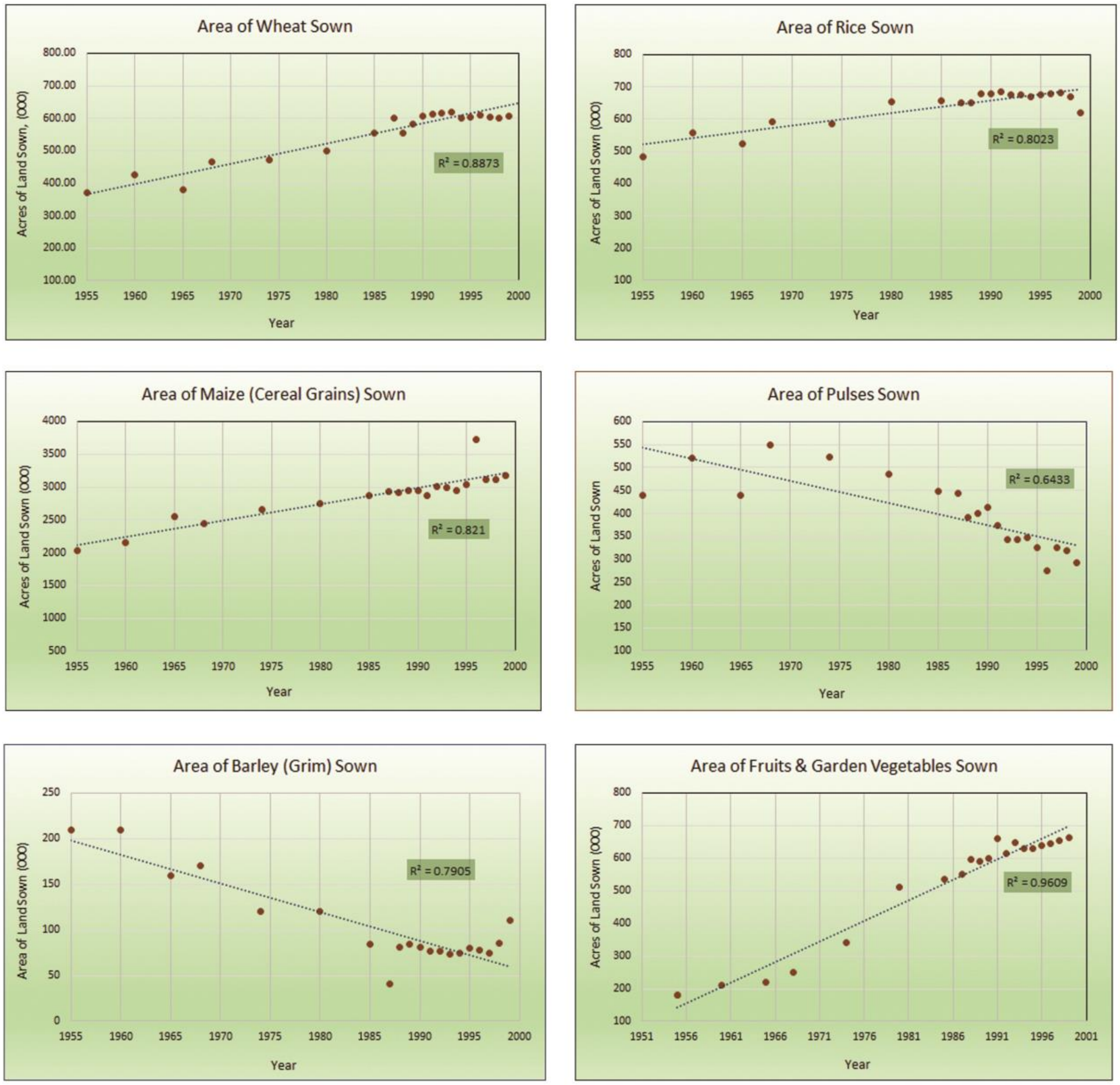
In contrast to the high production levels of wheat, a decreasing trend was identified in the yield and land area sown for both barley and pulses. Like other cereal grains, barley which is a traditional staple for Ladakhi families, has been declining in both land cover and yields since the

Figure 4.1: Agricultural Grain Yields for Ladakh, India



Source: Dept. of Agriculture, LAHDC (1964-1999)

Figure 4.2: Land Sown for Crop Cultivation, Ladakh, India



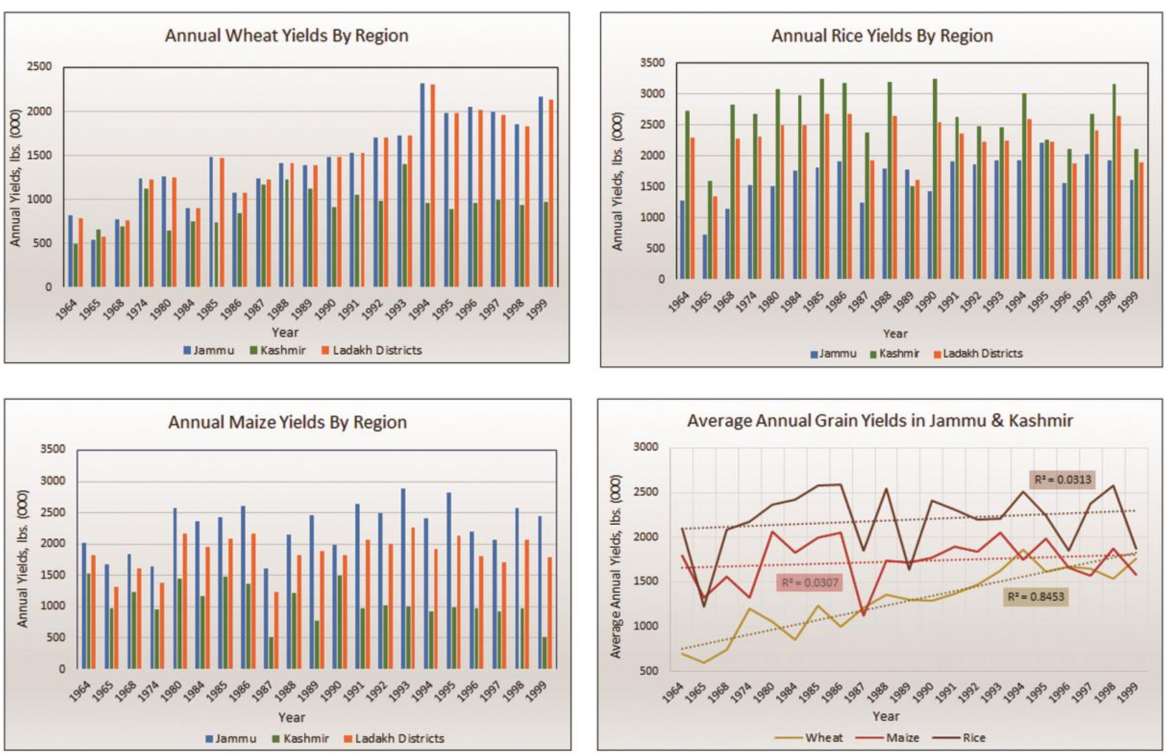
Source: Dept. of Agriculture, LAHDC (1955-2000)

1950s (r^2 = 0.725, p <.001). Similarly, the amount of land planted with pulses such as legumes and lentils (r^2 = 0.74, p <.001) and the total annual yields for pulses (r^2 = 0.35, p <.01) have declined over the latter half of the century. Recent agricultural data collected since 2000 however indicates barley and pulse production in Ladakh has stabilized and both crops are no longer in decline (LAHDC, 2010). As a whole, food grain yields in Ladakh are on the rise (r^2 =

0.15, p <.05) as well as some non-grain food items such as fruit, primarily apples and apricots, and cash crop vegetables like potatoes and cauliflower (r^2 = 0.15, p <.05).

Production trends in Ladakh are reflective of similar agricultural patterns illustrated throughout the districts of Jammu and Kashmir (Figure 4.3). Like Ladakh, wheat production across the state has steadily increased since records began in the 1960s. Wheat increases were particularly strong in Jammu and Ladakh (r^2 = .78, p < .01) and to a lesser degree in Kashmir (r^2 = .33, p < .01). Wheat yields in the state peaked in 1994 and increased an average of 3.5 percent every year during the 1990s. Although not as dramatic, average annual maize yields have additionally increased in Jammu (r^2 = .332, p < .01) and Ladakh (r^2 = .194, p < .05) since the mid-1960s. Alternatively, maize yields in Kashmir have reportedly declined in recent decades (r^2 = .18, p < .05).

Figure 4.3: State Grain Yields by Region for Jammu and Kashmir, India



Source: Dept. of Agriculture, LAHDC (1955-2000)

Annual rice yields in Jammu and Kashmir have been more variable in comparison to wheat and maize production. For instance, while Kashmir and parts of Ladakh have shown a slight to moderate increase in average rice production, Jammu has recorded a significant gain in rice yields ($r^2 = .56$, $p < .01$) (Table 4.2). Given Ladakh's extreme aridity, cold temperatures and high elevation, the lack of rice cultivation and production is not surprising. By contrast, the topography of Jammu is more conducive to a wet and temperate climate and regional rice productivity is relatively high (2.2 t/ha), even in comparison to India's national average of around 1.9 t/ha (Gupta et al., 2011). In the Jammu region, rice cultivation extends from the plains at an elevation of around 600 feet to the higher foothills of the Himalayas, at an elevation of around 7,600 feet (ibid). These preferred agroecological zones are slightly higher in Kashmir, where rice growing extends from around 5,500 feet upwards to 7,600 feet. Lower than Ladakh and more humid than the eastern part of the state, Jammu and Kashmir are favorably situated for rice cultivation.

Table 4.2: Agricultural Yield Correlations By Region, State of Jammu & Kashmir, India

Region	Rice	Maize	Wheat
Jammu	.75**	.58**	.88**
Kashmir	.03	-.43	.58**
Ladakhi Districts	.19	.44*	.89**

Note: *$p < .05$ **$p < .01$

In addition to wheat, rice is increasingly supplanting barley as the predominant grains consumed in many Ladakhi households. In large part, this is due to heavy imports of rice and wheat flour into Leh by the central government of India. Given Leh's explosive growth in recent decades, there has been a widening food gap and an inability to sufficiently feed Leh's burgeoning population. Subsequently, the difference between the total quantity of food required to feed Leh's population exceeds the quantity locally available and is resulting in an annual food-grain deficit (Pelliciardi, 2013). In response, commercial traders from India, cooperatives in Leh, and the Indian Consumer Affair Department have facilitated the large-scale importation of particular food-grains into Ladakh, primarily wheat flour and rice. Administered under the auspices of the Public Distribution System (PDS), the amount of food-grains imported into Leh has doubled over the past decade. Whereas in 2000, PDS imported 2,741 metric tons of food-grains, by 2009 the amount of imported food-grains increased to 5,042 metric tons (LAHDC, 2009).

The yawning divide between food supply and grain demand in Ladakh is not necessarily reflective of insufficient small-farming production systems, rather it suggests the cumulative pressures Leh and the surrounding area is experiencing from significant socioeconomic and demographic shifts. According to Pelliciardi (2013), population growth, urban migration, land use change, new dietary habits, off-farm income opportunities and national policies are the main limiting factors influencing food-grain dependence from the outside into Leh. Indeed, close examination of the Ladakhi traditional farming systems demonstrates relatively high annual agricultural yields in relation to local geographic context. For instance, estimated government statistics of grain yields in Ladakh range from 1.2 to 1.5 tons per hectacre (t/ha) (Osmaston, 1985). Ladakhi farmers have reported higher yields of around 2 to 3 t/ha in the more fertile villages (Osmaston, 1989). This is confirmed by estimates of yields in small sample plots in crops in the Zanskar area (Chalmers and Ramm, 1984) and in the Upper Indus Valley (Norberg-Hodge et al., 1989), which indicate average crop yields in soil-rich areas to be around 3 to 3.5 t/ha. This is in comparison to an average grain yield estimate of around 2.84 to 3.26 t/ha for central India (World Bank, 2012).

The above yield estimations suggest Ladakhi farmers heavily sow their land in order to maintain moderate to high levels of production (Osmaston, 1995). This is particularly true for barley and maize where the amount of land planted exceeds average annual yields. Alternatively, wheat production is on par with wheat cultivation and is subsequently surpassing other crops as Ladakhi farmer's preferred agricultural commodity. Perpetuated by high market demands and subsidized through government programs, wheat production will likely continue to dominate many local small-farming operations. Such trends are indicative of an overall shift from traditional Ladakhi crops, such as barley and pulses, to more commercialized cash crops like wheat and potatoes. Although many households will continue to grow barley, maize and pulses, this will mainly be used for family consumption and not household income (Pelliciardi, 2013; Demenge, 2007).

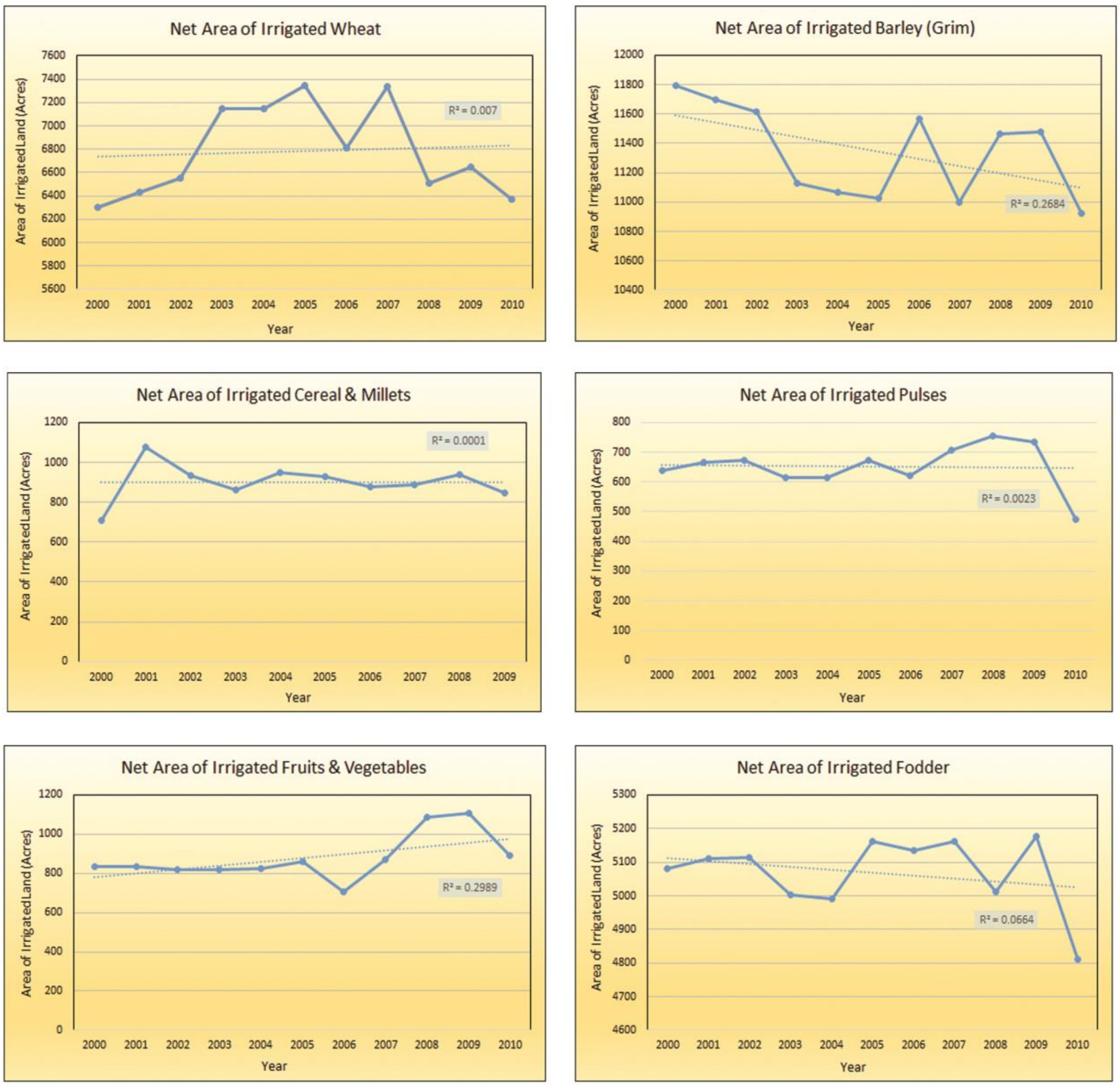
Together, the shift to cash crops and increasing importation of food-grains reinforces a growing dependence on external food sources, most of which is supplied from central India. According to one administrative document, "Ladakh is getting excessively reliant on the outside world for critical needs such as food" (LAHDC, 2005). Unsurprisingly, the constant stream of imported cereal grains, rice and other food items has influenced household dietary preferences. For instance, Dame and Nüsser (2011) reported that in recent years, there has been a marked transition in seasonal food habits for many Ladakhis. Locally produced cereals are now increasingly supplemented with imported subsidized wheat flour during the winter and an increasing consumption of imported rice during the summer. This evolving dependency on external food suppliers will bring a myriad of multifaceted challenges to Leh, such as infrastructure needs, transportation oversight and maintenance, vacillating market values, administrative controls and other political and managerial considerations. Traditionally practicing subsistence farming, the importation of crops such as wheat and rice will increasingly shape cultivation and production patterns of locally grown crops across Ladakh.

Irrigation Patterns and Domestic Water Requirements

Shifting Ladakhi farming practices that favor large-scaled wheat production over smaller commodities like barley and pulses may have long-term implications for local irrigation patterns. Like many arid landscapes, water in Ladakh is a scarce resource and many households depend on the region's dense concentration of glaciers and permanent snowpack for irrigation needs, drinking water and other domestic tasks. In the Leh district for instance, the Central Groundwater Board of Jammu (2009), reports groundwater irrigation is essentially non-existent in the area and 100 percent of agricultural cultivation efforts are supported by gravity fed systems. Already constrained by limited arable land and absence of rainfall, sole dependence on glacial meltwater and stream run-off for irrigation requirements further exposes Ladakhi farmers and households to potential complications arising from water shortages, drought and other hydrological variability.

Water requirements for irrigation in Ladakh largely mirror recent trends in agricultural production and annual yields. For example, records collected since 2000 indicate the net area of irrigated land for wheat has increased over the past decade, as well as for certain fruits and garden vegetables. Alternatively, the net irrigation for barley has decreased over the past decade (LAHDC, 2011). For pulses, millets and other cereal grains the amount of irrigated land has remained relatively stable (Figure 4.4). Understandably, land irrigation and crop cultivation are strongly associated with one another. In other words, as wheat cultivation has increased in Ladakh so has the amount of land irrigated for wheat production ($r = 0.866$, $p < .01$) (Table 4.3). A similar correlation was demonstrated with fruit and vegetable cultivation and irrigation patterns (r = 0.856, p < .01) as well as with barley planting and irrigation trends (r = 0.827, p < .01).

Figure 4.4: Net Area of Irrigated Crops, Ladakh, India



Source: Deputy Commissioner's Office, Leh District, LAHDC (2000-2010)

Table 4.3: Irrigation and Crop Cultivation Correlations, Ladakh, India

	Wheat	Barley	Pulses	Millets	Fruits	Total
Irrigated Area	0.886**	0.827**	0.088	0.965**	0.856**	0.998**

Note: $^*p < .05$ $^{**}p < .01$

Water for agricultural irrigation in Ladakh is predominately supplied through available surface waters, such as stream run-off and meltwater. Originating from glaciers situated in the upper cirque basins, the water is distributed to downstream villages through an extensive network of canals, ponds and pipelines. Indeed, canals are the predominant source of irrigation used in Ladakh and irrigate close to 25,000 acres of land annually (LAHDC, 2010). In towns like Leh and more concentrated developments, land irrigated by canals is confined to smaller household plots averaging 7,900 square feet in size. Conversely in peripheral rural areas with more cultivable land, household plots can easily exceed 45,000 square feet in size with much larger farming tracts available on the outskirts of the village (Akhtar, 2010).

Additional sources of surface water for irrigation include watering tanks and springs. The watering tanks, known as *zings*, are constructed as large open-aired pools and harvest water from nearby tributaries and drainages. Zings are particularly useful due to the lag in timing and slow percolation of glacial meltwater from the input source to the output of the canal. In Ladakh for instance, solar radiation is the greatest during mid- to late afternoon which corresponds with the run-off of the glacier. By the time the meltwater travels the circuitous canal system and reaches downstream households, it is likely late in the day or early evening (Akhtar, 2010). The zings therefore serve to store the water until the following morning when it is most needed for irrigation and domestic activities.

In larger towns such as Leh, zings are utilized for communal purposes and support critical infrastructure for the town's municipal water supply. In Leh for example, there are nearly thirty zings situated along the town's primary tributary, the *Leh Tokpo*. The release of water from these zings is controlled by a *churpon*, or an elected water official (Angchok and Singh, 2006; Agarwal and Narain, 1997). Traditionally, the role of *churpon* was a highly respected position requiring religious ordination from the local lama and an intimate knowledge of the village water system, however nowadays the *churpon* is an obligatory position frequently filled by a hired migrant worker (Tiwari and Gupta, 2008). As a result, there is a lack of in-depth understanding regarding the holistic hydrologic system and the even distribution of water from household to household. Families geographically situated upstream are therefore advantageously positioned to receive more water than families located downstream.

While historically, geographic distribution of water for irrigation and domestic use has not been a critical issue in Leh, with increasing water shortages and rising urban demands, downstream communities are increasingly concerned about the paucity of consistent water supply. Consequently, water allocation has recently shifted to a temporal management scheme with periods of the day designated to each *churpon* and village block. During the identified time slot, the *churpon* is responsible for opening the valve to the zing and closing it after a six-hour period. Yet wide disagreement about the timing and administration of water allocation between different households and village blocks in Leh remains strong and will likely be exacerbated by population growth, tourism infrastructure, variability in water supply and other effects associated with an overall increase in demand.

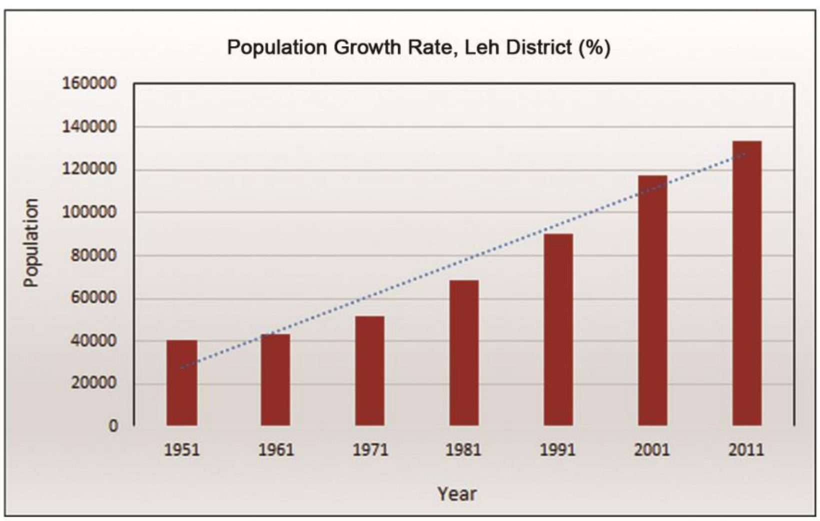
Perhaps a more urgent concern for Leh's residents and community water requirements is the diminishing coverage of the Khardung Glacier, the town's exclusive resource for surface water (Figure 4.5). Situated slightly above Leh in the upper mountain basin, many local residents have observed a shrinking of the glacier and a retreat of the permanent snowline in recent years (GERES, 2009; Shrager, 2008). In parallel, water supply is becoming less reliable with each succeeding decade and water shortages are more prolonged compared to past years (Norphel, 2009). During the summer, available water from surface discharge is quickly consumed by upstream households and villages, leaving minimal resource for downstream communities. Furthermore, near complete exhaustion of surface waters during the summer inadequately recharges the water table and reduces what scant groundwater resources marginally exist throughout the rest of the year.

Figure 4.5: Khardung Glacier is Leh's exclusive source for irrigation (Image: K.Nygaard)

Irrespective of meager groundwater yields, digging pumping wells to meet rising commercial, development and domestic needs has become increasingly popular. As reported by the Central Groundwater Board in Leh (2009, 10), "surface water, springs and other traditional sources of water supply for villages and habitats are getting dried up and causing hardship to the [Ladakhi] people. To mitigate the water supply crisis, hand pumps and tubewells can be constructed at suitable locations..." However, the presence of "suitable" sites for groundwater wells in Ladakh is limited given the steep and hilly terrain. Moreover, many wells will likely fall short of producing enough water to sufficiently supply the region's ample irrigation and municipal requirements. The availability, accessibility and allocation of water resource in Leh and elsewhere in Ladakh will therefore be a considerable concern for city planners, government officials and villagers in the foreseeable future.

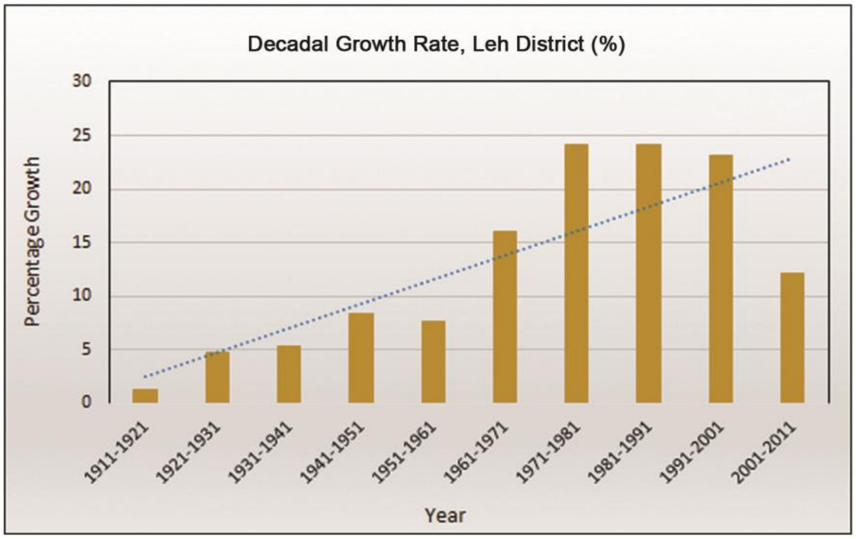
Indeed, overall water consumption in Ladakh is rising and parallels the growth in the region's urban population, tourism industry and shifting lifestyle preferences. These transformations are most pronounced in the town of Leh, where the population has increased from 3,720 people in 1961 to nearly 41,000 in 2010 (Sudhalkar, 2007). Within the larger Leh district, the population has jumped from 40,484 in 1951 to 133,487 in 2011; nearly a 70 percent increase (LAHDC 2009; Census of India, 2011) (Figure 4.6). Much of this growth has occurred during the latter half of the century, with an average increase of 19.9 percent each subsequent decade since 1961 (Figure 4.7). Similar to the rest of India, these figures are projected to double by 2040 if development and population growth continues unabated (Sudhalkar, 2007).

Figure 4.6: Population Change, Leh District, Ladakh, India



Source: National Indian Population Census (1951-2011)

Figure 4.7: Decadal Population Change, Leh District, Ladakh, India

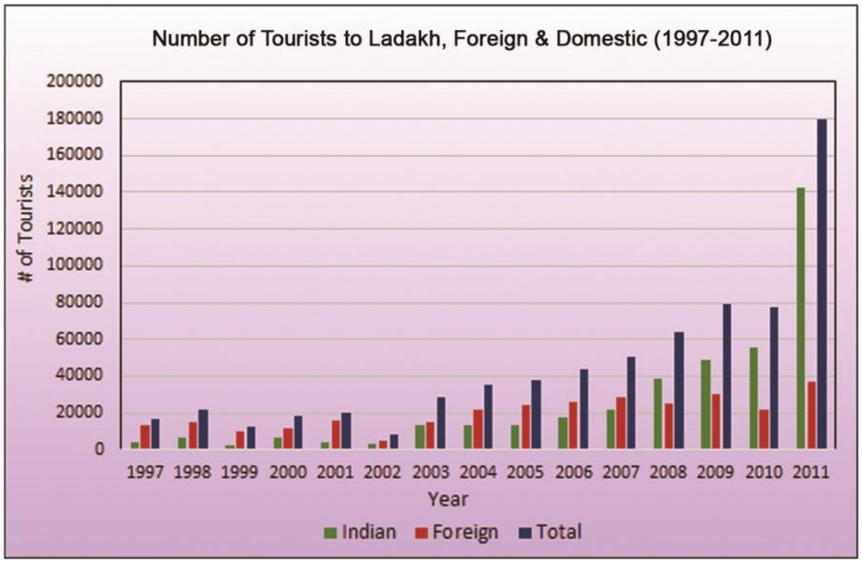


Source: National Indian Population Census (1911-2011)

In addition, Leh is becoming an increasingly desirable tourist destination for both domestic Indian tourists as well as foreign visitors. In 1997 for example, there were less than 17,000 tourists who entered Ladakh yet in 2011 nearly 180,000 tourists were reported, more than a ten-fold increase in just over a decade and four times the permanent resident population (LAHDC, 2012) (Figure 4.8). The accelerated influx of tourists into Ladakh and particularly into Leh, has placed unprecedented demands on local water resources and infrastructure. While the most visible impacts include the construction of hotels and guesthouses, even more acute changes involve the rapid and modernizing demands on Leh's municipal systems, including water, sanitation and waste disposal.

