

## Article

# The Role of Place in Adapting to Climate Change: A Case Study from Ladakh, Western Himalayas

Kimiko Barrett <sup>1,\*</sup> and Keith Bosak <sup>2</sup><sup>1</sup> Headwaters Economics, Bozeman, MT 59715, USA<sup>2</sup> Department of Society and Conservation, College of Forestry and Conservation, University of Montana, Missoula, MT 59812, USA; keith.bosak@umontana.edu

\* Correspondence: kimi@headwaterseconomics.org; Tel.: +1-406-243-6062

Received: 9 February 2018; Accepted: 19 March 2018; Published: 21 March 2018



**Abstract:** This research explores the nexus of climate change and socio-economic change with a focus on the significance that local conditions (physical and cultural) can have in influencing vulnerability and resilience. In order to better examine how climate change impacts interact with socio-economic changes and are experienced at the community scale, this research integrates household survey data with geospatial processing techniques. Two comparative study sites, one rural and one urban, were selected in the region of Ladakh; an area experiencing severe climate change impacts alongside rapid socioeconomic and political changes. Archival data was used to supplement survey responses and provide additional historical context. Survey responses were then combined with Hot Spot and Kernel density analysis in ArcGIS to identify areas of high and low spatial concentration and correlation. While climate change is widely perceived in many Western Himalayan mountain communities, impacts of climate change as an issue of high importance are moderated by other pressing socioeconomic, cultural, and political concerns. The role of locality and place-based themes such as community attachment, social cohesion, and sense of place, emerged as influential factors in enhancing social resilience and thereby reducing dimensions of local vulnerability to climate change impacts.

**Keywords:** climate change; adaptation; vulnerability; resilience; sense of place

## 1. Introduction

For communities situated in the world's high mountain areas, climate change is generating an unpredictable, and at times, hazardous environment [1–3]. Climate change impacts are altering ecosystem functions and the human activities that depend on them. Rising air temperatures, receding glaciers, and extreme weather events are increasing at a scale and pace that poses significant challenges to many mountain populations [4]. Further, climate change impacts exacerbate ongoing socioeconomic, political, and ecological stresses, making it difficult to effectively respond to present and future risks [5,6]. The goal of this research is to understand the interactions between climate change and socio-economic change with a focus on the role that local conditions (physical, social, economic, and political) have in influencing vulnerability and resilience. We argue that it is important to take into account particular local conditions and the influence they have on vulnerability and resilience in order to develop effective climate change policies at larger scales.

In the Himalayas, climate change interrelates with other forces within the wider political economy to reshape traditional ways of life. Processes such as globalization, migration, and tourism, converge with climate change impacts to disrupt traditional subsistence systems [7–9]. At the local level however, there is limited understanding on how climate change interacts with broader social and economic forces to steer community response efforts [10]. This knowledge deficit in turn, hinders

effective policy-making and may increase vulnerability [11–13]. Such an oversight can lead to maladaptation, or the generation of unfavorable response strategies to climate change in the long-term. We argue that for climate change adaptation to work at community scales, an understanding of particular local conditions must be accounted for, and within the context of broader socioeconomic and ecological changes.

In this article, we assess community attitudes, perceived site-specific impacts, and preparedness, to climate change in the context of rapid socioeconomic change and geographic context. To do so, we apply a critical approach, taking into consideration scalar processes from global to local. To guide the research approach, three related research questions are answered: (1) what role does geographic setting play in shaping climate change perceptions; (2) how is climate change perceived in relation to other socioeconomic and development challenges; and, (3) what does a focus on geography and perceptions tell us about social resilience and adapting to climate change? Within western Himalayan villages, climate change is largely viewed in light of other pressing socioeconomic and political concerns brought about through globalization of the economy and environment. Further, rural and urban environments generate different connotations of sense of place, community attachment and social cohesion which in turn, influences how climate change is perceived and responded to [11,12]. In this way, proximity and access to natural resources and community social resilience are key determinants of local engagement with larger adaptation planning efforts.

As a politically charged concept, climate change represents the social production of nature as it highlights the uneven exchange between those who are impacted by the appropriation of nature against those who profit from its exploitation. Climate change combined with various forces of power and politics therefore produces clear winners and losers [13,14]. With that acknowledgement, this research takes a political ecology approach with a focus on scale. Concepts such as adaptation, vulnerability, and resilience come into play as important descriptors of power relations [9,15–17]. There is also a material reality needing to be recognized as communities responding to climate change all have a unique geographic context within which they derive their culture and livelihoods. Natural hazards and risk management are particularly salient concepts in addressing geographical context and provide insight into how communities perceive and respond to rapid environmental changes such as flash floods, landslides, and glacial lake outbursts.

Viewing vulnerability as a socioeconomic and political construct presupposes discriminatory conditions whereby the most marginal populations are the most impacted by natural hazards [18]. 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 [19]. 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 [4,20]. 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. 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 care access, infrastructure support, and livelihood opportunities, that facilitate uneven exposure to environmental threats [21,22].

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 [23].

Until recently, most approaches toward climate change adaptation represented a technocratic solution and a prescribed “one-size-fits-all” approach for climate change policy that consistently failed to capture the uniqueness of local settings and the climatic realities already taking place on-the-ground [9]. As a result, there is often disconnect in climate change policy between the national and state levels with local needs for adaptation [24,25]. Within the discourse on climate change, adaptation, vulnerability, and resilience are constructive concepts. *Adaptation* implies an active set of

strategies and actions taken in reaction to or in anticipation of change by people in order to enhance or maintain their well-being [10,26]. The ability to make these necessary adjustments, or *adaptive capacity*, is correspondingly influenced by a multitude of interrelated factors and significantly varies from place to place [17,27]. Adaptive capacity is therefore determined by the availability and accessibility to tangible and intangible assets, such as financial resources, technology, information, social capital, and infrastructure [5,21]. Compounded by other socioeconomic, institutional and ecological variables, these attributes determine who adapts to climate change, where adaptation takes place, and how adaptive practices are developed [28].

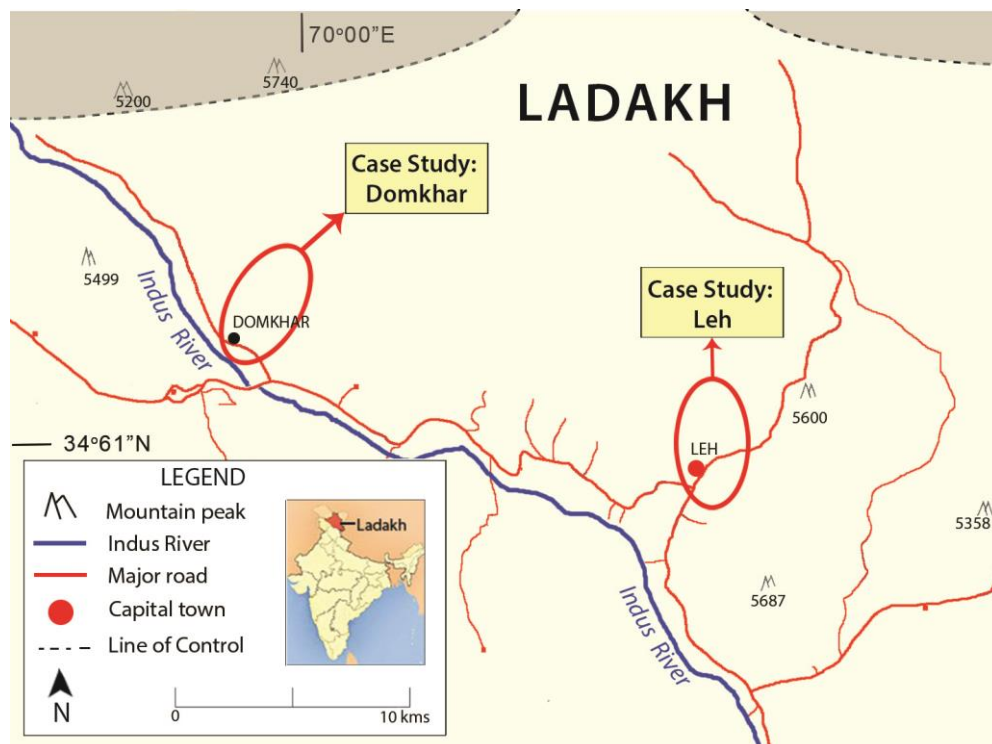
Coupled with adaptive capacity are themes of resilience. Similar to adaptation, *resilience* has its roots in the biological sciences and suggests the ability for a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks [29]. Often framed in opposition to resilience are components of vulnerability. In this sense, *vulnerability* refers to the degree of susceptibility and exposure to adverse conditions imposed by climate change and can be viewed in terms of both biophysical and social systems [30,31]. 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 [21,30,32]. Social vulnerability is determined by factors such as poverty, health, food entitlements, and access and control over natural resources [20,33]. 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 [34].

