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ORIGINAL ARTICLE

Climatic and environmental change in the Karakoram: making sense of community perceptions and adaptation strategies

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Abstract In this paper, we investigate how mountain communities perceive and adapt to climatic and environmental change. Primary data were collected at community and household level through in-depth interviews, focus group discussions, and quantitative questionnaires covering 210 households in six villages of the West Karakoram (Hundur and Darkut in the Yasin Valley; Hussainabad, Altit, Gulmit, and Shiskat in the Hunza valley of Gilgit-Baltistan). The relevance of the area with respect to our scopes is manifold. First, this is one of the most extreme and remote mountainous areas of the world, characterized by complex and fragile institutional and social fabrics. Second, this region is one of the focal points of research for the hydro-meteo-climatological scientific community, because of its relevance in terms of storage and variability of water resources for the whole Indus basin, and for the presence of conflicting signals of climate change with respect to the neighboring regions. Third, the extreme hardships due to a changing environment, as well as to the volatility of the social and economic conditions are putting great stress on the local population. As isolating climate change as a single driver is often not possible, community perceptions of change are analyzed in the livelihood context and confronted with multi-drivers scenarios affecting the lives of mountain people. We compare the collected perceptions with the available hydro-climatological data, trying to answer some key questions such as: how are communities perceiving, coping with, and adapting to climatic and environmental change? Which are the most resorted adaptation strategies? How is their perception of change influencing the decision to undertake certain adaptive measures?

Keywords Climate change · Perception · Indus · Karakoram · Adaptation

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Introduction

The permanently ice-covered portion of the Hindu-Kush-Himalaya region (HKH) covers about 37.000 km^2 (Raup et al., 2000), and its glaciers are feeding ten of the largest rivers in Asia, including the Indus, in whose basin about 193 million people find their livelihood. Pakistan accounts for 72 % of the population; India for 23 %; the Afghani part of the basin accounts for 5 % of the total population on the Indus basin, while the Chinese sector is very sparsely inhabited (Laghari et al. 2011). There is general support to the idea that climate change will strongly affect the HKH region, which has been identified as one of the most crucial and challenging areas when it comes to future climate change impacts (IPCC 2007), for both mountain people and for the million of users living downstream. Nonetheless, a large uncertainty prevails over the nature and magnitude of climate variations and related impacts at the local scale.

The observed climate trends in the second half of the XX century in the Upper Region of the Upper Indus Basin (UR-UIB) (Fig. 1) are anomalous with respect to the neighboring mountain areas, which are facing intense temperature increases and fast retreat of glaciers (Scherler et al. 2011). In contrast, the UR-UIB is experiencing since

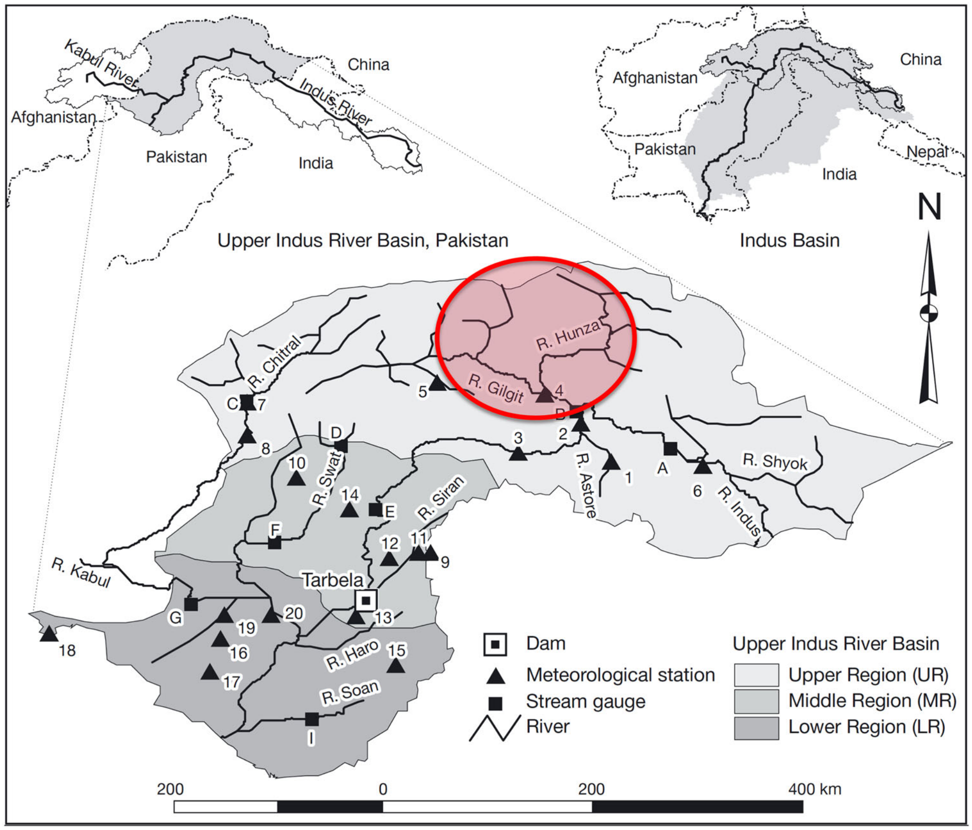

Fig. 1 The Upper Indus Basin and study area indicated by the ellipses. Adapted from Khattak et al. (2011)

decades cooling trends in the summer season, weak trends of annual temperature, and increasing or stable precipitations throughout the year (Archer and Fowler 2004; Fowler and Archer 2006), accompanied by mass gains in the glaciers of the region (Bolch et al. 2012) and by decrease in the summer discharge of rivers (Khattak et al. 2011).