Perhaps one of the more demonstrative manifestations of modernity in Leh has been the shift to flush-toilets from traditional Ladakhi "dry toilets." Whereas the former is the preferred amenity by foreign tourists and increasingly domestic Indian visitors, the latter system has been operational in Ladakhi households for centuries and is the most conducive for Ladakh's dry and

Figure 4.8: Number of Tourism Receipts, Leh, Ladakh, India

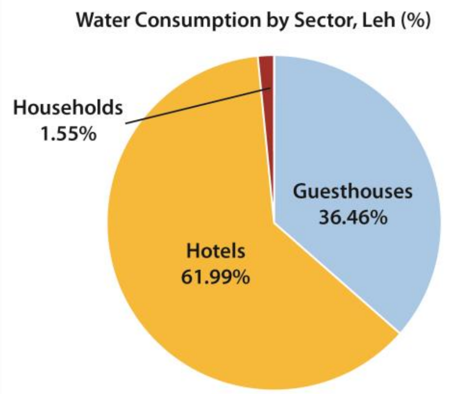


Source: Tourism Department (LAHDC) (1997-2011)

arid climate. Utilizing no water, this type of latrine involves a process of natural decomposition and waste recycling in contrast to the more water intensive flush-toilets. Due to the rising popularity away from dry toilets to flush toilets, municipal water demands from commercial use far exceed domestic household needs in Leh (Figure 4.9). For instance, according to a study conducted by Akhtar (2010), the average per capita daily water consumption rate for local residents in Leh is around 20 liters in the summer and 14 liters in the winter. In comparison, during the summer tourists consume an average of 55 liters to 81 liters of water per day. In a recent survey conducted by the Ladakh Ecological Development Group (LEDeG), the 375 hotels in Leh were extracting 852,000 liters per day (Parvaiz, 2013). While nearly all commercial hotels offer water-based flush-toilets, 93 percent of guest houses offer the option of traditional dry toilets however surveys suggest less than 2 percent of tourists are comfortable using this method of latrine. Consequently, Leh's many guest houses are steadily converting to flush-toilets and standing showers in order to remain competitive within the town's booming accommodation sector.

The converging pressures from Leh's escalating tourism industry, developing infrastructure, and shifting food production patterns is straining the quantity and quality of local water resources. This triage of forces will undoubtedly present a host of challenges that will fundamentally shape how local water supplies are conserved, managed and allocated in the Ladakh's near-term future. Moreover, recent dietary preferences and market trends that favor wheat and subsidized rice over traditional crops such as barley and pulses are also influencing local farming practices. In turn, Ladakhi farmers are encouraged to shift to more intensive cropping patterns which support wheat cultivation and other cash-crops over less commercialized crops. As a result, more land and water is being utilized for wheat production while fewer efforts are being put into the cultivation and irrigation of other food grains such as barley and millets.

Figure 4.9: Water Consumption in Leh



Perhaps more disconcerting for Ladakh's water reservoirs, particularly in the town of Leh, is the projected rise in tourism and municipal needs. Given Ladakh's continued integration into the global economy, it is highly likely the town of Leh and its residents will face significant complications resulting from potential variability and reliability in the hydrologic cycle. The noticeable retreat of the Khardung Glacier and surrounding snowpack foreshadow an uncertain and in many ways, worrisome future for Leh's population. Climate stresses such as drought and extreme weather events will compound water shortages resulting from diminishing snowpack levels and severely test the ability for Leh residents, businesses and government to meet growing water requirements.

Not immune to the region's water challenges, Ladakhi farmers will be equally pressed to secure sufficient water resources for crop production particularly within close proximity to Leh. As water availability in Leh and other developing towns becomes increasingly more sporadic, farmers and households will have to compete against one another as well as private and public sectors for resources. When water supplies falls short of demand, crop production will wane thus propagating Ladakh's food-grain deficit and continued reliance on food suppliers from outside the region.

Temperature Trends and Precipitation Patterns

Climate conditions are a critical determinant of water availability in Ladakh and understanding the nature of this exchange may shed light on the short- and long-term implications for local Ladakhi farming systems and other livelihood activities. While past studies suggest the climate is changing in this part of the world, heterogeneity exists with regard to the scope, magnitude and frequency that regional climate change impacts are occurring (Hewitt, 2013; Shekhar et al., 2010; Bhutiyani et al., 2007; Brazel and Marcus, 1991.) Fowler and Archer (2006) for instance, suggest the western Himalayas are responding differently to global warming trends relative to other mountain ranges, even in comparison to the central and eastern Himalayas. While many of the world's mountain glaciers have receded in recent decades, some glaciers in the Hindu-Kush and Karakoram mountains have expanded in size or experienced periodic surges (Hewitt, 2005). Measured trends in observed glacial movement, diurnal temperature ranges, and precipitation patterns subsequently reflect the varied topography, extreme gradient and remote terrain of Ladakh and neighboring western Himalayan places.

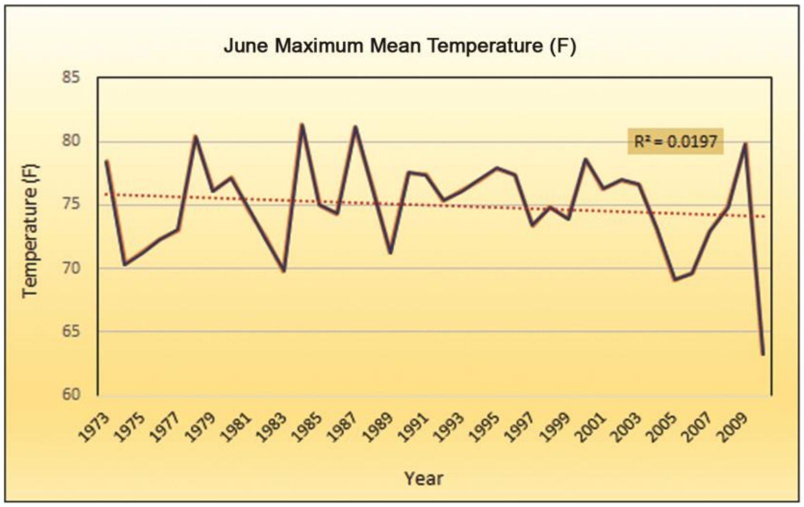
Researchers attribute the discrete and sometimes contradictory findings on climate trends in the western Himalayas to the region's orographic processes, feedback loops and monsoonal influences (Dimri and Mohanty, 2009; Archer and Fowler, 2004; Yadav et al., 2004). In addition to effects on glacial mass balance, research findings indicate the seasonal mean, maximum and minimum temperatures have generally increased in the western Himalayas while precipitation trends have conversely decreased (Shekar et al. 2010). According to Dimri and Dash (2012, 797), "there are more warm events compared to fewer cold temperature events. The coldest nights are getting warmer and hence percentage number of cold nights is decreasing while percentage number of warm nights is increasing, particularly during the winter." Fowler and Archer (2006) additionally report higher regional air temperatures during the winter which is associated with a decrease in the ratio of solid to total precipitation at lower elevations. This implies an increase in rain-on-snow events and less overall precipitation in the form of snow. Climatological analysis of the western Himalayas however is rife with uncertainty and many agree the region's extreme altitudinal variation and dearth of data and monitoring stations hamper the ability to establish long-term climatic patterns within the region (Forsythe et al., 2012; Hewitt, 2011; Archer and Fowler, 2004).

With respect to climatological studies specific to Ladakh, GERES has performed the only published preliminary analysis of both temperature and precipitation trends for the Leh District (2009). In their analysis, GERES cites a clear indication of rising minimum air temperatures in Leh with nearly a 1^{o}C increase during the winter months since 1973; for the summer months, an increase of 0.5^{o}C was observed. Also included the GERE report (2009) was a trend analysis of precipitation in Leh which indicated a decline in snowfall during the months of November through March. Alternatively, during the summer months no significant trends were identified. A reduction in winter snowfall is disquieting because Ladakh receives close to 70 percent of its annual precipitation from December through March, all of which is crucial to glacial nourishment and the balancing of perennial snowpack (Angmo and Mishra, 2009). When coupled with a rise in winter temperatures, decreasing snowfall can subsequently affect river runoff levels and the amount of water available for irrigation, industry and related domestic consumption. Understanding regional temperature and precipitation trends is therefore an essential component of assessing the direct and indirect implications of climate change on local ways of life.

Analysis of climatological data for this study, including temperature and precipitation records, largely draws off research findings from the GERES report (2009) and government records, and is further supplemented by analogous studies conducted in the Hindu-Kush and Karakoram mountain ranges. While many of the same conclusions are reproduced in this study, there are some notable exceptions. One area of divergence for instance, involves summer maximum mean temperature trends in Ladakh. Whereas the GERES report concluded there has been an increase of 1^{o}C since 1973, analysis in this study identified a decreasing trend in summer maximum mean temperatures over recent decades (r^2 = .02, $p < 0.50$) (Figure 4.10). Although this relationship was not determined to be significant, a summer cooling trend does parallel similar studies conducted by Fowler and Archer (2006) in the Upper Indus Basin, the Karakoram range (Bocchiola and Diolaiuti, 2013; Hewitt 2013; 2005) and other sub-basins within the western Himalayas (Yadov et al., 2004).

According to the former study, summer cooling can be partially attributed to pre-monsoonal weather conditions, cloud cover variability, increased storminess and a myriad of other climatic coincidences that are still being examined and understood. In addition, a potential explanation for the discrepancy in findings between this study and the GERES report is the inclusion of the most recent temperature data for 2010, a year that recorded below average summertime temperatures relative to previous years. In contrast, the GERES temperature dataset terminates in 2009 and analysis within the report is based on average to above average temperature records thus positively contributing to the slope analysis. In omitting the 2010 data record, the linear analysis does indeed reflect an incremental rise in Leh's temperatures.

Figure 4.10: Maximum Temperature Trends, Leh, Ladakh, India



Source: Indian Meterological Dept. (1973-2009); GERES, (2009)

In lieu of the research findings generated within this report, a cooling of summer mean temperatures in the western Himalayas may explain why some glaciers in the Karakoram mountain range are surging in contrast to glaciers in the central and eastern Himalayas shrinking. A reduction in summer temperatures implies reduced ablation and a positive mass balance of glaciers. In other words, a cooling effect in the summer can correlate with an increase in winter precipitation and at higher elevations, these two processes can converge in the accumulation zone of the glacier's termini to feed its expansion (Hewitt, 2013; Quincey et al. 2011). Further, cooling summer temperatures can have an effect on river runoff levels and according to Fowler and Archer (2006), the observed 1°C decline in summer temperatures near Skardu, Pakistan accounts for a 17 percent decrease in runoff for the Shyok River. By contrast, a rise in mean air temperatures correlates with an increase in river runoff. According to one study by Singh and Kumar (1997), an average gain of 1°C for mountains in the western Himalayas is equivalent to a 16 percent to 18 percent increase in runoff levels for glacial catchments within the region.

It is important to note that despite a recent summer cooling trend, annual mean temperatures in Ladakh are on the rise as a whole. Indeed, most published studies concur with the GERES report and cite a rate of ~1°C warming respectively, for much of the Himalayas over the course of the past century (Dimri and Dash, 2012; Shekhar et al., 2010; Fowler and Archer, 2006; Kothawale and Kumar, 2005). The summer cooling anomaly indicated for Ladakh, as well as the Karakoram mountain range and parts of the Hindu Kush, should therefore not discredit worldwide evidence of anthropogenic warming. Rather it further complicates the narrative of climate change and if nothing else affirms the nuances and unpredictability of the climate change trajectory. Accelerating temperatures are anticipated to augment the effects of climate change at higher elevations and Ladakh, like other high mountain regimes, is not exempt (IPCC, 2013; 2007). It is therefore essential to contextualize temperature variability within the broader holistic climate change framework and recognize potential impacts from anthropogenic warming are not spatially or temporally symmetrical in nature.

Changes in temperature are expected to closely align with fluctuations in precipitation. For Ladakh and elsewhere within the Upper Indus River Basin, annual precipitation falls in winter and spring and is largely influenced by weather systems migrating from the west, especially the Indian Asian monsoon. The Asian monsoon is one of the most important features in the coupled ocean-land-atmosphere system and significant links have been identified between Indian monsoon rainfall and a wide range of large scale climatic processes, such as El Nino Southern Oscillation (ENSO) (Shengping and Wang, 2013), westerly winds in the Northern

Hemisphere (Liu and Wang, 2013) and Mediterranean pressure indices (Raicich et al., 2003) (Archer et al., 2004).

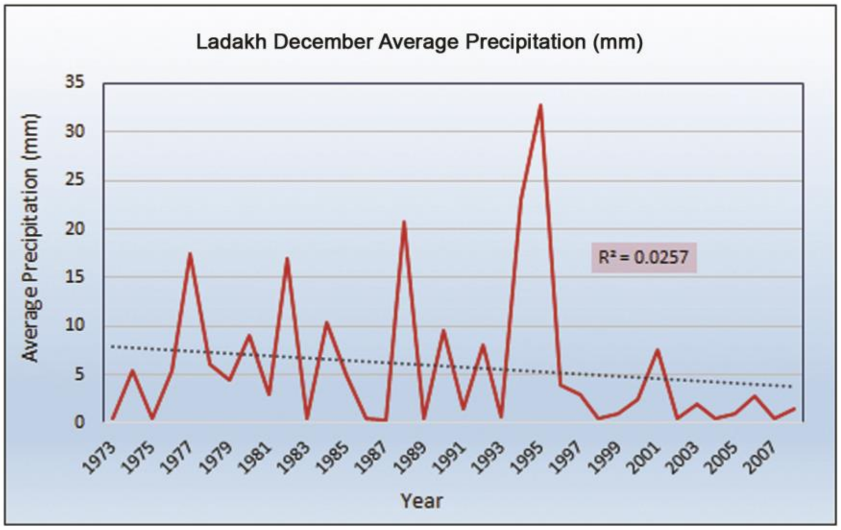
The effects of the monsoon in the northwest Himalayas and Ladakh are less pronounced in comparison to the central, southern and eastern Himalayas. Precipitation resulting from monsoonal flows remains relatively minor in this region and generally arrives between July and September. Irrespective of its minimal incursions into Ladakh, monsoonal weather flows likely have an effect on precipitation patterns in the western Himalayas by influencing atmospheric circulation systems, westerly weather disturbances and cloud cover extent (Dimri and Mohanty, 2007). In addition and as noted above, determining precipitation trends over any temporal range for the western Himalayas is challenged by the region's extreme thermodynamic processes, orographic uplifting and slope differentiations. The location of particular weather stations hence plays an influential role in reporting measured precipitation amounts and many records indicate an uneven distribution across the range. In short, terrain, altitude and topography largely determine how, when and where precipitation falls across the western Himalayas.

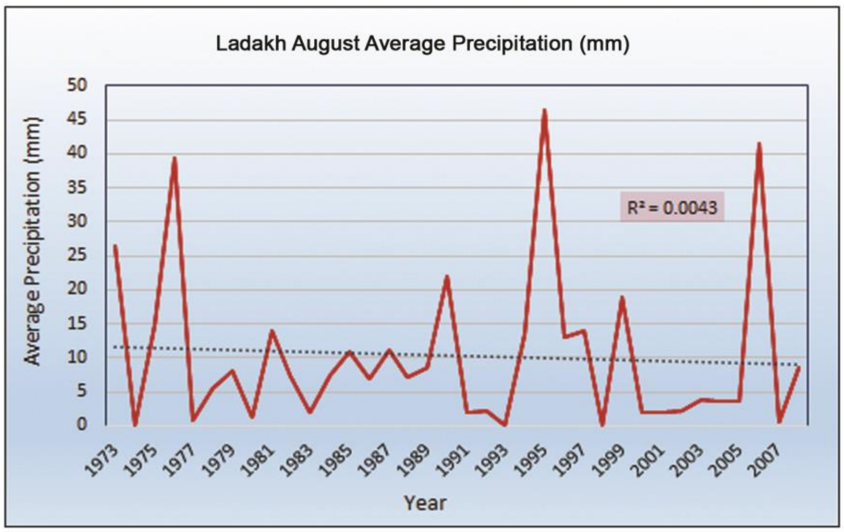
Nevertheless, numerous studies suggest the mountains in and around the Upper Indus Basin are experiencing a decreasing trend in annual precipitation though with substantial spatiotemporal variation (Dimri and Dash 2012; Shekar et al. 2010; Basistha et al., 2009; Archer et al., 2004). Moreover, much of this precipitation is coming in the form of rain in contrast to snowfall. Alternatively, analogous studies conducted in the central and eastern part of the Himalayas indicate an increasing trend in precipitation, including Uttaranchal, India (Singh and Yadav, 2005), the Tibetan Plateau (Gao et al., 2012; Li et al., 2010), and parts of Kashmir Pakistan (Bocchiola and Diolaiuti, 2013). Again, the high degree of geographic variability characterizing the Himalayan front is generating a mixed climatological milieu where the effects and outcomes of climate change play out differently across the region.

Analysis of meteorological records for Leh indicate a decreasing trend in annual precipitation and support similar findings for this area of the Himalayas. From 1973 to 2008, a decline in precipitation is observed during the month of December although this was not determined to be significant ($r^2 = .03$, $p < 0.5$) (Figure 4.11). This equates to a reduction in precipitation of around 1 to 2 millimeters (mm) per decade. A slightly less and non-significant decreasing trend was additionally observed during the month of August.

While a subtle drop in precipitation may not visually amount to much, the shear aridity of Ladakh accentuates the importance of any moisture to this region at all. On average, Leh receives around 93 mm of precipitation during the year, substantially less than areas situated just beyond Ladakh's northern and western borders. Villages in Pakistan and India Kashmir for instance, report an average of 683 mm to 1,700 mm of annual precipitation (Archer et al., 2004). Even the towns of Gilgit and Skardu, located slightly north of Ladakh's border with Pakistan, record an average of 137 mm to 222 mm per year (Bocchiola and Diolaiuti, 2013) (Table 4.4). In comparing worldwide precipitation averages, Ladakh ranks in the same tier as countries in the world's high pressure zones, including central Africa (~ 50-70 mm) and the Arabian Peninsula (~59-80 mm) (World Bank, 2012). Ladakh is therefore somewhat of a geographical paradox given its vast mountainous landscape and high elevation, yet exceptional lack of moisture.

Figure 4.11: Average Precipitation Trends (Dec/Aug), Leh, Ladakh, India





Source: Indian Meterological Dept. (1973-2009); GERES, (2009)

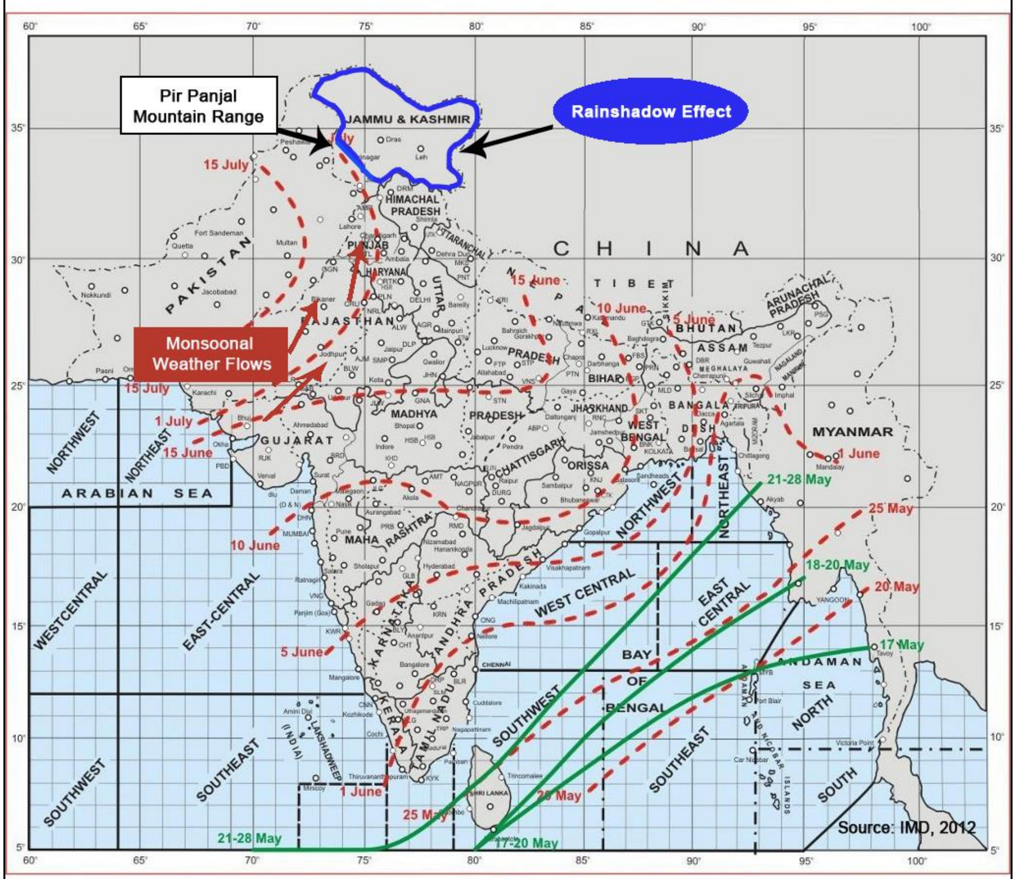
Table 4.4: Regional Precipitation Totals (mm)

REGION	RAINFALL	REGION	RAINFALL
Leh	92.7	Balakot	1731.0
Srinagar	683.0	Chitral	441.7
Gilgit	131.2	Muzafferabad	1,367.2
Skardu	222.3	Manali	1,363.0
Drosh	636.8	Shimla	1,575.0

Source: Archer et al., 2004; Bocchiola and Diolaiuti, 2013

As evidenced above, Ladakh exhibits unusually dry conditions particularly for a high altitude environment set amidst the world's heaviest concentration of glaciers and ice. Positioned in the rain shadow of the Tibetan Plateau, much of the precipitation carried in by northern flowing air masses is deposited on the windward side of the Himalayas causing heavy rainfall events in the southern foothills and adjoining plains of India. While some of the monsoonal currents reach Srinagar and the lower elevations of the Kashmir region, thus accounting for the heightened precipitation levels in that area, the Pir Panjal range in India's Himachal Pradesh effectively traps this moisture and inhibits it from migrating further northward (Nandargi and Dhar, 2011). By the time the air masses migrate over the Pir Panjal range and seep into Ladakh, there is little moisture remaining (Figure 4.12).

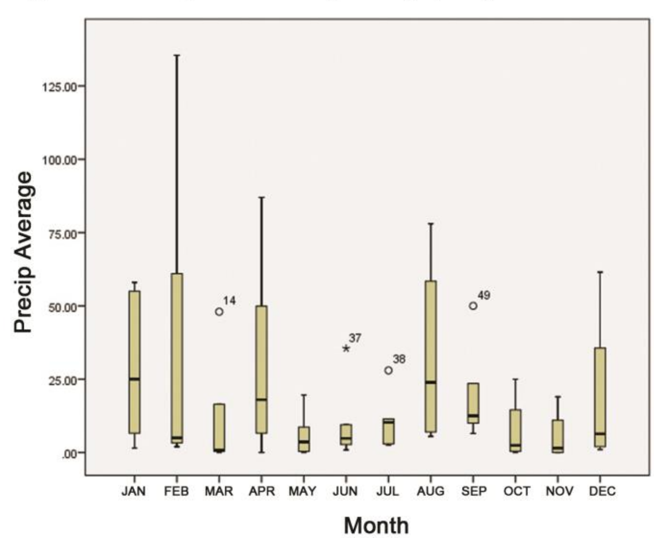
Figure 4.12: Monsoonal Weather Flows for India, IMD (2012)



With the exception of monsoonal disturbances, what little precipitation Ladakh does receive generally arrives between December and April (Figure 4.13). Over the course of recent decades however, a number of unusually heavy and unseasonable rainfall events have been reported in Ladakh and the larger Himalayan-Hindu Kush region (Singh et al., 2011). A driving mechanism of these sudden and extreme precipitation occurrences is a mesoscale weather system known as a cloudburst. Cloudbursts manifest as a result of moisture-laden air masses encountering an obstacle, such as a mountain, and through a process of rapid orographic uplifting and convection forcing, the pregnant cloud releases a sudden downpour of rain. Characterized as a highly intense and localized precipitation event, a cloudburst can result in more than 100 mm of rainfall in under an hour leading to flash floods, debris flows and landslides (Das et al., 2006). Given the unanticipated timing and dramatic occurrence of these weather perturbations, cloudbursts can be devastating to mountain populations, local infrastructure and village life.

Perhaps the most memorable and in many ways most destructive extreme weather events for many Ladakhis took place in early August 2010. From August 4th through August 6th, a successive wave of cloudbursts washed over the town of Leh and nearby villages, killing 255

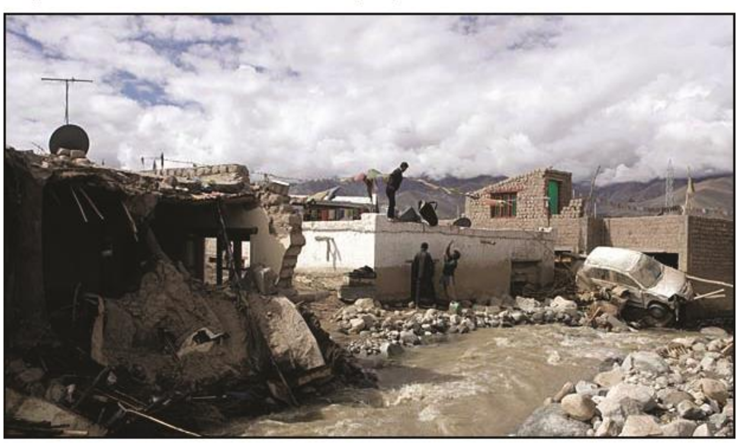
Figure 4.13: Precipitation Monthly Averages, Leh, Ladakh



people (Thayyen et al., 2013). The heaviest downpour occurred on August 5th, leading to a spate of flash floods throughout Ladakh but predominantly in the villages in and around Leh. At the end of the three day torrential assault, 52 villages were severely damaged, over 3,500 acres of land was covered in mud and debris, and 1,749 houses were destroyed (ibid). Approximated rainfall amounts from the cloudbursts range from 40 mm to 70 mm in a three-hour period to 120 mm in one day on August 5th (Kumar et al., 2012; Ashrit, 2010). Yet in a recent study by Thayyen et al. (2013), the authors estimated the storm intensity in the town of Leh to be around 209 mm in under a 12-minute period. Even more significant, the same study estimated a storm intensity for the catchment of Sabu, located directly east of the Leh catchment, to generate around 320 mm of precipitation in less than a 9-minute period (ibid). In effect, the town of Leh and neighboring villages received more than twice, and in some cases up to three times their annual precipitation yields in less than 12-minutes due to the early August rainfall event (Figure 4.14).