In understanding how vulnerability manifests at the local level to reflect both social and environmental pressures, it is important to note the role that sense of place and community attachment can play in promoting adaptation efforts. While formal definitions of social vulnerability refer to the access and availability of resources; place attachment and community awareness are of additional value because they can motivate people to respond to climate change impacts that threaten the integrity of community [35,36]. For example, people with high levels of place attachment are more likely to be inspired to prepare for flooding events because of their social and economic investments within their region [37,38]. Heightened connection to a particular place and profound sense of belonging to a community can facilitate solidarity among community members, increase recognition of environmental changes, and result in social action to respond to these changes.

In response to the need to examine multi-scalar vulnerability from the local scale up, studies have increasingly embraced mapping applications as way to identify and illustrate the host of stresses exerted upon particular places. Spatially representing vulnerability and adaptation can pinpoint areas of immediate concern, identify site-specific impacts, facilitate entry points, and direct resources accordingly. Modeling efforts by O'Brien et al. illustrated that the combined effects from climate change and globalization yielded a "double exposure" effect and disproportionately positioned some people and places at risk to climatic and economic shocks [39]. Similarly, Brody et al. spatially analyzed risk to climate change impacts in the United States as a product of physical geography and public perceptions [40]. By applying a spatial element in their vulnerability assessment, both studies identified key indicators that shaped individual perceptions of risk and thus the ability and willingness to respond to these climatic threats. The authors' findings suggest the need to go beyond the traditional constructivist viewpoint to better understand climate change vulnerability as an outcome of unique and context-specific social and ecological processes.

## 2. Materials and Methods

Situated on the western edge of the Himalayas, is the region of Ladakh (Figure 1). Ladakh encompasses 37,018 square miles (95,876 sq. km) and has an average elevation over 11,000 feet (3352 m). Located within the expansive rain shadow of the Tibetan Plateau, Ladakh is characterized as an arid high elevation desert.



**Figure 1.** Location map of Ladakh and case study sites of Domkhar and Leh, Western Himalayas.

In more closely examining the role locality and geographic context plays in shaping community response to climate change, 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. 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 is unfolding to shape community activities, societal outlooks and public engagement. In addition, both study sites were affected by recent weather events, including a cloudburst in August 2010, which resulted in extensive damage to local properties, infrastructure and households. As a result, these incidences have left a lasting impression in the Ladakhi social psyche regarding climate change potential and extreme weather events.

Further, the purpose of selecting two individual 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 in land use practices, settlement patterns, political institutions, financial opportunities, sociocultural shifts, and physiographic characteristics. Identifying how these dynamic characteristics intersect to shape household and community response to climate change provides useful details on the structural and nuanced features propagating conditions of vulnerability.

In the villages of Domkhar for instance, livelihoods are heavily dependent on agriculture and the surrounding natural resources for food and income. Domkhar is a relatively isolated valley located approximately 78 miles northwest of Leh and is situated near the northwestern border of India, Pakistan, and China. It is comprised of three separate villages; Domkhar Dho, Barma, and Gongma, with a collective population of less than 800 people.

Alternatively, Leh is the capital town of Ladakh and is composed of nine different districts, with a total population of 133,487 people [41]. Leh is the geographic epicenter of government, tourism, commerce, and education in Ladakh. As a region officially closed to foreign tourists until 1974, Leh and its peripheral communities have substantially grown in size and population over recent

decades. While farming and agriculture remain dominant sources of income for many households, opportunities for supplemental forms of employment, particularly within the government and tourism industry, are more prevalent in Leh compared to elsewhere in Ladakh. Traditional livelihoods in farming and agriculture therefore operate alongside, and at times are superseded by tourism and other sectors of employment to drive and develop Leh's economy.

Over time, human activities coupled with ecological processes have both quietly and abruptly shaped the Ladakhi landscape. 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, Ladakh was central to the Silk Road and 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 surrounding mountains as corridors of exchange made them important and contentious grounds since humans first settled there.

More recently, Ladakh like the rest of the Himalayas, have been characterized as the geographical nexus where old customs meet and assimilate into new processes of modernity [42,43]. 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 in the Himalayas are correspondingly embedded within a larger theoretical canvas examining broad patterns of development and modernization. Change often comes in the form of infrastructure projects (e.g., Tehri Dam in India), national and transnational development schemes (e.g., Qinghai-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.

In addition to globalization and other socioeconomic and political forces, climate change is affecting Ladakh and the Himalayan region as a whole. Recent studies suggest that temperature increase in the Himalayas over the past 100 years has accelerated much faster than previously predicted [44–47]. While temperature changes differ in magnitude, and by location, studies suggest an overall warming trend for the region. In Nepal and the Tibetan Plateau for example, research suggests that since 1961, average annual temperatures have increased by up to 0.14 °C per decade and could potentially rise between 1.5–3 °C by 2040 [48–51]. This continual warming trend has had significant effect on the region's water resources, most visibly with the retreat of glaciers and snowpack [52–54]. The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment report 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 [4,46].

Reflecting region-wide changes, Ladakh is experiencing similar affects, with the most visible changes including glacial recession, migration of flora and fauna species, shifting precipitation patterns, and a rise in the frequency of extreme weather events [55,56]. In the principle town of Leh for instance, where temperatures have increased by 1 °C since 1973, the snow line has receded by nearly 500 feet and the adjacent glaciers have retreated by as much as 6.2 miles in the past century [57]. Moreover, a greater proportion of annual precipitation is falling in the form of rain instead of snow which hinders the renewability of many of the region's perennial snowpack zones [45,58].

Variations in precipitation trends reflect major changes in the strength and timing of the predominant weather systems driving Himalayan climatic patterns, including the Asian monsoon, inner Asian high pressure systems, winter westerlies, and other atmospheric disturbances [59]. For instance, the Madden-Julian Oscillation (MJO) is significantly influential in altering precipitation patterns and snow cover in eastern Asia [59,60]. Pronounced warming trends have been shown to amplify the effects of such climatic variabilities such as the MJO in the Western Himalayas, generating heavier and more frequent precipitation events [61]. Alterations in weather systems



have cascading effects down the ecosystem chain, with potentially adverse effects to food production systems, irrigation requirements, and other water consumption needs.

The methodology for this research involved two stages. The first component of data collection involved conducting household surveys in the two different case study locations, including the urban core of Leh and the rural area of Domkhar. The intention was not to select sites that would be representative of the entire region but rather to have contrasting sites in order to be able to highlight differing physical and socio-economic conditions. The household surveys, together with archival datasets, provided trends and descriptive statistics to understand how climate change is affecting local Ladakhi villages. Household 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 [62]. In Ladakh, like many Himalayan communities, the household is the critical focus for the organization of village life, work, and exchange [63–65]. The household was therefore 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 total, a sampling frame of both research sites involved 400 household surveys, with 255 surveys completed, or a response rate of approximately 63%. In the town of Leh, 145 surveys were completed and in the village of Domkhar, 110 surveys were completed.

The sampling geography for the surveys involved thirteen different municipal wards in Leh and three separate villages in Domkhar. As the urban core of Ladakh, 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 survey administration and approximately 10 to 12 households within each ward were administered the survey. In the more rural area of Domkhar, three villages were administered the survey, with 25 to 45 surveys administered and completed in each village.

Surveys were administered in-person and were semi-randomized, with every other household within each selected ward/village being approached. Due to the minimal population size of each ward, a semi-randomized approach involving every other household ensured that approximately thirty to fifty percent of the ward's population was sampled. The head of the household was requested to complete the survey. If no head of household was available at the time the survey was initially administered, the next house was approached. In addition, the respondent had to be over the age of thirty years, and had to have been a year-round resident in Domkhar or Leh for at least five years. This provided a reasonably high response rate of 63%, and an accurate representation of rural and urban communities in Ladakh.