The changes in the glacial regimes of the UR-UIB are of extreme relevance, as the relative contribution of snow and ice melt to the Indus flows is the largest among the nine major rivers of South Asia originating from the HKH region. Specifically, the Indus receives 85 % of the annual flows from snow and ice melt (Archer and Fowler 2004) so that seasonal water availability is likely to be affected substantially by climate change in the near future (Archer et al. 2010; Immerzeel et al. 2010; Bolch et al. 2012).

State-of-the-art global climate models (GCMs) are not able to reproduce accurately the anomalous historical climate change in the UIB. Observational data are scarce due the remoteness and political isolation of the region,[1] and limited to some hydro-meteorological stations, in an area where the presence of extreme topographical features implies a strong inhomogeneity in the climatology, and, potentially, in its trends. Therefore, any information allowing to complement climate trends derived from stations data is precious for reconstructing local climate features at the level of valleys.

Even more importantly, integrating "views form the vulnerable" (Tschakert 2007) proves crucial in making sense of how communities perceive risks and of how such perceptions influence the decision-making process leading to the adoption of certain adaptation strategies or coping mechanisms rather than others. Perceptions of climatic and environmental change are widely recognized as a *sine qua non* for adaptation (Roncoli et al. 2002; Vogel and O'Brien 2006; Thomas et al. 2007; Tschakert 2007; Silvestri et al. 2012). In order to be able to *adapt* to climatic and environmental change, farmers first need to *perceive* the change and hence identify strategies that can potentially mitigate the risk they are exposed to.

Vulnerability to climate change refers to the susceptibility of socio-ecological systems to the adverse impacts of climate change. Vulnerability is multi-layered and multifaceted, and it is influenced by physical, socio-economic factors (e.g., resources distribution, development path) and political factors (e.g., governance and institutional capacity) that negatively affect communities' ability to respond to adverse impacts of climatic and environmental change (Adger 2006; Smit and Wandel 2006). The poverty-stricken communities inhabiting

[1] The study area is part of the Kashmir stalemate and is included in the Indian claims over the region. Since August 2009 the former Northern Areas of Pakistan gained self-rule and obtained a self-elected "Gilgit-Baltistan Legislative Assembly". Yet, the province still enjoys only a non-constitutional status within the country and has a peripheral role in the country's economic and political life, resulting in a lack of proper governance, as well as in difficulties for researchers to access data on the region, that is typically not included in official statistics.

the Karakoram are highly vulnerable as they largely depend on natural resources and ecosystem services for their livelihood sustainability and security and have a very low and risk-prone natural production potential. Moreover, entrenched inequalities at the intersection of gender, class, ethnic/religious affiliation, and political marginalization coupled with rising sectarian violence in the region (Bansal 2008) further lower their adaptive capacity, understood as "an active set of strategies and actions taken in reaction to or in anticipation of climate change by people in order to enhance or maintain their well-being" (Goulden et al. 2013).

Climate change and variability along with extreme events impact resource-dependent societies, affecting both assets and livelihoods. Yet, in most rural communities, climate is only one among many socio-environmental drivers of change influencing the choice of certain coping and adaptation strategies (Campbell and Olson 1991; Adger 1999; Thomas and Twyman 2005; Smit and Wandel 2006; Mertz et al. 2009; Tambo and Abdoulaye 2013). Livelihoods are influenced by a number of drivers ranging form environmental stresses and shocks to socioeconomic and political set ups at the local level, which are influenced and transformed by global dynamics and processes such as globalization and climatic and environmental change. Consequently, adaptation strategies are rarely the sole outcome of changes in the climate patterns. Any reductionist understanding of adaptation is misleading and fails to capture the complex response, which is an outcome of multiple variables. As put by Meze-Hausken (2008, p. 3000), ''the driver of the response is the evolution or variation in socio-economic conditions that determine whether a specified climate change is experienced as acceptable or problematic''.

The present study examines the climate change context faced by the marginalized mountain communities of the West Karakoram in the Gilgit-Baltistan Province of Pakistan (see Fig. 1), comparing the local perceptions with the available hydro-meteorological data and analyzing to which extent these perceptions have a role in shaping their adaptive responses to a changing environment.

The next section outlines the major features of climate change in the UR-UIB. We then describe the study areas, the field methods used and data collected. Local perceptions of climate change are presented and contrasted with the historical data. Subsequently, we discuss the livelihood strategies adopted by the surveyed communities in response to the perceived climatic and environmental change, and we present the major coping mechanisms and adaptation strategies adopted by the local communities.

Climate change in the upper Indus River Basin

Climate change in the UR-UIB has been studied by Archer and Fowler (2004) and Fowler and Archer (2006) and later by Khattak et al. (2011) and Bocchiola and Diolaiuti (2012). Two main facts emerge from these investigations, which have dealt with the collection and analysis of rain gauges, temperature, and streamflow water gauge data in the area. First, despite the unprecedented warming observed worldwide, as well as in the Eastern Himalayas, about half of the observational record in the UR-UIB shows since the 1960s a cooling tendency of mean annual and seasonal temperatures, except for the winter season (Fowler and Archer 2006). Moreover, Fowler and Archer (2006) found an increase in diurnal temperature range over all the seasons, which reflects into an overall decrease in minimum and increase in maximum temperatures on an annual basis, and a clear decrease in the seasonal cycle of surface temperature, with strong summer cooling accompanying a slight winter warming (see Table 1). Between 1961 and 1999, Gilgit received on the average very little precipitation, with a reported annual mean of about 130 mm. Nonetheless, in the last 40 years of the XX century, there has been a remarkable 10 % decadal increase in the annual precipitation (Archer and Fowler 2004). The climate change signal has been especially pronounced in spring and summer, but the trend is positive for all the seasons (see Table 2). Increases in winter precipitations and decreases in summer temperatures are reported also in a recent analysis (including data up to 2010) by Bocchiola and Diolaiuti (2012), who also clarified, through statistical techniques, that the Gilgit station trends are representative for the climate signal of the hydro-meteorological stations of the UR-UIB. The understanding of the climatic processes behind the peculiar behavior of the temperatures in the UR-UIB is still limited, as climate models are not currently able to reproduce the observed historical trends. GCMs simulate an even higher temperature increase in the UIB for the latter part of the XX century, as compared to the surrounding lowland areas. However, for precipitation, both