The frequency and magnitude of extreme rainfall events is projected to increase with climate change (IPCC 2011; 2007). For much of the Himalayas and Ladakh, this implies more severe and repeated cloudburst occurrences along with residual flash floods, debris flows and

Figure 4.14: Cloudburst Event in Leh, August 2010



Source: Reuters, 2010

landslides. For instance, many locals surveyed in this study have perceived an increase in untimely and heavy rainfall events (78 percent, *M*=1.26, *SD*=.52) as well as flash floods (93.3 percent, *M*=1.9, *SD*=.42). As discussed in the previous chapter, most respondents estimated they had witnessed between two to three extreme rainfall events over the course of their lifetime (85.4 percent, *M*=1.16, *SD*=.41), with some respondents indicating they had experienced four or more extreme precipitation occurrences (14.6 percent). These observations are supported by climatic records indicating comparable though slightly less damaging extreme rainfall events in 2005 and 2006 in Ladakh as well as several cloudbursts occurring during the 1990s (Xu et al., 2006). However, empirically ascertaining the degree of spatial and temporal change in extreme weather events in Ladakh is encumbered by the lack of historical data and baseline trends for the region.

Elsewhere in the western Himalayas, analogous case studies do suggest an increase in extreme rainfall events. Dhar and Nandargi (1998) for example, illustrate a considerable increase in heavy rainfall episodes across the larger western Himalayas, particularly during the 1950s and 1990s with a slight decrease from 2001 to 2007. Similarly, in a regional analysis conducted by Deshpande et al. (2012), an increase of extreme rainfall occurrences in shorter time durations along the Indian Himalayan foothills was measured. Closer to Ladakh, other observations of heavy rainfall events have been made in the nearby Kullu Valley and Sutlej Valley, where more than four major cloudbursts were reported in the past 12 years (Xu et al., 2006). An increase in extreme rainfall events has additionally been observed across Pakistan (Rasula and Zahida, 2011), the sub-Himalayan belt near Sikkim (Nandargi and Dhar, 2011) and in Nepal (Shrestha, 2005).

The amount of precipitation resulting from a cloudburst is a considerable amount of rainfall for any location and the consequences to local people are physical as much as mental and emotional. In Ladakh, and for a region historically unaccustomed to heavy inundations and wet conditions, excessive rainfall can be especially damaging to homes, structures and other property. Traditionally constructing from mud, stone, timber and other materials less resilient to heavy rainfall and flooding, Ladakh's community and household infrastructure is negatively exposed to these types of natural disasters. For example, according to the most recent national census, more than 40 percent of homes in Jammu and Kashmir utilize grasses, mud and stones for wall materials (Census of India, 2011). If an increasing trend in extreme precipitation events and other weather perturbations is linked to climate change, as projected by the IPCC (2013; 2011; 2007), then the August 2010 cloudburst in Ladakh is a foreboding precursor of future climatic conditions and underscores the need for effective hazard risk management.

In examining mean annual temperature trends and precipitation patterns in Ladakh, the influence of the region's variable topography, physiography and altitude on climate is strongly demonstrated. In addition, the positioning and monitoring of weather stations has not been uniformly managed across the region, somewhat interrogating the accuracy of any authoritative statements regarding Ladakh's changing temperatures and precipitation levels over time. However, in referencing the ample representative case studies conducted in similar and proximal settings, it can be argued with a high degree of confidence that overall, annual mean temperatures in Ladakh are rising. While also illustrating significant spatial and temporal variability, precipitation trends in the region appear to be decreasing with time.

Discussion

Gathering evidence suggests climate change is altering basic socioecological systems and the relationships that define them. In Ladakh, these interlinkages unfold at the local level to shape land use patterns, food production systems and domestic activities. Like other mountain populations, bioclimatic parameters are keenly tied to Ladakhi livelihoods and this unique interaction determines the agricultural and settlement landscape. In particular, the availability of local and regional water resources is fundamental to the productivity and viability of household farming systems. Hence, in a region simultaneously undergoing rapid changes in development and a perpetual rise in water demands, climate change poses a very real threat to the long-term stability of local and regional water reserves. The security of water will therefore be instrumental in the ability for Ladakh to effectively support life and land in the future.

Changing climatic conditions implies increasing variability in the hydrologic cycle which will likely influence the cultivation and reliability of local food growing operations. Over recent decades, there has been a statistically significant trend favoring more wheat production in Ladakh in contrast to a decrease in barley, maize and other cereal grain production. Since the latter half of the century, increasing wheat cultivation in the region has mirrored a steady rise in annual wheat yields, meaning more land is being converted into wheat production and less land is being appropriated for conventional crops like barley. Indeed, a recent survey found 55.6 percent of a household's cropping area was dedicated to wheat (Baba, 2011). The paralleled correlation between cropping area and wheat production indicates Ladakhi farmers are gradually shifting their agricultural practices to meet contemporary market demands. Supplemented by rice imports, wheat production is dominating traditional farming systems and reflects recent changes in local lifestyle preferences, economic trends and government food policies.

Water is clearly vital for the photosynthetic conversion of agriculture into food and is one of the largest energy input factors integral to the plant production process. While Ladakhi farmers have historically exercised frugality in addressing agricultural irrigation needs, a broad transition to wheat cultivation may stress existing and future water storages. For instance, Ladakhi farmers traditionally grew wheat alongside barley as the two primary food commodities thus offsetting high water consuming crops with moderate to low water consuming crops. Complemented by secondary crops such as maize, pulses and garden vegetables, wheat and barley were production counterparts in that if one crop harvest failed the other crop could still provide a revenue stream and source of household food. As stated previously, this reciprocated relationship has become increasingly disproportional as wheat has absorbed much of the agricultural market and standardized farming practices. In turn, more land, labor and resources are being reallocated for wheat cultivation in comparison to barley, maize and other crops. Furthermore and perhaps most importantly, more water is needed to satiate the relatively high irrigation needs of wheat.

Indeed, in comparing crop production of wheat to barley, the former is less efficient in terms of total energy input and water consumption. In separate studies conducted in Australia and Iran for instance, agricultural researchers determined wheat used three times as much water as barley and required more energy with regard to the labor needed for sowing and harvesting (Ziaei, S. et al., 2013; Khan et al., 2010). Wheat additionally necessitated more fertilizer and seed preparation in comparison to barley. The authors therefore concluded barley was the more efficient crop with regard to both energy and water consumed. Additionally, in a more recent study by Sahabi et al. (2013), researchers found production in barley fields was more sustainable than wheat production because, in view of ecological indices such as amount of energy use and renewable energy consumption, it was overall less demanding on the environment. In the context of water efficiency and production output, particularly for an arid and cold landscape like Ladakh, barley is well-suited to the region’s ecological and climatologically restrictive environment.

Despite levying a heavy toll on Ladakh’s minimal water reserves and contrary to the many drawbacks of climate change, rising global air temperatures may be manufacturing a more agreeable climate for wheat production in the region. Studies have suggested at least initially, a warming world may be beneficial to some area’s cropping yields (Ashfaq, 2011; Ortiz et al., 2008; IPCC, 2007). Elevated air temperatures and increased precipitation trends may propagate a more favorable environment for wheat, potato and rice planting by effectively shifting optimal agrecological zones northward and upward in elevation (Asseng et al., 2013). In a region persistently cold like Ladakh, warming seasonal mean temperatures can potentially shorten the number of frost-freeze days, induce an earlier spring and prolong the harvesting period thus promoting year-end agricultural yields. In nearby Punjab, Pakistan for instance, researchers determined heightened rainfall accumulations due to climate change buoyed overall wheat productivity and a 1 percent increase in water availability within the region accounted for nearly a 0.68 percent growth in wheat production (Ashfaq, 2011; Khan et al., 2003).

While climate change may engender a more advantageous climate for wheat production in places like Ladakh, it conversely introduces in a suite of potentially negative and unforeseeable outcomes as well. For example, climate change may generate conditions too hot for wheat and crop production and may stunt seed and flowering development before plant maturation (Sommer et al., 2013). Further, climate change will likely worsen existing drought conditions therefore adversely exposing wheat fields to water deficiencies and related irrigation stresses.

In addition, warming temperatures provide a more benign environment for insect and pest infestations as well as disease pathogens which can be severely detrimental to crop yields. In the Zanskar region for instance, villagers have perceived a remarkable increase in locust invasions.

First reported in the summer of 2005 in the Ating area of the lower Zanskar, the locust plagues rapidly migrated up the valley, decimating crops along the way (Mankelow, 2007). In addition to destroying fields of barley, the locusts ate the hay and fodder meant for livestock and winter provisions. In response to the locust outbreaks, Zanskar farmers flooded their fields with pesticides and chemicals, known as "Chlorpyriphos 20%", made available to them through the government's Department of Agriculture (ibid). However, even these industrial methods to eradicate or contain the numbers of locusts have so far been ineffectual and their potential to multiple and spread remains a significant problem for Zanskar farmers and others impacted by the pests. Moreover, the permanent use of pesticides within Ladakh is not financially viable given the large extent, remoteness and lack of infrastructure within the region. Nor have the long-term effects of this type of pesticide in Ladakh been assessed, in terms of both the ecological impacts as well as the economic and cultural implications. For instance, many Ladakhi farmers are practicing Buddhists and therefore refuse to participate in killing locusts preferring instead to rely on religious intervention of the earth lord *sa bdag* and the *naga* deities. The threat of a future locust epidemic across all of Ladakh is an unsettling yet a highly realistic scenario that will be promulgated by warming air temperatures and the generation of a more habitable host environment.

Another compounding pressure for Ladakhi farmers and one that will likely be intensified by climate change is the spread of plant pathogens to agricultural crops. As a high altitude desert with prolonged winters, Ladakh has historically been more insulated from invasive plant diseases in comparison to the more temperate agroecological zones in central India. However warming air temperatures, particularly during the winter months, is affecting the geographical distribution of plant pathogens and allowing certain diseases to migrate into unprecedented terrain (Shaw and

Osborne, 2011). This has been observed with coffee pathogens in Brazil (Ghini et al., 2008), forest diseases in France (Sturrock et al., 2011; Desprez-Loustau et al, 2007), pine beetle distributions in North America (Marini et al., 2012; Logan et al., 2010; Six and Bentz, 2007), and pathogenic influences in grassland ecosystems (Mitchell et al., 2003).

The absence of long-term pathology records in Ladakh inhibits the ability to make a conclusive argument regarding the advancement of plant diseases into the region. However recent research by Vaish et al. (2011) identified several prevalent pathogens presently infecting barley crops in and around the town of Leh. In particular, leaf spot blotch/blight, root rot, yellow rust and powdery mildew were observed in local barley fields with moderate to severe consequences on agricultural yields. For example in some fields, as much as 66 percent of barley yields were lost as a result of yellow rust although results varied with soil type, temperature and humidity. While the authors acknowledge the complexity of confirming distributional trends of pathogenic incidences in Ladakh, they caution warming air temperatures and a rise in humidity levels could lead to an alarming epidemic of plant diseases into the region. Efforts to avert potential agricultural losses from plant pathogens requires the application of fungicides, resistant cultivars and added treatments by the farmer. In turn, farmers must re-allocate valued time, energy and money to mitigate pathogenic infections or absorb the devastating hit to their annual yields and incomes. Unfortunately for many Ladakhis, the latter approach is not an option and adoption of the former technique will divert much needed resources away from other urgent household obligations.

The arrival of diverse pathogenic influences and pests into Ladakh is troubling because they visually herald a change in local and regional climatic conditions. The increasing presence of plant diseases and invasive insect populations generate palpable ecological and economic consequences for Ladakhi farmers, particularly with respect to losses in agricultural yields and household revenue. Correspondingly, a widespread reprioritization of wheat production over other crops inadvertently exposes Ladakhi farmers to non-diversifiable risks such as infections, drought and market failure. By steadily supplanting the cultivation of barley, maize and other cereal grains with wheat, farmers are heavily relying on high production outputs and economic returns of a single crop in contrast to multiple crops. In this way, farmers are accepting a high level of risk symptomatic of larger monocropping practices and limiting their ability to financially and ecologically sustain adversities that may arise as a result of changing climatic conditions, market oscillations and other unknown factors.

In the case of drought for example, wheat is less tolerant to water stress compared to barley. During prolonged periods without water, a farmer who sows a large majority of their field with wheat is differentially susceptible to crop failure of the entire harvest in contrast to a farmer with a more diversified agricultural operation. Recent trends indicating a gradual conversion to wheat cultivation in Ladakh therefore warrants caution because the short- and long-term repercussions of climate change remain highly unpredictable. As Ladakh increasingly embraces the appeal of global capitalism, local farmers are encouraged to become specialists rather than generalists. While the growing tendency for Ladakhi farmers to “put all their eggs in one basket” may have more immediate financial gains with wheat production, it also disproportionately places them at higher risk to the volatilities of climate change and other socioeconomic and ecological uncertainties.

Indeed climate change is not an isolating event but rather aggravates other difficult complexities such as population growth, sustainable development and natural resource conservation among other issues. For example, a predominant shift to wheat cultivation in

Ladakh can additionally be explored in view of recent socioeconomic and demographic labor configurations. As detailed in the previous chapter, in past decades, fewer men are participating in the farming business and instead opting for employment in the tourism industry, security forces or other vocations. Reflecting this transition has been a steady out-migration of mostly young male adults from rural areas into the urban center of Leh. In turn, women are quickly outnumbering men in the rural agricultural labor sector and this is growing at a rate of 2 percent each year (Baba, 2011) (Figure 4.15). In response to the shortage of available men in farming and in order to maintain cropping yields, land use patterns are being restructured to accommodate more commercialized crops like wheat (ibid). The pervasive switch to wheat production in Ladakhi farming systems is therefore bolstered not only by converging economic trends and market incentives but also internally reinforced through labor arrangements and broader livelihood changes.

Figure 4.15: Female farmers are increasingly replacing men as the main food producers in Ladakh (Image: K.Nygaard)

That said, due to the unrestrained trajectory of warming air temperatures and the aggregated nature of related impacts, climate change will ultimately usurp other challenges facing Ladakh to intrinsically reorganize traditional ways of life, such as water procurement, irrigation requirements and land use patterns. Farmers and particularly female agricultural laborers will be hardest hit by the mercurial behavior of climate change, further deterring young Ladakhis from participating in household agricultural activities. Accordingly, the capacity for local farmers to generate enough food to supply Leh's population and emergent tourism industry will likely continue to fall short of demand hence strengthening the widening deficit between Ladakh's food producers and external commercial suppliers. While shortages in food self-sufficiency in Himalayan communities may be nothing new, farmers in the past have adjusted to food shortages by practicing transhumance grazing patterns and trading with neighboring settlements. By contrast, the fetishized nature and rapacious consumptive behavior of modern capitalism does not afford the luxury of time. Demand for food commodities and coveted goods must therefore be immediate to satisfy market preferences. As a result, local autonomy is further diminished and traditional food staples like barley are increasingly subsidized with less expensive grain imports like rice and wheat flour. In response and in an attempt to conform to contemporary market trends and policy incentives, Ladakhi farmers are steadily converting to wheat cultivation which unintentionally primes them for financial and ecological failure should the coincidence of climate-related risks, unfavorable economic trends and other unknown variables fatefully transpire.

Definitively identifying causal links between climate change and agricultural yields in Ladakh is complicated by the lack of historical meteorological records and baseline trends. While statistical analysis indicates a non-significant relationship between regional temperature trends, precipitation patterns and agricultural yields it would be a mistake to discount the interdependency of these socioecological systems. In Ladakh, agricultural output is closely coupled with biological parameters thus wedding social activities and behavior to environmental conditions. On-the-ground observations and personal narratives therefore provide crucial experiential context that quantifiable analyses fails to adequately measure. Local perceptions of climate change impacts in Ladakh, including increasing variability in precipitation, growing aridity in the mountains and warming winter temperatures support climatological analyses. In this way, the practice and theory of climate change are synchronized and both clearly suggest a change in local and regional climatic conditions for this part of the Himalayas.

Conclusion

Since the last half of the century, there has been an observed increase in annual mean temperatures in Ladakh. This is sharply demonstrated during the winter months with a decreasing trend in minimum temperatures, implying fewer cold days on average over the year. The most recent meteorological data for the region indicates a slight decreasing trend in summer mean temperatures though this relationship was not determined to be significant and does not negate an overall rise in annual mean temperatures. Precipitation patterns indicate a decrease in annual accumulations but with significant spatiotemporal variation across the region. In particular, the occurrence of untimely and heavy rainfall events in Ladakh, like the cloudburst in early August 2010, are indicative of future extreme weather events and are projected to increase in both magnitude and frequency. While variability in temperature gradients and hydrologic patterns are some of the quieter signatures of climate change, other climate-related disasters and hazards resulting from weather perturbations such as flash floods, droughts and heat waves provide considerable concern with regard to the immediate risks of climate change.

Concurrent with issues stemming from climate change, Ladakh is grappling with the impacts of a rapidly developing urban core, booming tourism industry and shifting socioeconomic and demographic profile. The collective assemblage of these forces is exacting heavy demands on the region’s infrastructure, especially with respect to the management, allocation and quality of local water resources. Water scarcity is the common numerator relating many of the current and impending issues facing Ladakh and like many regions throughout the world, the acquisition and control over water supplies will be a confounding challenge fraught with political, economic and ethical implications.

Moreover in Ladakh and elsewhere throughout the Himalayas, the permanence of glaciers and perennial snowpack is imperative for mountain communities to prosper and sustain. The present and predicted retreat of ice and snow within the region therefore infers an increasingly perilous future for Ladakhi farmers and households. Water harvesting techniques and conservation of water consumption will have to factor into local food production strategies as well as play a role in Ladakh's future development outlook. Integrated with appropriate policy mechanisms, a water conservation management scheme will temporarily ease pressure on Ladakh's local and regional water reserves. Until such solutions can be effectively formulated and deployed however, Ladakhi households and communities will likely have to draw on traditional adaptation strategies, pragmatic innovation and social resilience to navigate the gauntlet of climate-related impacts and other onerous issues increasingly confronting high mountain populations.

Chapter 5:
Spatial Distribution of Perceptions and Values on Climate Change Impacts

Introduction

Although global in reach, the phenomenon of climate change is most realized and experienced at the local level. However as intimated with previous chapters and numerous analogous case studies, climate change impacts differentially manifest and vary with geographic context. Given the heterogeneous nature of climate change impacts, it is reasonable to assume local observations and narratives of these effects are similarly diverse in nature. Recognizing the asymmetric outcomes of climate change is tantamount to informing accurate place-sensitive assessments of community vulnerability and the identification of appropriate adaptation scenarios. Characterizing the geographic landscape where climate change impacts are observed can correspondingly aid in the design of the site-specific response measures that are consistent with local resources, needs and priorities.

Site-specific observations of climate change can enhance identification of both the abrupt and latent impacts resulting from weather variability, temperature changes, natural hazards and other climatic uncertainties. In turn, the spatial configuration of these perceived impacts portrays an evolving dialogue on the realities of climate change as they emerge at the surface. Mapping this conversation across a community setting can subsequently establish a common understanding on how climate change is valued, prioritized and contextualized at spatially-explicit scales. In superimposing geographic scale as the conceptual lens with which to better examine local perceptions of climate change, a refined assessment of vulnerability to present and predicted climate change impacts is elicited.

In this chapter, scale provides the theoretical premises for more closely interrogating the spatial arena where climate change impacts materialize to acutely affect individuals, households and communities. In doing so, this chapter utilizes spatial geoprocessing techniques and GIS-based mapping applications to examine the geographic intersection between locally observed climate change impacts, physical context and demographic attributes. The purpose of applying this approach is to assess how climate change impacts transpire at the household and community level to tangibly shape interpretations of environmental change. By visibly "connecting-the-dots" of the climate change conversation in Ladakh, a sharper understanding of the spatial and temporal dimensions characterizing local vulnerability and adaptation is distilled.

Research Question #3 – Approach and Discussion

Unique to this chapter is the incorporation of a spatially-explicit assessment of the human and environmental interface where climate change impacts are experienced. In achieving this, individual observations of climate change are identified and then collectively evaluated to more fully detail the affect geographic context may or may not have in shaping the meaning and value of climate change. Accordingly, the following research question is used to steer this chapter's analysis and accompanying discussion:

> *RQ #3: In a mountainous setting such as Ladakh, how does the dialogue and interpretation of climate change shift down the valley (i.e. upstream to downstream and/or rural to urban*)?

In contrast to the preceding chapter that examined the *temporal* profile of changing climatic conditions in Ladakh, including temperature shifts, precipitation trends and potential associations with agricultural patterns, this chapter incorporates a *spatial* model as a way to better understand how climate change impacts are engaged with at different levels of exposure and susceptibility. In areas where communities are intimately connected with the land and its natural resources for sustenance, local people often have a deep understanding of the relationship and interactions involved with changing environmental conditions (Berkes et al., 2000). These understandings are reciprocally embedded in the local social and cultural context that inherently influences how environmental change is interpreted, experienced and acted upon. This is important because community perceptions reflect individual and household concerns and focus on the actualities of climate change as they play out "on-the-ground" (Byg and Salick, 2009; Danielsen et al. 2005; Wilbanks and Kates, 1999).

All too often, localized framings and symbolic meanings are overlooked within the dominant scientific discourse and decision-making regime. The remarkable absence of integration between on-the-ground practice and broader climate change paradigms hinders effective and fair implementation of climate change policy (Tschakert and Dietrich, 2010). Given the vast ambiguities of climate change, including extreme weather events, precipitation and temperature variability and natural hazards, it is disadvantageous to bypass such communicational and operational multi-scalar discrepancies. The aim of this chapter therefore is to identify spatially-explicit place-based accounts and attitudes toward climate change impacts. Individual and household narratives of climate change are then scaled-up in order to extract a larger evolving narrative of climate change values across the Ladakhi landscape. By spatially profiling local climate change perceptions, an aggregated examination of the socio-ecological exchange between mountain communities and climatic variability is afforded. In doing so, the contributing role locality and physical setting plays in influencing community perceptions of climate change is highlighted. By emphasizing the importance of place, this chapter identifies the coincidences between socioeconomic, biophysical and environmental variables in forming attitudes and interpretations on climate change. This knowledge is useful in guiding planned adaptation and response measures to be consonant with the people and places most affected by climate change.

Methodological Approach

In an effort to bring synergy between the practice of climate change and the theory supporting climate change discourse, this chapter draws on concepts commonly articulated in community-based vulnerability assessments. As vulnerability is closely wedded to the capacity to adapt and the two concepts frequently operate in opposition to one another, identifying components of the former process can support and enhance measures of the latter process. Spatially characterizing vulnerability and adaptation within site-specific locations can correspondingly pinpoint areas of particular concern and direct resources accordingly. Such assessments can additionally provide comparative datasets across multiple scales that when combined at the local level, can uncover commonalities and gaps in how climate change is acknowledged within households and communities. Understanding these local ideological references provides collective guidance regarding the trajectory of the larger climate change debate. By contextualizing climate change vulnerability as a function of local impacts, demographic attributes and physical geography, opportunities for adaptation can be identified and bolstered.

Previous studies that seek to identify the scope and spread of vulnerability to climate change impacts commonly develop indices to calculate the degree of exposure and susceptibility to various types of climate risk. These indices are often measured by proxy variables, including biophysical attributes, population densities, climate-sensitive data and natural hazard mapping.

The index provides a representative correlation of vulnerability based on the integrated analysis of multiple converging variables. Vulnerability index assessments are particularly popular among institutions and government and frequently inform the design of policy (UNFCCC, 2010b; Yusuf and Francisco, 2009; IPCC, 2007).

Yet as Fussel and Klein (2007) point out, while the underlying aim of all vulnerability assessments is to contribute toward sound decision-making and reduce risks to climate change, there is a diversity of valid methods for implementing this approach. Brooks et al. (2005) for example operationalize vulnerability in terms of both physical exposure as well as internally derived vulnerabilities critical to most social systems. In doing so, not only are the generic determinants of vulnerability considered (i.e. poverty factors, elements of governance, health status, etc.) but also the specific determinants relevant to a particular place, such as the price of certain types of food, the number of local resources and/or the distribution of relief aid. Alessa et al. (2008a) applied a similar approach in their vulnerability assessment of Arctic communities to climate change and emphasized vulnerability as a function of resiliency within both physical and socio-ecological systems. Again, the authors cite the value of integrating local context into scientific assessments in order to adequately diagnose processes of vulnerability at multiple scales.

Partially in response to the need to examine multi-scalar vulnerability from the community level up, studies have increasingly embraced mapping applications as way to identify and illustrate the host of stresses exerted upon particular localities. For instance, O'brien and Lichenko (2004) modeled the combined effects from both climate change and globalization in districts throughout India, with the exception of Jammu and Kashmir. The authors illustrated how simultaneous challenges posed to certain sectors and places yielded a "double exposure" effect and disproportionately positioned some people and places at risk to climatic and economic shocks. The areas of double exposure correspondingly represented those districts requiring the most policy changes and other interventions in order to aid in adjusting to future changes in the global economy and climate. Similarly, Brody et al. (2008) spatially analyzed risk to climate change impacts in the United States as a product of physical geography and public perceptions. By applying a spatial element in their vulnerability assessment, the authors identified key indicators that shaped individual perceptions of risk and thus the ability and willingness to respond to these climatic threats. Their findings reinforce the need to go beyond the basic binary between empirically measured data and constructivist viewpoints in order to achieve a holistic understanding of climate change vulnerability as an outcome of both social and ecological processes.

In the Himalayan region, vulnerability and adaptation assessments have been conducted at the state and regional level and focus on the attributes of natural-resource dependent users, such as livelihood assets, food security, access to resources and observable environmental change. Only until recently has attention been reoriented around local communities and individuals' vulnerability to potentially hazardous and risky scenarios resulting from changing climatic conditions. In particular, the International Centre for Integrated Mountain Development (ICIMOD) has proposed a framework to assess community-based climate vulnerability and adaptive response in the Himalayas (Maachi, 2011). By concentrating on a smaller scale, ICIMOD seeks to provide direction on how innate coping and adapting capacities traditionally evident within many mountain communities can be strengthened in the face of rapid environmental change. The rationale for the framework is based on the assumption that in order to identify the key determinants for future adaptation, there is an urgent need to better understand current climate change impacts, mountain communities' perception of these changes and the traditional repertoire of response strategies (ibid).

This chapter addresses the dualistic interplay of vulnerability and adaptive capacity to climate change in Ladakh by integrating and analyzes multiple spatially-explicit datasets. An assessment of the Domkhar and Leh watersheds were individually performed to evaluate household and community values and opinions on climate change relative to physical location. Results were then combined to establish a larger interconnected dialogue on climate change impacts across the regional landscape. Analysis of the data suggests the spatial configuration of community observations and attitudes on climate change are varied in their distribution and are influenced by the physiographic layout of the larger watershed, including elevation, topography and access to water and other natural sources.

Data Analysis

A two-tiered approach was utilized in examining the spatial dimensions of climate change impacts, local observations and evolving community dialogues on environmental change in Ladakh. The first component involved acquiring knowledge on how local people perceive and contextualize climate change impacts within each of the study sites. This information was obtained with a community survey and analysis discussed at length in Chapter 3. In recapping, a total of 255 surveys were completed within the two separate research sites of Domkhar and Leh. Survey questions probed individuals to identify and rank various climate change impacts based on frequency, distribution and degree of impact. In addition, respondents were asked to value the effect climate change was having on their community and long-term attitudes regarding community response and planning for future climate-related risks.

Surveys conducted in both study sites were individually georeferenced using latitude and longitude coordinate points. During administration of the survey, each participating household was tagged using GPS waypoints. The X and Y coordinates were exported as a .gpx file and converted into a .csv file, the preferred import file for ArcGIS 10.2 software. Each waypoint identifies the location, date and time of individually surveyed households. Location points were subsequently populated with survey responses. Survey questions specifically focusing on household attitudes, values and beliefs on climate change were targeted and integrated into ArcGIS. In order to analytically process and display nominal data, responses were coded with a numeric scale. Alternatively, qualitative observations of explicit climate change impacts such as rainfall variability and regional snowmelt, were measured with a 5-point Likert scale. Operationalizing local observations of climate change impacts in this way allowed for the spatial representation, symbolization and statistical processing of survey responses.

The second component of the data analysis involved using Geographic Information Systems (GIS) as an application to visually map and spatially process how the framing and understanding on climate change varied with geographic context. A terrain and elevation model was first generated for the research site and then populated with relevant geographic attributes, such as hydrology, infrastructure, administrative boundaries and other reference layers. Digital elevation information was received as an exportable geo.tif file from the United States Geological Survey (USGS) and the National Aeronautics and Space Administration's (NASA) Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) program. In contrast to other global imaging data, such as STRM, ASTER references a 1 arc-second grid which provides a resolution of approximately 30 meters. Using ArcGIS 10.2, the exported

ASTER files were converted into readable raster files. All coordinate systems are referenced to the 1984 World Geodetic System (WGS84) and the Geographic Coordinate System.