Survey questions were designed to probe individual's personal attitudes and values regarding climate change and future planning efforts at the community level. Specific questions addressed respondents' views of climate change as an issue of importance, the positive or negative impact climate change has had on the community, and the local planning capacity to respond to future climate change impacts. In addition, respondents were asked to identify and rank observed climate change impacts based on increasing or decreasing frequency. Survey questions on observed climate change impacts addressed changes to local water availability, regional glacial extent, spring timing of the cropping season, altering precipitation patterns, and changing annual temperatures. Survey questions addressing climate change attitudes, perceptions, and observed impacts were measured with a five-point Likert scale. Responses ranged from 1 (strongly observed), to 3 (slightly observed), to 5 (no observation). The survey also included open-ended questions, which were used to supplement and provide further clarity on specific responses. Data from the surveys was entered and organized first in a Microsoft Excel spreadsheet and later exported and transferred into IBM Statistical Package for the Social Sciences (SPSS V.21, Armonk, NY, USA) for processing and analysis. To identify statistically 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% and 99% ( $p < 0.05$ ,  $p < 0.001$ ). Survey responses on climate change observations were supplemented by agricultural, flood, hydrological, precipitation, census and other datasets

collected from government and non-government organizations, including Ladakh's Agriculture, Forestry, and Flood Departments, the Ladakhi Autonomous Hill Development Council, and the Deputy Commissioner's Office, based in Leh.

The second phase of research involved using Geographic Information Systems (GIS) as an application to visually map and spatially model how the framing and understanding of climate change varied with geographic context. To do so, completed surveys collected during the first phase of work, were individually georeferenced with waypoints and then imported into ArcGIS 10.2 using the X and Y coordinates. Each waypoint identifies the location, date, and time of individually surveyed households. Location points were subsequently populated with survey responses, providing incident point data for geospatial analysis. Due to the proximity of households being surveyed within each study area, spatial representation of each waypoint accurately reflected the ward or village involved in the survey process. Survey questions specifically focusing on household attitudes, values, and observed impacts of climate change were targeted and integrated into ArcGIS. Operationalizing local observations of climate change in this way allowed for the spatial representation, operationalization, and statistical processing of survey responses.

Two geoprocessing methods were applied to assess and model the shifting narrative on climate change perceptions in Ladakh. Initially, Hot Spot analysis (Getis-Ord  $G_i^*$ ) in ArcGIS 10.2 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 relationship of high values and were thus identified as "hot spots" relative to other places on the map. Survey responses were divided into two primary categories for geospatial analysis, (1) observed climate change impacts, including air temperature, availability of local water sources, precipitation patterns, timing of cropping season, and glacial extent; and (2) attitudes towards climate change, such as local planning capacity and prioritization of climate change as an issue of community importance. Individual survey responses correspondingly provided incident point data for the input field in Hot Spot analysis. For both climate change observations and attitudes towards climate change, point data was aggregated using the spatial join tool to identify the intensity of high to low values. For this analysis, Hot Spot features were normalized using the  $p$ -value classification ranging from less than 0.001 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. 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 m was used to demarcate the neighborhood distance parameters. Following a similar method applied by Alessa et al. (2008), 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 m [66,67]. 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.

### 3. Results

Comparisons within and between different study sites suggest climate change is a ubiquitously observed trend within Ladakh and its impacts are felt at both the local and regional level. However, differences between rural and urban setting and socioeconomic context play an important role in how climate change is locally interpreted and socially constructed relative to other non-climate risks, such as village outmigration, political border disputes with China and Pakistan, and agricultural labor shortages, among other ongoing challenges.

### 3.1. Demographics and Socioeconomic Context

For both Domkhar and Leh, the population is increasingly elderly and consists of people who were born in the area. This trend was a little more prominent in Domkhar, where 45.4% of the participants surveyed were over the age of 56 years and 87.3% were born in Domkhar (Table 1). In Leh, approximately 38% of the surveyed respondents were over the age of 56 years and 51.4% were born there. Of the total population surveyed in Domkhar, 58% were women and 42% were men. Results from the survey may therefore favor the female perspective regarding changing climatic conditions in Domkhar over the male viewpoint. In Leh, the ratio of males to females was nearly equal, with 49% of surveyed individuals being male and 51% participants being female.

**Table 1.** Demographic and Community Characteristics for Households in Domkhar and Leh, Ladakh.

Characteristic	Full Sample (%)	Domkhar (%)	Leh (%)
Gender			
Male	46.1	42.0	49.0
Female	53.9	58.0	51.0
What is your age?			
25–30 years	9.1	4.6	12.5
31–35 years	9.8	5.5	13.2
36–40 years	12.6	10.9	13.9
41–45 years	6.7	8.2	5.6
46–50 years	10.6	13.6	8.3
51–55 years	9.8	11.8	8.3
>56 years	41.4	45.4	38.2
How long have you lived in Leh?			
I was born here	66.9	87.3	51.4
Under 5 years	6.7	0.9	11.1
5–10 years	3.5	0.0	6.3
10–20 years	13.4	3.6	20.8
20+ years	9.5	8.2	10.4
What level of education do you have?			
Never attended	56.7	64.5	50.7
Primary school	9.4	9.1	9.7
Secondary school	19.7	13.6	24.3
Middle school	6.7	7.3	6.3
College/University	7.5	5.5	9.0
What is your main type of employment?			
Farmer/Laborer	62.2	81.8	47.2 *
Employed (salaried)	14.2	11.8	16.0
Tourist Guide/Tourism	1.6	1.8	1.4
Shopkeeper, Housewife, Other	17.7	1.8	29.9
Military/Army	4.3	2.8	5.5
Including yourself, how many people live in your household?			
1 household members	4.3	4.5	4.2
2 household members	4.3	2.7	5.6
3 household members	4.7	2.7	6.3
4 household members	17.7	14.5	20.1
5 household members	16.1	11.8	19.4
6 household members	13.0	10.9	14.6
7+ household members	39.8	52.7	29.9
Sample Size	254	110	144

Statistical Significance Levels are indicated as: \* =  $p < 0.001$ .

This uneven gender spread in Domkhar directly relates to the availability of employment opportunities Ladakh's rural areas. For instance, 81.8% of the people living in Domkhar earn their primary form of income 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 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. Survey results indicate more men than women perceived specific climate change impacts. These include increases in heavy rainfall events, the spread of plant and animal species, and an increased occurrence of wind storms. These results are slightly counterintuitive in that women are predominantly undertaking farming activities and thus are spending more time outside and interacting with the environment in a subsistence context. Overall therefore, gender differences in perceiving climate change impacts were statistically significant but counterintuitive. Similar confounding results were found in examining other demographic and socioeconomic variables across the study sites (education levels, age, and household size).

Across the full sample of respondents surveyed for this research, 57% never attended school. In looking at the differences in climate change perceptions between those who attended school and those who did not, there were a number of statistically significant relationships between educational attainment and perceptions of climate change. In particular, survey respondents with no education, were more likely to perceive an increase in air temperatures and were very worried about climate change. This may be more correlated with type of employment more than with level of education. Many respondents with no education were farmers, and more observant of changes in climate and weather patterns. Similarly, their livelihood is closely tied, and potentially jeopardized, by climate change. Conversely, respondents who received an education were more likely involved in alternative forms of employment, such as shopkeepers, tourism, government, and military.

There was a strong correlation between age and perceived climate change impacts. Respondents who were 41 years and older, perceived an increase in air temperatures as well as a noticed decrease in agricultural yields; for respondents under 40 years old, they perceived an increase in agricultural yields. A perceived increase in yields may be a result of other, more recent changes in the agricultural sector. Data from the Department of Agriculture of the Ladakh Autonomous Hill Development Council (LAHDC) for agricultural yields and land area under cultivation since 1955 shows that overall there has been a rise in agricultural production. However, the types of crops under cultivation have changed. The production of traditional crops such as barley and pulses has decreased while the production of commercial crops such as wheat, rice, maize, potatoes, and fruit trees has increased. Even with the increases in crop production and yields, Ladakh is no longer food self-sufficient. This is due in part to population growth, urbanization, demographic, and livelihood changes. Ladakh now imports food grains in order to meet the needs of its population. Given these trends, it makes sense that older people in Ladakh who might remember a time when the region was food self-sufficient would perceive a decrease in agricultural yields while younger people would perceive an increase in yields due to intensification and commercialization of agriculture.

The examination of household size and perceptions of climate change also produced some statistically significant results. Households with five and fewer members were compared with households of six or more members, with the understanding that larger households are more likely to be multi-generational and/or include extended families versus smaller households that are more likely to be composed of a nuclear family. In particular, survey respondents who lived with more than six members in their household perceived a decrease in agricultural yields, as well as a decrease in water levels. The most statistically significant relationship was found for households with six or more and a decrease in agricultural yields. This may be because there is an increasing shortage of food production relative to population growth in Ladakh. In part this is due to a rise in annual subsidies from Central India and the importation of rice and flour, in contrast to declining local production of barley and maize.

Although statistically significant relationships were found for some of the demographic and socioeconomic variables measured in this study, they were inconsistent across variables and thus not

as useful as explanatory factors. In addition, the perceptions (such as decreasing versus increasing crop yields) that were prevalent across various categories (age and household size) have explanations related more with socioeconomic shifts than climate change. We therefore maintain while there are some interesting and statistically significant results that arise from looking at demographic and socioeconomic variables across the study sites in this case, when the focus is on climate change perceptions and responses, the most pronounced and consistent differences are found along the rural and urban divide. The rural and urban divide in this case is also a demographic and socioeconomic divide as evidenced by the survey results from Leh and Domkhar.