Table 1 Temperature trends 1961–1999, Gilgit station

T trend (°C/10 years)	Annual	DJF	MAM	JJA	SON
Daily mean	−0.13	+0.17	−0.08	−0.38	−0.15
Daily MAX	+0.20	+0.27	+0.16	−0.01	+0.35
Daily MIN	−0.45	+0.02	−0.32	−0.75	−0.62

Source Fowler and Archer 2006)

Table 2 Precipitation climatology for 1961–1999, Gilgit station

P average (mm)	Annual	JFM	AMJ	JAS	OND
Mean	131	25	55	37	14
P trends (%/10 years)	Annual	JFM	AMJ	JAS	OND
Mean	+10	+1	+9	+5	+11

Source Archer and Fowler 2004)

observational records and GCMs are in agreement and suggest increase in precipitation over the UIB in the second half of the XX century (Archer and Fowler 2006).

The presence of decreasing temperatures in three out of four seasons and of strong increases in autumn and winter precipitations suggest the possibility of a positive contribution to the mass balance of glaciers. As opposed to the global and regional trend (IPCC 2007), the Karakoram glaciers are mostly stagnant or expanding. In particular, Scherler et al. (2011) found that half of the studied glaciers in the Karakoram region are stable or even advancing, whereas about two-thirds are in retreat elsewhere in the Western, Central, and Eastern Himalaya. These results have been recently confirmed (Bolch et al. 2012).

The above-reported climatic trends are related to the observed decreasing trend of summer river runoff in Gilgit (Archer and Fowler 2004; Khattak et al. 2011). The physical mechanisms behind this can be described following Khattak et al. (2011). A strong positive correlation exists between local summer temperature anomalies and anomalies in the summer streamflow of the Gilgit River. This is due to the fact that higher temperatures allow for more extensive melting of the glaciers. A negative correlation is found between the anomalies in the streamflow and precipitation anomalies. Despite seeming counterintuitive, this correlation results from the following dominating effect: more precipitation during the summer comes together with more cloud cover, which hinders the melting of ice by reducing direct insolation. Insolation and temperatures anomalies are hence the main drivers of the summer streamflow. These results have been also confirmed by Sharif et al. (2013). Analogous findings are reported also for the Hunza river (Fowler and Archer 2006) and are supported by a recent study, which looks at snow cover (Hasson et al. 2013a, b).

It is reasonable to relate the peculiar climate signal of the UIB to the fact that the UIB is located in a very special climatic region, at the boundary between the areas of influence of the South Asian monsoon and of the mid-latitude extra-tropical cyclones. During winter and spring, the UIB hydrology is dominated by the (mostly solid) precipitation due to extra-tropical disturbances located in the southern flank of the eastmost sector of the Atlantic/Mediterranean storm track (Bengtsson et al. 2007), while the rest of the precipitation is due to the summer monsoon system (Rees and Collins 2006).

Methods

Study area

This paper is based on primary data collected in May and June 2012 in the Karakoram region of Pakistan as part of the larger project Gender and Environmentally-induced Migration (GEM). The project is divided into three main components aimed at collecting the local perceptions of change in climate patterns and natural hazards; gathering information of the impacts of climate change and variability on the household's productivity and livelihood security and on the main adaptation strategies, and analyzing the role of migration in the context of environmental change and its gendered impacts. This paper will largely focus on the first two points. Gender analysis is beyond the scope of the present study and has been reported elsewhere (Gioli et al. 2013).

The Hunza and the Yasin Valleys of Gilgit-Baltistan were selected through consultative meetings with native key informants and local NGOs. The criteria for purposive selection were the socio-ecologic comparability of communities located on a tributary river of the Indus and recently affected by a major environmental hazard, with a high incidence of labor migration (See Table 3 for a profile of the study area and Table 4 for some details on the surveyed villages). For logistical and security reasons, it has been impossible to visit other neighboring areas matching our criteria, like Skardu or Astore.

Both the Yasin and the Hunza Valley present a high rate of labor migration, combined with partial reliance on subsistence agriculture. The Yasin valley was severely impacted by the 2010 flood, while the Hunza valley, less affected by the flood, suffers from recurrent landslides. In particular, in 2010, a massive landslide occurred on the Hunza River in the Gojal area, thus originating the clogged lake known as Attabad Lake (see Schneider et al. 2011). The lake has submerged houses, agricultural land and infrastructures, including part of the vital Karakoram Highway.

The altitude of the selected villages ranges between 1,800 and 2,700 m. Hunza and Yasin share unique agro-ecological features characterized by an extreme environment and an arid climate, where agricultural production is made possible by the high incidence of radiation in the UR-UIB (Cradock-Henry 2002), and by a complex indigenous irrigation system relying on meltwater. Such meltwater is channeled to the limited available flat areas at the bottom of the valleys, forming the characteristic "irrigation oases," which cover less than 1 % of the Karakoram region (Kreutzmann 1998, 2000, 2011; Stöber 2000).