Additional spatial data was provided through a variety of online GIS data clearinghouses. The Indian National Informatics Centre in particular provided data on infrastructure and general geography, including administrative and political boundaries, population densities, transportation infrastructure, utility networks and hydrologic information such as the location and size of rivers and lakes. All shape files were exported as vector files and provide reference and thematic support for the larger analysis of local climate change perceptions in Domkhar and Leh. Cartographic finalizing of maps was formatted and stylized using Adobe Creative Suites 6.0.

Two geoprocessing methods were applied to assess and model the shifting narrative on climate change perceptions in Ladakh. Initially, Hot Spot analysis was used to identify the distribution of statistically significant spatial clusters of high values (hot spots) and low values (cold spots). Features with high standard deviations (*z*-score) and small probability (*p*-value) indicates a spatial clustering of high values and were thus identified as "hot spots" relative to other places on the map. For this analysis, Hot Spot features were normalized using the *p*-value classification ranging from less than .001 to 0.50 and greater. Outcomes were correspondingly divided into seven classes using the Natural Breaks (Jenks) method.

After performing a Hot Spot analysis, point kernel density estimation was performed using the Hot Spot exported features. Kernel density analysis measures a particular quantity of an input feature across a gridded landscape to produce a continuous surface. In this analysis, mean values identified in the Hot Spot analysis were imported as the input features and a search radius of 150 meters was used to demarcate the neighborhood distance parameters. Following a similar method applied by Alessa et al. (2008b), the kernel density estimation calculates the density of point features around each output raster cell and within a defined search radius, in this case 150 meters (Sherrouse, et al. 2011). In effect, this method of density analysis calculates the magnitude per unit area from each hot spot feature and applies a smooth curve fit. Together, performing Hot Spot and kernel density analysis identified the spatial distribution, concentration and intensity of values regarding climate change across a landscape. In doing so, the commonalities and discrepancies regarding climate change perceptions were mapped at multiple spatial scales and within different geographic settings.

Results

Attempts to elicit community-wide understandings on climate change resulted in semi-randomly and non-randomly sampling households within individual villages or wards in both Domkhar and Leh. The Domkhar research area is substantially smaller than Leh, with three distinct villages comprising the inclusive study site. Located in the upper reaches of the basin and hosting the smallest population, rests the village of Domkhar Gongma. Situated approximately 5 miles down the valley is Domkhar Barma, and at the junction with the Indus River is the village of Domkhar Dho, hosting the largest population. In total, 110 surveys were conducted within the Domkhar research area, with the heaviest concentration of data collection performed in Domkhar Barma (Figure 5.1).

Alternatively, the town of Leh boasts Ladakh's largest and most urban population of nearly 60,000 people. The town is divided into more than twenty different districts or wards that range in size and population. For this research, twelve different wards were sampled including, Changspa, Gonpa, Ibex Colony, Main Bazaar, Mitsay Chulungs, Norgas Ling, Tukcha, Sankar, Skampari, Skara, Skara Yokma and Yurtung (Figure 5.2). In Leh, 145 households were surveyed for a total of 255 completed surveys.

Fig. 5.1: Distribution of Survey Points - Domkhar, Ladakh

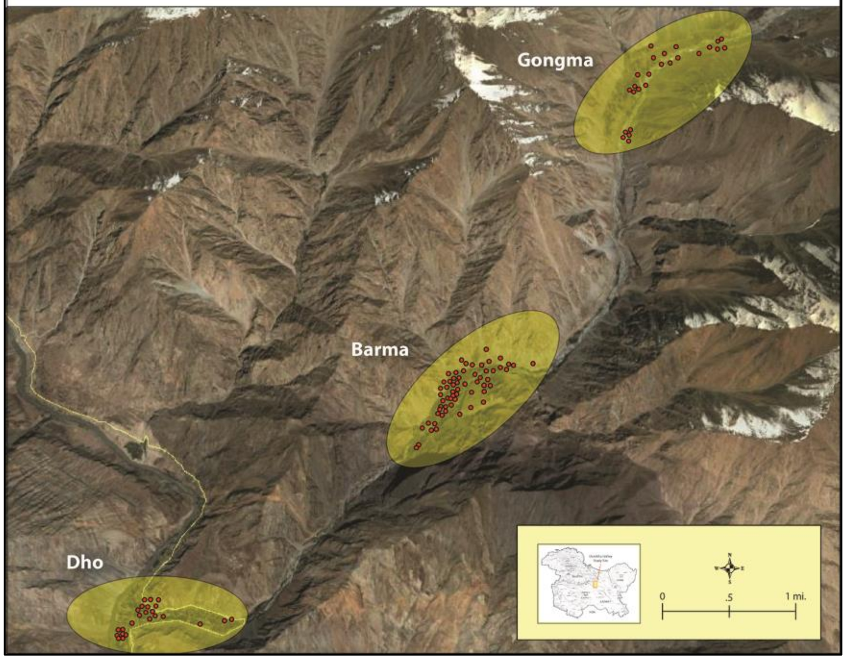
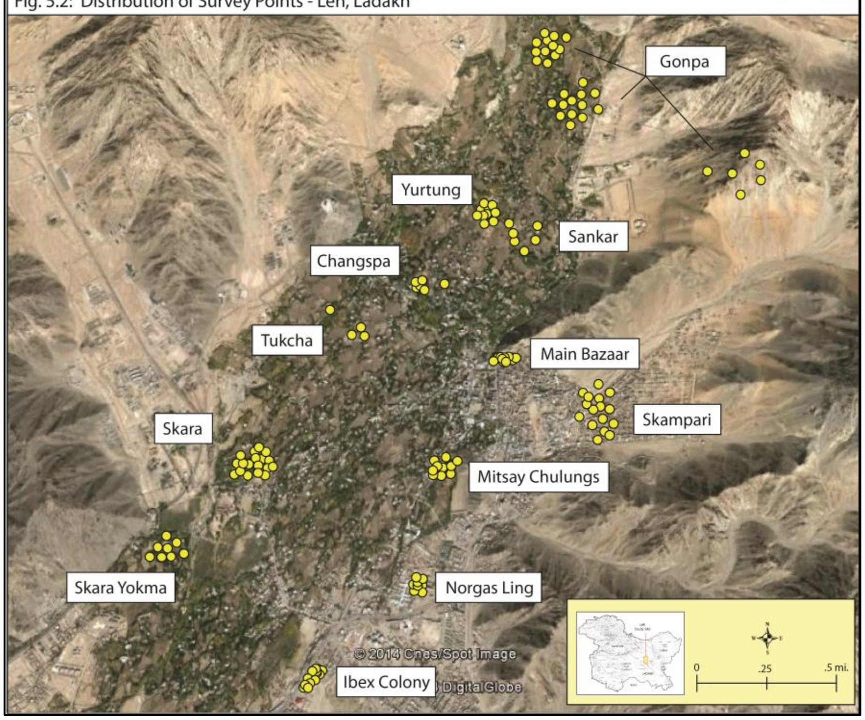
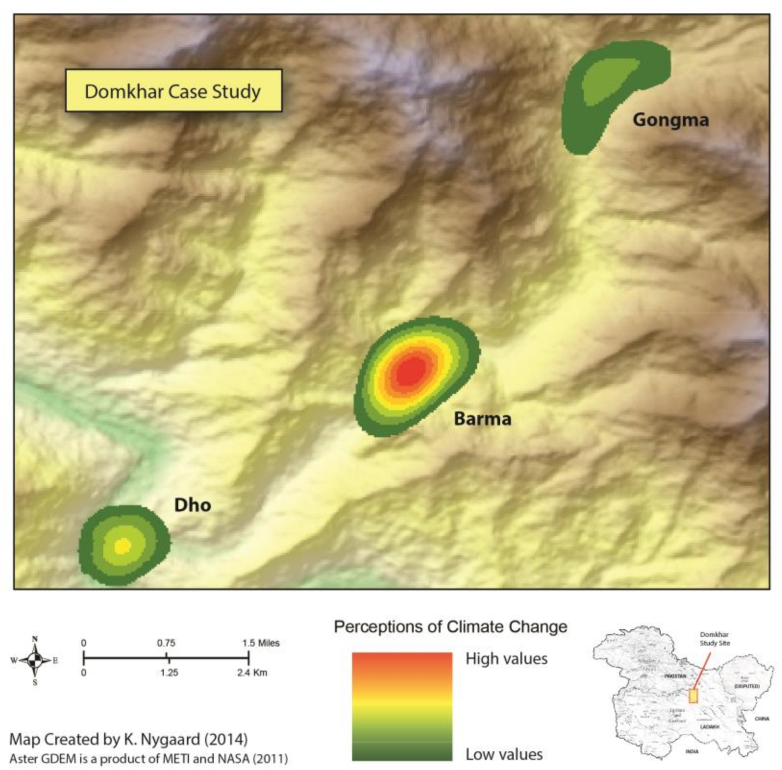


Fig. 5.2: Distribution of Survey Points - Leh, Ladakh



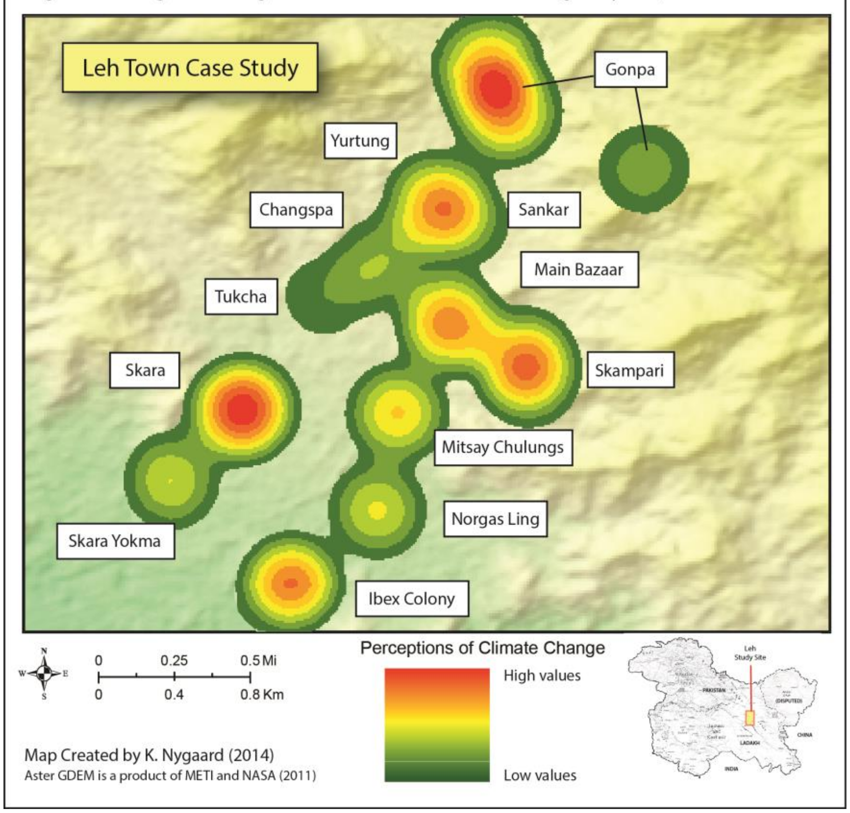
Research findings suggest observed climate change impacts are unanimous across Ladakh yet the intensity that these impacts are perceived varies widely within individual communities. In the Domkhar research site for example, density analysis indicates a heightened level of perceived climate change impacts in the village of Domkhar Barma over the neighboring villages of Dho and Gongma. Situated in the middle of the Domkhar valley, observations of climate change impacts in Barma, including changes in snowpack, drier environmental conditions, rising air temperatures, changes in the timing of the cropping season and variable precipitation patterns were statistically significant at confidence levels above 97 percent. In comparison, the upper village of Gongma did not perceive substantial changes in the climate, with non-significant confidence levels. The downstream village of Dho observed a moderate to low change in the climate (Figure 5.3).

Fig. 5.3: Strength and Magnitude of Perceived Climate Change Impacts, Domkhar Ladakh



In comparison to Domkhar, observed climate change impacts in the town of Leh were more muted and evenly distributed. Of the twelve different wards, households within the Skara, Ibex Colony, Skampari and the Main Bazaar perceived significant to moderate changes in recent climatic conditions (Figure 5.4). The wards of Mitsay Chulungs, Yurtung and Gonpa followed with moderate to low values of perceived climate change impacts and the remaining wards of Changspa, Tukcha, Sankar, Norgas Ling and Skara Yokma suggested relatively low observations of climate change impacts.

Fig. 5.4: Strength and Magnitude of Perceived Climate Change Impacts, Leh Ladakh



With respect to community opinions on climate change, it is perhaps unsurprising that general observations of climate change impacts in Domkhar (Figure 5.3) and Leh (Figure 5.4), closely align with the spatial distribution and concentration of overall values on climate change (Figure 5.5 and Figure 5.6). For instance upon initial view, the village of Barma in Domkhar and the Skara, Ibex Colony and Main Bazaar wards in Leh consistently illustrate strong values regarding the degree of importance, effect, attitude and other views on climate change relative to additionally surveyed areas. In Domkhar, the lower village of Dho expressed moderate to strong feelings regarding climate change while Gongma remained relatively neutral. Similarly in Leh, the Skampari and Gonpa wards shared a moderate yet slightly conservative approach toward climate change impacts.

Fig. 5.5: Distribution and Concentration of Values on Climate Change: Domkhar, Ladakh, Northern India

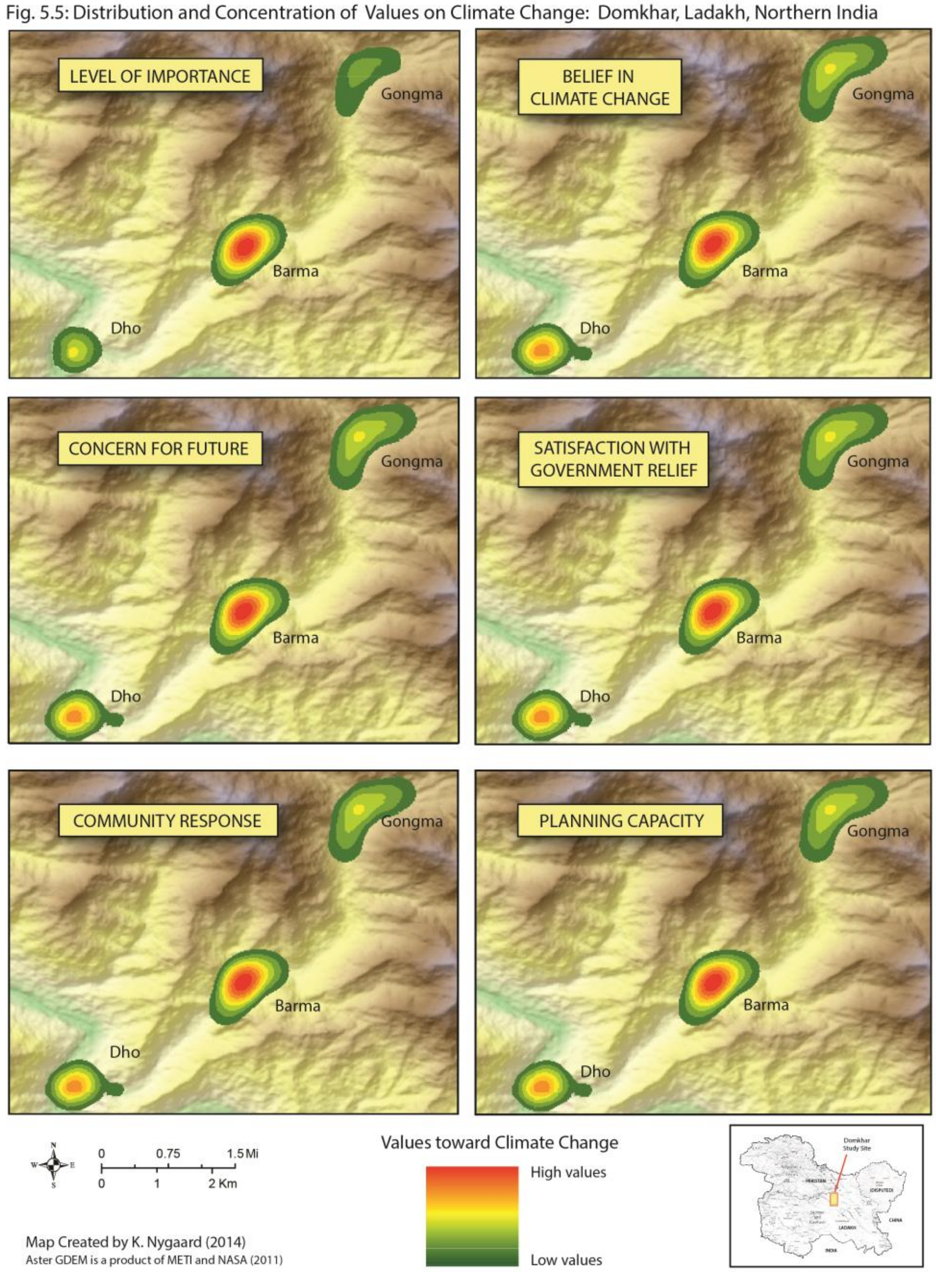
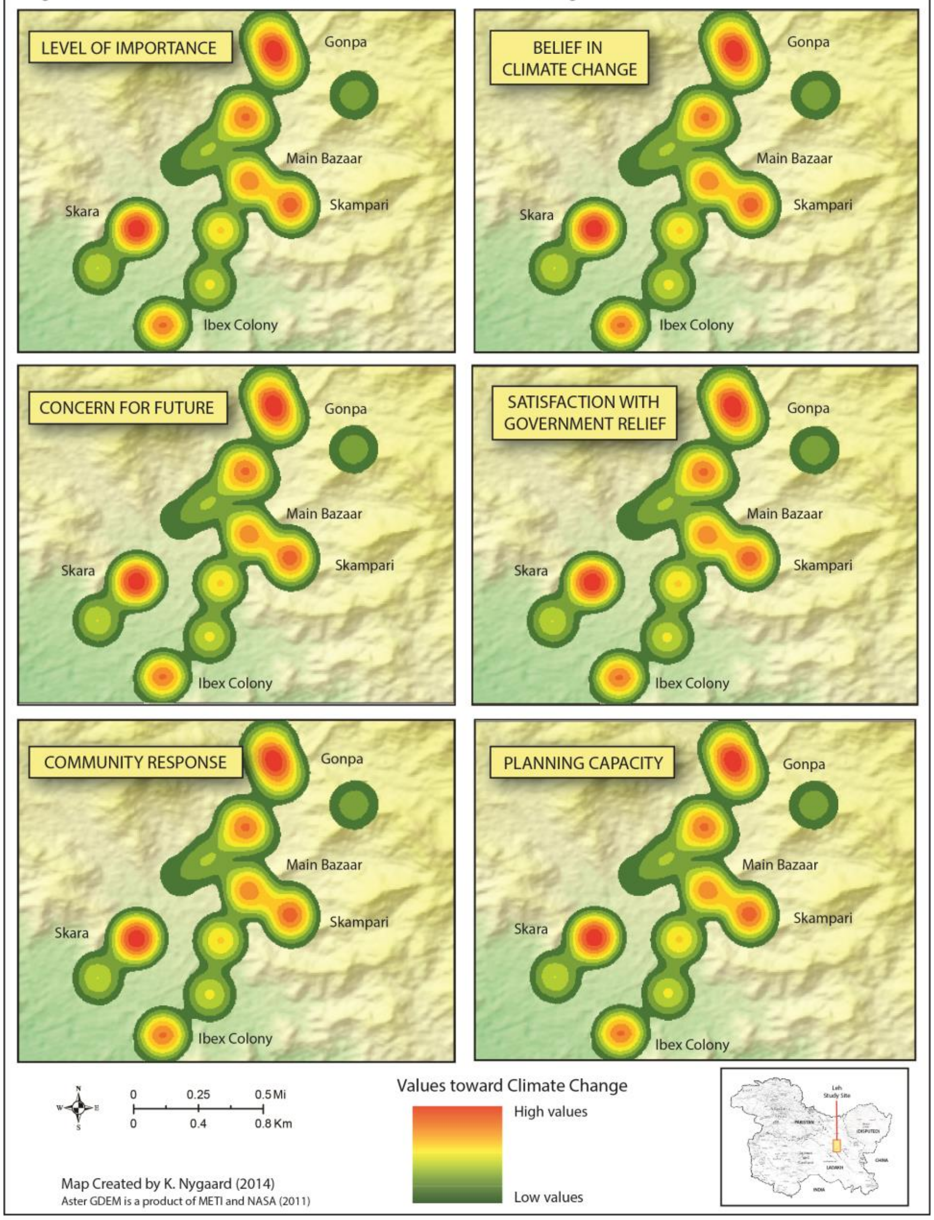


Fig. 5.6: Distribution and Concentration of Values on Climate Change: Leh, Ladakh, Northern India



Again, within both study areas, the range of opinions on climate change closely reflects overall observations of climate change impacts with the strongest attitudes toward climate change correlating with heightened observations of climate change impacts. In particular, the strongest indicators of public opinion on climate change seemed to associate with personal experience of climate change impacts. For instance, in areas where respondents strongly observed climate change impacts, a high level of importance and priority was attached to the issue of climate change response and policy. Similarly, belief in climate change and concern regarding present and future climate change risks were substantially higher in communities where climate change impacts were frequently observed. The only exception was the village of Dho in Domkhar, where a slight variation was evidenced with respect to the level of importance attributed to climate change relative to the degree of belief in and concern over present and future climate change risks. In general however, both study areas exhibited a consistency in opinions regarding the level of importance, belief and concern over climate change.

Regularities were also exhibited in the amount of satisfaction and conviction villagers expressed about local government and community capacity to handle climate change scenarios. Like other general attitudes on climate change, approval ratings of the government's response to particular weather incidents, such as flash floods and droughts, were comparatively higher in areas more impacted by climate change events. In the case of Domkhar for example, Barma and to a lesser degree Dho, both illustrated high levels of government satisfaction while also indicating strong to moderate observations of climate change impacts. In Leh, the Skara, Ibex Colony and Main Bazaar wards suggested above average levels of satisfaction with the government relief work, which spatially correlated with high observations of climate change impacts. At the same time, in both study areas, individual households heavily impacted by climate change also felt very strongly about the ability for their community to effectively respond to current climate change threats as well as the community's capacity to plan for future risks.

The association between Ladakhi attitudes valuing climate change as an issue of importance, concern, and response interrelate with the physical scope and spread of climate change impacts. Areas where community members observed high levels of climate change impacts largely overlapped with strong community feelings toward climate change. In this way, climate change was contextualized as an ongoing process presently affecting households as well as an impending danger requiring some consideration of future response and management.

Discussion

While each village remained relatively homogenous in their responses regarding observations and attitudes on climate change impacts, variability existed *between* different communities. There are a number of variables that may effectively explain this outcome. Physical geography for instance, is a contributing factor in shaping community livelihood practices and spatial land use patterns across Ladakh. In looking at Domkhar, the village of Gongma is located in the broad upper basin of the Domkhar valley and is therefore granted open space and is less confined by the physiographic constraints characterizing downstream settlements. Not having to contend with steep valley walls and condensed tracts of land, Gongma households are relatively spread out and farming and cultivating activities occur on moderate to large parcels of land. Indeed, Gongma households benefit from relatively large plots of land ranging from two or more acres (Singh, 1995). By contrast, households in Barma and Dho share traits common with many narrow valley or urban settlements and are generally restricted to landholdings consisting of an acre or less.

Furthermore and perhaps more importantly, being situated at the confluence of several surface tributaries advantageously positions Gongma to watershed resources and a consistent supply of runoff from nearby glaciers. Despite its extreme elevation, ranging from 12,000 feet to 14,000 feet, the geographic setting of Gongma favorably prioritizes the village in the accessibility, use and withdrawal of Domkhar's coveted water supply. Together, having more space, larger landholdings and access to greater water reserves may provide Gongma households with more flexibility when it comes to agricultural operations. With comparitively more land and resources, less pressure is exerted on Gongma households and simply stated, there is less people with more to go around. As a result, villagers in Gongma may not perceive climate change impacts or equate these changes as potential future risks to the same degree as downstream populations.

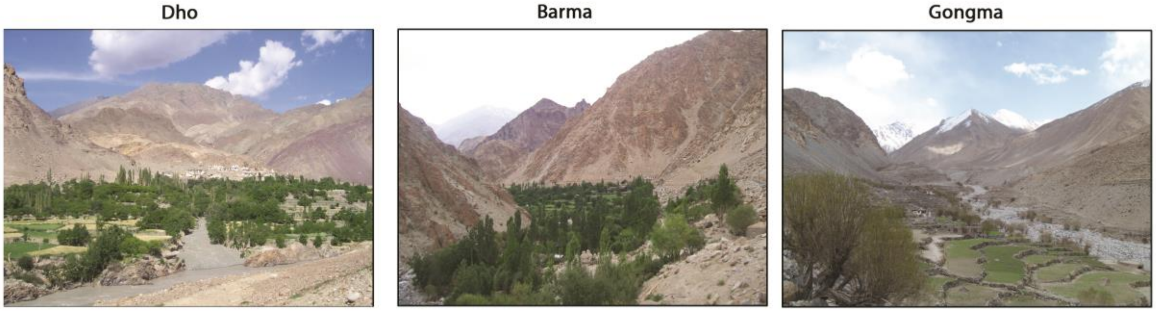
Similarly, the geographic locale of Domkhar's lower village of Dho is suitably positioned for both settlement and farming cultivation. Resting adjacent to the Indus River and along the valley floor, Dho households commonly utilize land and resources on both sides of the river. Contrary to most Ladakhi villages, which are distanced from the Indus River and situated in high mountain valleys like Barma and Gongma, Dho is located along the front of the Indus River and is able to capitalize on this proximity with respect to both water and infrastructure. For example, conveniently nestled between the Indus River and the base of Domkhar valley has allowed Dho to serve as a congregating point and depot station for traffic commuting to and from the border with Pakistan-controlled Baltistan and the larger towns of Kheltsi, Kargil and Leh. As such, both the primary and middle schools are located in Dho as well as a small market for essential goods. Therefore farming, though largely predominant in Dho, is not the exclusive economic base for the community. Together, these elements of space, access to added natural resources and a slightly more diversified economy are possible explanations for the villagers' moderate to low perception of local and regional climate change impacts.

As a whole, perhaps the most plausible explanation for the asymmetric distribution of observed climate change impacts in Domkhar valley is predicated on the fundamental role water plays within village life. Positioned near the cirque of the upper basin for example, water in

Gongma is supplied on a relatively reliable and steady basis from several neighboring glaciers. Even in the years with minimal snowpack and low rainfall, water resource in Gongma is in general, more dependable and renewable than it is for downstream communities simply due to its physical hierarchy within the larger Domkhar watershed. Accordingly, villagers in Gongma have first access to the water supply and are able to use gravity-fed systems to adequately distribute water throughout the community. In contrast, the villages of Barma and Dho, both located below Gongma and down the valley, are more likely to experience decreased water levels in the tributaries during severely dry years, particularly when upstream villages are equally pressured by drought (Figure 5.7).

Figure 5.7: Domkhar valley contains the three separate villages of Dho, Barma and Gongma Photo: B.Barrett (2010-2012)

Dho Barma Gongma



Unlike Barma however, households in Dho have alternative sources of surface water independent of the Domkhar watershed, such as the Indus River and other nearby water tributaries. For the village of Dho, being aligned with the bottom of the Domkhar valley and parallel to the Indus River strategically places the community at the confluence of several merging drainages thus alleviating demand on a single source of water. This is not the case in Barma, which is largely dependent on minor springs and the main water tributary running the course of the Domkhar watershed. Originating at the head of the watershed and near the village of Gongma, the Domkhar tributary is fed by runoff from small springs and glacial melt water.

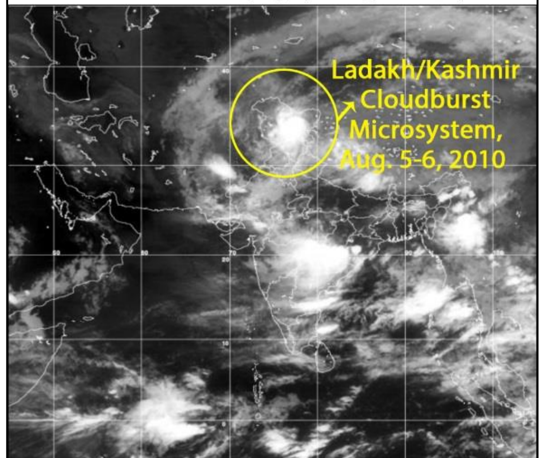
With few wells and little to no consistent precipitation, Barma relies on the surface water from the tributary for all of the community's irrigation and domestic requirements. Consequently, households in Barma are keenly aware of daily water flow in the tributary as well as upstream discharge levels. Being actively mindful of these knitted socio-ecological processes and the community's close dependence on one water tributary may work to visually and cognitively groom individual perceptions of climate change impacts.