In Leh, results from the survey suggest people living there 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 47.2% of those surveyed still farm, 52.8% worked as salaried employees, shopkeepers, tourist guides, and in the military. For women who didn't work as farmers, other forms of employment included shopkeeper or staying at home as a housewife.

With respect to the level of education obtained, nearly 65% of residents living in Domkhar had never received any education compared to 50.7% of residents in Leh. Of those who attended school, nearly 40% of students in Leh advanced to secondary school and beyond, relative to 26.4% of students in Domkhar.

In assessing overall community demographics, residents in the rural village of Domkhar are increasingly elderly and were born in one of the three villages. More women live in Domkhar than men, likely due to the draw of other employment opportunities elsewhere, such as tourism or military border patrol jobs. Therefore, women are often the primary caregivers, working on the farms to provide food and income support for the family. Many Domkhar residents have never attended school, though this is likely changing with the increasing availability and emphasis on education opportunities.

By contrast, there are more young people living in Leh and the workforce is more diversified. With a strong tourism base, employment opportunities range from guiding operations to government position, to work in hotels, retail, and food services. Leh also has a stronger education base compared to Domkhar and other rural areas in Ladakh. More Leh residents have therefore received some degree of schooling and in some cases, completed higher levels of education as well.

### *3.2. Perceived Impacts and Community Attitudes toward Climate Change*

Regardless of geographic context, a vast majority of Ladakhis overwhelmingly agree that there has been a perceived change in the climate over the course of their lifetime. While 8% of the sampled population did not believe in the likelihood of climate change or felt neutral about it, a significant majority or 92%, believed climate change was slightly to strongly affecting their way of life (Table 2).

Among the most observed climate change impacts, more than 80% of respondents perceived decreasing regional glacial extent, increasing onset of the spring cropping season, and altering precipitation patterns. In both Domkhar and Leh, a perceived decline in regional glacial extent was statistically significant. Domkhar and Leh respondents also mutually perceived a change in precipitation patterns, implying more rain-on-snow events or unusually heavy rainfall occurrences. More than 78% of Domkhar respondents believed this has been a strong increase compared to nearly 90% of Leh respondents.

Leh respondents additionally perceived higher average annual temperatures compared to Domkhar respondents. While 40% of Leh respondents perceived a strong increase in the annual temperatures, more than 85% of Domkhar respondents perceived very little change or no change in annual temperature. Nevertheless, both respondent groups observed a change in the spring timing of cropping season, with 88% believing that spring is coming earlier than it has in the past.

**Table 2.** Perceptions of Climate Change in Domkhar and Leh, Ladakh.

Characteristic	Full Sample (%)	Domkhar (%)	Leh (%)
Belief in climate change			
Very likely	85.0	77.3	90.1
Slightly likely	7.1	15.5	0.6
Neutral	5.9	3.6	7.6
Slightly unlikely	0.4	0.9	0.0
Very unlikely	1.6	2.7	0.7
Availability of local water sources			
Strongly increasing	0.8	0.9	0.7
Slightly increasing	2.4	1.8	2.8
Neither	34.6	55.5	18.2
Slightly decreasing	46.1	7.3	76.2 ***
Strongly decreasing	16.1	34.5	2.1
Regional glacial extent			
Strongly increasing	0.4	0.9	0.0
Slightly increasing	0.0	0.0	0.0
Neither	4.3	4.5	4.2
Slightly decreasing	13.8	24.5	5.6
Strongly decreasing	81.5	70.1 ***	90.3 ***
Spring timing of cropping season			
Strongly increasing	87.8	86.4	88.9
Slightly increasing	7.5	10.9	4.8
Neither	3.9	1.8	5.6
Slightly decreasing	0.8	0.9	0.7
Strongly decreasing	0.0	0.0	0.0
Altering precipitation patterns			
Strongly increasing	84.6	78.2	89.6
Slightly increasing	12.6	17.3	9.0
Neither	2.8	4.5	1.4
Slightly decreasing	0.0	0.0	0.0
Strongly decreasing	0.0	0.0	0.0
Changing annual temperatures			
Strongly increasing	26.8	10.0	39.6
Slightly increasing	16.9	27.3	9.0
Neither	49.6	58.2	43.1
Slightly decreasing	5.9	2.7	8.3
Strongly decreasing	0.8	1.8	0.0
Spread of animal and plant species			
Strongly increasing	94.1	91.8	95.8
Slightly increasing	4.3	5.5	3.5
Neither	0.8	0.9	0.7
Slightly decreasing	0.0	0.0	0.0
Strongly decreasing	0.8	1.8	0.0
Importance of climate change			
Very important	23.6	33.6	15.9
Slightly important	8.3	16.4	2.1
Neutral	24.0	21.8	25.7
Slightly unimportant	3.1	6.4	0.7
Very unimportant	40.9	21.8	55.6
Impact of climate change on community			
Positive	11.5	23.6	2.1
Neutral	27.2	44.5	13.6
Negative	61.3	31.9	84.3 **
Community capacity to plan for climate change			
Strongly agree	40.2	47.3 ***	34.9
Slightly agree	25.6	28.2	23.4
Neither	19.7	16.4	22.4
Slightly disagree	9.4	6.4	11.5
Strongly disagree	5.1	1.7	7.8
Sample Size	254	110	144

Statistical Significance Levels are as follows: \*\*\* =  $p < 0.001$ , \*\* =  $p < 0.01$ , indicating a statistically highly significant relationship exists between variables.

In contextualizing perceived changes in the hydrologic cycle, a majority of the surveyed households agreed there has been an overall decrease in water availability. In comparing study sites, 78% of the residents living in the urban area of Leh noticed a strong to slight decline in local water resources, in contrast to 41.8% of rural residents living in Domkhar.

Overall, a decrease in water availability combined with other observed climate change impacts, were associated with the belief that climate change was going to have a negative impact on communities. In Leh, 84% of respondents expressed concern that climate change was going to have a negative impact on their communities, in comparison to 32% of respondents in Domkhar. Interestingly, however, no significant differences were determined between the two study areas regarding the degree of importance placed on climate change with respect to other social, political, and economic issues. For instance, 44% of Domkhar respondents considered climate change to be a somewhat to very important issue, yet a majority or 81.9% of Leh respondents did not perceive climate change to be important or felt neutral about it. In many ways, this is because climate change is one of many competing challenges increasingly confronting Ladakhi communities. Non-climate related issues such as youth outmigration, tense political relations with neighboring Pakistan and China, and ongoing negotiations with mainland India, were often viewed with equal or greater concern. Irrespective of the negative connotations and unease associated with future climate change, many respondents living in Leh and Domkhar were generally less inclined to merit climate change as an issue of high importance relative to other socioeconomic and geopolitical issues.

When addressing the local planning capacities of communities to effectively respond to climate change impacts, a significant difference was noted between rural and urban residents. Many of Domkhar's rural respondents, or 75.5%, slightly to strongly felt their community had the capacity to respond to future weather hazards, climate impacts, and other non-climate related events. Conversely, 58% of urban residents living in Leh believed their community had the local planning capacity to adequately manage future climate change impacts. Hence rural residents, who are accustomed to a self-reliant lifestyle and embrace a very tight-knit social fabric within their community, were more self-assured in the ability for their village to manage potential climate change impacts compared to urban residents.

