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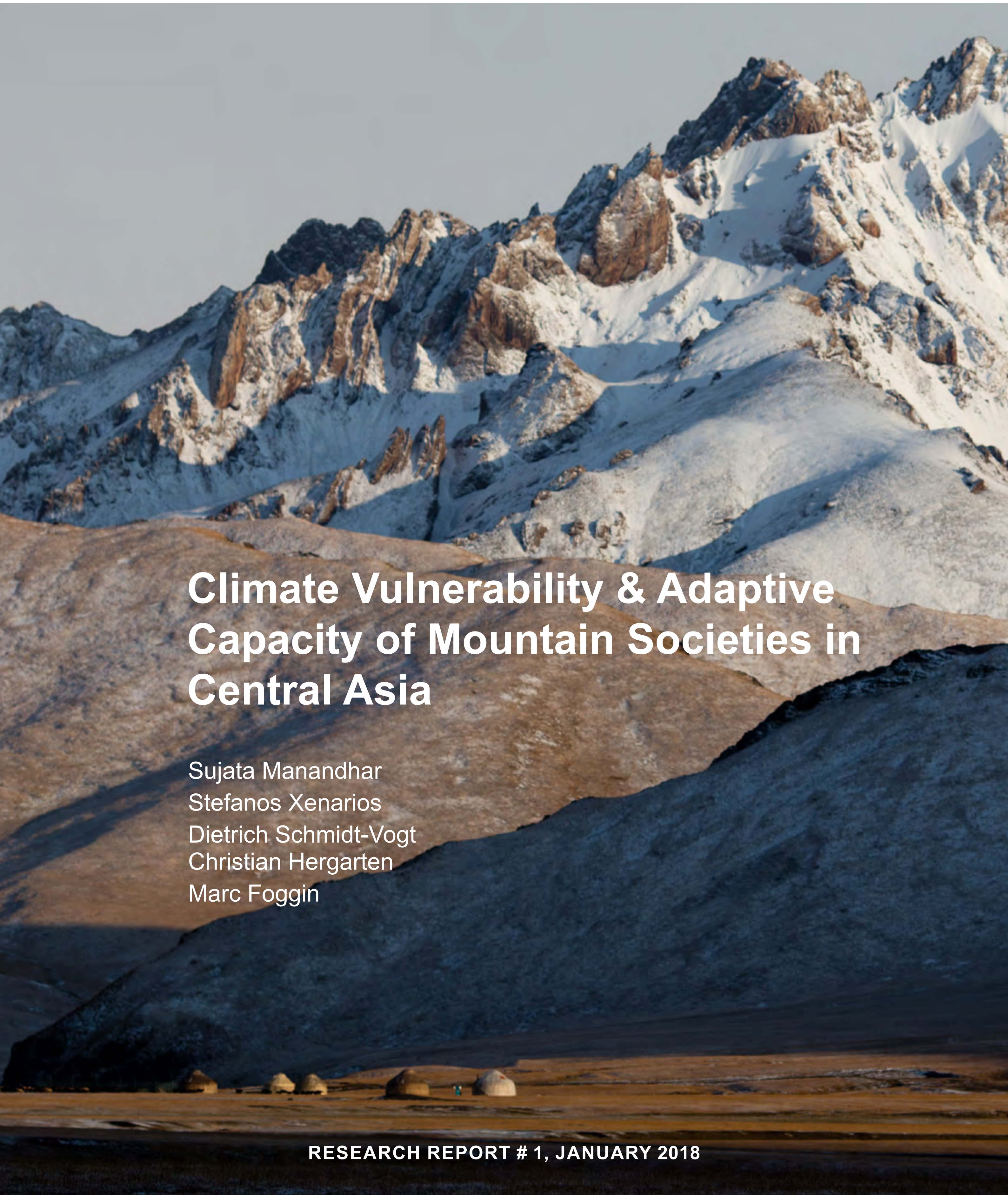

Climate Vulnerability & Adaptive Capacity of Mountain Societies in Central Asia

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This *Research Report* is produced by the Mountain Societies Research Institute (MSRI), University of Central Asia (UCA), based on a comprehensive review of existing scientific literature and project and donor agency reports as well as a series of consultations with climate change specialists and conservation and development professionals with direct work experience in Kyrgyzstan and Tajikistan. However, the authors alone are responsible for the content.