In the other study area of Leh, a similar explanation can be applied to the Ibex Colony and Skara wards and the comparatively high values of perceived climate change impacts by villagers living within each community. Like Barma, geography and location can play an influential role in disadvantaging both the Ibex Colony and Skara wards from accessing available water resources. Situated at the bottom of the Khardung watershed, the Ibex Colony and to a lesser degree the Skara ward, are some of the last wards to receive water from the contributing upstream tributaries or *tokpos*. Lying slightly above the relatively lush valley floor and subsequently too high and inaccessible to the Indus River, the Ibex Colony is characterized by especially remarkably dry and barren conditions. In addition, being positioned near the base of the Khardung valley has created a very open and exposed landscape for the Ibex Colony households. Unlike the other wards, which abut the valley sides and are relatively sheltered from climatic elements, such as high winds, sand storms and flash flooding, the Ibex Colony is highly vulnerable to erratic and extreme weather conditions. This bare setting is unprotected and when combined with the visible lack of water resources, locality unfavorably places the Ibex Colony at present and future risk to climate change impacts. Households living in the Ibex Colony may therefore be predisposed to diagnose all types of environmental change as consequences of climate change.

Furthermore, in examining elevated levels of perceived risk and climate change impacts in Leh as in the case of the Skara, Main Bazaar, Skampari and Ibex Colony wards, it is worth noting the contributing role experiential learning plays in formulating public perceptions of climate change. As Myers et al. (2012) explains, witnessing an extreme weather event or natural hazard firsthand enables cognitive processes to work automatically, effortlessly and instantly, and has the strength and immediacy that analytical information, such as charts, reports, and models lack. For many, the multi-scalar nature of climate change often implies an abstract phenomenon operating beyond the immediate realm of tangible reality. The general public often feels distanced or removed from the direct implications of climate change and thus less concerned or impressed by the need to respond (Leiserowitz, 2006). Experiential learning on the other hand, such as surviving a flood or hurricane, convincingly connects people to climate change on a deeply personal and provocative level. For those who have experienced the consequences of a warming world, climate change transgresses beyond the theoretical to become a very vivid account of future possibilities.

In applying this concept toward the case studies of Domkhar and Leh, the flash flooding event that took place in early August 2010 provided a very concrete and meaningful memory of climate change risks (Figure 5.8). Leaving hundreds of people dead, injured and displaced in its wake, the flash floods were particularly devastating to settlements located along major drainages, such as Barma in Domkhar and the Skampari, Skara and Main Bazaar wards in Leh. This singular event had longstanding repercussions that in turn, impacted the social, ecological, financial and infrastructural foundations of Ladakh. Descriptive reports of damage to property, homes and crop yields left a formidable impression of Mother Nature's fury and foreshadowed a future of high uncertainty and even peril.

Figure 5.8: Satellite image of water vapor distribution over Indian subcontinent (Aug. 5, 2010 @ 9:00 P.M.)



Source: Indian Meteorological Dept., 2010.

Indeed, one catalyzing outcome of experiencing climate change personally is the generation of a perceived risk environment. Witnessing an extreme weather event or ongoing climatic stress provides a compelling example of possible climate change scenarios. For those who contextualize it this way, climate change is truly a "dangerous interference" with the climate system and a legitimate threat to their personal security. This is important because experiential learning about climate change reinforces engagement with the climate change discourse and on a more fundamental level, serves as motivation to respond to future climate change circumstances. Alternatively, low levels of perceived threat and a "distancing" from climate change impacts indicates low level of concern with the issue, which is strongly associated with reduced levels of support for taking action to address the problem (Roser-Renouf et al., 2011; Myers et al., 2012). While political ideology, religious affiliation and other sociocultural variables also bias belief in climate change, personal experience is a significant factor in enriching and enhancing a person's cognitive awareness and "sense" of climate change.

Communities in Ladakh particularly affected by flash flooding in 2010 or other previous climatic anomalies, may interpret and value climate change to a greater magnitude than communities less impacted by changing climatic conditions. Living through an extreme weather event, such as a flood, severe drought or other climatic hazard, can be a persuasive testament to climate change realities and correspondingly reinforce belief in its occurrence and causality. Other considerations, such as proximity to accessible water and natural resources, may play a supporting role in shaping community opinion and incentive to act on climate change. In embracing the possibilities posed by a risk environment, especially one fraught with the challenges and dangers of an extreme climate, households and communities can become better equipped to anticipate, plan and adapt to a variable climate future.

Conclusion

In both the Domkhar and Leh research areas, observations of climate change impacts were spatially disproportionate. Communities situated near water resources where flow levels were sporadic or seasonally fluctuated were especially attentive to climate variability. Alternatively, communities located near the head of the watershed or proximal to multiple water sources were less receptive to climate change impacts. Availability of additional natural resources, like land for farming, may also facilitate community framings of climate change and related impacts. Villages with access to the most water and land resources were seemingly less concerned with the risks and impacts of climate change compared to villages with limited water and space.

As such, access to water among other variables, appeared to be a strong indicator of perceived climate change in Domkhar and Leh. Many surveyed households operationalized water variability as an outcome of changing local environmental conditions. For example, in addition to a decreasing trend in overall snowpack, respondents noted the mountains were increasingly drier and when it did rain, storms were heavy and untimely. Water variability often implied a reduction in tributary water discharge and was thus a material and immediate threat to community livelihood security. In short, in areas where water is relatively less predictable such as some downstream populations, respondents were particularly attuned to recent environmental changes. Increased recognition of climate change impacts connoted a heightened sense of concern and unease about future climatic scenarios yet similarly implied a strong confidence in community preparedness and the capacity to anticipate and plan for climate change. Paradoxically perhaps, the villages and households who felt most impacted by climate change simultaneously felt most encouraged by the ability for their community to effectively respond. Locality was therefore important in shaping community opinions on climate change by determining proximity to natural resources, level of initial physical exposure to impacts and in some cases, the degree of impact from climate-related hazards.

Recognizing the unique marriage between locality and climate change impacts provides insight regarding the meaning of biophysical and social vulnerability in mountain settings like Ladakh. Findings from this study suggest that in some areas, physical geography and in particular proximity to water and other natural resources, is closely associated with perceptions of a risk environment. Constituting elements of biophysical vulnerability, mountain watersheds and the populations that reside there, are particularly sensitive to climate change because of their topographic, physiographic and altitudinal setting. In other words, like many of the world's mountainous locations, Ladakh is characterized by open, steep and high elevation terrain that disproportionately exposes households and communities to the elements of the environment, including the risks and hazards related to climate change.

However, the underlying social fabric within many mountain communities is strong, as evidenced with their extended households and deeply instilled sense of place. Social cohesion and community attachment within Ladakhi mountain villages is prevalent among adults and this may affect and moderate community concern about climate change. Overall, villagers are confident in their abilities to respond to potential climate change impacts and believe that planning for climate change is a necessary yet achievable endeavor. Connections toward place and sense of community are thus influential in shaping societal frameworks on climate change response and require a reconsideration of social vulnerability itself. Conventionally, social vulnerability has referred to the acquisition and availability of both material goods, such as income and financial capital, as well as immaterial services, like access to resources, power and networks. Expanding social vulnerability to include connotations of attachment to place and community belonging subsequently considers the value culture plays in shaping local perceptions of risk to climate change. In some areas like Ladakh, where biophysical vulnerability is high and further compounded by economic and political marginalization, social vulnerability is seemingly buffered by relatively strong levels of community connectedness and ties to the land.

Distinguishing social vulnerability in this way requires a versatile understanding of the immaterial and less visible linkages that facilitate perceptions of a risk environment to climate change impacts. In this context, social vulnerability may not be as exaggerated as demographic and socioeconomic indicators suggest, and in fact may be lessened by a strong sense of community awareness. Place attachment and personal links to a community may in turn influence local adaptive responses. Hence, the meaning and role of place is emerging as an important factor for climate adaptation in regions where existing livelihoods are unlikely to be maintained as the impacts of climate change are increasingly manifest (Adger et al., 2012; Igor, 2005). In broadening the scope of social vulnerability to include the nuances of place attachment and community cohesion, locality is once again underscored as a crucial foundational component of climate change adaptation.

Chapter 6:
Key Areas of Local Vulnerability to Climate Change and Opportunities to Adapt in Ladakh, India

Introduction

While climate change is inextricably linked to the long-term sustainability of many Ladakhi villages, it is one of several competing issues confronting the region's communities. Over time a profusion of political, sociocultural and environmental forces have sharply steered the course of Ladakh's evolving socio-ecological dialectic. While climate change is presenting novel and obstinate challenges, these issues often augment existing stresses related to population growth, health and educational enhancement, poverty alleviation, youth migration, globalization, and political disenfranchisement among other ongoing pressures. Identifying the impacts and processes explicit to climate change and further, the response strategies most appropriate for particular settings, is therefore complex and multidimensional.

In most places, the short- and long-term implications of climate change foster a higher risk environment and strain local and regional economic, political and social resources. Climate change is altering how individuals and groups of people engage and rely on ecological systems. Although varied in its outcomes, a warming world will threaten food production, economic stability, energy development, national security, water availability, health and infrastructural support. It will promote competition over natural resources and amplify existing sociopolitical tensions through civil unrest and political instability. Further while climate change is transboundary in nature, the ability to effectively respond to climate change impacts is differentially influenced by conditions of socioeconomic, political and biophysical vulnerability. Due to its ubiquitous yet uneven effects, climate change is an especially unwieldy and wicked problem.

Households and communities presently dealing with a wide suite of socioeconomic and politic adversities will be at greater risk to future climate change impacts and other compounding threats. Vulnerability manifests in places with minimal and marginalized resources, such as underrepresented mountain populations in Ladakh. As stated in the most recent IPCC report, "This heightened vulnerability is rarely due to a single cause. Rather, it is the product of intersecting social processes that result in inequalities in socioeconomic status, income, and exposure" (2014: 7). The report continues, "Understanding differential capacities and opportunities of individuals, households, and communities requires knowledge of these intersecting social drivers, which may be context-specific and clustered in diverse ways. Few studies depict the full spectrum of these intersecting social processes and the ways in which they shape multiple aspects of vulnerability to climate change" (ibid).

In response to the above critique, this research has sought to address this gap in the literature by systematically detailing the myriad geographic processes propelling conditions of vulnerability in Ladakh, including the climatic and non-climatic drivers of change. Structured as a synthesis of the preceding three chapters, this concluding chapter identifies main sociocultural, economic, political and biophysical variables that work to sustain and reinforce vulnerability to climate change at the local scale. Guided by the previously stated results and discussion, the fourth and final research question asks:

> ***RQ#4:*** *What do local perceptions, observed climate trends and community values on climate change reveal about climatic and non-climatic drivers of vulnerability and risk to present and predicted climate change impacts?*

Climate change functions as a process of multi-scalar exchanges and while the policy and action to stabilize greenhouse gases is articulated at broad levels of decision-making, the everyday outcomes of climate change are experienced at the local scale. Attempting to commensurate conceptual, communicational and operational discrepancies between multiple scales is thus a key ingredient in establishing a long-term resolution and functional regime for climate change policy. Scale, in all its nuances and inclusiveness, subsequently presents itself as a compelling epistemological framework to better examine the dynamic nature of climate change, as well as the ability to respond to its impacts at different levels of engagement and dialogue.

As an analytical tool, scale can be interpreted and applied in several ways. In its broadest and most theoretical sense, scale refers to the social arrangement of power relations and the circulation of capital and entitlements within the wider political economy. Within this context and particularly important to the climate change discourse, scale can additionally connote the degree of differential access and availability of resources, including political, social, economic, technological and natural assets. The more fluid and reciprocated this exchange of resources is, the better equipped an individual, household or community is to respond and anticipate for climate change. Indeed, while many marginalized societies are adversely impacted by climate change, privileged members of society may even benefit from climate change impacts and response strategies due to their flexibility in mobilizing and accessing resources and positions of power (IPCC, 2014: 7).

It is important to note the discriminatory nature of cause and effect in climate change and the disparate capacities between and within different groups of people to effectively respond to these outcomes. Taking into account the vertical and horizontal dimensions of scale as part of the climate change discourse can inform adaptation decision-making pathways to reflect and integrate context-specific criteria. As described by Adger et al. (2005), the relevancy and success of adaptation efforts is predicated on the assumption that the action meets the objectives of adaptation at implementable scales and further, that the action doesn't interfere with others to meet their own adaptation goals. Distinguishing adaptation objectives at multiple levels can be conceptually explored by distilling scale into its theoretical, temporal and spatial components.

In this research, three unique definitions of scale were applied to assess vulnerability and adaptive capacity to climate change impacts in Ladakh. In Chapter 3, the first of the three data analysis chapters, scale is contextualized in its most abstract and metaphorical sense by emphasizing the arrangement of socioeconomic, demographic and political relations within sampled Ladakhi households and villages. Research methods involved household surveys to characterize predominant community traits that in turn, teased out associations, perspectives and values regarding climate change impacts. These surveys provided largely qualitative understandings of climate change and intimated the degree that climatic risks are interpreted and prioritized at the household and community level.

Alternatively, Chapter 4 and Chapter 5 applied the literal meanings of scale as a process of both time and space in order to examine climatic variability in Ladakh. While the former chapter assessed temporal variability in climate trends using statistical processing methods, the latter chapter focused on the spatial distribution and concentration of climate change impacts and values within each community by using geospatial modeling techniques. Together, the abstract, temporal and spatial framing of scale became the analytical lens to evaluate how different geographic processes intersect within the same landscape to influence the gestation of a local climate change narrative. These three meanings of scale provided the theoretical pillars that this research was expanded upon and hence, established a larger dialogue on community response and engagement with climate change impacts in the Ladakhi region.

Accordingly, the following section profiles climate-related stresses and other extraneous factors that aggregate at the household and community scale to undermine overall capacity to respond to risks from predicted climate change. While independently, many of these drivers appear as products of modern lifestyle trends and shifting cultural preferences, collectively they signify a marked transition in how contemporary Ladakhis are interacting with the surrounding natural environment. In many ways, the culmination of these influential variables is inadvertently priming Ladakhi households and communities for deleterious results given current development trajectories and unmitigated emission scenarios. That said, proactively recognizing the processes that bolster community resilience and minimize exposure to unavoidable future climate risks will enable active community planning and response for the future. Lessons learned in this assessment, including key areas of risk and the identification of processes that facilitate initial conditions of risk and vulnerability, provide analytical and representational analogs for other similar settings around the world. In turn, identifying multi-scalar processes that foster exposure to future climatic and non-climatic threats can similarly work to isolate entry points for adaptation and risk management.

Key Climatic and Non-Climatic Drivers of Vulnerability to Climate Change Risks

In Ladakh, drivers of vulnerability work to both quietly and coercively erode the foundations of long-term resilience to climate change and other considerable challenges. While shifting land use patterns, transitioning demographics and increasing development demands are byproducts of modernity in Ladakh, they are also instigating an increasingly more insecure and susceptible environment. When coupled with climate-induced changes, such as extreme weather events and variability within the hydrologic cycle, the congregation of these forces may diminish local capacities to respond. Moreover, the impacts from climate change are heterogeneous in distribution and concentration, as are the resources to effectively counter adverse outcomes. It is therefore crucial to thoroughly investigate local-level contexts on climate change in order to inform appropriate decision-making processes to be compatible with site-specific needs, resources and goals.

Neglecting the value of local context will misdirect policy initiatives, squander valuable time and financial efforts and may worsen overall vulnerability in the long-run (Brody, 2012; Ireland, 2012). Inasmuch as identifying opportunities to reduce local vulnerabilities is essential, so too is it necessary to recognize those strategies that unintentionally accentuate elements of vulnerability. Referred to as maladaptive responses, such measures tend to be short-term coping mechanisms that often shift risks to other social groups, sectors and systems (Barnett and O'Neill, 2009). Very frequently, future generations are implicated in the process of maladaptation because such responses focus on remedial solutions that act as temporary band-aids to climate change impacts rather than resolving the causal drivers of climate change. The continual use of greenhouse gas technologies, increasing costs of energy-efficient services and building in flood-prone areas are examples of maladaptive practices that increase long-term vulnerability to climate change. Proposed adaptation measures must therefore consider the temporal continuum of available resources, labor and capital, as well as the long-term objectives and feedback processes associated with different adaptation responses. Adaptive strategies that momentarily alleviate climate change impacts yet reinforce longstanding vulnerabilities need to be recognized and filtered from decision-making arenas in order to avoid generating even more adverse conditions to climate change impacts in the future.

In an effort to characterize local vulnerabilities and positive adaptation opportunities to climate change impacts in high mountain areas like Ladakh, the following section details key areas of exposure to future climate-related risks. In examining the intervening nature of biophysical, sociocultural, economic and political variables onto one landscape, the importance of locality in climate change response is underscored. Geographic and physical constraints are first addressed, particularly with respect to the unique environmental features that inherently place mountain populations at heightened risk to climate change. In this context, special attention is given to the fundamental role water plays in community life and how the quality and quantity of future water resources will unequivocally determine Ladakh's future development pathways and livelihood options.

Following this discussion on biophysical vulnerability is a look at the social and demographic shifts underway in Ladakh, that also increase overall sensitivity to present and predicted climate change impacts. Other climatic and non-climatic drivers of vulnerability are then examined within the context of local to global relations and the manifold pressures exerted within the wider political economy. Based on this evaluation, a set of possible adaptation recommendations are advanced that recognize both the practical and conjectural limitations of climate change response in Ladakh. Finally, the chapter concludes with a discussion of the forwarded adaptation scenarios and a proposed direction for future work and contributions in the climate change field. This research ultimately argues for a critical interrogation of biophysical and social vulnerability and a heightened awareness of the role locality and cultural attachments to place and community can play in shaping local engagement with climate change response.

The Geographic Landscape: Biophysical Factors Shaping Vulnerability to Climate Risk

As a high mountain desert landscape, Ladakh is physically predisposed to the extremes and abruptness of environmental change. As with many other high mountain settings, never has this been more visible than with recent anthropogenic warming. Retreating snowlines, parched fields and unpredictable precipitation patterns are just a few preliminary signatures of the environmental changes already underway. The combined effects from climate change will have extensive and reverberating ramifications across Ladakh's natural and human landscape. The region's geographic attributes, such as physical remoteness, mountain topography and minimal natural resources, further contribute to the region's high level of exposure and sensitivity to changing climatic conditions.

Distinguishing the role of biophysical vulnerability from other social and economic vulnerabilities is the contextualization of climate change impacts as climate-induced *hazards*. This concerns the degree of damage resulting from externally imposed risks in contrast to viewing vulnerabilities as an outcome of internally structured factors. As Brooks and Adger (2003) state, it is the interaction of a hazard with social vulnerability that produces an outcome, generally measured in terms of physical or economic damage or human mortality. Hence biophysical vulnerability is often hazard-specific whereas social vulnerability is influenced by a range of more generic determinants, such as poverty, inequality, health and other factors (Brooks, 2003). Social vulnerability can therefore be a component of biophysical vulnerability and together, both definitions describe the severity, likelihood, degree of damage and ability to mediate such damage by a system when encountered with a hazard.

Perhaps the most tangible climate-induced hazard looming over Ladakh is related to water variability and the foreseeable shortage of future water resources. On average, Ladakh receives less than 200 mm of rainfall each year, constituting it as a high elevation and arid environment (Rizvi, 1996). Ladakhis are historically accustomed to such restrictive conditions and have developed intricate and carefully orchestrated networks for water collection and distribution. For example, gravity-fed irrigation systems canvas individual farming plots and water flow is methodically directed by multi-tiered ditches, canals and pipelines. This irrigation scheme saturates the most amount of surface area with the least amount of flow. Similarly, traditional Ladakhi lifestyle patterns are appropriately sensitive to the local water budget and have historically used 'dry toilets' in place of water-intensive flush toilets. Such adaptive livelihood measures ideally cater to Ladakh's dry climate and are less demanding on the region's scarce year-round water supply.

Despite conventionally conservative consumption practices, Ladakhi households are increasingly strained by the overall lack of water resources. Rising global air temperatures are heralding a new and uncertain hydrologic regime in the region, changing the timing, quality and quantity of flow levels. Across Ladakh, glacial meltwater supplies a vast majority of urban residents with water supply and is often the exclusive provider of water in rural areas. Consequently, upstream snow and ice reserves in the upper cirques and basins is important in sustaining seasonal water availability to downstream populations (Immerzeel et al., 2010). Receding glaciers correspondingly implies less long-term water supply for agricultural, livestock and domestic needs. Heavy dependence on glacial water discharge combined with the net demands from irrigation and development are setting the stage for future water shortages in Ladakh, particularly in areas with increasing population growth, commercial growth and industrial development like the town of Leh.

Although the degree that climate change will affect glacial meltwater in Ladakh is undetermined, a continued reduction of Himalayan glaciers is projected across the region (IPCC, 2013). While stream flow levels may vacillate as a result of accelerated glacial recession, prospects for long-term water security in the region are poor especially in light of anticipated population trends. For instance, Immerzeel et al. (2010) estimate the cascading effects of glacial retreat will have considerable impact on food security throughout Asia. In the Indus River Basin alone, the authors calculate approximately 26 million people will be underfed as a result of water shortages from recent and predicted glacial recession in the Himalayas. Even if the climate model projections are meso-scale in analysis and slightly overstate predictions for micro-climates in Ladakh, any additional decrease in glacial coverage could be detrimental to the region's upstream villages and towns.

Given the dearth of annual rainfall in Ladakh, irrigation is essential to the region's agricultural cultivation. The amount of winter snow determines the anticipated supply of water during summer, which further dictates whether marginal fields should be sown or not in the spring. This in turn affects the ploughing, sowing and harvesting time of crops and the sequence that crops are planted (Angchok et al., 2008). When water supply is low, fewer crops are planted and more fields are left fallow. With fewer crops grown, annual yields decrease and individual farmers have less income to support themselves and their households. People gradually move elsewhere and soon, there is not enough labor available for agriculture to be viable.

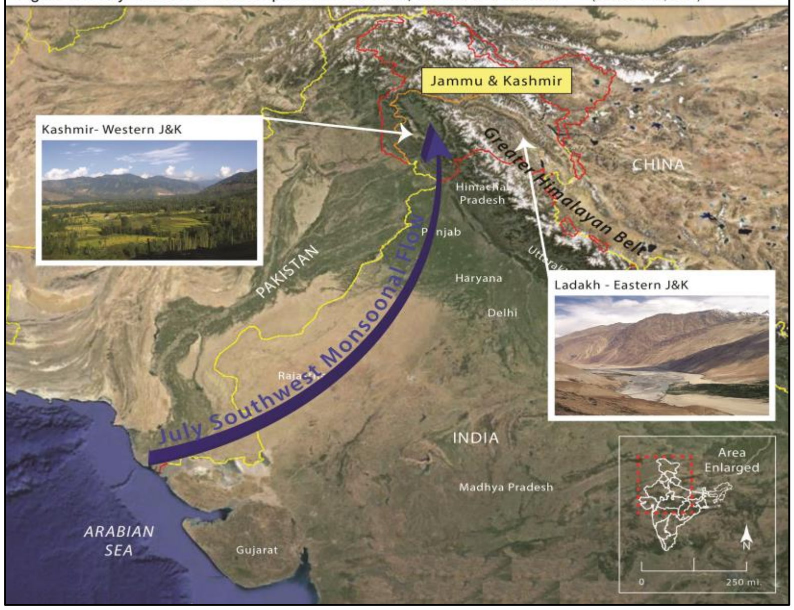
Moreover, due to the hierarchal configuration of gravity-fed irrigation systems in most places across Ladakh, villages located at the bottom part of the valley and downstream are less likely to receive sufficient water supply relative to upstream populations. Paradoxically, as downstream villages are located lower in elevation and thus in a slightly warmer climatic zone, these villages are in need of the most water at the earliest time of the year. For instance, farmers located in the Skara ward of Leh district are situated at the bottom of the Khardung watershed and experience warmer temperatures compared to other more northern wards in Leh. As a result of this slight temperature variance, crops in Skara are ripe before their upstream counterparts located in cooler agroecological zones. Yet being located at the tail-end of the irrigation allocation system also implies Skara farmers are the last to receive water, which often falls short of their requisite needs. As Akhtar (2010: 75) describes, "Farmers in Skara often face water scarcity that was earlier compensated by additional spring water dispersed around the nearby area. However, in recent years, spring water got less and the lack of water often means that the farmers in Skara can only produce their vegetables for the market later than other farmers in Leh town." The earlier the vegetables come to market, the better the prices are for the farmers. The geographic location of Skara farmers therefore economically disadvantages them in comparison to other upstream farmers who receive more adequate water supply and at more opportune times.

In addition to the extreme topography, desert landscape and high altitude of Ladakh, the region is landlocked from India's central core. The predominant physical obstacle dividing Ladakh from mainland India and the reason it falls within a rainshadow, is India's northern Great Himalayan belt. This vast stretch of mountains runs laterally east to west, effectively separating the state of Jammu and Kashmir from the state of Himachal Pradesh and central India. To travel from India's northern capital of Delhi to Leh takes three to four days and is approximately 670 miles (1,075 km). The single road is poorly maintained and due to snow accumulation, avalanches and landslides, is frequently and periodically closed for long durations of the year. Other than air travel, the only alternative option is to drive west from Ladakh through Srinagar and Kashmir. This route is just under 800 miles (1,274 km), with two significant mountains passes to contend with including Fotu La at 13,478 feet (4,108 m) and Zoji La at 11,575 feet (3,528 m). Travel to and from Ladakh is hence riddled with complications related to its relative inaccessibility, steep terrain and uncompromising physiographic landscape.

Being physically isolated and distanced from India's central core also suggests minimal representation, resources and support is available to Ladakh. The movement of goods, services and supplies to Ladakh from Delhi and elsewhere is frequently stymied by unfavorable weather conditions and lack of services and infrastructure. Despite the central government of India annually funneling resources into Ladakh for improved infrastructure, such as roads and bridges, all planning efforts must submit to the capricious nature of the region's unforgiving environment. For example, in the fiscal year 2012, the central government of India allocated 53,992.14 lakhs (approximately $121 million) for expenditures related to road and bridge construction within the state of Jammu and Kashmir (Annual State Plan, 2012). While seemingly significant, this was far less than other neighboring mountain states were allotted, such as Himachal Pradesh ($1.6 billion), Uttar Pradesh ($616 million) and Uttarakhand ($259 million) (ibid). While it must be noted that Uttar Pradesh has a substantially larger population than other states and hence government earmarked for higher transportation investment, Jammu and Kashmir is still one of India's fastest growing states, increasing its population by 23.7 percent between 2001 and 2011 (Census of India, 2011). However given the vast size of the state (85,806 square miles) and its rough topography, the population density of Jammu and Kashmir is relatively sparse in comparison to its southern counterparts. Funding to improve the nearly 8,000 miles of road (12,976 km) must be considered relative to road density use, distance, durability and national priorities (PHD Research Bureau, 2011).

Despite infrastructure development in Jammu and Kashmir lagging in comparison to many of India's other states, the region promises to be one of the country's most lucrative future caches of natural resources. The diverse land cover of the state yields high timber, mining and other natural commodities in the western districts of Kashmir and strong tourism potential in the eastern districts of Ladakh. Unlike Ladakh, with its minimal annual precipitation and high desert biome, Kashmir is lower in elevation and is characterized by its relatively temperate and humid climate. Nestled against the western fringe of the Pir Panjal Range, India's Valley (Vale) of Kashmir enjoys more annual rainfall and higher seasonal temperatures than Ladakh. Every summer, the southwest monsoonal flow carries warm and wet air masses out of the Arabian Sea and due to orographic lifting from the Pir Panjal Range, deposits precipitation in the Kashmir valley (Figure 6.1). Correspondingly, the western half of Jammu and Kashmir is characterized by its rich terrestrial landscapes and biodiversity, as well as the prevalent cultivation of agricultural goods such as rice, nuts and fruits. Indeed, Kashmir supplies nearly 57 percent of India's annual apple production and 97 percent of the country's walnut production (PHD Research Bureau, 2011).