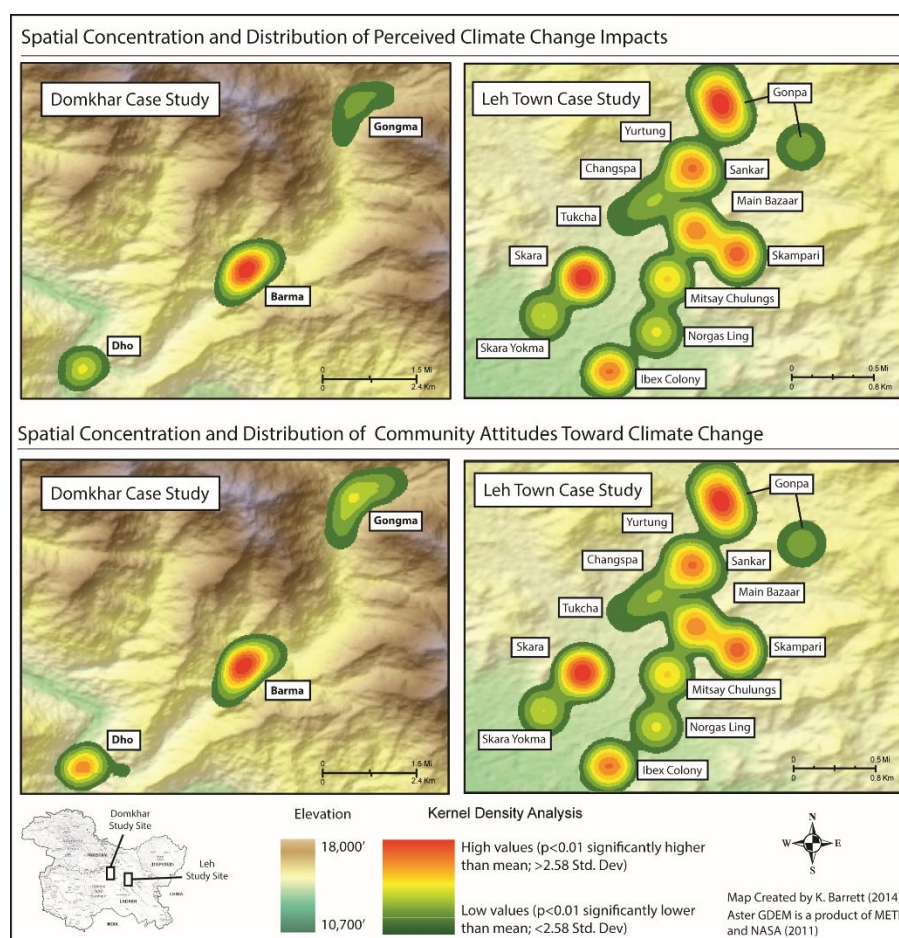
### *3.3. Spatial Distribution and Concentration of Perceived Impacts and Community Values on Climate Change*

Geospatial analysis suggests that while climate change is widely perceived across Ladakh, there is a great degree of heterogeneity regarding the distribution of these observed changes. In assessing observed climate change impacts in Domkhar for example, density analysis indicates a heightened level of sensitivity around water security issues in the village of Barma over the neighboring villages of Dho and Gongma. Situated in the middle of the Domkhar valley, perceived climate change impacts in Barma, including changes in snowpack, rising air temperatures, the spring onset of the cropping season, and variable precipitation patterns were pronounced. Alternatively, in the downstream village of Dho, perceived climate change impacts were consistently ranked moderate to low, and respondents in the upper village of Gongma reported low perceived climate change impacts. In particular, and relative to the villages of Barma and Dho, Gongma respondents did not perceive the same decrease in regional glacial extent nor a decrease in local water availability.

By contrast, in the urban center of Leh, observations of climate change were more evenly distributed. Of the twelve different wards surveyed in Leh, households within the Skara, Ibex Colony, Skampari and the Main Bazaar perceived significant to moderate changes in recent climatic conditions. The wards of Mitsay Chulungs, Yurtung and Gonpa followed with moderate to low values of observed climate changes and the remaining wards of Changspa, Tukcha, Sankar, Norgas Ling and Skara Yokma suggested relatively low observations of climate variability.

As evidenced within both study areas, the spatial distribution of climate change observations closely reflects community attitudes towards climate change, with the strongest attitudes toward climate change correlating with heightened observations of climate change (Figure 2). In particular,

the strongest indicators of public opinion on climate change were associated with personal experience of climate change impacts. For instance, in areas where climate change observations were high, a high level of importance was attached to climate change as an issue of priority for the community. Similarly, belief in climate change and concern regarding present and future climate-induced risks were substantially higher in communities where climate change observations were frequent. What this suggests is that communities that have experienced acute or severe impacts from events attributed to climate change are more likely to prioritize climate change as an issue. This is important for two reasons. First, these are likely to be the communities who are ready to undertake adaptation efforts. Second, a focus on climate change impacts in these communities has the potential to ignore the socio-economic conditions that are likely to have contributed to severe or acute impacts. For example—A community that has experienced recent water shortages might be focused on drought-related adaptation measures without taking into account the impacts other changes such as land use, land cover or commercialization of agriculture have had on water availability.



**Figure 2.** Strength and location of aggregated responses of observed climate change impacts, and attitudes toward climate change in Domkhar and Leh, Ladakh, western Himalayas.

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 rural villages of Domkhar, Barma and to a lesser degree Dho, both illustrated high levels of government satisfaction while also indicating strong to moderate



observations of climate change. 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 heightened perceptions of climate change impacts. At the same time, a greater proportion of community respondents living in Domkhar over Leh not only felt very strongly about the ability for their community to effectively respond to current climate change impacts, but also had confidence in their community to plan for future climate-related risks.

#### 4. Discussion

Identifying and visually mapping the configuration of perceived climate change observations and attitudes across a community landscape refines the broader climate change dialogue into spatially relevant scales. Integrating these site-specific concepts into climate change decision making can enhance identification of both the abrupt and latent impacts resulting from climate change, as well as guide resources for adaptation to climate change [68]. In doing so, advanced measures for adaptation are more sustainable and align with local capacities, resources, and needs [69]. To shed light on how climate change is observed and valued in the Western Himalayas of Ladakh, this research sought to better understand the role geographic setting played in shaping perceptions of climate change, how this narrative fits into the other concurrent socioeconomic and development challenges, and what this implies for local social resilience and climate change adaptation.

While each village ward within Leh and Domkhar demonstrated relatively homogenous responses regarding perceived impacts and attitudes on climate change, variability existed *between* different village wards. Site-specific characteristics and community traits collectively shaped the interpretation and contextualization of climate change at the household level. Spatial analysis indicated that biophysical parameters, such as access and proximity to water, land and natural resources, combined with other livelihood characteristics, such as type of employment and urban/rural setting, to influence climate change awareness at the household and community scale.

There are a number of factors that may account for the interdependent relationship between geographic context, including biophysical parameters and socioeconomic livelihood conditions, and perceptions towards climate change. For instance, visual changes in weather and climate tend to be more easily observed compared to less tangible and more long-term changes. As Vedwan and Rhoades (2001) explain, visual salience, or the immediate appearance of a perceived impact like snowfall, might make it more noticeable relative to a non-material change, such as rising air temperatures [70]. In Ladakh, respondents were more likely to perceive a visual decrease in glacial extent and water flow in the river, compared to a rise or fall in temperature extremes. This is especially evident given the shorter temporal distribution of snowfall over a couple of months, relative to annual temperature ranges.

Vedwan and Rhoades additionally point out that people often perceive climate change impacts in relation to predicted outcomes and performance-related parameters. In this view, Ladakhi farmers are more likely to perceive changes in the timing of the cropping season because their family income is intimately tied to cropping output and production value. Similarly, Ladakhi farmers were particularly acute to changes in water supply and the impact it had on cropping yields. For them, a decrease or increase in water supply corresponded with cropping outputs, and combined with other extraneous factors, such as changing market trends, to explain fluctuations in household farming revenue. In this way, perceived climate change impacts in Domkhar and Leh were framed in lieu of utilitarian outcomes and potential impacts to cropping production.

Physical geographic location also contributes to varying perceptions of climate change. In Leh's Ibex Colony and Skara wards for example, farmers are predisposed to experience water shortages given their geographic location at the bottom of the irrigation network. Due to the hierarchal configuration of gravity-fed watering systems used across Ladakh, households situated at the bottom of the watershed, such as the Ibex Colony and Skara wards, are unfavorably situated to receive sufficient water supply relative to populations located at the head of the watershed. Whereas in the past, there was enough spring runoff water from surrounding tributaries to offset the gravity-fed watering system, nowadays

increasing pressure on the irrigation systems, combined with more upstream water demand and an overall decrease in glacial runoff, generates a high degree of uncertainty for downstream water users. As Akhtar describes, “Farmers in lower wards often face water scarcity that was in the past, 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 (and other downstream wards) can only produce their vegetables for the market later than other farmers in Leh town” [71] (p. 75). The earlier the vegetables come to market, the better the prices are for the farmers. The geographic location of the Ibex Colony and Skara wards therefore economically disadvantages community farmers in comparison to upstream farmers who often receive adequate water supply and at more opportune times. Community members adversely affected by the lack of water are more likely to contextualize this outcome as an impact from climate change and thus perceive climate change impacts more frequently compared to other farmers with sufficiently irrigated fields.