The vast majority of the population owns small pieces of land transmitted from generation to generation along patriarchal lines, while most of the grazing areas are communal and assigned to different villages according to the customary laws of Gilgit-Baltistan.[2] Wheat is the main

[2] A comprehensive account of the Customary Laws of Gilgit-Baltistan can be found at: http://iucn.org/about/union/secretariat/offices/asia/asia_where_work/pakistan/pk_elaws/na_laws/na_sub_laws/).

Table 3 Study area profile

Study area	Yasin and Hunza valleys
Survey overview	
Total population (inhabitants)	Ca. 105.000 (65.000 Hunza/ 45.000 Yasin)[a]
Altitude	1,800–2,700 m
Households in survey	210 (69 Yasin, 141 Hunza)
Average HH's size	9
Dependency ratio	0.4
Natural hazards	2010 flood/landslide causing the Attabad Lake
Own land (%)	85 % (Yasin)/95 %(Hunza)
Irrigated land	99 %
Average HH income per capita	16.000 PKR (120 Euros) in Y/34.000 PKR in H
Average property size	12 Kanal (−50 % in 5 years; 1 Kanal ≈ 0.05 Ha)
Gender-age-literacy	
Average age (respondent)	50
Female illiteracy (respondent)	58 %
Male illiteracy (respondent)	39 %
Female respondents (%)	57
Migration	
Migrant-sending households	76 % (Yasin 75 %; Hunza 77 %)
Sex of the migrant	99 % M
Age of the migrant (first migration)	20 in Yasin (SD: 5) and 27 in Hunza (SD: 7)
Age of the migrant (present)	25 in Yasin (SD: 8) and 33 in Hunza (SD: 10)
Migrant destination	97 % intra-national; 50 % intra-provincial; 2.6 % international

When not specified, data refer to both Yasin and Hunza Valleys

[a] Population Census Organisation 2000

Table 4 Summary of the qualitative and quantitative samples

Yasin valley (Ghizer district)	Lower-central Hunza	Upper Hunza
Hundur	Hussainabad	Gulmit
Lat: 36°36′45″, Long: 73°27′18″	Lat: 36°14′55″, Long: 74°23′39″	Lat: 36°23′17″, Long: 74°51′56″
40 questionnaires	46 questionnaires	35 questionnaires
2 FGDs	2 FGDs	7 qualitative interviews
8 qualitative interviews	7 qualitative interviews	
Darkut	Altit	Shishkat
Lat: 36°38′39″, Long: 73°26′28″	Lat: 36°19′5″, Long: 74°40′57″	Lat: 36°21′15″, Long: 74°51′59″
29 questionnaires	24 questionnaires	36 questionnaires
2 qualitative interviews	2 qualitative interviews	2 FGDs
	1 group discussion	5 qualitative interviews

The approximate coordinates of the surveyed villages are indicated

crop, heavily subsidized by the government since the official annexation of the princely state of Hunza and of Yasin to Pakistan in the late 1970s. Since the 1980s, various NGOs and in particular the Aga Khan Development Network (AKDN) and its Aga Khan Rural Support Program (AKRSP) have introduced cash crops such as potatoes and orchards (mostly almonds, apricots, grapes, and cherries), which have become a major source of income for the local people.

Growing population and environmental hazards have led also to a significant reduction in agricultural land and of the grazing pastures *per capita*. The lack of employment opportunities in situ has been further aggravated by the decline in international tourism due to the post-9/11 scenario and to rising sectarian violence (Khan 2012). The local communities are increasingly shifting from an agro-pastoral economy to a "combined subsistence-labor system" (Herbers 1998 and Ehlers and Kreutzmann 2000). The households have hence integrated the highly risk-prone mountain agriculture with external income-generating opportunities, such as labor migration, wage labor, and trade, facilitated also by pivotal infrastructural works, such as the opening of the Karakoram Highway in 1978.

Increased education rates have also contributed to increasing the share of people employed in governmental jobs and in the third sector (Malik and Piracha 2006). Yet, still almost every household cultivates land, rears cattle, sheep, goats and poultry on a small scale. Yasin is lagging behind Hunza in terms of economic improvement and development. However, the strategies, as well as the problems and the challenges faced by the two mountain communities, are analogous, and they have followed the same model of development (implemented by the AKRSP). Such parallel patterns are caught in our sample, and this is the reason why the data are disaggregated only in case of a significant divergence between the valleys.

Data description

A mix of quantitative and qualitative methods was employed for data collection. The quantitative sample has a size of 210 households (69 households in Yasin, 70 in lower-central Hunza, and 71 in upper Hunza—see Table 4). The sample has been stratified by gender, in order to reach a gender-balanced representation. 24–46 households were selected from each village, and this represents about 12 % of the estimated number of households per village. The sampled households represent smallholders with an average farm size of 0.6 ha, a large size comprising of about nine people per household and a dependency ratio of 0.4. The selected team comprised of six enumerators (4 males and 2 females), all local graduates from Gilgit-Baltistan, Burushaski and Wakhi native speakers (the two most widely used languages in the study area). The questionnaires were administered through face-to-face interviews with respondents.

As for the qualitative methods, we conducted 31 interviews with key informants and stakeholders from the communities (10 in Yasin and 21 in Hunza), and six gender disaggregated focus group discussions (FGDs) comprising of 8–10 people in three different villages (Hundur, Hussainabad, and Shiskat) to countercheck the information collected in the quantitative questionnaires.

Data obtained from the questionnaires and FGDs were analyzed using descriptive statistics and content analysis, respectively. The results of the data analysis and, namely, the adopted adaptation strategies, are discussed in the framework of the Sustainable Livelihood Approach that defines livelihood diversification as “the process by which (rural) households construct an increasingly diverse portfolio of activities and assets in order to survive and to improve their standard of living” (Ellis 2000, p. 14) and often consider livelihood diversification as having a positive impact on the household ability to face and endure climatic and environmental change (Kollmair and Gamper 2002; Tacoli 2009).