Figure 6.1: July monsoonal weather patterns in Kashmir, Jammu and Kashmir (Source: IMD, 2011)



In many ways therefore, Ladakh is the geographic antithesis of Kashmir and wanes in comparison to the concentration of natural resources. Situated on the northeast side of the Pir Panjal Range and within the rainshadow of the Tibetan Plateau, Ladakh largely lacks the lushness and varied ecozones distinguishing the western part of the state. For example, out of the 17,413 square miles (45,100 sq. km) that comprise the Leh district, only 11.2 square miles (29 sq. km) contain forests (LAHDC, 2012). Whereas Kashmir's mixed land cover and moderate climate have induced an abundant resource base with tremendous potential for commercial development and industrial extraction, Ladakh's arid landscape is less favorable for natural resource production. Furthermore, Kashmir is a promising setting for mineral mining and energy generation, particularly with regard to the region's ample hydroelectric capacity. For instance, of the forty three large hydroelectric projects being proposed, under development and/or already producing electricity in the state of Jammu and Kashmir, thirty five of them are located in Kashmir (JKSPDCL, 2014). As pressure from population growth and development continues to increase throughout India and other parts of Asia, Kashmir's reservoir of natural resources offers a wide and profitable range of commercial opportunities.

Largely absent of the natural resources housed in Kashmir and many other parts of India, Ladakh is limited when it comes to manufactured services and supplies. Many items, food products and materials that cannot be produced in Ladakh are transported in, commonly by road via Manali or Srinagar. As previously stated, all shipments must adhere to the seasonal accessibility of the high mountain passes and typically take place during a four or five month period, from late May or early June through October or September. Frequent closing of the mountain passes due to snow and other variable weather conditions implies that Ladakh goes extended periods of the year self-sustained and without support from central India. The opening of the mountain passes subsequently signals the arrival of long-awaited deliveries, shopping goods, food products and tourists.

Historically, Ladakhis have adjusted to such a restrictive environment, utilizing what resources are plentiful and available to them. Ladakhi houses for example, are traditionally constructed from mud, stones and poplar branches. While commercial, government and business structures are increasingly built using modern concrete and rebar materials imported from India, it is still common for Ladakhis to construct one to two story residential structures using locally resourced materials. Resident homes typically consist of multiple small rooms and have a flat roof for drying dung, storing barley, dehydrating apricots and other useful applications. Yet given Ladakh's increasingly changing environment, such as heavy and untimely rainfall and resultant flash floods, these same architectural materials inadvertently expose households to risk because they are ineffective in withstanding such extreme inundation. Traditionally built in response to the region's dry climate, homes easily crumble and erode upon the onslaught of debris, boulders and water accompanying a flooding event. If climate change projections are even remotely accurate, then Ladakhis will have to anticipate an increase in both the frequency and magnitude of extreme weather events. As a result, new building constructions with sloped roofs and reinforced walls will likely have to become an integrated modification to contemporary Ladakhi structural design. Altering traditional architecture planning to better reflect future climate changes would be an anticipatory, albeit reluctant, acquiescence to the legitimate threats posed from global warming. In short, while influences of globalization and modernization in Ladakh are increasing overall vulnerability, Ladakhi's can no longer exclusively rely on traditional ecological knowledge because climate change has altered the environmental context within which they live.

Supporting some of the world's highest mountain populations, Ladakh is unique in both its severity as a desert landscape and in its physical remoteness. Geography plays a formative role in determining the nature and extent of biophysical vulnerabilities to climate change because it inherently places some people and places at unequal exposure to the impacts from climate change. In Ladakh, biophysical setting and other external variables align with internally structured systems to generate conditions of vulnerability to climate change impacts. Externally derived environmental factors that largely work in concert with other socioeconomic and political processes to facilitate conditions of vulnerability to climate change impacts in Ladakh, include the following:

- **High elevation and arid environment:** Receiving little rainfall and at altitudes commonly exceeding 11,000 feet, many Ladakhi villages depend on surface water sources for their agricultural, domestic and irrigational water needs. Meltwater from glaciers provide the main lifeline for many Ladakhis and have sufficiently satiated the region's requirements in the past. However, receding snowlines and variable precipitation patterns, particularly in the winter months when Ladakh accumulates its snow and ice, is straining the quality and quantity of local water reservoirs. A significant dependence on glaciers for irrigation and households water needs correspondingly influences the timing, cropping patterns and yields of annual farming harvests. In turn, household incomes, community stability and local economies are effected and potentially jeopardized by the portending threat of hydrologic variability and shortages due to warming global air temperatures.
- **Relative isolation and physical remoteness:** Travel to and from Ladakh must defer to the spatial and geographic limitations of physical circumstance. With the exception of air travel, there are only two commercial access routes into Ladakh both of which require time and resources. Given the vastness of Jammu and Kashmir, government funding for essential infrastructure is thinly spread over large areas. Furthermore, upkeep, construction and maintenance of roads and bridges is constant and is exacerbated by the region's severe and erratic weather conditions. Consequently, the transportation of goods, services and materials into Ladakh is not consistent or reliable, despite an increasing dependence on imported products and capital from the central part of the country. Overcoming these physical barriers is a necessary yet exhaustive challenge in the arrival of government resources, relief aid and political representation.
- **Limited availability of natural resources:** Unlike its western counterpart Kashmir, Ladakh is a relatively barren and dry landscape. Devoid of timber, heavy vegetation and ample rainfall, Ladakh is limited in its natural resource base. In response, Ladakhis have specialized in particular livelihood strategies that tailor to the region's stringent environmental conditions, such as cultivating drought-resistant crops like barley and building homes from locally resourced materials like mud and poplar branches. However in the town of Leh and surrounding area, climate change together with population increase and development, have placed an unprecedented demand on Ladakh's available resources. Domestically manufactured materials and locally-grown food items are increasingly supplemented if not entirely supplanted, by imported products. Added reliance on central India for necessary goods is a one-sided exchange and

> further distances Ladakhis from a tradition of subsistence living. With time, such a distorted relationship can lead to exploitation of Ladakhi markets and engender instability within local and regional economies.

Together, the above physical and geographic attributes of Ladakh generate a higher level of exposure to present and predicted climate change impacts and related risks. Biophysical variables are not mutually exclusive however and often work in consonance with other socioeconomic and political forces to drive conditions of susceptibility and sensitivity to climate change impacts. While foremost among these precipitating and interlinked factors is the heavy dependence on local glacial-fed water sources, other forces of modernity like climate change and globalization, are merging to collectively determine the outcome of Ladakh's future.

Facilitating Factors of Social Vulnerability to Climate Change Impacts in Ladakh

Internally structured processes mediate the ability for human systems to respond to the impacts and risks of climate change. The nature of this exchange determines the degree that a climate-related hazard becomes a social and economic disaster. In viewing climate-related hazards as an external consequence of larger changing climatic conditions and hence biophysical vulnerability, social vulnerability implies factors that internally work to shape the outcome of a climate event (Brooks, 2003). Social vulnerability considers a range of properties that adversely exposes a system to climatic risks, all of which operate independently of the hazard itself. Although environmental variables may physically foster a more risky environment, socially constructed processes often determine the extent of damage, scope of impact and rate of recovery. Viewed holistically, the threat of a specific hazard is geographically filtered through proximity and location while the social fabric of a place enhances or constrains the ability to respond. Social fabric is composed of community knowledge, history and experience that in turn, is influenced by economic, demographic and housing characteristics (Cutter et al., 2003). Together therefore, social vulnerability interacts with physical exposure and sensitivity to produce the overall vulnerability of a place.

Conceptualizing social vulnerability in this way elicits an identification of the indicators and contributing components that endogenously structure and organize groups of people. In doing so, social vulnerability is concerned with the underlying configurations of power, representation and assets that make climate change impacts differentially risky for some households and communities over others. In short, social vulnerability is a pre-existing condition or inherent property of existing communities, irrespective of the hazard of interest (Cutter et al., 2009; Bohle et al., 1994). Outcomes of climate change are thus derivatives of social causality and can be both buffered and amplified by the arrangement of social, political and economic entitlements, resources and capital.

For this research, characteristics of age, gender, employment, education and other socioeconomic factors were used to operationalize social vulnerability to climate change in Ladakh. Both case studies demonstrated a range of socially constructed forces that have subsequently assembled onto the local and regional landscape to influence household and community response to climatic variability. Each of these processes is deeply interconnected with one another and in many ways, illustrate the region’s ongoing dichotomy between tradition and modernity. For example aside from climate change, recent pressures imposed by globalization, contemporary market trends and changing lifestyle preferences are rapidly altering Ladakhi demographics. Prioritizing climate change relative to other, potentially more pressing concerns must therefore consider the scale and omnipresent effect of this larger shifting milieu.

Perhaps it is precisely due to the convergence of multiple issues onto the local and regional landscape that best reveal aspects of social vulnerability in Ladakh. For example in Ladakh, one approach for assessing multidimensional vulnerability is to examine evolving livelihood strategies and in particular, changing ways of life that center on agriculture. With the exception of urban areas like Leh, few alternative opportunities for economic diversification exist outside farming and livestock rearing within the region. Agriculture unsurprisingly plays a vital and prevalent role in Ladakh's culture and community setting. Across the state of Jammu and Kashmir, the agricultural sector contributes 27 percent to the state gross domestic product and provides direct livelihood to about 49 percent of the workforce (Baba et al., 2011). Similarly in Ladakh, the proportion of agricultural laborers in the workforce constituted 47 percent in 2011.

However, unlike many other rural areas in India, the number of agricultural workers in Ladakh has steadily declined in past decades. While the absolute number of agricultural laborers has increased with the region's population trends, the ratio of agricultural workers in comparison to other occupations is decreasing. For instance in 1971, the agricultural workforce comprised 73 percent of the region's total working population and by 1991, the proportion was down to less than 53 percent (ibid). Although this relationship varies across the region and with different geographic context, there is a consistent downward trend in the overall number of agricultural workers and cultivators in Ladakh (Ladakh Census Dept., 2011).

The noticeable decline in the agricultural labor sector is in contrast to the growing amount of land area under cultivation. Recent census figures for Ladakh suggest the number of laborers per thousand hectacres of cropped land has decreased despite an increase in the area under labor-intensive vegetable cultivation. In other words, since the 1970s, there are fewer farmers working on larger yet less efficient areas of land. While new technologies and modern mechanization may partially account for the reduction in labor, this does not fully explain the changing dynamics underway. Rather, a significant reason for the descending trend in the agricultural workforce is due to tilting demographic patterns and changes in lifestyle preferences.

In particular, Ladakh's recent trends in the agricultural sector resonate with the broad restructuring of local gender roles and generational turnover patterns. Markedly pronounced since the 1970s, Ladakhi men have been deliberately migrating away from farm and cultivation work in favor of government, military or tourism employment. The onus of food production and agricultural development subsequently falls on the remaining women in the household. According to Baba et al. (2011), female agricultural laborers in Ladakh are increasing at an annual growth rate of about 2 percent and in 2011, composed 56.5 percent of agricultural workforce. Alternatively, men constituted 43.5 percent of the agricultural labor market in 2011, which was down from 66.53 percent in 1981. One study estimated that in the Indian Himalayas, a man averages 1,212 hours a year on a one hectacre farm in contrast to 3,485 hours worked by a woman (Shiva and Jalees, 2005). Such trends are common throughout rural India where the number of female agricultural workers often trumps their male counterparts by more than double. For instance, a broad statistical profile of India's population indicates female agricultural laborers constitute 46.9 percent of the total workforce, and in rural areas, nearly 85 percent of female workers are classified as either agricultural laborers or cultivators (Rao, 2006; Census of India, 2001). Women therefore are principal players in India's agricultural development and tangential sectors, such as food production, horticulture, livestock operations and forestry.

Results from this study similarly found female farmers outnumbered male farmers in Ladakhi villages. Of the total workforce surveyed, women represented more than 62 percent of the agricultural sector including farmers and laborers. Nearly 70 percent of all female respondents worked as farmers with the remaining 30 percent involved in small businesses, teaching or staying at home as traditional housewives. Furthermore, men were often more educated than females and were thus better positioned to work in alternative occupations such as salaried workers, government employees, business owners or as tourist guides. In the rural village of Domkhar for example, nearly 45 percent of the female respondents never received any formal education and less than 1 percent attended middle school and beyond. For many Ladakhi village women supporting a household and a livelihood, going into farming and agriculture is not an option but a necessity.

In view of predicted climate change scenarios, women farmers in Ladakh will be disproportionately impacted by climate change impacts because they are taking on more dominant roles in the fields and within the home. In effect, climate change aggravates the tendency of the feminization of agriculture while men are pushed into migration (Abeka et al., 2012). As primary caregivers and food producers, women farmers in Ladakh are on the frontlines of climate change and will be discriminately affected by water shortages, food insecurities, extreme weather events and other climate-related hazards. In their segregated roles within both society and the family, women are commonly tasked with water collection, food procurement and domestic chores. As a warming world increasingly alters the reliability and renewal of vital ecosystem services, women will have to expend more time, energy and resources satisfying the dual needs of farm and home. Furthermore, these added pressures imply women will be physically exposed to climate change impacts on an increasing basis because they will be consistently working outside in the fields or attending to other household needs. Already disadvantaged by low literacy rates, minimal education, unequal pay and uneven access to resources, women are especially at risk to climate change impacts.

Other demographic forces are at work to reinforce the gender gap in Ladakh's agriculture sector. Widening generational divides for instance increasingly reconfigure the cultural landscape of many rural mountain villages. With fewer economic opportunities and livelihood options, many young people are relocating to urban centers where a rapidly emerging employment base offers diversified lifestyle choices. Young people are also more likely to be educated and frequently view agricultural work as a less attractive career option in comparison to other employment potentials (Sumberg and Okali, 2013). In Ladakh, a majority (54.9 percent) of the people engaged in farming activities were over the age of 56 years. Conversely, it was much more common for people under the age of 35 years to be working in salaried positions, government agencies or running a small business as a shopkeeper or other retail service. With marginal economic incentives and higher labor demands, agriculture holds minimal appeal for aspiring young adults who prefer to capitalize on Leh's surging development and growth prospects. Like Ladakh's male population, young people are increasingly migrating out of the rural hinterlands and creating a labor shortage in the domestic agricultural sector. As a result, women must supplement the workload capacity and assume the collective responsibilities traditionally supported by the husband, children and extended family.

Other factors are also at play when it comes to the broad redistribution of labor and burden sharing in Ladakh's agricultural sector. As stated previously, while the ratio of agricultural workers has declined in recent decades, the size and resource-intensity of the average farm has risen. The increasing cultivation of wheat, rice and cash crops across the state of Jammu and Kashmir is demonstrative of this relatively recent shift in land use patterns. In tandem with a growing demand for greater food selection and other pressures within the wider political economy, there has been a popular push for specialized crop production across the region. For example commercial crops such as potatoes, cauliflower and apricots yield a higher value and demand in the market, despite the relatively high-energy input needed to grow, cultivate and harvest these crops. Similarly, research findings from this study indicate wheat production is increasingly preferred over more traditional crops like barley and pulses. While the move to commercialized crops like wheat, vegetables and fruit is coerced by a variety of diverse forces, it signifies a fundamental transition in modern land use practices that favors a greater dependence on surrounding resources, particularly water.

For example, in comparing traditional land use patterns with contemporary crop cultivation in Ladakh, the latter increasingly utilizes more natural resources like water and land, and human resources such as labor. In particular, wheat requires up to three times more water in contrast to crops like barley and maize (Ziaei, S. et al., 2013; Khan et al., 2010). Wheat production additionally involves more fertilizer, seed preparation and harvesting time relative to other traditional crops. Furthermore, findings from this research and Osmaston (1995) suggest, the ratio of land sown, irrigated and maintained versus the total annual crop yield is uneven in many Ladakhi farms. In keeping pace with modern market demands, Ladakhi farmers are planting larger areas of land with crops requiring higher-inputs yet producing low to moderate harvests. In effect, local farmers who are mostly women, are increasingly exerting valuable time, energy and labor in order to maintain and satisfy expected crop quotas. This in turn diverts much needed attention away from other and equally pertinent concerns such as domestic chores, caregiving and running a household.

The progressive inclination toward energy-intensive and water-reliant crops like wheat may provide short-term gains but with potentially long-term consequences. As more farmers switch to wheat cultivation, cropping patterns becomes standardized and accommodate a single crop in contrast to multiple crops. Embracing monocropping techniques can negatively expose farmers to the exclusivity and volatility of a non-diverse investment. In essence, planting the majority of a field with wheat instead of a variety of different crops makes the collective harvest susceptible to economic and ecologic risks. Price fluctuations in the market, sudden crop failure, insect invasions, pathogenic infections and other threats could single-handedly and uniformly deplete a farmer's harvest therefore compromising potential economic profit and the ability to financially support the household.

Perhaps more importantly, shifting toward a more water-intensive product does not bode well in light of Ladakh's present and predicted variability in the hydrologic cycle. Indeed, growing preference for wheat cultivation in Ladakh may even be regarded as a maladaptation in lieu of the region's receding glacier reserves, lack of alternative water resources and absence of significant rainfall. The relatively high irrigation needs of wheat is an agroecological contradiction to Ladakh's arid environment and should be supplemented with less water-intensive crops like barley. While wheat has been an agricultural mainstay for Ladakhi farmers for many generations, its relatively recent and increasing dominance over other traditional crops heeds caution for long-term water prospects and other economic and environmental uncertainties.

In the big picture, the added stress on the local water budget from wheat cultivation is only one of several contending challenges facing Ladakh's long-term water security. Escalating pressures from development, tourism and urbanization are similarly taxing local water reserves and unfavorably positioning Ladakh for potentially severe water shortages in the future. Yet proactively addressing the causal forces nurturing conditions of vulnerability to water scarcity and other climate-related issues is complicated by the different ways that humans conceptualize, process and anticipate future change. Less tangible than other material obstacles to climate change adaptation efforts, cognitive and behavioral processes psychologically prepare a society for climate change impacts and related hazards. For instance, differences in spatial and temporal frameworks can partially account for why individuals and groups of people respond and interpret climate change in unique ways (Leiserowitz, 2006). Some scholars have argued that as distance from a particular impact, threat or risk increases, mental representations become less concrete and more abstract (Scannell and Gifford, 2013; Trope and Liberman, 2003). Awareness of climate change and its related consequences is thus spatially and temporally correlated with the degree of personal incidence.

In this view, Ladakhi community members should have an acutely high recognition of climate change due to the immediacy and localized expression of climate-related impacts. As this research has argued, climate change is already effecting the region's precipitation patterns, snowline levels, glacier mass balance and related weather systems. In parallel, Ladakhi people undisputedly agree the climate is changing, particularly with respect to retreating snow fields and unpredictable rainfall patterns. Yet broad acknowledgement of these changes does not necessarily imply the prioritization of climate change within dominant social spaces and decision-making arenas. While public awareness of climate change is high in Ladakh, engagement with planning for climate change impacts is nominal compared to other socioeconomic and political processes. The reason for this relational consideration is due to customary norms, realities and circumstances in Ladakh where climate change may not always visibly and forcibly affect daily ways of life.

According to Scannell and Gifford (2013) and others (Chess and Johnson, 2007; Leiserowitz, 2007), awareness of climate change is not sufficient for engagement because it is often perceived as a distant threat. In the case of Ladakh, this only partly explains the neutral attitude most community members have towards climate change, despite its pervasive presence. In the urban area of Leh for instance, nearly 56 percent of surveyed respondents believed climate change was an unimportant issue. While this figure was lower in the rural periphery of Domkhar, where 28.2 percent of the population believed climate change was unimportant, there remains a significant number of people who regard climate change as a relatively minor issue, again despite unanimous agreement that it is taking place. Given the proximity and immediacy of climate change in this part of the Himalayas, the negligible concern many villagers share toward climate change impacts seems an apparent contradiction. In Ladakh therefore, cultural framings of climate change is more of a determinant of a perceived risk environment in comparison to physical linear distancing from climate-related threats.

While Ladakhi people are some of the most impacted communities effected by global warming, the social prioritization of climate change is blunted by other intervening scenarios. Consequently, the temporal premises and cultural understanding of climate change risk must be valued against the impending threat of other converging issues. For example, one respondent interviewed for this research noted that there wasn't much concern for climate change in his village because there were no young people to work in the fields anyways and therefore, there was no need to worry about climate change impacting the crop harvest if no one was there to maintain crop production to begin with. Perspectives of climate change are hence contingent on the circumstances of everyday life and the cultural valuation of climate-related risks relative to other orbiting issues.

Furthermore, in a society predominantly characterized by agrarian practices and calibrated to the rotation of crop harvests, it is not surprising many temporal orientations of climate change in Ladakh tend to focus on the cyclical, seasonal or near-term timeframe. Although many Ladakhis perceive the melting of glaciers and notice other putative impacts from climate change, annual agricultural yields are also perceived as going up in recent years and this is interpreted as a positive change. Despite only wheat and fruit production rising, and this because of changing agricultural patterns and likely not a result of global warming, the potential severity of climate change impacts is tempered by short-term positive feedback in the form of increasing agricultural yields. This view is in contrast to a more long-term consequential outlook which highlights the dangers increasing agricultural yields poses for Ladakh's water regime and development forecasts. As a result, short-term returns on crop harvest and market value encourages a myopic understanding of the long-term range of climate change impacts and lessens the gravity and urgency of the overall situation.

In addition to temporal distancing, spatial perspectives of climate change impacts influences how individuals and communities prioritize climate change. For instance, surviving an extreme weather event can work to temporarily galvanize social response and planning efforts for future climate change disturbances. After withstanding the flash flooding events in August 2010, many Ladakhi households were confident in the ability for their community to respond to other similar incidents in the future. Villages in Domkhar and Leh were significantly impacted by the flash floods yet households in both areas felt very strongly about the planning capacity of their community, particularly in the rural valley of Domkhar where 75.5 percent of the population believed their village was capable of managing climate change impacts. Through the process of experiential learning and witnessing a natural disaster firsthand, Domkhar and Leh residents are intimately aware of climate change yet ironically remain disinclined to consider it a substantial concern for the future. In this way, personally surviving a climate change impact worked to reinforce individual sense of place and community attachment while strengthening conviction in the response capabilities of the village. By uniting community members in their shared experience of the flash flooding event, a deepened sense of social cohesion was afforded that in turn, fortified belief in the ability for their community to effectively handle future climate change disturbances.

The suggestive influence spatial proximity plays in perceiving the risks from climate change can be similarly explored by looking at Ladakh's varying geographic landscape. The previous chapter for example discussed in detail how households situated closer to primary sources of water, such as the base of a glacier or along the main Indus River, were less likely to perceive changes in the climate. Alternatively, households located in areas where water was less reliable and more variable, like the middle of the watershed, observed more changes in recent climate. In this latter context, heavy dependence on a continual and renewable water source significantly contributed in the formation of cognitive connections that noted fluctuations in water supply. Low flow levels imply less land can be irrigated and thus, fewer crops can be harvested and sold at the market. Farmers living in areas where water was minimally supplied through springs and other surface sources were especially attuned to the availability of water and consequently more concerned with predicted threats from climate change compared to other farmers physically situated near principal water sources.

The temporal and spatial referencing of environmental changes in Ladakh correspondingly shapes how communities approach and contextualize climate change. Integral to the community valuation of climate change is the integration of dominant cultural frameworks and societal outlooks that weigh climate-related risks against other critical concerns. The interplay between natural and human processes determines the degree that biophysical vulnerability allies with social vulnerability to influence the scope, depth and magnitude of climate change impacts. Communities are widely diverse in composition and socioeconomic status, and this contributes in the ability for households to both respond and recover from climate-related hazards in different ways. In particular, the following demographic and cultural factors underpin and sustain social vulnerability to climate change in Ladakh

- **Agriculture and increasing dependence on female labor:** Similar to other peripheral and rural areas around the world, agriculture predominately supports villages across Ladakh. Crop production is a financial mainstay for many Ladakhi communities and is conventionally, the primary occupation for most households. However, with greater employment diversity and improved educational opportunities, dynamics in the agriculture sector are shifting. In particular, men and young people in Ladakh are migrating out of traditional farming activities and opting to work in the government, security forces or tourism industry. As a result, the remaining women in the household, who tend to be less educated and older, are dually saddled with the responsibilities of not only maintaining the household but also running the farm and its related activities. Hence, women are differentially exposed and threatened by potential risks such as extreme weather events, prolonged droughts, altering precipitation trends and variability in the timing and seasonality of cropping patterns. Women are subsequently on the frontlines of climate change impact and as the principal caregiver and farm laborer within the household, will be among the most affected by global warming.
- **Shifting land use practices that favor high-energy, water-dependent crops:** Over recent decades, there has been a marked trend in Ladakhi agricultural patterns toward high-intensity crops requiring more land, water and labor. The cultivation of wheat and cash crops in particular is utilizing more resources than traditional agricultural staples like barley. In contrast, the ratio of agricultural

laborers in the workforce is decreasing, implying fewer farmers are working on larger yet less efficient farms. Converting to larger and more intensive agricultural operations further compounds the workload capacity and household expectations for women and is an ill precursor for future water security. Further, wheat cultivation is standardizing farming practices throughout Ladakh and encouraging farmers to homogenize cropping patterns. Monocropping techniques and other non-diverse agricultural strategies endanger farmers to market fluctuations, insect invasions, pathogenic diseases and other non-systematic risks circulating within the political economy. With a highly uncertain future water budget and limited labor force, a growing preference for wheat production in Ladakh may challenge the long-term sustainability of many small farmholders.

- **Consideration of temporal and spatial cognitive frameworks:** Social ethos, cultural norms and everyday realities individually and collectively generate unique perspectives on environmental change and climatic variability. In turn, different conceptualizations of time and space are formulated and are influential in environmental knowledge production. The value and importance attached to issues like climate change is weighted against other persistent and contextually specific challenges. While proximal to the immediate impacts from climate change impacts, many Ladakhis are indisposed to regard climate change as their community's most pressing concern. While variation exists with geographic context, for example households spatially situated adjacent to primary water sources were less inclined to value climate change as a significant issue compared to households situated further from primary water sources, in general climate change is a moderate to low perceived concern. Indeed, given the gamut of intervening issues, such as globalization, youth migration and population growth, climate change remains a seemingly distant and secondary consideration. In the process, the temporal framing of climate change impacts is subsumed within the larger development paradigm that often endorses short-term gains at the expense of long-term benefits.

In Ladakh, social processes such as out-migration, gender gaps, labor markets and modern consumer trends closely couple with cultural frameworks, situational perspectives and personal experience to influence how climate change risks are interpreted at the local scale. There are multiple intersecting concerns vying to top the list for urgent social action and political attention. While climate change may be robust enough in both scale and scope to propel collective and swift social transformation, efforts to reduce aspects of vulnerability will have to be holistic, iterative and dynamic with other ongoing issues. A closely related challenge is therefore to ally local needs, social priorities and cultural customs with the conditional parameters imposed by processes within the broader political economy.

Influences from the Global Political Economy and Implications for Vulnerability to Climate Change in Ladakh

In less developed countries where vulnerability is already high, although climate change poses a grave and emerging threat, vulnerabilities are generally symptomatic of deep socio-economic and political inequalities that have historically characterized their societies (Lemos et al., 2013; Adger, 2006; Eakin and Luers, 2006; Blaikie et al., 1994). In other words, vulnerability is as much, or more, determined by the political economy of risk than by changing climate circumstances. (Lemos et al., 2007). In Ladakh, permutations of the global political economy are perhaps best represented with the region's burgeoning tourism industry and by extension, the demands that this accelerated development has exacted from local people and places. As Ladakh becomes increasingly promoted to the forefront of India's adventure tourism agenda, local spaces are rescripted to better align with evolving market trends, popular consumption patterns and modern lifestyle preferences. In turn, this broad restructuring of local economies has precipitating and often hefty implications for the sustainability of Ladakh's natural resources, landscapes and customs.

While in the past, Ladakh has been largely buffered from global-reaching processes due to its relative remoteness, it is precisely due to its geographic isolation that the region is undergoing rampant and unprecedented recent development. Often popularized as India's "Little Tibet," tourism in Ladakh is rapidly replacing other economic sectors to be the region's leading industry. By the mid-1990s for example, tourism receipts already accounted for 50 percent of

Ladakh's GNP despite only employing roughly 4 percent of the population at the time (Gillespie, 2006). Presently, tourism constitutes around 15 percent of the state-wide GNP and employs as much as 60 percent of Jammu and Kashmir's workforce. Projections for economic growth and tourism development are optimistic for Jammu and Kashmir, and estimates tourism will generate nearly $3 billion annually in direct and indirect revenue by 2020, making it one of the most popular tourism destinations in the country (Mir, 2014). Tourism is consequently a central economic pillar for Ladakh and given current unremitting trajectories, will likely expand its financial dominance and presence within the region.