Similarly, in Domkhar, the village of Gongma is located in the broad upper basin of the valley and is therefore afforded open space and is less confined by the physiographic constraints characterizing settlements down the valley. Perhaps more importantly, being situated at the confluence of several surface tributaries strategically positions Gongma to watershed resources and a consistent supply of runoff from nearby glaciers. Correspondingly, survey respondents in Gongma reported fewer observations of climate change impacts related to glacial extent and water availability. Even in the years with minimal snowpack and below-average rainfall, water in Gongma is in general, more dependable and renewable than it is for downstream populations. Accordingly, villagers in Gongma have first access to the valley’s valuable water supply and are less vulnerable to water shortages. Given the perceived linkages between water supply and climate change, Gongma residents were less inclined to prioritize climate change as a substantial concern for future planning relative to their downstream counterparts. Due to their location near the head of the glacial watershed, Gongma residents were confident in their communities’ ability to plan and respond to future climate change impacts.

In Ladakh, climate change must be placed within the context of a rapidly transitioning milieu. Other socioeconomic and political challenges, such as tourism, urban growth, migration, and infrastructure development, aggregate at the local scale to moderate public attitudes toward climate change. While public awareness of climate change is high in Ladakh, social prioritization of it is thus blunted by multiple converging forces. Consequently, cultural understandings of climate change risk must be valued against the impending threat of other intervening 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 concurrent issues.

Awareness of climate change is not sufficient for engagement because it is often perceived as a distant threat [36,72,73]. Differences in a perceived risk environment may therefore explain the variation between community attitudes and observed impacts of climate change in Ladakh. Witnessing an extreme weather event, natural hazard or other climate-related risk firsthand enables cerebral processes to work automatically, effortlessly and instantly, and has the strength and immediacy that analytical information may lack [74]. 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 and act on future climate change threats. Alternatively, low levels of perceived risk and a “distancing” from climate change impacts indicates low levels of concern with the issue, which is strongly associated with reduced levels of support for taking action to address the problem [75,76].

In Ladakh, extreme weather events often manifest in the form of flash floods and episodes of heavy and untimely rainfall. Such events have been particularly impactful to settlements located along major drainages, and which are adversely exposed to inundations. Flash floods and other

climatic hazards have longstanding repercussions that in turn, erode the social, ecological, economic, and infrastructural foundations of local communities. Significant damage to property, livestock and crop yields leave a lasting impression of nature's devastation and are difficult to financially and emotionally recover from. Villages in Ladakh especially affected by flash flooding or other extreme weather events, such as Barma in Domkhar and the Skampari, Skara, and Main Bazaar wards in Leh, consequently interpreted and valued climate change to a greater magnitude than communities less impacted by past events.

Given the suite of intersecting forces shaping attitudes toward climate change in Ladakh, effectively planning for adaptation strategies must work in tandem with other sustainable management approaches. In recent years for example, the Ladakhi government has been subsidizing and providing households with solar panels as a form of renewable energy. 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. LREDA has ambitious plans to deploy a widespread renewable energy network across Ladakh, installing thousands of solar powered greenhouses, water heaters, and cookers [77].

Approaches that incorporate traditional local knowledge into the broader climate change dialogue can also advance mutual objectives of planning for climate change alongside other complex development challenges. Ladakhis have long been accustomed to environmental change and with time, generations of knowledge and practice have been accrued. 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. Near Leh, some innovative villagers are constructing a network of retaining walls around the base of a glacier, thus catching runoff water and effectively creating an artificial glacier when the meltwater freezes [78].

Similar to many areas undergoing rapid adjustments, climate change is not a stand-alone issue in Ladakh. Although households may be aware of climate change, contextualizing it as an issue of community importance is often superimposed by other rapid socio-economic changes. Therefore, planning strategies that mutually consider climate change alongside other socioeconomic and political challenges, and draw from local resources, will be more effective.

Concepts of place attachment and sense of place emerged as important determinants in shaping local understandings of climate change planning and preparedness. Framed in the context of climate change adaptation, rural communities in Domkhar and other Ladakhi villages that demonstrate strong social cohesion and place identity, similarly illustrate enhanced social resilience to the adverse effects of climate change. As social resilience increases, aspects of adaptive capacity are strengthened. This suggests that when it comes to the rapid and latent risks of climate change, rural communities who exhibit a deep sense of place attachment may be more effective and immediate in their response strategies compared to more autonomous urban communities.

In other words, when confronted with the impacts of climate change, rural residents who are part of a tightly knit social group and have deep connections with the land, exhibited a heightened confidence in their community's ability to effectively manage climate change impacts compared to urban residents. In Ladakh, rural residents living outside of Leh are almost exclusively dependent on agriculture for their living and as such, community members often share the mutual responsibilities of food production, irrigation distribution, and other farming activities (Figure 3). Correspondingly, traditional patterns of life, community relations and a strong sense of self-preservation are core values within Ladakhi rural culture. In contrast, urban residents in Leh are accustomed to a more diversified community demographic and a slightly less consolidated social network. Leh respondents felt less prepared to deal with climate change impacts and were more dependent on government assistance in the case of severe future climatic events.



**Figure 3.** Shared responsibilities within the community of Domkhar, such as food production, strengthen social cohesion.

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 fundamental concept of vulnerability and associated processes of adaptation. In particular, determining which groups of people are better equipped to respond to climate change must be evaluated in the context of social capital, such as strong attachments to community and place and social cohesion. While conventionally overlooked in the climate change literature, expanding definitions of social vulnerability to consider concepts of locality, place attachment, and community awareness are of value because it underscores the importance of social resilience in responding to climate change at the local level. Heightened connections to a particular location and profound sense of belonging to a community can subsequently facilitate solidarity among community members and not only increase recognition of environmental changes but motivate social action and political will to respond to these changes.

## 5. Conclusions

Climate change in the two sites studied in this research was widely perceived but seen as only one of many issues confronting communities. In Leh and Domkhar, less than half of the respondents indicated that climate change was a somewhat or important issue. In Leh, 81.9% of respondents felt either neutral about climate change or thought it was not an important issue with respect to other issues, such as outmigration that took precedence over climate change. Even so, climate change impacts were reported in both study sites by 80% of the respondents and these include receding

glaciers, altered precipitation patterns, and a change in the timing of the seasons. An overall decrease in water availability was also reported across both study sites (78% in Leh and 42% in Domkhar) however, local conditions played a significant role in the severity of perceived impacts with 31.9% of Domkhar residents perceiving climate change to have negative impacts while 84.3% of Leh residents perceived climate change to have negative impacts. A decline in water availability was more strongly felt in Leh where there was also more concern for the negative impact on communities from climate change. The difference in levels of concern for the negative impact on communities from climate change reflects differences in perceived adaptive capacity between the rural and urban sites studied in this research (47.3% in Domkhar and 34.9% in Leh felt their communities had the capacity to effectively adapt). Urban communities are less self-reliant and the social structures are less robust than in rural communities. Therefore, urban communities perceive themselves to have less adaptive capacity than do rural communities. In rural communities where villagers had strong familial ties and social cohesion was high, perceptions of climate change risk were moderated due to heightened levels of confidence within the community. In this way, a strong sense of place bolstered resilience and reduced social vulnerability, despite a high level of exposure to physical risks and impacts.

In developing regional policies for climate change that will enhance community resilience, we suggest the following be taken into consideration. Climate change is one of many issues being faced by communities. Measures that seek to only address climate change without addressing issues such as outmigration, joblessness, and changing demographics are far likely to have successful outcomes. We suggest that climate change adaptation policies be formulated to address the multiple issues facing communities and be based on an understanding of local socio-economic conditions and vulnerabilities. It is also important that variability at a local scale be taken into account in developing adaptation measures. In that way, adaptation measures can align with local conditions, resources, and needs. Finally, building community cohesiveness can build adaptive capacity. Results from this study show communities that have strong social bonds are more confident in their ability to deal with hazards and adapt to climate change impacts going forward. This was particularly evident in the rural communities and could be a valuable component for urban areas to integrate into climate change adaptation efforts.

Self-reliance, connections to place, social cohesion, and sense of community are therefore valuable themes in shaping societal frameworks on climate change response and should be incorporated into expanded understandings of vulnerability and related adaptation efforts. Otherwise, well-intentioned interventions by national or global level institutions have the potential to lead to maladaptation. Understanding factors at the local scale such as social capital, place attachment, and access to resources that enhance adaptive capacity will reduce the likelihood of government or non-governmental organization interventions leading to maladaptation.

**Acknowledgments:** This research was supported by the University of Montana College of Forestry and Conservation, Missoula, Montana.

**Author Contributions:** Kimiko Barrett proposed the research, conducted field work, lead analysis, and drafted the original manuscript. Keith Bosak supervised the overall research project and significantly contributed to the editing of the manuscript.