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The Mountain Societies Research Institute (MSRI) is dedicated to supporting and enhancing the resilience and quality of life of mountain societies through the generation and application of sound research. MSRI has five objectives:

- To generate new knowledge on mountain societies from academic research;
- To enhance Central Asian capacity to conduct research relevant to mountain societies;
- To serve as a knowledge hub for scholars, development practitioners and decision-makers;
- To inform policy and practice through research; and
- To contribute to the development of the University of Central Asia's (UCA) academic programmes relevant to mountain societies.

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List of acronyms

BMZ	German Federal Ministry for Economic Cooperation and Development
CAREC	Central Asia Regional Environmental Centre
CBA	Community-Based Adaptation
CBO	Community-Based Organization
CA	Central Asia
CC	Climate Change
CCA	Climate Change Adaptation
CSA	Climate Smart Agriculture
CSDRM	Climate Smart Disaster Risk Management
DRR	Disaster Risk Reduction
EbA	Ecosystem-based Adaptation
FAO	Food and Agriculture Organization
GEF	Global Environment Facility
HKH	Hindu Kush Himalayas
ICIMOD	International Centre for Integrated Mountain Development
IDRC	International Development Research Centre
IPCC	Intergovernmental Panel on Climate Change
IISD	International Institute for Sustainable Development
MSDSP	Mountain Societies Development Support Programme
MSRI	Mountain Societies Research Institute
NAPA	National Adaptation Programme of Action
NGO	Non-Governmental Organization
SDGs	Sustainable Development Goals
UCA	University of Central Asia
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change

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Executive summary

Mountain societies in developing and low-income countries are highly vulnerable to the impacts of climate change, which may severely threaten people's livelihoods and wellbeing. The situation of mountain communities in the Pamir and Tien Shan mountains in Central Asia (CA) is exacerbated by their often remote location along with outdated infrastructure and poor access, in a region with a distinctively continental climate.

Climate change models based on ''most likely'' greenhouse gas concentrations have projected future temperature and precipitation changes in CA. The modeling studies suggest that mean temperature in CA will increase between 2.6 and 3.2°C by the year 2050, though considerable variation is expected across the region. While modeled precipitation changes are afflicted with higher degrees of uncertainty, increases in overall precipitation during the winter season (and concomitant decreases across the remainder of the year) are projected.

In Kyrgyzstan and Tajikistan, the countries that encompass the largest portions of the Pamirs and Tien Shan mountains, social and legal strategies have been adopted to reduce vulnerabilities and enhance nationwide adaptation. Numerous international donors and development organizations are currently working with Tajikistan and Kyrgyzstan to implement projects aiming at strengthening local adaptive responses to climate change in both urban and rural regions.

Assessing the vulnerability of mountain societies in the Pamirs and Tien Shan mountain regions and assisting them to develop adaptation strategies is, however, a challenging endeavor that demands a thorough understanding of a range of technical and socio-economic parameters. On the technical side, microclimatic processes as determined by mountain topography, geophysical parameters and energy exchange from solar radiation are still insufficiently explored. Currently, there are only few studies that investigate the role of mountain hydrological regimes in triggering or exacerbating extreme hydro-meteorological hazards. Moreover, institutional and socio-economic changes that have affected mountain societies in CA over the last quarter century may also impact their capacity to adapt to a range of direct and indirect effects of climate change.

Strengthening research to address climate change challenges in mountainous CA is essential. In this regard, this MSRI study reviews the state of research on climate change, vulnerabilities, impacts and adaptation measures, and attempts to identify knowledge gaps as well as opportunities for the improvement of adaptive capacity of mountain societies in CA.

Current climate change adaptation (CCA) initiatives that have been adopted at national level in Kyrgyzstan and Tajikistan face various limitations. This review highlights several apparent weaknesses in the areas of policy and related institutions and governance mechanisms; in economic and financial information and resources; in education and knowledge sharing; and in science-based information. Moreover, adaptation activities in mountain regions of CA generally lack a solid scientific understanding of the effects of climate-water-energy-land system interactions on the local population.

The present study proposes priority areas of research as well as development and policy initiatives in climate monitoring and assessment, climatic processes and hazards, vulnerability and adaptive capacity, resource governance, and economic opportunities, that could help support and improve people's livelihoods and wellbeing in mountain societies in CA. The study also highlights the need for enhanced collaboration between research institutions and communities, government and private sectors, and development agencies and civil society. It helps identifying and better understand the obstacles and challenges as well as new promising opportunities in the development of effective CCA strategies at local, national and regional levels in CA.