Tourism is an effective vehicle and preferred economic modality for capitalism in Ladakh. The choreographed exchange of goods, services, people and products between global networks and local settings is increasingly reorienting local livelihood strategies, consumption patterns and traditional ways of life. Subsequently, processes taking place within the wider political economy are deeply intertwined with actions and values shaping the household and community scale. This 'mutual constitution' of the global and the local can be conceptualized with reference to contemporary market trends, local commodity preferences and capital distribution flows (Swyngedouw, 1997). The global-local nexus thus functions within an amalgamated space where broader processes aggregate and influence local production patterns and attitudes toward consumer behavior. In this respect, the local does not exist as an oppositional reality to the global, but rather constitutes a dynamic cultural negotiation with the changing structures of the political economy (Oakes 1993; 47).

Areas where tourism has recently superseded traditional means of income to become the primary source of local and state revenue are uniquely indicative of global-local linkages and the inter-scaling of socioeconomic spaces. The implications of this exchange are diverse and include effects to the local cultural, natural and political landscape. As Urry (2000) explains, contemporary tourism is a function of scapes and flows of capital, resources and information across and within transnational systems of economy. The tendency for capitalism to conceptualize and promote dominant cultural perspectives within the tourist paradigm largely influences the relationship between the tourist and the local setting. Implicit in this process is the fetishism of resources for tourism purposes therefore pandering to broader cultural constructs and socially predetermined criterion that serve to frame and filter the behavioral and visual consumption of sights, places and experiences.

In order to effectively compete within the global political economy, local places must differentiate themselves as distinctive settings while concomitantly adhering to the predetermined and latent expectations of tourists. What commonly results is the commodification of place and aside from the cultural ramifications, such as loss of authenticity and the McDonaldization of social mores (Stephens, 2009; Cohen, 1988; MacCannell, 1973), the ecological consequences can be equally severe. As globalized space increasingly annihilates the uniqueness of place, a standardized repertoire of consumer goods, images and lifestyles is disseminated worldwide. In turn, extensive efforts are made in ensuring preconceived notions about a particular locality are met, often at the detriment and exploitation of the environment and local heritage.

In Ladakh, the impacts of tourism and its accompanying influences of modernity are most recognizable at the local scale where direct exchange between tourists and local community members transpires. In order to avoid marginalization by competing external markets, local spaces of economy and culture have had to adjust and incorporate global preferences of consumption and production. Assimilating processes of capitalism into local economies not only drives regional development but also significantly shapes cultural and social values. Tourists routinely present paradoxical frameworks largely based on Western ideologies that inadvertently challenge and redirect traditional assumptions of Ladakhi culture and society. For example, one of the many demonstrative manifestations of this societal shift is the recent and widespread conversion to flush toilets from conventional Ladakhi dry toilets. As their namesake implies, common flush toilets are reliant on water supply and require power. Non-existent in Ladakh until the late 1970s, flush toilets were introduced and have grown in popularity with the arrival of western tourists. Alternatively, dry toilets consume no water or energy and are conducive to Ladakh's arid climate.

As described in detail in Chapter 4, modern consumer trends hugely favor flush toilets over dry-toilets and as a result, current municipal water supplies are increasingly strained by the rise in demand. Nearly all of the increase in municipal water consumption in the past two decades has come from the commercial sector, including hotels and guest houses. Together, hotels and guest houses account for 98.45 percent of Leh's water usage, totaling 852,000 liters per day (Parvaiz, 2013; Akhtar, 2010). In 2009, a survey of Leh households indicated 23.8 percent of them owned a flush toilet and among those interviewed, 50 percent of those households currently without a flush toilet desired one (Sudhalkar, 2010). This suggests a growing tendency toward water-intensive sanitation and other modern appliances that require water, such as dish washers and washing machines. Due to their concentrated use of water and energy, many contemporary amenities are ill equipped for Ladakh's desert-like landscape.

In establishing new standards of consumption and materialism in Ladakh, tourism and its capitalistic veins have persuaded a change in lifestyle preferences and transformed local markets. As Ladakh becomes increasingly integrated into the broader political economy, the demand for commodities produced outside Ladakh has risen and so too has the region's dependence on external suppliers. This is perhaps best evidenced with the incorporation of global food habits and the gradual supplementation of Ladakh's traditional diet. As a region transitioning from a land-based agrarian economy to a more diverse global economy, Ladakh has increasingly relied on imported goods such as rice and wheat flour to satisfy rising consumer demands. In the last few decades, these imported crops have steadily replaced traditional staples and have encouraged a food-grain deficit in the district of Leh and surrounding area. Paralleling a persistent increase in population and tourism, the Leh district is no longer self-sufficient in food-grain production and every year, there is a shortfall between the amount of food produced in Leh and the amount of food needed to feed the population (Pelliciardi, 2013). As a result and in order to satisfy high demand, large quantities of cereals, produce and other food-grains must be transported in by the central government and commercial vendors.

Presumably, with projected growth rates, population trends and future tourism prospects, the gap in food production and food consumption in Leh will only widen with time. Further driving this asymmetrical divide are government food policies that incentivize local Ladakhi's to consume products from beyond their border. In the guise of India's Food-Grain Program and the Public Distribution System (PDS), rice and wheat flour are provided to the local population at cheap subsidized prices. Where rice was once a coveted luxury, it is now consumed up to three times a day within the average Ladakhi household (Dame and Nüsser, 2011). Conversely, local grains such as barley and wheat which is grown in abundance across Ladakh, are rarely if ever purchased and exported out of the region. As described by Ladakhi farmer, Stanzin Dawa (2006), the result is "the government distortion of Ladakh's centuries old self-sustaining agriculture system by making [imported] rice and wheat available in the local market and through government owned stores at a cheaper price than barley or Ladakhi wheat, despite the distance."

While it must be noted India's subsidized food policies provide grains at an affordable rate and in copious amounts, the influx of outside rice and wheat products works to undermine local farming practices. Following suit, Ladakhi farmers are compelled to mimic larger agricultural trends and consumer demands that favor imported crops over traditional grains. As stated previously, this land use conversion leads to more water-intensive and higher energy-consuming cropping patterns that are in contrast to Ladakh's minimal water budget. Furthermore, subsidized food policies bolster Ladakh's reliance on outside sources and weaken the region's ability to independently support itself. In the context of climate change therefore, Ladakh is increasingly leaning towards food production patterns that, despite being economically reinforced by government regulations and broad consumer trends, require more water, land and human resources. Hence by switching over to more intensive cropping patterns, farmers are adversely exposed to future variability in the hydrologic cycle and financial risks in the political economy.

Recently, the tentacles of globalization have surfaced in Ladakh to fundamentally alter how local people are engaging with and responding to modern market trends. Operative drivers within the wider political economy that best express this local-to-global transformation include:

- **Tourism development and prospective growth patterns:** Since the 1990s, tourism in Ladakh has experienced a dramatic upward trend. Catalyzing the global-to-local nexus, tourism has had widespread and permeating effects. The most blatant of these influences has been the importation of contemporary consumer trends, values and materialistic standards. Tourists coming to Ladakh frequently arrive with premeditated expectations and this facilitates the commodification of place. As a result, Ladakhis must succumb to this criterion or risk economic failure. With mass modern tourism, the exchange between the tourist experience and the local setting often comes at the expense of cultural heritage, nearby natural resources and the environment. The near universal conversion to flush toilets from dry toilets in Leh's hotels, guest houses and homes is an example of a modern convenience ill-suited and maladapted to Ladakh's inherently arid conditions. Consequently, effectively managing Ladakh's thriving tourism industry with resource conservation practices will invariably determine the longevity and maturation of the region's future development pathways.

- **Government subsidized food programs:** On the surface, government agricultural policies in Ladakh provide sustenance and food surplus to a growing and marginalized population. In actuality however, these same programs tacitly reconfigure local economies and progressively breakdown traditional food production systems. For example, barley has historically been a central staple in the Ladakhi diet and requires minimal water and labor while providing high caloric intake. However, government policies are increasingly prioritizing rice and wheat consumption and driving down local barley production levels. In turn, Ladakhi farmers are transitioning into cultivation patterns that similarly accommodate modern market demands and planting more wheat and commercial crops in place of traditional crops. The transition to this type of food cultivation pattern does not adequately regard the severity and limitations of the region's dry environment. While in the short-term, considerations of water security may seem irrelevant and distract from Ladakh's recent economic gains, in the long-term, water shortages will become one of the most crucial and decisive determinants of the region's development potential. Government programs and economic incentives that encourage the added consumption of water and other valuable resources are thus incongruous with Ladakh's ecological limitations.

Agriculture is the backbone to Ladakh's local social, cultural and economic livelihood. Farming is the predominant way of life in this region and agrarian traditions are grafted into the landscape. Yet changing consumer habits, diversified dietary preferences and new lifestyle choices are redirecting local and regional economies around values stipulated within the wider political economy. In doing so, agricultural patterns have shifted to better mirror broader consumer preferences and are shying away from traditional cropping practices. Over time, Ladakhis have specialized in the cultivation of crops highly tolerant to the region's extreme desert environment, producing the most of amount of grains with the least amount of water.

Contemporary land use patterns however conserve less water than in the past and inadvertently nurture conditions of vulnerability to water scarcity issues in the future. In an effort to secure its position within the globalized economy of commerce and consumption, Ladakh is tempting its fate and long-term sustainability.

Discussion and Key Recommendations

With high elevations and receiving remarkably little precipitation, Ladakh is an onerous and in many ways, inhospitable landscape. Hardened by exposure, time and the elements, the people and places here demonstrate a unique adaptability and perseverance. Local perspectives and observations of climate change correspondingly contribute valuable insight regarding the intimate exchanges taking place between humans and the natural world. At the same time, an arsenal of social, political, economic and ecological forces are interfacing to aggressively steer the course of local and regional development scenarios in Ladakh. Far from being a stand-alone issue therefore, climate change piggybacks other ongoing challenges to disperse much needed resources and in doing so, curtails local efforts to respond and recovery from climate change impacts.

In assessing aspects of biophysical and social vulnerability to climate change impacts in Ladakh, entry points for adaptive capacity building and anticipatory planning can be identified. In contextualizing adaptation and thereby adaptive capacity, as a function of adjustments made by human systems in response to changing environmental conditions, it is advantageous to consider only those adaptive options that are practical, realistic and economically viable given site-specific parameters. For example, it is nonsensical to assume that in the face of impending water shortages, Ladakhi establishments will revert back to traditional dry-toilets. While this may be true for some water-conservative households, the vast majority of Ladakhi homes and buildings will continue to use flush toilets, as mandated by modern consumer trends. There are however a number of other suitable adaptive measures that align with Ladakh's austere environmental conditions while concomitantly preparing local households and communities for a future of climatic uncertainty.

Clearly, the most effective way to combat global warming is to curb greenhouse gas emissions through an international climate change regime and accountable governance framework. However, this is a lofty and at least for now, highly improbable scenario. The proposals suggested below are therefore customized to the geographic advantages and circumstances distinctive to the Ladakhi region. While individually, each recommendation is discrete in its potential to enable adaptive capacity building, as a whole they are meant to marshal dialogue around an integrated outlook that mutually observes Ladakh's development pathways as well as a conservative use of local human and natural resources. In doing so, Ladakh may be better positioned to capitalize on its own place distinctiveness within the wider political economy while also insulating itself against the worst predicted impacts from climate change.

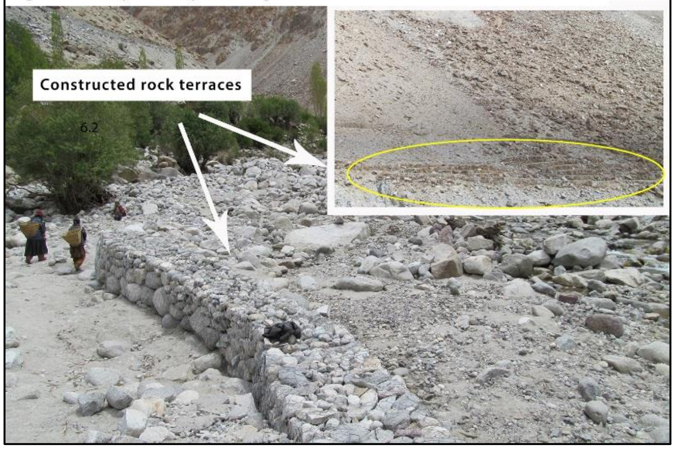
Incorporation of Local Knowledge and Identification of Maladaptive Measures

Taking local knowledge and practices into account can bridge the conceptual and communication gap that arises between local people and state or global institutions, particularly with multi-scalar and complex problems like climate change. Shared learning processes and the co-production of knowledge are predicated on participatory approaches that promote a democratic partnership between local constituents and the externally involved agencies, such as researchers, government officials and institutions. In an effort to encourage the advancement of both science and social welfare, shared learning processes involve community perspectives in the research process, from the initial conceptualization and design process to the final stages of project synthesis and dissemination. Perhaps more importantly, shared learning processes and the co-production of knowledge ideally enables equal access to resources, a collective understanding of the mainstream political agenda and joint involvement in the decision-making and planning of issues directly impacting local livelihoods.

In the context of climate change, a reciprocated exchange between local people and broader decision-making and policy arenas can facilitate in the interpretation and execution of implementable adaptation measures. Often, when it comes to effective adaptation planning, researchers, practitioners and community members alike encounter major obstacles due to their communal lack of awareness, access to climate resources and sparse communication platforms, (Tschakert and Dietrich, 2010; Leary et al., 2008). Approaches that advance the shared production of knowledge can attempt to remedy these operational discrepancies through the explicit identification of information that is most relevant to particular settings. In other words, through the swapping of dialogue and personal interaction, shared learning spaces between local people and outside stakeholders can identify the multiple constraints applicable both within and outside a community and hence more effectively determine which adaptation options are realistically appropriate.

Ladakhis have long been accustomed to environmental change and with time, generations of knowledge and practice has been accrued. While climate change has accelerated the pace, spread and scope of environmental incidences, such as flash floods, droughts, strong winds and variability in precipitation, local people have responded to environmentally adverse conditions for centuries. As a result, there is a rich history and narrative of adaptation to environmental change embedded within Ladakhi society. For example, modifications to land use practices, intricately webbed irrigation patterns and everyday livelihood activities reflect the evolving connections between Ladakhis and their environmental setting. Constructed rock terraces, dams, diversion canals and early warning systems are adaptive strategies for water conservation and flood prevention across Ladakh. Adopted as standard procedure in Ladakhi agriculture, these types of land use measures help villages prepare, mitigate and proactively respond to both abrupt and prolonged environmental change (Figure 6.2).

Figure 6.2: Examples of adaptive strategies to floods in Domkhar, Ladakh



In addition, many local people are carefully attuned to their surroundings and with time, have learned to read shifting weather patterns, changes in the atmosphere and incoming pressure systems and weather fronts. In neighboring Pakistan for example, it was documented that villagers in Shishikoh were able to predict flash floods by observing the rotation and density of clouds circulating around adjacent mountains. Furthermore, villagers were able to sense rapid atmospheric change by watching the behavior of birds and animals (Nadeem et al., 2009). Incorporating traditional techniques and knowledge into adaptation scenarios can subsequently save time and resources by emphasizing the strategies, applications and local relevance of climate change response planning activities most conducive to specific localities.

Community-oriented response strategies to climate change can range in size, from localized tributaries to valley-wide watersheds. For example, another contemporary and notable illustration of applying local knowledge in climate change response is the geoengineering of artificial glaciers in Ladakh. Chewang Norphel, a Ladakhi engineer, developed the idea after observing the rapid recession of the glaciers supporting his village's water supply. By constructing a system of retaining walls and diversion channels, Norphel has been able to essentially arrest the movement of meltwater from the glaciers and create a water reservoir that later freezes when the temperatures drop (Shrager, 2008). By 2012, twelve "artificial glaciers" had been constructed in villages on the outskirts of Leh. Such innovative concepts are economically feasible, utilize local materials and include neighborhood stakeholders in the design, construction and maintenance of adaptation response (Figure 6.3). Furthermore, the artificial glaciers have been a social and financial godsend to community members who would otherwise be significantly strapped by the lack of water and resulting loss of crop returns.

Figure 6.3: Residents in the village of Stakmo construct sand and rock embankments to create "artificial glaciers".

(Source: National Geographic, 2012)

Alternatively, possible response strategies to climate change can focus on minor adjustments at even smaller scales of land use and land management. For instance, an increase in the frequency and magnitude of extreme weather events, such as flash floods and landslides, is predicted for many mountainous locations. Modifying local tributaries and stream beds to anticipate and mitigate these hazards could be effective in lessoning the negative aftereffects. For example, installing a filtering system to sieve out debris flow and large sediments from floods and high waters reduces damage to prime agricultural lands, infrastructure and household properties. In Bangladesh, community member's constructed lengthy nets made from bamboo and reeds and positioned them at the confluence of major tributaries (Ensor and Berger, 2009). When flooding took place, the nets served to strain the current of rocks, shrubs, trees and other moderate to large deposits thereby decreasing the amount of sedimentation and debris covering fields and grazing grounds. Although similar mechanisms and options are limited in Ladakh due to minimal vegetation, the branches of poplar and willow trees could be interwoven to construct a screen to filter slope debris, rock accumulations and stream sedimentation. Such demonstrations of local ingenuity illustrate a cost-effective, pragmatic and "no-regrets" approach toward climate change response.

By drawing off cultural histories, collective memories, community intuition and personal experience, local knowledge can produce salient information that is often overlooked in the larger climate change discussion. Omitting contextualized accounts and site-specific information in decision-making pathways can yield unfavorable outcomes that are misrepresentative of the long-term situation and lead to maladaptive responses. For instance and as previously stated, the increasing trend toward commercial crops and wheat monocropping in Ladakh is maladapted to the region's scarce water supply and unfavorable climate predictions. Ladakhi farming practices that require additional land, labor and water work in opposition to climate change preparedness and increase vulnerability to climate-related risks in the future. The increasing shift to flush toilets over traditional Ladakhi dry toilets is similarly demonstrative of a maladapted development strategy that neglects to consider the region's lack of long-term water security.

Another example of maladaptation in Ladakh illustrates an institutional response strategy to climate change impacts that was inappropriately aligned with local context. Following the August floods in Ladakh in 2010, the central government of India provided many impacted communities housing relief in the form of prefabricated shelters. While the initial assistance was largely appreciated, community members soon complained about the ineffectiveness of the prefabricated shelters. Distributed to approximately 450 households who had lost or severely damaged their home during the flooding event, the premade structures were relatively small units constructed from cheap plastics and other materials ill-conducive to Ladakh's austere environment (Falcao, 2011). Built to be air-tight and with only one small window, the units did not allow any ventilation and were poorly insulated. Consequently, crops spoiled easily when stored in the units, indoor temperatures were too cold during the winter and occupancy levels were minimal. Additionally, the light materials used in construction meant the shelter was often unable to withstand Ladakh's gale force winds and during cold months, each unit required extensive amounts of fuel and heat. While sufficient as a temporary shelter, prefabricated homes were not a permanent or viable substitute to Ladakh's traditional housing structures. Costing more than $6,600 each, many community members felt the importation of prefabricated units was a lost opportunity to invest in local Ladakhi architecture, labor, community and economies (Figure 6.4).

Figure 6.4: Prefabricated shelter distributed to Ladakhi households post-August 2010 floods

Mountain populations have long known how to adjust livelihood patterns and societal behaviors to environmental change, asserting otherwise would be a fallacy. Yet given the speed and scale of climate change, a unified approach is needed that synergistically draws off the skills, information and resources of people from the local level to the global political regime. Local histories and experiences are hence an invaluable database for knowledge on social-ecological processes and can provide convincing examples of practical and appropriate adaptive practices to climate change. By actively integrating these understandings into the broader climate change conversation, constructive ways for dealing with the multitude of climate change threats and stresses may be realized.

Encourage Ecotourism Planning Over Mass Tourism Development

Since officially opening to tourists in 1974, Ladakh has been launched to the forefront of India's tourism campaign. Over the past five decades, unrestrained tourism development in Ladakh and particularly in Leh, has substantially affected the local landscape and the people who live there. Yet given the region's relatively recent recognition as a travel destination, there remains ample opportunity to implement tourism planning that mutually benefits the environment, culture and local economies of Ladakh. For example, endorsing ecotourism operations rather than mass tourism development and establishing financial mechanisms to support sustainable growth initiatives can maintain community development while working to conserve local resources and traditional customs.

Recent patterns in tourism worldwide suggest a growing disenchantment with conventional forms of travel and a preference toward a more personal and unique tourist experience. Such trends are diversifying and segmenting the tourism market and are allowing for the development of innovative and specialized businesses to evolve. These alternative tourism operations and in particular ecotourism, have emerged to shape the visitors experience in some of the world's more remote places. Countering the more popular mass tourism of modern travel, ecotourism and other non-conventional forms of tourism focus on a more symbiotic approach between local spaces and the ecological and cultural footprint left by visitors.

In Ladakh, ecotourism is a relatively recent enterprise and markets itself as a distinctive travel experience that endorses traditional Ladakhi principles of simplicity, family and self-sufficiency. Interestingly, it is precisely due to the unmaterialistic and more spiritual tenets of Ladakhi culture that are a strong allure for foreign travelers, who have become disenchanted with the ennui of Western capitalism and consumeristic ideology. Indeed, the popularization of ecotourism in Ladakh parallels broader global environmental and social movements evident since the late 1960s and 1970s (Figure 6.5). Tourists seeking a removal from the pressures compelled by dominant Western paradigms frequently come to Ladakh for renewal and self-discovery or as Helena Norberg-Hodge writes in her book *Ancient Futures: Learning from Ladakh*, "tourists want to learn another way to live" (1991, 5). For many, Ladakhi culture not only advocates a departure from the reality most tourists have become accustomed to but also elicits the deeper underpinnings and interrelated forces shaping contemporary Western values. In doing so, the tourist feels rewarded with a sense of revival and a return to the simple things in life.

The business model for most ecotourism ventures promotes a nature-based and local experience and as such, presupposes an inherent ethical agency of low impact, non-consumptive

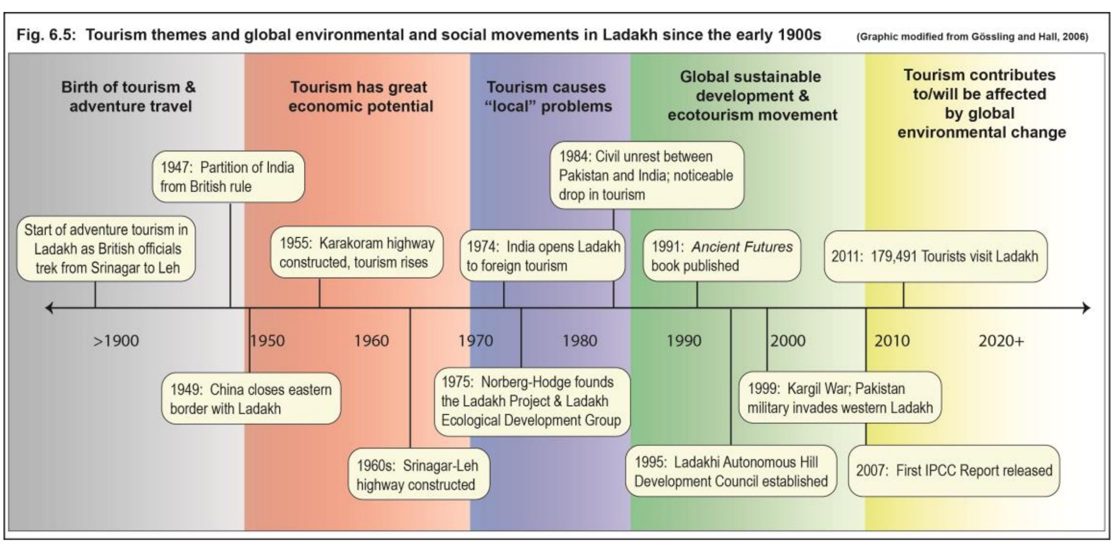


Fig. 6.5: Tourism themes and global environmental and social movements in Ladakh since the early 1900s (Graphic modified from Gössling and Hall, 2006)

and locally-oriented awareness (Cohen, 2002). Due to its interconnectivity to the local environment, ecotourism can be a powerful mechanism for empowerment, mobility and social and environmental equity (Ballesteros and Ramírez, 2010; Bosak, 2010). In this view, ecotourism is a catalyst for sustainable development while additionally bridging global market demands with local resources and livelihoods. Correspondingly the operational scale ecotourism embraces is oriented around the community and household as a unit of interaction and exchange. Through the fusion of global forces with local interests, a 'glocal' consciousness is bred that brings situational problems into the contextual framework of a broader venue. Circumstantial issues of local concern are consequently projected into the global arena thus raising widespread recognition of the problem. In addition, these linkages permit for the rapid and widespread dispersion of information and material. Through these spaces of engagement, local capacities to respond to the challenges of tourism development and auxiliary issues are enhanced via the role of empowerment, mediation and participatory action.

In Ladakh, the presence of international and national non-governmental organizations are particularly vital players in negotiating regional tourism development with environmental and cultural preservation. The most successful endeavors have been able to strategically incorporate local and community participation into larger processes of decision-making and planning. For example, the Ladakh Ecological and Development Group (LEDeG) is an enterprise striving for a sustainable future by demonstrating ecologically sound development models and appropriate regional development policies (LEDeG, 2010). LEDeG engages with global research partnerships to find scientific practices applicable to Ladakh's ecological and cultural sustainability. In an effort to emphasize local traditions in the face of rapid and modern change, LEDeG promotes the inimitable and irreplaceable qualities of the Ladakhi culture while actively involving community members in the planning of the region's future.

While LEDeG examines the long-term consequences of development, a supplementary organization, Dzomsa, has focused on the more immediate impacts of Ladakh's tourism development. Formed as an indigenous extension of LEDeG, Dzomsa is involved with the local business and marketing opportunities presented by tourism. Based in Leh, Dzomsa provides tourists the alternative option of purchasing sustainable goods produced and manufactured by neighboring communities. In particular, the organization endorses products made by local women cooperatives and farmer's coalitions, such as souvenirs, books, clothing and food items. Perhaps the most successful of Dzomsa's operations however, is the availability of refillable potable water. For less than twenty cents, tourists can fill their empty plastic containers and water bottles with filtered drinking water. This logistically simple enterprise has proven very lucrative and more importantly, is playing a large role in the reduction of plastic for which Ladakh has no method of removal. Dzomsa's water station ingeniously demonstrates the implementation of practical and sustainable applications that meet the need of the tourist without compromising the resources and labor of the local community.

Other organizational models have exploited the business of ecotourism itself as a method of global-local engagement. In particular, homestay accommodations are an alternative form of travel that affords the tourist a unique and individual experience while financially supplementing local host household incomes. Though not new to tourism, homestays are becoming increasingly popular amongst tourists who prefer personal interconnectivity with the local population. As such, there is a significant degree of community participation in tourism activities and homestay operators, in direct contact with tourists, have strong feelings about tourism impacts on their community (Gu and Wong, 2006).

In Ladakh, the Snow Leopard Conservancy (SLC), is a non-governmental organization that promotes ecotourism as a local economic opportunity and is actively working with community households to implement homestay initiatives. Created in 2001 under the auspices of The Mountain Institute and UNESCO, SLC's Himalayan Homestay Program attempts to ensure a fair financial return between the host and guest interchange while additionally conserving local resources crucial to the snow leopard habitat. Through coordinated efforts with participating communities, the Himalayan Homestay Program has developed programs in Ladakh's major tourist and trekking areas. Since its inception, the Homestay Program has spread to twenty villages and includes over 100 families (Kershaw, 2009). By endorsing the homestay experience as an authentic glimpse of local reality, the tourist pays for both the services provided and their supervised inclusion into the community. The homestays are an opportunity for enrolled families to benefit from the presence of tourists while further diversifying their dependency on traditional sources of income.