**Conflicts of Interest:** The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

## References

1. Beniston, M. Climatic Change in Mountain Regions: A Review of Possible Impacts. *Clim. Chang.* **2003**, *59*, 5–31. [[CrossRef](#)]
2. Bajracharya, S.; Mool, P.; Shrestha, B. *Impact of Climate Change on Himalayan Glaciers and Glacial Lakes: Case Studies on GLOF and Associated Hazards in Nepal and Bhutan*; International Center for Integrated Mountain Development: Kathmandu, Nepal, 2007.



3. Eriksson, M.; Xu, J.; Shrestha, A.; Sandström, K. *The Changing Himalayas-Impact of Climate Change on Water Resources and Livelihoods in the Greater Himalaya*; Special Report; International Centre for Integrated Mountain Development: Kathmandu, Nepal, 2009.
4. Intergovernmental Panel on Climate Change (IPCC). Technical summary for policymakers. In *Climate Change 2014: Impacts, Adaptation, and Vulnerability*; Part A: Global and Sectoral Aspects; Contributions of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change; Field, C., Barros, V., Dokken, D., Mach, K., Mastrandrea, M., Bilir, T., Chatterjee, M., Ebi, K., Estrada, Y., Genova, R., et al., Eds.; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2014.
5. Eakin, H.; Luers, A. Assessing the Vulnerability of Social-Environmental Systems. *Annu. Rev. Environ. Res.* **2008**, *31*, 365–394. [[CrossRef](#)]
6. Lemos, M.C.; Agrawal, A.; Eakin, H.; Nelson, N.; Engle, L.; Owens, J. Building adaptive capacity to climate change in less developed countries. In *Climate Science for Serving Society: Research, Modeling and Prediction Priorities*; Asrar, G., Hurrell, J., Eds.; Springer: New York, NY, USA, 2013.
7. Morton, J. The Impact of Climate Change on Smallholder and Subsistence Agriculture. *Proc. Natl. Acad. Sci. USA* **2007**, *104*, 19680–19685. [[CrossRef](#)] [[PubMed](#)]
8. Altieri, M.; Koohafkan, P. *Enduring Farms: Climate Change, Smallholders and Traditional Farming Communities*; Environment & Development Series 6; Third World Network: Penang, Malaysia, 2008.
9. Adger, N.; Lorenzoni, I.; O'Brien, K. *Adapting to Climate Change: Thresholds, Values, Governance*; Cambridge University Press: Cambridge, UK, 2009.
10. Tschakert, P.; Dietrich, K. Anticipatory learning for climate change adaptation and resilience. *Ecol. Soc.* **2010**, *15*, 11. [[CrossRef](#)]
11. Hofferth, S.; Iceland, J. Social capital in rural and urban communities. *Rural Soc.* **1998**, *63*, 574–598. [[CrossRef](#)]
12. Soini, K.; Vaarala, H.; Pouta, E. Residents' sense of place and landscape perceptions at the rural-urban interface. *Landsc. Urban Plan.* **2012**, *104*, 124–134. [[CrossRef](#)]
13. O'Brien, K.; Leichenko, R. Winners and losers in the context of global change. *Ann. Assoc. Am. Geogr.* **2003**, *93*, 89–103. [[CrossRef](#)]
14. Caney, S. Climate change, human rights, and moral thresholds. In *Human Rights and Climate Change*; Humphreys, S., Ed.; Cambridge University Press: Cambridge, UK, 2010.
15. Brooks, N.; Adger, N.; Kelly, M. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Glob. Environ. Chang.* **2005**, *15*, 151–163. [[CrossRef](#)]
16. Gallopin, G. Linkages between vulnerability, resilience, and adaptive capacity. *Glob. Environ. Chang.* **2006**, *16*, 293–303. [[CrossRef](#)]
17. Smit, B.; Wandel, J. Adaptation, adaptive capacity and vulnerability. *Glob. Environ. Chang.* **2006**, *16*, 282–292. [[CrossRef](#)]
18. Gardiner, S.; Caney, S.; Jamieson, D.; Shue, H. *Climate Ethics: Essential Readings*; Oxford University Press: Oxford, UK, 2010.
19. Shaw, R.; Pulhin, J.; Pereira, J. Climate change adaptation and disaster risk reduction: Overview of issues and challenges. In *Climate Change Adaptation and Disaster Risk Reduction: Issues and Challenges*; Emerald Group Publishing: Bingley, UK, 2010.
20. Cutter, S. *Hazards, Vulnerability and Environmental Justice*; Earthscan: London, UK, 2006.
21. Wisner, B.; Blaikie, P.; Cannon, T. *At Risk: Natural Hazards, People's Vulnerability and Disasters*, 2nd ed.; Routledge: London, UK, 2004.
22. Wilbanks, T.; Kates, R. Beyond adapting to climate change: Embedding adaptation in responses to multiple threats. *Ann. Assoc. Am. Geogr.* **2010**, *100*, 719–728. [[CrossRef](#)]
23. Helmer, M.; Hilhorst, D. Natural disasters and climate change. *Disasters* **2006**, *30*, 1–4. [[CrossRef](#)] [[PubMed](#)]
24. Leary, N.; Adequwon, J.; Barros, V.; Burton, I.; Kulkarni, J.; Lasco, R. *Climate Change and Adaptation*; Earthscan: London, UK, 2008.
25. Twomlow, S.; Mugabe, F.T.; Mwale, M.; Howden, S. Building adaptive capacity to cope with increasing vulnerability due to climatic change in Africa—A new approach. *Phys. Chem. Earth* **2008**, *33*, 780–787. [[CrossRef](#)]
26. Goulden, M.; Naess, L.; Vincent, K.; Adger, N. Accessing diversification, networks and traditional resource management as adaptations to climate extremes. In *Adapting to Climate Thresholds, Values, Governance*; Cambridge University Press: Cambridge, UK, 2009.

27. Paavola, J. Science and social justice in the governance of adaptation to climate change. *Environ. Politics* **2008**, *17*, 644–659. [[CrossRef](#)]
28. Pelling, M. *Adaptation to Climate Change: From Resilience to Transformation*; Routledge: New York, NY, USA, 2011.
29. Folke, C. Resilience: The emergence of a perspective for social-ecological systems analyses. *Glob. Environ. Chang.* **2006**, *16*, 253–267. [[CrossRef](#)]
30. Brooks, N. *Vulnerability, Risk and Adaptation: A Conceptual Framework*; Tyndall Centre for Climate Change Research Working Paper 38; University of East Anglia: Norwich, UK, 2003.
31. Adger, N. Vulnerability. *Glob. Environ. Chang.* **2006**, *16*, 268–281. [[CrossRef](#)]
32. Adger, N.; Kelly, M. Social vulnerability to climate change and the architecture of entitlements. *Mitig. Adapt. Strateg. Glob. Chang.* **1999**, *4*, 253–256. [[CrossRef](#)]
33. Sen, A. *Resources, Values and Development*; Basil Blackwell: Oxford, UK, 1984.
34. Jodha, N. Adaptation strategies against growing environmental and social vulnerabilities in mountain areas. *Himal. J. Sci.* **2005**, *3*, 33–42. [[CrossRef](#)]
35. Igor, K. Attachment and identity as related to a place and its perceived climate. *J. Environ. Psychol.* **2005**, *25*, 207–218.
36. Scannell, L.; Gifford, R. Personally relevant climate change: The role of place attachment and local versus global message framing in engagement. *Environ. Behav.* **2013**, *45*, 60–85. [[CrossRef](#)]
37. Mishra, S.; Mazumdar, S.; Suar, D. Place attachment and flood preparedness. *J. Environ. Psychol.* **2010**, *20*, 187–197. [[CrossRef](#)]
38. Adger, N.; Barnett, J.; Brown, K.; Marshall, N.; O'Brien, K. Cultural dimensions of climate change impacts and adaptation. *Nat. Clim. Chang.* **2012**, *3*, 112–117. [[CrossRef](#)]
39. O'Brien, K.; Leichenko, R.; Kelkar, U.; Venema, H.; Aandahl, G.; Tompkins, H.; Javed, A.; Bhadwal, S.; Barg, S.; Nygaard, L.; et al. Mapping vulnerability to multiple stressors: Climate change and globalization in India. *Glob. Environ. Chang.* **2004**, *14*, 303–313. [[CrossRef](#)]
40. Brody, S.; Zahran, S.; Vedlitz, A.; Grover, H. Between physical vulnerability and perceptions of global climate change in the United States. *Environ. Behav.* **2008**, *40*, 72–95. [[CrossRef](#)]
41. The Registrar General and Census Commissioner. *Census of India Population Enumeration Data*; Census Abstract: State of Jammu & Kashmir, Leh District; Government of India: New Delhi, India, 2011.
42. Zurick, D.; Pacheco, J. *Illustrated Atlas of the Himalaya*; University Press of Kentucky: Lexington, KY, USA, 2006.
43. Brower, B.; Johnston, B. *Disappearing Peoples? Indigenous Groups and Ethnic Minorities in South and Central Asia*; Left Coast Press: Walnut Creek, CA, USA, 2007.
44. Liu, X.; Chen, B. Climatic warming in the Tibetan Plateau during recent decades. *Int. J. Clim.* **2000**, *20*, 1729–1742. [[CrossRef](#)]
45. Intergovernmental Panel on Climate Change (IPCC). *Intergovernmental Panel on Climate Change (IPCC) Climate Change 2013: The Physical Science Basis*; Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change; Stocker, T.F., Qin, G.-K., Plattner, M., Tignor, M., Allen, S., Boschung, J., Nauels, A., Xia, Y., Bex, V., Midgley, P., Eds.; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2013.
46. Eriksson, M.; Fang, J.; Dekens, J. *How Does Climate Change Affect Human Health in the Hindu-Kush-Himalaya Region? Regional Health Forum*; International Centre for Integrated Mountain Development: Kathmandu, Nepal, 2008.
47. Xu, J.; Grumbine, R.; Shrestha, A.; Eriksson, M.; Yang, X.; Wang, Y.; Wilkes, A. The melting Himalayas: Cascading effects of climate change on water, biodiversity, and livelihoods. *Conserv. Biol.* **2009**, *23*, 520–530. [[CrossRef](#)] [[PubMed](#)]
48. Bhutiyani, M.; Kale, V.; Pawar, N. Climate change and the precipitation variations in the northwestern Himalaya: 1866–2006. *Int. J. Clim.* **2009**, *30*, 535–548. [[CrossRef](#)]
49. Shrestha, A.; Aryal, R. Climate change in Nepal and its impact on Himalayan glaciers. *Reg. Environ. Chang.* **2011**, *11*, 65–77. [[CrossRef](#)]
50. Salinger, M.J.; Shrestha, M.L.; Dong, W.; McGregor, J.; Wang, S. Climate in Asia and the Pacific: Climate variability and change. In *Climate in Asia and the Pacific*; Manton, M., Stevenson, L., Eds.; Springer: Dordrecht, The Netherlands, 2014.