1. Introduction

Mountain societies in developing and low-income countries are particularly vulnerable to constraints imposed by their natural environments and geographic location. Scarcity of natural resources, land degradation, exposure to natural and human-induced hazards, deteriorating infrastructure and poor communications constitute some of the principle obstacles to achieving sustainable development and wellbeing. Climate change has recently been added to this list as a major force which, in association with other hazards and constraints, can severely affect the lives of mountain dwellers. Numerous studies point towards the fact that mountain people and communities – especially in developing countries – are more susceptible to the effects of socioeconomic and climatic pressures than lowland communities (Foggin, 2016; Heltberg et al., 2011; Kohler et al., 2014).

The remote communities of the Pamir and Tien Shan highlands of Tajikistan and Kyrgyzstan constitute a representative case of rural agricultural and agro-pastoral people facing adversities, which may be yet further aggravated by climate change. These two mountain regions are among the highest in the world, with peaks reaching well over 7,000 meters above sea level (asl). These ranges constitute a continuum with the Himalayas orogenic belt and an area of approximately 10,500 km^2 in the Pamirs and 2,300 km^2 in the Tien Shan mountains are covered by glaciers (Alford et al., 2015).

According to a recent study, Tien Shan glaciers are controlled primarily by temperature – particularly the rising summer temperatures– which is of high importance for the region since glaciers receive snowfall virtually only during the summer months. This means that glaciers are not only melting due to increased summer temperatures, but they also receive less precipitation in the form of snowfall (Farinotti et al., 2015).

Photo 1. Marginal plots in the Pamir mountains of Tajikistan (credit: Dietrich Schmidt-Vogt)

The Tien Shan region particularly, is vulnerable to global and regional warming trends as well as increasing climatic variability. Most rural communities in the Pamirs and Tien Shan mountains are agro-pastoralists who practice a combination of subsistence farming and livestock herding. Indicatively, in eastern Tajikistan, only very small plots are available for cultivation due to steep sloping land and poor soil conditions. In the high Eastern Pamirs, more extensive rangelands are available and Kyrgyz herders maintain long-standing pastoralist traditions. In Kyrgyzstan, the high plateaus of the Tien Shan mountains also offer significant grazing potential, which has been underused since the collapse of the state controlled pasture management regime of the soviet period (Robinson et al., 2010). Across the region, however, land use patterns are changing, and in some places intensifying land use and new climatic conditions are affecting pasture quality (Zhumanova et al., 2016).

Developing effective strategies and adaptation measures to mitigate the severe impacts of climate change on mountain communities in CA is a major challenge that requires thorough knowledge of technical/scientific matters and socio-economic contexts alike. Due to the overall dry climate of the Pamirs and Tien Shan, climate change is likely to affect both water and energy balances. Climate processes and the spatio-temporal distribution of climate impacts are especially complex in CA due to the multi-dimensional interactions of the atmosphere with highly dissected mountain topographies, seasonal water regimes, and the variable distribution of people and their livestock along with agro-pastoral practices. Many of these aspects of CA mountain social-ecological systems remain poorly understood, largely as a result of limited investment in research and in monitoring infrastructure and systems.

Photo 2. Traditional yurt and livestock grazing in mountains of Kyrgyzstan (credit: Marc Foggin)

In addition, livelihoods and wellbeing amongst CA mountain societies are precarious not only because of climatic factors, but also due to other environmental and socio-political forces. Welfare inequalities in rural communities, including lack of access to basic amenities and services, are a fact of life for the majority of people in the region, resulting from a complex array of interrelated factors – of which climate is one that yet often exacerbates nearly all others.

Climate change will likely aggravate existing vulnerabilities caused by a wide range of climatic and non-climatic drivers (Wu et al., 2017). Local and regional capacities for weather observation and hazard monitoring and management (as well as provisions in the welfare system) were seriously impaired in the early 1990s following the dissolution of the Soviet Union. Most weather monitoring and forecasting systems and also hazard monitoring systems have become derelict. The social services system equally has nearly collapsed, especially in remote districts. Discussions and planning are underway for reestablishing/improving what has been lost, however financial constraints, multiple concurrent development priorities, corruption and other factors together have hindered much progress to date.