In the next sections the key findings on climate change perceptions are presented along with a critical analysis of the most resorted adaptation measures.

Results and discussion

Climate change and variability: local perceptions

In this section, we compare the local perceptions of change with the climate change observations for the UR-UIB outlined in section “Climate change in the upper Indus River Basin.” In the proposed questionnaire, local people were asked to provide their perceptions regarding the changes in climate conditions over the last 10 years, while the qualitative sample cover 20 years or more. The data reported discuss the trends of the last 50 years. Since the observed climatic trends are indeed long-lasting, and our goal is to seek qualitative agreements or disagreements between observed and perceived changes, we believe that our comparison is robust and meaningful.

Despite the topographical and geographical differences in the surveyed villages, we have found a remarkable agreement in the collected local perceptions on climate variability and climate-related risk. First the interviewees were asked whether they have heard or read about climate change and whether they could tell what climate change is. In Yasin, 80 % of the sample had not heard about climate change and 83 % declared to be unable to tell what climate change is. In Hunza the percentages are 49 and 66 %, respectively. The difference in the knowledge is largely due to the fact that in Hunza, after the Attabad disaster, a larger number of trainings have been held under the umbrella of the AKDN and of INGOs, tackling the issue of disaster preparedness in a changing climate. The lower literacy and education rates of Yasin might have also a role. Linguistic problems in conveying the correct message shall also be considered (see Tschakert 2007; Tambo and Abdoulaye 2013): in the local languages, there is no term corresponding to “climate,” but only to “weather.” An illiterate woman in Yasin referred to “global warming” (in English), when asked to explain what is climate change, yet she was not able to further elaborate on this. In order to avoid possible misunderstandings due to the adoption of abstract and unfamiliar terms, we have framed our questions by focusing on specific manifestations of climate and on the related natural hazards, and have asked the respondents to identify whether any changes appeared to have occurred over a range of different timescales.

Overwhelmingly, in both Hunza (94 %) and Yasin (86 %), people reported to have witnessed change in the last 10 years and wide agreement among the inhabitants of Hunza and Yasin was found also regarding the nature of the changes. The temperature patterns were clearly perceived as following a decreasing trend (Fig. 2) throughout the year. In particular, summers are perceived as significantly colder in both valleys (75 % in Yasin and 85 % in Hunza), and a large majority also reports a cooling trend for the cold season as well. This agrees remarkably well with what reported by Fowler and Archer (2006), especially considering that the “cold season,” for local people, is not solely restricted to the JFM months but relates to the traditional crop season of *rabi* (from November to April).

Looking at precipitations (Fig. 3), the local perceptions qualitatively agree with the results by Archer and Fowler (2004). The locals have witnessed an increase in the annual precipitation and specifically an increase is observed in summer. Interestingly, the increase in the annual rainfall is attributed to an increase in both the number of rainy days and of the average intensity of the single precipitation event. Rainfall is also reported to have been more erratic. It would be indeed interesting to check these qualitative observations against the hydro-meteorological data, since no information on the changes in the proportion of dry/wet days and in the timing of rain has been provided in the literature.