Organizations like LEDeG, Dzomsa and the SLC have brought issues of environmental and cultural import to the forefront of Ladakh's global-local community. Through these linkages, tourists are not only exposed to local Ladakhi culture but often reciprocate the exchange with engagement and genuine interest in Ladakhi issues. More importantly, ecotourism as an appendage of Ladakh's glocalization, has intertwined scalar constellations of economy and politics. Issues of local concern are diffused into the international domain where they are reframed and reconceptualized as a matter of broad consideration. The efficacy of ecotourism as a vehicle for local empowerment thus depends on the degree of penetration and participation throughout the layering of scales. Through a series of intricately webbed networks and associations, global spaces become the audience as well as part of the solution. In this manner, the modern challenges plaguing local communities, such as maintaining environmental resources and cultural heritage, can be resolved with collaborative and mutual partnerships.

Installing financial mechanisms that generate revenue for the shared support of local tourism opportunities and the conservation of environmental and cultural resources can additionally assist in the sustainable management of Ladakh's tourism development. For instance, a mandatory tariff could be taxed on all domestic and foreign tourists. While presently a nominal fee of 450 rupees ($7.50) is supposedly levied on all incoming tourists, this is only imposed on air travelers and is non-enforceable. Implemented in 2004, the tourist entry fee is designed to procure much needed funds for the Ladakh Autonomous Hill Development Council (LAHDC), with directives to protect Ladakh's ecological landscapes, promote and preserve cultural heritage, provide environmental friendly sanitation and sewage disposal systems and improve Leh's civic amenities on all trekking routes (LAHDC, 2004). While well-intentioned, the current tourist entry fee falls short of accountable and tractable change because it is not compulsory for all tourists, including those arriving by vehicle, and what fees are accrued can easily be subsumed and redistributed within the larger administrative framework. Collected fees are consequently reallocated to other LAHDC prerogatives or lost within the bureaucratic minutia and tourism impacts are largely overlooked.

A mandatory tariff on all tourists arriving into Ladakh has the potential to mitigate adverse consequences to the environment and local culture if it is obligatory, transparent and accessible. Mirroring similar articulations implemented by Bhutan's "high-yield, low-impact" approach to tourism, the tax would theoretically allow a more manageable and maintained supervision over the number and type of tourists visiting Ladakh (Namgyel, 2011). While the risk of segregating incoming tourists by socioeconomic status is evident, an elevated entry fee could provide a middle ground to modern mass tourism. Unlike Bhutan however, this hypothetical tourist levy would be a blanketed fee on all incoming tourists, including domestic Indian travelers as well as foreigner visitors. While the monetary details associated with each type of entry fee may differ according to nationality, age and season, collected fees would contribute toward a larger fund that would seek to address environmental conservation practices and cultural heritage preservation. The fund would be divided into specific task forces, including an administrative and operational section, a research and development section and an area for education and outreach. The administrative portion of the fund would cover all expenditures related to the overall oversight and execution of collecting tourist entry fees, including employee wages. The research and development (R&D) component identifies primary areas of concern, focus areas and high priorities for environmental, cultural and tourism management. An example of an R&D deliverable would be to assess the overall impact tourist arrivals are having on the accumulation and disposal of wastes, plastics and other refuse, particularly in the town of Leh. A third yet vital area of work that would be supported through a tourist entry fee fund includes public outreach efforts about Ladakh's unique environmental resources and cultural heritage, such as workshops, conferences and presentations. Overall, the primary purpose of a required entry charge for incoming tourists is to provide Ladakhis with more regulatory control and influence regarding the integration of tourism's economic potential and the long-term protection of local natural and human resources.

There are however significant drawbacks to a requisite tourist levy in Ladakh that must be dually noted. For example, there is a degree of theoretical dissonance in attempting to commensurate economic development with environmental and cultural preservation. By imposing a universal entry fee on all tourists, for the benefit of preserving local landscapes and traditions, tourists are promised an authentic experience that has been relatively undisturbed by modern development. Yet, authenticity is not a static concept and in the process of tourist interactions, it becomes pliable and negotiated. As described by Gale et al. (2013), tourists play an active role in the determination of authenticity, bringing their own cultures, experiences, preferences and values into both determinations of, and satisfaction with, authenticity and tourism experiences. In the process, tourism becomes the agent of inevitable change despite concerted efforts to limit its reach and influence on local places and cultures.

Furthermore, in attempting to safeguard traditional ways of life and prevent cultural and environmental pollution, there is the potential of inhibiting the natural cultural evolution of Ladakhi society. In effect, local places become saturated with artifice and contrived simulacres of what tourists are wanting to see and in the process, there is the ‘museumification’ of place and culture. Local societal behavior is encouraged by tourists’ expectations to remain unchanged by modernity, irrespective of their own desires to develop. In this way, guaranteeing an authentic experience in exchange for a tourist entry fee could adversely inhibit the creative, visionary and progressive potential of Ladakhi society.

There are additional logistical considerations associated with implemented an entry tax on all incoming tourists, such as administrative oversight and bureaucratic accountability. Yet the ultimate objective of an entry fee is to raise awareness for the sustainability of environmental and cultural resources and at the least, momentarily temper the influx of tourists into Ladakh while simultaneously supporting and maintaining economic revenue. An obligatory tourist tax would allow more internal control over Ladakh’s carrying capacity, particularly during the summer months when the amount of resources and services demanded by tourists far outweighs the needs of local residents. Generated income from the tourist levy would then be distributed to a designated body of the LAHDC or alternative acting agency for the execution, management and continued validation of sustainable goals and deliverables.

Deploy Localized Alternative Energy Planning

Installing small-scale renewable energy sources is a way for local Ladakhis to become energy self-sufficient. In Ladakh, localized alternative energy planning that utilizes solar power technologies is a cost-effective and sustainable approach to small-scale energy generation. Households equipped with solar powered energy distribution devices are able to offset their dependence on more traditional sources of electricity, such as kerosene and petroleum generators. This saves families time and money and reduces demand on commercial contractors, private investors and government vendors for power generation. Small-scaled renewable energy devices are overall advantageous because the production of energy takes place within the same vicinity where that energy is later consumed hence minimizing reliance on outside sources.

Inasmuch as Ladakh's physical landscape dictates, and in many ways, limits the spread of infrastructure and settlement, so too does it afford enormous potential for renewable power generation. Primarily delivered in the form of solar energy, Ladakh receives an average of 320 sunny days a year and is therefore strategically and geographically positioned to utilize the energy potential from the sun (Parvaiz, 2013). Solar radiation is one of the most abundant natural resources in Ladakh, with annual solar radiation exceeding averages elsewhere in India (Purohit and Purohit, 2010). Although the government and private companies have recently developed power generating schemes to capitalize on this valuable asset, solar energy should be a widespread service across Ladakh and installed within every household.

Given Ladakh's geographic remoteness and the distance between villages, it is difficult to implement a comprehensive power grid across the region. Many communities subsequently rely on power generators that operate off kerosene or diesel. As a renewable energy source, solar power has the potential to replace these more polluting devices and provide a cheap and plentiful option for energy generation. Recognizing the vast potential for solar power in Ladakh, India's Ministry of New and Renewable Energy created the Ladakh Renewable Energy Development Agency (LREDA) in 2000. Tasked with exploiting the ample resource from Ladakh's solar power, LREDA has worked to implement a widespread renewable energy network. As part of this, in 2011, LREDA established the Ladakh Renewable Energy Initiative Project which ambitiously sought to install "11 micro-hydro projects with a total capacity of 11.2 MW, 125 solar-photovoltaic power plants, solar water heaters for 40 percent of the buildings in Leh, 3,000 solar greenhouses, 4,500 solar cookers, solar driers and solar passive housing project" (Mirani, 2013) (Table 6.1).

Table 6.1: New LREDA renewable energy systems for Ladakh — Source: Daultrey and Gergan, 2011

Technology (2010-2013)	Number of Installations	Technology (2010-2013)	Number of Installations
Solar water heating systems	Total 15,000 m^2	Commercial solar greenhouses	250
Solar dish cookers	4,500	Solar dryers	500
Steam cooking systems	15	SPV power plants (5-100 kWp) (for villages)	40
Domestic solar greenhouses	2,500	SPV power plants (5-10 kWp) (for institutions & defense)	65

Development of solar power in Ladakh is growing and as of 2011, more than 30 global and domestic companies have submitted proposals for the construction of solar thermal and solar photovoltaic projects (Daultrey and Gergan, 2011). Individual projects are partially or fully subsidized by the central government of India, giving energy developers substantial incentive to develop in Ladakh. As of November 2013, the Indian government announced the construction of the world's largest solar renewable energy project adjacent to the Leh district. Extending over 20,000 acres of land, the project optimistically seeks to produce 5,000 megawatts of electricity. Provided with enough land, there is certainly enough sun to adequately satisfy capacity requirements.

A close alternative and companion of renewable solar energies is developing Ladakh's geothermal potential. First explored in the 1970s, Ladakh's geothermal capabilities are an anomaly relative to the rest of the country and is the most promising source of geothermal energy in India (Harinarayana et al., 2006). Estimates for the Puga Valley for instance, located along Ladakh's eastern fringe, are as high as 40 megawatts (ibid). Presently, there is a proposal for a 3 megawatt facility to be developed outside Leh. However, tapping into Ladakh's underground web of geothermal pockets is entirely experimental at this time and could present significant challenges with regard to infrastructural requirements, geophysical constraints and issues related to operational maintenance. Thus, in comparison to solar renewable energies, geothermal technologies are not an immediate candidate for everyday energy generation and to meet the growing needs of individual households.

Modern technologies that emphasize and accommodate Ladakh's environment to generate renewable sources of energy could be an economic boon for local livelihoods and alleviate pressure on limited nearby natural resources. Geographically located within the rainshadow of the Greater Himalayan Belt has fortuitously placed Ladakh at the disposal of the sun. By gradually substituting popular sources of energy such as kerosene and/or diesel generators with renewable solar devices, Ladakhi households can enhance self-sufficiency and rely less on the petroleum products transported from the outside. Moreover, household solar devices are implementable at the local scale and consequently easier to maintain and disseminate across Ladakh. Once again, by endorsing the attributes of locality, viable adaptation strategies are identified that are complementary with the region's stringent environmental conditions.

As with all recommended pathways, there are potential shortcomings associated with each of the above considerations yet they are an attempt to harness awareness around the applicability of site-specific adaptation measures. By stressing the importance of location and context, strategies for responding to climate change impacts can be synchronized with the resources, priorities and needs of households and communities. One of the most effective means for identifying what legitimizes a locally appropriate adaptation measure is to systematically inventory local perceptions of climate change impacts, baseline knowledge frameworks and existing practices of climate change response. In doing so, a plethora of information is gleaned that predates most research perspectives and government agendas. Engaging with the planning and management of climate change at the local level can in turn expedite and mainstream the adaptation process to be cost-effective, time sensitive and operationally functional.

Conclusion

Processes of vulnerability and adaptation interact with a succession of physical, social, political and economic factors to influence the outcome of climate change impacts at the local level. The nature of this exchange at the household and community scale enhances or hinders the ability for individuals and groups of people to respond and recover from global environmental change. At the same time, climate change impacts amplify existing inequalities and further diminishes adaptive capacity at the local, regional and state level. While processes within the wider political economy externally direct consumer patterns and development pathways, shifting social and demographic trends work to internally restructure livelihood activities and approaches toward climate change. For marginalized areas, such as mountain communities in Ladakh, effectively adjusting, responding and engaging with climate-related risks must therefore be negotiated with other and equally imperative concerns.

The exchange between vulnerability and adaptation to climate change functions within a broad scaffolding of scales. Scale was subsequently used as the guiding theoretical construct for assessing vulnerability and adaptive capacity in Ladakh. In doing so, it was possible to conceptually differentiate components of the research design into explicit analytical approaches. For instance, Chapter 3 utilized a one-on-one approach to assess individual household vulnerability to climate change while Chapter 4 and Chapter 5 examined the community and regional scalar implications of vulnerability. Furthermore, in an effort to distinguish this research apart from other climate change vulnerability assessments, which often apply either technical or subjective techniques for evaluation, a mixed and multidisciplinary methodology was used. As a result, vulnerability to climate change risks and impacts was evaluated with respect to shifting behaviors within both social and ecological systems and at different levels of exchange.

Closely aligning with the theoretical underpinnings of scale are geographic principles of space and time. Accordingly, the spatial and temporal implications of scale were examined in relation to the unfolding of climate change impacts at the local and regional level. Like elsewhere throughout the world, physical geography is a crucial factor in shaping the scope, spread and intensity of climate change effects in Ladakh. When compounded by other ongoing socioeconomic and political adversities, physical geography can work to differentially expose some groups of people to the unequal risks and impacts from climate change. Location is therefore a key constituent of biophysical vulnerability and when coupled with social vulnerability, is a significant determinant in shaping the extent and outcome of climate change impacts.

Ladakh, a high mountain area, is especially sensitive to warming global air temperatures and related changes in the climate. Of the many identified effects of climate change, increasing extreme weather events, variable precipitation patterns, receding glaciers and shifts in the timing and seasonality of crops are among the most predominant and detrimental impacts Ladakh is experiencing. While the cascading implications from each of these larger changes are diverse in nature, on a very fundamental level, they are collectively united in their contributing influence within the water cycle. Particularly in a place where water scarcity is so acute, lack of water and management over existing water resources will bring all other primary and secondary issues to a head. The potential of running out of water is consequently not only a very real threat but will conclusively decide how and where people can live, work and thrive in Ladakh.

Physical setting is not mutually exclusive with climate change however, and when interfaced with socioeconomic and political variables, the impacts of climate change can be highly varied and nuanced from place to place. Indeed, an overview of Ladakh's modern livelihood conditions suggests how formidable grappling with multidimensional challenges such as climate change can be. Among the host of congregating issues facing many Ladakhis, the increasing migration of men and young people away from rural villages, lack of widespread infrastructure, minimal employment opportunities, political tensions with neighboring countries and other social and demographic changes present substantial dilemmas. Development prospects alone raise considerable concerns regarding Leh's municipal services, food security, water availability and the acculturation of Ladakhi society. Given the projected growth trends for the town of Leh, wanton development practices will converge with climate change impacts to generate a particularly problematic and desperate situation for community members and city managers.

Yet compartmentalizing the array of geographic forces driving vulnerability in Ladakh is complicated by conventional assumptions of vulnerability in the first place. While theoretically distinguished as separate influences contributing to the overall vulnerability of a place, group of people or societal sector, the interplay between biophysical and social vulnerability is dynamic. Individually, biophysical and social vulnerability are composed of very different material and non-material elements that intersect to determine the degree of risk associated with climate change impacts. While biophysical vulnerability infers the level of physical exposure and susceptibility to climate change and can therefore often be visually referenced, social vulnerability is much less tangible and measurable. Nevertheless, because the two collectively inform vulnerability, it is crucial to synergistically evaluate how both systems manifest within locality to shape behavior and engagement with climate change impacts.

It has been argued in this research that Ladakh is characterized by high levels of biophysical vulnerability due to its physical remoteness, extreme mountain topography and high elevations. By reciprocation, aspects of social vulnerability must additionally be identified in order to characterize overall conditions of risk and exposure to climate change impacts at the local scale. Social vulnerability is multifaceted and must be conceptually unpacked in order to recognize the distinct social, cultural, political and economic dimensions that when combined, amplify overall sensitivity to climate change. While this work has already highlighted the demographic and socioeconomic forces propagating social vulnerability in Ladakhi villages, cultural constructs also emerged as significant factors in determining levels of local engagement with climate change. Previously alluded to in Chapter 5, cultural perspectives of place and sense of community require special attention in the climate change discourse because they are hugely influential in shaping the acceptance and execution of climate change response at the local scale.

Dominant cultural frameworks and community attitudes regarding environmental change are meaningful indicators of social resilience to climate change. Findings from this research suggest relatively high levels of social capital in Ladakhi mountain villages, despite economic, political and institutional underrepresentation. As evidenced by a strong sense of community, place attachment and familial ties, social capital in terms of cultural networks and community bonds, is widespread among adult villagers. Understanding the applications of social capital is important because it commonly constitutes and is used to calibrate measures of social vulnerability. Hence, results from this conducted assessment of vulnerability to climate change in Ladakh suggests relatively high levels of biophysical, economic and political vulnerability yet a moderate to low degree of social vulnerability.

In places like Ladakh, where expressions of social and biophysical vulnerability seemingly contrast one another, social cohesion and sense of community emerge as instrumental factors in rousing local participation on climate change. Indeed, while formal definitions of social vulnerability refer to the access and availability of resources, information and social relations, concepts of locality, place attachment and community awareness are of additional value because they can motivate people to respond to climate change impacts that threaten the location and integrity of community. For example, Mishra et al. (2010) observe that people with high levels of place attachment were more likely to be inspired to prepare for climate change events such as flooding because of their social and economic investments within their region (Adger et al., 2012). Heightened connection to a particular location and profound sense of belonging to a community can correspondingly facilitate solidarity amongst community members and not only increase recognition of environmental changes but persuade social action to respond to these changes.

In Ladakh, community awareness and place attachment is inculcated as part of Ladakhi culture, particularly within the region's rural areas. For example, extended families living in a single household, small village populations, and longstanding livelihood activities that nurture social connections are contributing influences to sense of place and community identity in Ladakh. Traditional agricultural practices often involve the gathering of neighbors, friends and family in the preparation, planting and harvesting of crops. Similarly, the distribution and management of watershed tributaries and irrigation systems requires collective communication and interaction amongst the community. As a result, rural mountain populations in Ladakh illustrate closely knit societies with strong linkages to location and village life. Perceived threats to the cultural landscape, such as relocation and migration resulting from climate change, can therefore catalyze interest in anticipatory response planning. Although difficult to conceptually gauge, integrating concepts of place into the climate change framework may provide much needed insight regarding cultural dimensions of social resilience and the adaptive capacities of different groups of people.

The underlying social fabric evident within many rural mountain settlements accordingly generates a keen confidence in the ability for the community to effectively respond to future climate change threats. While climate change is commonly perceived as a concern for the future, Ladakhi villagers remain relatively unperturbed by predicted risks because they have faith in their fellow community members to mobilize in response to aggressive climate change impacts. Although other social and cultural variables also partly explain Ladakhis tempered concerns toward climate change, such as addressing youth outmigration issues and tense political relations with China and Pakistan, strong conviction in their community's response capacities may account for relatively moderate societal values and prioritizations of climate-related risks.

Indeed, confidence in community behavior and the management of climate change impacts may be so steadfast that cultural optimism may blind full acknowledgement of the severity climate change impacts pose. Even with respect to extreme weather events and drastic weather variability, which promise to generate highly risky scenarios for many Ladakhis, villagers remain largely undaunted by the prospect of an unpredictable and at times, dangerously changing climate. Furthermore, many Ladakhi villagers are willing to participate in climate change adaptation planning in order to prevent the most dire climate change scenarios from coming true, in this case the relocation of entire communities. Cultural dimensions of social cohesion and place attachment therefore enhance positive perceptions of community response toward climate change and as in the case of Ladakhi villages, may even occlude the need for urgent and immediate adaptation planning due to strongly shared beliefs in community resilience.

Areas with relatively low social vulnerability yet still exposed to other significant adversities, such as biophysical constraints, economic inequality and political marginalization, call into question the collective concept of vulnerability and associated notions of adaptation. In particular, determining which groups of people are better equipped to respond to climate change must be reconsidered in lieu of the influential nature community cohesion and place attachment plays in anticipating climate change impacts. Within this context, deep connections with community and landscape may bolster adaptive responses to climate change and in some cases, overcome other vulnerabilities to successfully moderate the impacts from climate change.

For instance, given the inverse situation where biophysical, economic and political vulnerability is comparably low but social vulnerability is high, it becomes difficult to discern which community is better prepared to effectively engage with climate change. Many urban communities in America are comfortably buffered from the worst impacts of climate change in comparison to communities in less developed countries. With comparatively high natural resources, income levels and ready access to information, technology, services and infrastructural support, American communities are advantageously positioned to respond to climate change. However studies suggest that as a whole, urban civilizations in the West increasingly lack the traditional community bonds and sense of alliance that often characterize more localized neighborhoods (Crowley and Hickman, 2008; Forrest and Kearns, 2001). Since the post-industrial era, societies have become increasingly fragmented and divided by contrasting values, behaviors and socioeconomic status. This is suggestively demonstrated with the contemporary polarization of American society by income levels, educational standing, religious affiliations and political parties. In comparison to Ladakhi communities that illustrate a strong unifying social fabric, less cohesive societies might be equally impaired if not worse off, in effectively responding to the immediate and rapid impacts from climate change. Consequently, categorically identifying the qualities comprising vulnerability and by inference adaptive capacity, is anything but straightforward and requires a robust understanding of the elusive cultural and social forces influencing perspectives of a climate-related risk environment.

Nevertheless, as Ladakh increasingly assimilates into the global political economy, notions of community attachment and sense of place are irrevocably questioned by larger prerogatives of consumption and materialism. In a place where tradition runs deep, the exchange of capital, labor and commodification becomes an increasingly precarious balancing act between maintaining cultural and environmental integrity at the expense of capitalistic gains. Like many societies, Ladakhis are encouraged by short-term returns over long-term benefits. This encourages a veiled and nearsighted outlook that may not consider the full spectrum of consequences. Similarly demonstrated with the excessive use of the Colorado River in America, the steady depletion of the Aral Sea in Central Asia and dropping flow levels in China's Yellow River, society commonly prioritizes immediate yields in contrast to lasting sustainable investments. In an era increasingly defined by rapid globalization and penetration into the world's most remote settings, a symbolic tug-of-war subsequently emerges between efforts to observe traditional livelihoods while simultaneously taking advantage of existing and future development potentials.

The evolving confluence of tradition, modernity and climate change in Ladakh is perhaps best epitomized with the struggle over local and regional water resources. Water is the lifeline of humanity and the mountains of Ladakh are a main hydrologic artery to a significant portion of the world's population. As the mounting pressures from climate change, development and population growth increasingly tax vital water reserves, fundamental choices will have to be made regarding how to best manage, distribute and renew Ladakh's existing water reserves. Like many of the world's places exhibiting water stress, access to and availability of water in Ladakh will determine the ability for humans to live with and off the land. As such, water stress is the underlying denominator and key factor characterizing Ladakh's vulnerability to climate change. Although water conservation practices are a clear need, supplemental approaches include technological innovations, actively utilizing local knowledge and broader outreach and educational efforts. Effective resolutions to abstruse and complex water scenarios will ultimately require transcending traditional boundaries of interaction to develop multi-scalar strategies for Ladakh's future water management regime.

With respect to future research trajectories, work is needed in the continued examination and identification of site-specific climate change impacts. Acquisition of accurate and reliable data at localized scales can inform larger-scaled climate projection models while substantiating community concerns regarding the most adverse effects of global warming. Further, localized accounts and observations of climate change can help thread the broader scientific narrative into a collective discussion on potential adaptation scenarios that are implementable at multiple levels, starting from the ground-up. Highly germane to this conversation is the explicit incorporation of cultural frameworks that fundamentally determine how climate change planning will be legitimized at the local scale. Concepts of place and community cohesion are central themes within human geography that could greatly contribute to the climate change discourse by directing attention to the quieter forces that work within and between different societies to embrace or reject climate change response. By proactively incorporating sense of place concepts into climate change planning efforts, the meaning and purpose of adaptation is authenticated because the protection of local spaces become central objectives in climate change response. The process of adaptation can be streamlined as more local people become encouraged to invest in the continuity of their community and livelihood.

Essential and highly interdependent ecological processes are already being altered by climate change, the effects of which are felt most at the local level. Ladakh, a region steeped in traditional mores and defined by its unique extreme geography, has an extensive history of social and ecological adaptation to environmental change. Pulling from this knowledge base will provide crucial insight often unheeded by modern science and contemporary policy paradigms.

Perhaps more importantly, local perceptions and observations of climate change can help pinpoint key impacts and designate areas where response needs should be prioritized. Yet climate change is at the bottleneck of widespread transformation in Ladakh, and is one of many issues competing for public attention and political awareness. Recognizing the distinctive role climate change plays within the prevailing hierarchy of diverse issues and concerns is fundamental to the design of implementable policy-making and practice for climate change adaptation. Given the gridlock of chronic development needs and other socioeconomic issues facing Ladakh, effective planning for climate change impacts will have to dovetail with other response mechanisms to collectively and iteratively address adaptation efforts at spatially-explicit scales.

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Survey #:__________ Date: __________

The University of Montana

Research Survey

Understanding Local Perceptions of Climate Change and its Impacts

Q1. What is your gender? (please check one) ☐ Male ☐ Female

Q2. What age you are:

☐ 18-24 years ☐ 25-30 years ☐ 31-35 years ☐ 36-40 years
☐ 41-45 years ☐ 46-50 years ☐ 51-55 years ☐ 56+ years

Q3. How long have you lived in Domkhar?

☐ I was born here ☐ Under 5 years ☐ 5-10 years ☐ 10-20 years ☐ 30+ years

Q4. What level of education do you have?

☐ Primary School ☐ Secondary School Other (Please specify) __________________
☐ College/University ☐ Never attended school

Q5. What is your main type of employment?

☐ Farmer ☐ Laborer ☐ Employed (Salaried) ☐ Traditional
☐ Tourist Guide ☐ Military/Army ☐ Other (Please specify) __________________

Q6. Including yourself, how many people live in your household?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7+

Q7. Since living in Domkhar, have you noticed a change in the climate or environment? ☐ Yes ☐ No

Q8. If yes to the above question, how have these changes affected your life?

☐ Strongly affected ☐ Slightly affected ☐ Neither affected nor unaffected ☐ Slightly unaffected ☐ Very unaffected

Q9. How likely do you think it is that climate change is occurring?

☐ Very likely ☐ Slightly likely ☐ Neither likely nor unlikely ☐ Slightly unlikely ☐ Very unlikely

Q10. How important is climate change to you?

☐ Very important ☐ Slightly important ☐ Neither important nor unimportant ☐ Slightly important ☐ Very important

Q11. How many times have extreme weather events, like flash flooding, taken place in your lifetime?

☐ 1-3 times ☐ 4-6 times ☐ 7-10 times ☐ 10-15 times ☐ More than 15 times

Q12. How satisfied are you with the government and emergency relief organizations' response to previous climate change impacts, including the August 2010 floods?

☐ Strongly satisfied ☐ Slightly satisfied ☐ Neither satisfied nor unsatisfied ☐ Slightly dissatisfied ☐ Strongly dissatisfied

Please continue on next page...

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Q13. How much have you observed the following changes?

	Very frequently		Neither frequently nor infrequently		Very infrequently
Flash floods, landslides, and mudslides	1	2	3	4	5
Drought	1	2	3	4	5
Heavy and untimely rainfall	1	2	3	4	5
Rise in temperatures	1	2	3	4	5
Snow and glacier melt	1	2	3	4	5
New animal and plant species	1	2	3	4	5
Changes in cropping and planting seasons	1	2	3	4	5
Cloudy days	1	2	3	4	5
Winds and sand storms	1	2	3	4	5
New diseases	1	2	3	4	5
Changing precipitation patterns	1	2	3	4	5

Q14. How have changes in the climate affected you and/or your family?

	Very affected		Neither affected nor unaffected		Very unaffected
Relocated home and/or property buildings	1	2	3	4	5
Damage to home and/or property	1	2	3	4	5
Injury to myself and/or family member	1	2	3	4	5
Death of a family member	1	2	3	4	5
Agricultural yields have increased	1	2	3	4	5
Agricultural yields have decreased	1	2	3	4	5
Water reliability has increased	1	2	3	4	5
Water reliability has decreased	1	2	3	4	5

Q15. Do you think climate change will have a positive or negative affect on your community?

☐ Very positive ☐ Slightly positive ☐ Neither positive nor negative ☐ Slightly negative ☐ Very negative

Q16. How do you feel about present and future climate change?

☐ Very worried ☐ Slightly worried ☐ Neither worried nor unworried ☐ Slightly unworried ☐ Very unworried

Q17. How important do you think it is to plan for climate change?

☐ Very important ☐ Slightly important ☐ Neither important nor unimportant ☐ Slightly important ☐ Very important

Q18. Do you think your community is able to respond to climate change impacts?

☐ Strongly agree ☐ Slightly agree ☐ Neither agree nor disagree ☐ Slightly disagree ☐ Strongly disagree

Q19. Do you think Domkhar needs assistance from the government to respond to climate change impacts?

☐ Strongly agree ☐ Slightly agree ☐ Neither agree nor disagree ☐ Slightly disagree ☐ Strongly disagree

Q20. How involved would you like to be in the local planning and management of future climate change impacts in your community?

☐ Very involved ☐ Slightly involved ☐ Not involved

Julley!

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