51. Xu, J.; Grumbine, E. Building ecosystem resilience for climate change adaptation in the Asian highlands. *Clim. Chang.* **2014**, *5*, 709–718. [CrossRef]
52. Dyurgerov, M.; Meier, M. *Glaciers and the Changing Earth System: A 2004 Snapshot*; Occasional Paper No. 58; Institute of Arctic and Alpine Research; University of Boulder: Boulder, CO, USA, 2005.
53. Immerzeel, W.; van Beek, L.; Bierkens, M. Climate change will affect the Asian water towers. *Science* **2010**, *328*, 1382–1385. [CrossRef] [PubMed]
54. Nepal, S.; Shrestha, A.B. Impact of climate change on the hydrological regime of the Indus, Ganges and Brahmaputra river basins: A review of the literature. *Int. J. Water Res. Dev.* **2015**, *31*, 201–218. [CrossRef]
55. Groupe Energies Renouvelables; Environment et Solidarités (GERES). Impacts of climate change in Ladakh, Lahaul, and Spiti of the Western Himalayan Region. In Proceedings of the International Seminar on Energy and Climate Change in Cold Regions, Leh, Ladakh, India, 21–24 April 2009.
56. Gautam, P. Climate change and environmental degradation in Tibet: Implications for environmental security in South Asia. *Strateg. Anal.* **2009**, *34*, 744–755. [CrossRef]
57. Vince, G. A Himalayan Village Builds Artificial Glaciers to Survive Global Warming. *Scientific American*. 2010. Available online: <https://www.scientificamerican.com/article/artificial-glaciers-to-survive-global-warming/> (accessed on 15 June 2010).
58. Archer, D.; Fowler, H. Spatial and temporal variations in precipitation in the Upper Indus Basin, global teleconnections and hydrological implications. *Hydrol. Earth Syst. Sci.* **2008**, *8*, 47–61. [CrossRef]
59. Jeong, J.; Kim, B.; Ho, C.; Noh, Y.-H. Systematic Variation in Wintertime Precipitation in East Asia by MJO-Induced Extratropical Vertical Motion. *J. Clim.* **2008**, *21*, 788–801. [CrossRef]
60. Li, W.; Guo, W.; Hsu, P.; Xue, Y. Influence of the Madden-Julian oscillation in Tibetan Plateau snow cover at the intraseasonal time-scale. *Nat. Sci. Rep.* **2016**, *6*, 30456. [CrossRef] [PubMed]
61. Madhura, R.; Krishnan, R.; Revadekar, J.; Mujumdar, M.; Goswami, B.N. Changes in western disturbances over the Western Himalayas in a warming environment. *Clim. Dyn.* **2015**, *44*, 1157–1168. [CrossRef]
62. Creswell, J. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, 2nd ed.; Sage Publications: Thousand Oaks, CA, USA, 2003.
63. Fricke, T. Talking About the Household: A Tamang Case from North Central Nepal, Himalaya. *J. Assoc. Nepal Himal. Stud.* **1984**, *4*. Available online: <http://digitalcommons.macalester.edu/cgi/viewcontent.cgi?article=1075&context=himalaya> (accessed on 15 September 2014).
64. Norberg-Hodge, H. *Ancient Futures: Learning from Ladakh*; Sierra Club Books: San Francisco, CA, USA, 1984.
65. Agergaard, J. The household as a unit of analysis: Reflections from migration research in Nepal. *Geogr. Tidsskrift* **1999**, *99*, 101–111. [CrossRef]
66. Alessa, L.; Kliskey, A.; Brown, G. Social-ecological hotspots mapping: A spatial approach for identifying coupled social-ecological space. *Landsc. Urban Plan.* **2008**, *85*, 27–39. [CrossRef]
67. Sherrouse, B.; Clement, J.; Semmens, D. A GIS application for assessing, mapping, and quantifying the social values of ecosystem services. *Appl. Geogr.* **2011**, *31*, 748–760. [CrossRef]
68. Adger, N.; Barnett, J.; Chapin, F.; Ellemor, H. This must be the place: Underrepresentation of identity and meaning in climate change decision-making. *Glob. Environ. Politics* **2011**, *11*, 1–25. [CrossRef]
69. Ireland, P.; Nepalgan, J. The centre of the world: Local perceptions of environmental change and the roles of climate-change adaptation actors. *Local Environ. Int. J. Justice Sustain.* **2012**, *17*, 187–201. [CrossRef]
70. Vedwan, N.; Rhoades, R. Climate change in the western Himalayas of India: A study of local perception and response. *Clim. Res.* **2001**, *19*, 109–117. [CrossRef]
71. Akhtar, A. Tourism and Water Resources in Leh Town, Northwest, India: Analysis from a Political Ecology Perspective. Master's Thesis, Ruprecht-Karls-University of Heidelberg, Heidelberg, Germany, 2010.
72. Chess, C.; Johnson, B. Information is not enough. In *Creating a Climate for Change: Communicating Climate Change and Facilitating Social Change*; Moser, S.C., Dilling, L., Eds.; Cambridge University Press: New York, NY, USA, 2007.
73. Leiserowitz, A. Communicating the risks of global warming: American risk perceptions, affective images, and interpretive communities. In *Creating a Climate for Change: Communicating Climate Change and Facilitating Social Change*; Moser, S.C., Dilling, L., Eds.; Cambridge University Press: New York, NY, USA, 2007.
74. Myers, T.; Maibach, E.; Roser-Renouf, C.; Akerlof, K.; Leiserowitz, A. The relationship between personal experience and belief in the reality of global warming. *Nat. Clim. Chang.* **2012**, *3*, 343–347. [CrossRef]

75. Leiserowitz, A. Climate change risk perception and policy preferences: The role of affect, imagery, and values. *Clim. Chang.* **2006**, *77*, 45–72. [[CrossRef](#)]
76. Roser-Renouf, C.; Maibach, E.; Leiserowitz, A.; Zhao, X. The genesis of climate change activism: From key beliefs to political advocacy. In Proceedings of the International Communication Association Annual Conference, Boston, MA, USA, 26–30 May 2011.
77. Mirani, H. Ladakh's Giant Leap in Renewable Energy. *Kashmir News. Srinagar*. 5 September 2013. Available online: <http://www.kashmirnewz.com/f000121.html> (accessed on 24 June 2014).
78. Shrager, H. Ice Man vs. Global Warming. *Time Magazine*. 25 February 2008. Available online: <http://content.time.com/time/world/article/0,8599,1717149,00.html> (accessed on 15 August 2010).



© 2018 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).