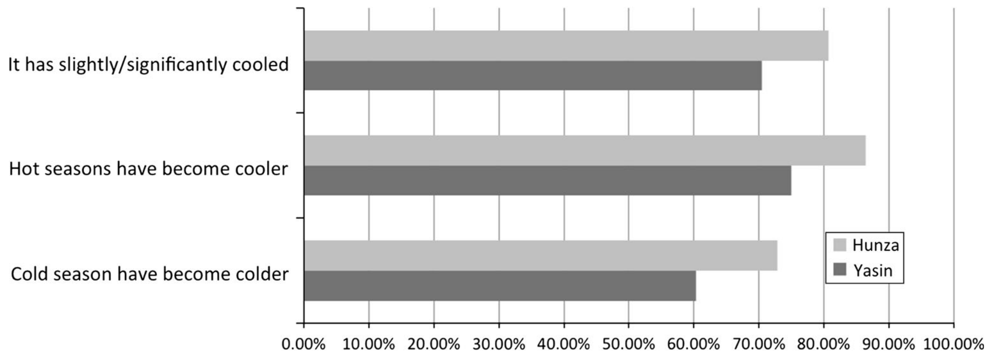

Fig. 2 Perceived changes in temperature patterns over the last 10 years

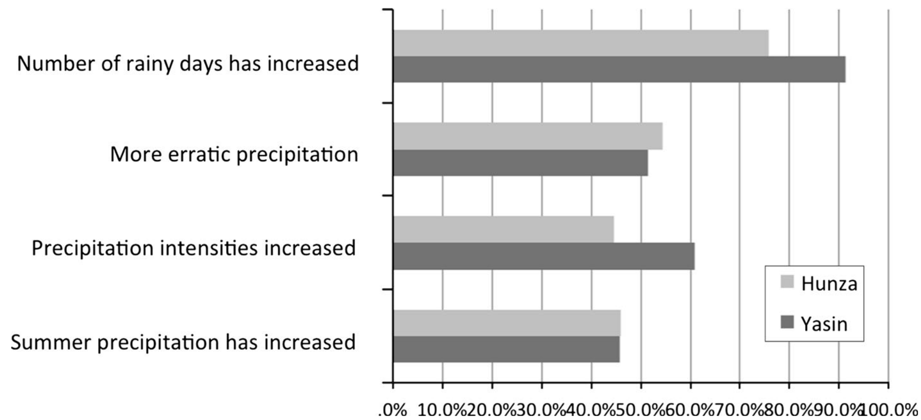

Fig. 3 Perceived changes in precipitation patterns over the last 10 years

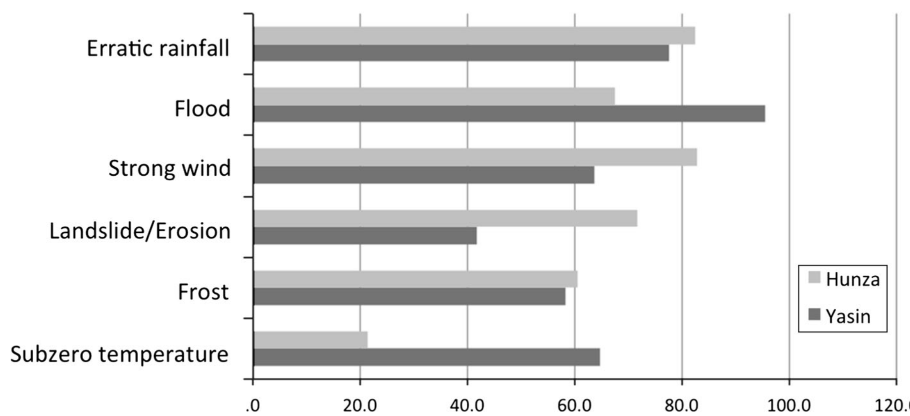

Fig. 4 Perceived changes in the frequency of hazards in the last 10 years

Additional information on the perception of climate change can be gathered from looking at the perceived increase in environmental hazards (Fig. 4). In both valleys, locals report an increase in subzero temperatures and frost; this matches reasonably well with the data reported in Fowler and Archer (2006), who suggest a slight increase in the daily minimum winter temperatures, and a large decrease in the daily minimum temperatures in spring and autumn, which can include subzero days.

Floods and landslides are perceived as increasingly recurrent threats to the local communities. These perceptions are in agreement with the measured increases in annual rainfall, and are consistent with the perception of increased intensity of the rainfall events. In relating the perception of environmental hazards to climate change, one should exert some caution. It should be noted that very likely the local population refers to specific major events (in Yasin the 2010 flood; in Hunza, the landslide originating the Attabad Lake), which cannot be univocally attributed to climate change, but rather describe a generally increased risk. It should also be considered that the occurrence of such natural hazards can be exacerbated through the combined effects of actual climatic processes and of detrimental changes in land usage, such as extensive deforestation, which is a widespread problem all over Gilgit-Baltistan (Schickhoff 2006). Both Hunza and Yasin rely almost entirely (94 %) on fuelwood to meet their energy needs for heating and cooking, and the depletion of their forest resources has forced the locals to buy fuelwood on the market (and fuelwood tops the list of remittances usage in our sample). Finally, in the qualitative sample (interviews and FGDs), the surveyed communities have reported, in agreement with what presented by Archer and Fowler (2004) and Khattak et al. (2011), a decrease in the summer flow of the rivers despite the observed increase in the summer precipitations.

As for the causes of change in the climate patterns, two dominant perspectives emerged: People referred to the will of God and to the break of the equilibrium of the agro-pastoral economy due to the fast changing demographic and socio-economic context. Recent natural disasters were also recognized as causes of the changing climate. Especially the Attabad Lake, which has led to a traumatic major transformation in the environment for the locals, was blamed as the source of change. A smaller number of people (belonging to the most educated segment of our sample) mentioned climate change and global warming as root-causes and highlight the high exposure and vulnerability of their community, and the lack of governance and investments as major hurdles to effective risk management and adaptations.

Although some (I)NGOs have been active in the areas after the 2010 natural disasters, providing aid, shelters, and training for the local people, no comprehensive early warning system has been adopted in the valleys. The respondents have mostly referred to "indigenous methods" (meaning that people uphill were alerting those down valley by shouting), radio and television as major mechanism to gather information on the risk they were facing. This correlate with the fact that in the whole Yasin Valley there is no access to the internet, and it is scant in Hunza. In Yasin, also the mobile phone network is extremely weak and entire villages are *de facto* cut off from the network. Hence, radio (72 % in Yasin and 60 % in Hunza) and, most of all, television (80 % in Yasin and 91 % in Hunza) are perceived as very important to communicate risks and alert the population.

Table 5 Adaptation practices and actions (following Macchi et al. 2011)

Hazard	Coping mechanism	Adaptive measures
Erratic rainfall	Adjusting the agricultural calendar	Changing to crops that can cope
	Repeat sowing and crop replacement after failure in early season	Building new canals for irrigation
		Cultivate off season vegetables
Hot season become colder	Adjusting the agricultural calendar	Switching to monocrop (subsidized wheat)
	Improve irrigation to cope with water shortages	Collection of NTFP
Physical shocks (flood, landslide)	Community self-help to rebuild the irrigation system	Seeking labor in nearby markets or through state/NGOs/Army
	Saving groups and cooperative	Rural/urban migration (mostly domestic, male members)
	Borrowing money from friends and relatives	Improved houses (replacing traditional *baipash*)
	Cut on health and education expenditures	Building protection wall against flood
	Selling asset (livestock)	Switching to cash crops that are easier to transport (peas rather than potatoes)
	Reliance on aid	

Community responses to environmental change: coping mechanisms and adaptations

The West Karakoram households are coping and adapting in various ways to climatic and environmental changes. Whereas coping strategies are taken after experienced change and can be defined as "short-term actions to ward off immediate risk" (Macchi et al. 2011) with a shorter-term vision (e.g., one season), adaptation is the process of adjusting to change, both experienced and expected, in the longer run. Adaptive measures can also proactively anticipate future problems and, depending on their degree of spontaneity, they can be planned or autonomous (Smit et al. 1999; Smit and Wandel 2006).

The coping and adaptive strategies observed in the study areas are grouped according to these definitions and are summarized in Table 5. Data on adaptive measures were collected also via qualitative interviews and FGDs, and contrasted with the quantitative questionnaires' results. The main question here is: to which extent are the adopted measures perceived as adaptive strategy to a changing environment?

Farmers operate in a context of extreme uncertainty, reacting to and coping with multiple stressors whose impacts are not always clear or predictable (Vogel and O'Brien 2006). Local people clearly perceive an increased risk for their agricultural production resulting from the increase in unexpected fluctuations of weather conditions and from the decrease in summer temperatures. In particular, the latter process impacts heavily the crops as it hinders the ripening during the short growing season. Note that, while the Government of Pakistan subsidizes the cultivation of wheat, thus indirectly encouraging farmers to dedicate their land to monoculture, no crop insurance scheme is active, so that no compensating mechanisms can reduce the economic impacts of a low wheat yield year.

The most resorted coping strategy adopted by the surveyed rural communities is the shift (anticipation) of the agricultural calendar, in order to allow for more time for the ripening process. Failed crops are also commonly used as fodder. However, such coping strategies are only emergency responses adopted on a seasonal basis. This might partially cushion the losses, but does not bring any substantial change in the capability of the household to respond to damages and losses caused by changes in the local climate conditions. Respondents claimed that in the last 10 years harvests had decreased drastically because of low yields and a loss of land due to environmental disruption and fragmentation of the properties (see Table 3). Also the lack of proper seeds and of good chemical fertilizers was lamented.

In the wake of natural disasters, such as the 2010 flood and landslide, the local people shared to have coped with the situation by selling property (livestock, and to a much lesser extent, land). Cuts on health and education expenditures were also reported as sometimes necessary to deal with environmental shocks. Such strategies may help alleviating the immediate pressure and help the household to cope; yet, this is an "erosive coping" (Warner et al. 2012), i.e., a coping that is detrimental in the longer run, as people are depleting their asset base and threatening their future livelihood sustainability by becoming more vulnerable and prone to future shocks and risks. Moreover, such erosive mechanisms are disproportionately adopted by the poorest segments of society, with the result of further augmenting the social gap.

Local communities are traditionally very cohesive, and community organizations and community self-help have been widely implemented by the AKRSP. Saving groups and cooperatives are prevalent in our study area, and money is collected from the members on a monthly basis in order to be readily available whenever the community face a threat and need to cope with losses and damages (e.g., to infrastructures). Community self-help was used to rebuild the irrigation system in upper Hunza (Altit and Gulmit), whereas in Hundur, after the 2010 flood, one of the local women's organizations raised money to build a protection wall. Reliance on social networks was also widely reported, especially borrowing money from friends and relatives to deal with the losses. In both Hunza and Yasin over-reliance on aid and aid-dependency have been pointed out, along with the politicization of aid and resources, which has been blamed for the deterioration of social relations and community cohesion.

In upper Hunza, since the 1980s, potato has been the main cash crop, and it has played a pivotal role in improving the income and the life standard of rural people. Since the Attabad disaster, due to the obvious costs and difficulties in transporting potatoes on the precarious boat service currently in place, the population has suffered from additional losses in their income, and some people are adapting to the lake by cultivating peas as cash crop, which are more easily transportable. In both Yasin and Hunza, people shared to have increasingly reduced the varieties of cultivated crops, often concentrating the production exclusively on the government-subsidized wheat.

Spatial diversification, involving the temporary migration of male members of the households—according to prevailing gendered norms at place—is the prominent livelihood strategy adopted at the level of the household to spread the risk embedded in the dependency on subsistence agriculture, by increasing and diversifying the income sources. In our survey, migrant-sending households counted for 76 % of the total sample (Table 3).

The study reveals a positive correlation between level of income and the probability of having a migrant in the household (80 % of the non-migrants belong to the first two economic quartiles). Such correlation is even stronger in the Yasin Valley, where the average income per capita, as found in our survey, is less than half as compared to Hunza (Table 3). As indicated by many studies (World Bank 2006; Tacoli 2009; Banerjee et al. 2011), it is not the poorest income group or the most deprived who migrate, but rather those who dispose of enough financial and social capital. Migration occurs predominantly at intra-provincial (50 %) or intra-national scales (97 %), (only 2.6 % international) from rural to urban areas. Migration is predominantly seasonal and circular, toward trade hubs in the region (such as Sost, Gilgit, Chitral), or to major cities within the country (especially to Karachi).

Migration in Hunza and Yasin has certainly been adopted as a form of *ex post* adaptation in the wake of environmental shocks. The number of new labor migrants peaked in 2010 (year of the two big natural disasters), and first-time migrants of the period 2010–2012 accounts for 34 % of the total. In the qualitative sample, people share to have adopted temporary labor migration to cope with the damages and the loss of agricultural land due to the flood and the Attabad Lake disaster. In order to meet the initial costs of migration, people reported to have sold livestock, cutting on health and education expenditures and borrowed money from friends and relatives.

However, predominately, migration rather than being perceived as a form of adaptation to climatic and environmental change, takes the form of a household sponsored-insurance mechanism (Yang and Choi 2007) adopted to mitigate risks and cope with long-term declines in livelihood. Interestingly, the "environmental/climatic" driver is not perceived by the local communities as the direct, most crucial determinant for migration. Over 90 %

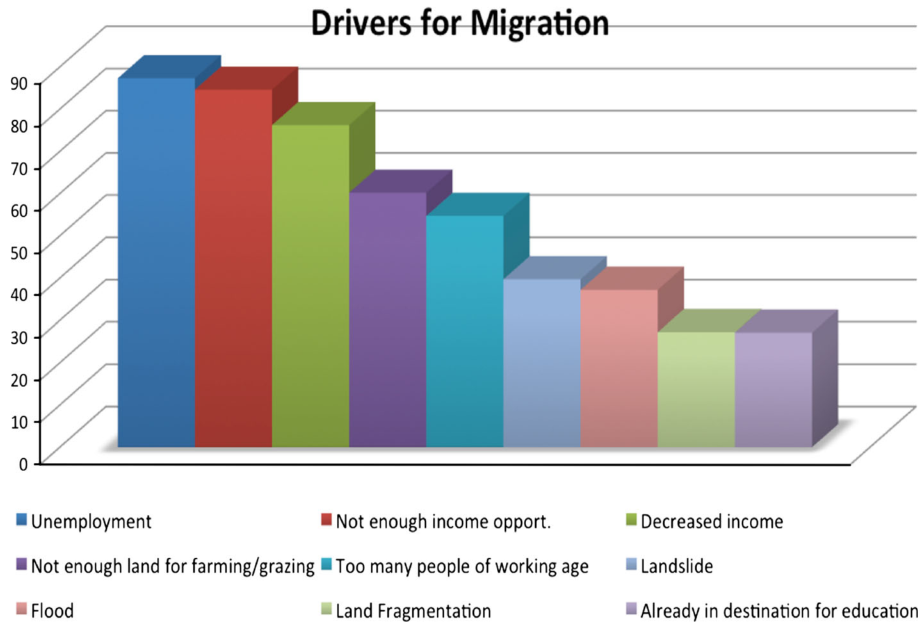

Fig. 5 Drivers for migration in the last 10 years

of the interviewees singled out "unemployment," and "not enough income" as key determinants for the decision to migrate (Fig. 5). Also demographical issues, such as "too many people of working age in my locality," and "not enough land for farming grazing/land fragmentation" have been listed as the most significant direct drivers for migration. Environmental hazards, such as floods and landslide, are mentioned as direct drivers for migration by almost the same percentage of respondents (ca. 40 %) in Yasin and Hunza.

Yet, environmental drivers are a major cause of the decline in income over the last 10 years for 93 % of the migrant households. "Low temperatures," "Erratic rainfall," "Flood," and Landslide are also indicated as the main reason behind the decreased household's productivity. Hence, in the perception of local people, environmental and climatic change can be considered as *indirect* driver for migration in the last decade: migration is not directly linked to the perceived environmental disruption, yet this is considered to be the root cause of the decline in agricultural productivity and hence in the household income.

Conclusions

In this paper, we have tackled the problem of understanding how mountain communities perceive and adapt to climatic and environmental change. Primary data were collected at community and household level through in-depth household interviews, FGDs, and quantitative questionnaires covering 210 households in six villages of the West Karakoram. These remote and marginalized communities have relied for centuries on agropastoralism. Only in the last four decades, thanks to enhanced infrastructures, population growth, the introduction of cash crops, and improved literacy, mountain people have been able to diversify their livelihoods and to partially improve their living standards by integrating farm labor with other form of employment, including increasing rural to urban male labor migration.

Our first goal has been to compare the collected perceptions on climate change with the available hydro-climatological data. Collecting local perceptions of climate change is relevant because it has been proved extremely challenging to construct a high-precision climatology of the region using hydro-meteorological stations and because the available data suggest that the climate of the region is experiencing a rather peculiar pattern of change in sheer contrast with respect to the climate change signal experienced in the Himalayas. In particular, in the UR-UIB, since the second half of the XX century, temperatures are following a cooling trend and precipitations are increasing (Archer and Fowler 2004; Fowler and Archer 2006; Khattak et al. 2011; Bocchiola and Diolaiuti 2012). We found a high degree of convergence between climatic data and the local narratives of change collected in our survey. Farmers across the region gave a coherent narrative of change, emphasizing an increased risk for their crops coming principally from colder summer temperature and erratic precipitation.

A second reason why collecting climate perception is relevant comes from the fact that adaptation is local and highly context-specific and, especially in marginalized and isolated mountain areas where structural/planned adaptation is virtually absent, communities' perceptions of change are the best proxy to measure their capacity to adapt and to plan adequate policies and feasible planned adaptation initiatives.

As for the responses to climate change and natural hazards, our study highlighted that most of the household resorted to coping mechanisms to ward off immediate risks rather than proactive adaptive strategies. The most resorted coping measure is the shift of the agricultural calendar in response to cooler summers and erratic precipitation. Moreover, they reported to have sold assets (especially livestock) and cut the spending on education and health. Such strategies are not sustainable in the longer run, as they are based on the depletion of crucial assets. They are rather likely to increase their vulnerability to future climatic and environmental hazards, in the absence of planned adaptation and conductive policy making.

Livelihood diversification and, in particular, spatial diversification via male labor migration is the most resorted measure undertaken by the household to improve its resilience to both economic and environmental shocks. Our survey shows that albeit environmental and climatic change are not perceived by the local people as main direct determinants for migration (which is instead motivated by economic reasons in the first place); they are in fact pivotal indirect drivers, because they are perceived as being overwhelmingly responsible for the decrease in income in the last 10 years.

More research is needed to better understand how to build the resilience of the fragile and risk-prone communities of the Karakoram. Despite the wide uncertainties over the future climate scenarios, the present adaptive capacity needs to be built keeping in mind how people's responses are determined by their perceptions of change in the context of the entire portfolio of multi-local and multi-sectoral household activities. This knowledge will provide an important basis for future adaptation planning, which shall build on existing autonomous strategies and work in synergy with poverty reduction policy.

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