This study initially describes the pronounced social and economic vulnerabilities of mountain societies and presents vulnerability concepts in the light of climate change. The study then proceeds with an overview of climate change trends and predictions in CA and elaborates the complex climatic processes occurring in the Pamirs and Tien Shan mountains. The initiatives already undertaken by various donors, organizations and national governments towards climate change adaptation are subsequently summarized, and some of the primary knowledge gaps and needs for improvement are identified. Finally, major areas in need of further intervention and improvement are identified for the design of better climate adaptation measures and enhanced resiliency as well as for the improved wellbeing in mountain societies of CA.

2. Vulnerability and adaptive capacities of mountain societies

Mountain societies in CA are facing major challenges to development such as poor or decaying infrastructure, limited access to natural resources or their unsustainable use, and lack of adequate communication systems including rural-urban social exchange networks. Although development levels vary greatly among mountain societies, there is a generally slower pace of change and progress in mountain areas as compared to lowland regions. At other times though, mostly external socio-political or environmental forces may impose or drive sometimes drastic, rapid changes (Wu et al., 2017). But whatever the direction or speed of changes, the majority of communities in mountain regions exhibit lower levels of socioeconomic development and greater vulnerability to regional and global forces.

A recent study has calculated the difference between mountain and non-mountain regions in terms of Human Development Index (HDI) and Gross National Income (GNI) (Rasul and Sharma, 2014). HDI is a composite index based on life expectancy, education, and per capita income indicators, while GNI refers simply to the mean per capital income of the country's citizens. As presented in Table 1, both HDI and GNI levels are much lower in low-income countries (see columns 3 and 6); with the most pronounced differences being in GNI, with mountain regions in low income countries having lowest income overall (see column 5, row 3).

Table 1. Human Development Index (HDI) and Gross National Income (GNI) in high and low-income countries, disaggregated by mountain regions only versus total country areas.

Indices	**Human Development Index (HDI)**			**Gross National Income (GNI)**		
Country Levels	HIC (HDI Unit) (1)	LIC (US$) (2)	HIC vs LIC (%) (2/1) (3)	HIC (US$) (4)	LIC (US$) (5)	HI vs LI (%) (5/4) (6)
All Regions (AR)	0.890	0.493	45%	40,046	2,904	93%
Mountain Regions (MR)	0.872	0.462	47%	35,621	2,227	94%
AR vs MR	2%	6%		11%	23%	

Note: HIC= High Income Countries; LIC=Low Income Countries. (Source: Rasul and Sharma (2014); modified by S. Xenarios)

Mountain societies in developing countries often depend to a large extent on subsistence farming (cultivation and livestock) and forest products (including non-timber forest products, NTFPs) for their living (Kreutzmann, 2001). In some instances, mountain areas in developing regions are endowed with abundant natural resources such as minerals, hydropower and timber products (Wymann von Dach et al., 2016). However, mountain geophysical conditions and consequent poor access often restrict the development of *economies of scale* in highland areas or regions with complex topographies. Frequently, mountain areas are recognized by outsiders merely as sources of raw materials.

Mountain societies also are often deprived of basic welfare amenities and social services and their economies are highly susceptible to external pressures and financial fluctuations. Overall, mountain societies in developing regions tend to be more vulnerable than societies in the lowlands with respect to economic welfare and people's sense of wellbeing (Kohler et al., 2014).

The term *vulnerability* has gained much prominence and significance in climate change studies in recent years, in an attempt to identify the major constituent parts of climate change impacts and variable social responses to such changes. The Intergovernmental Panel on Climate Change (IPCC, 2001) defines vulnerability to climate change as the "degree to which a [social] system is susceptible to and unable to cope with adverse effects of climate change, including climate variability and extremes." It is generally understood that a region's or community's vulnerability to climate change is determined by its levels of *exposure, sensitivity* and *adaptive* capacity to such change.

Although the IPCC provides a comprehensive listing and description of the various components of vulnerability, it remains difficult to define the multifaceted nature of vulnerability as a single, unified concept. Both natural and social scientists agree that vulnerability is *multi-dimensional* and *differential*, in that its effects are manifested and perceived differently across space and between different social groups (Cardona et al., 2012). Vulnerability also is *scale*- and *time-dependent*, as socioeconomic and biophysical impacts, often variable and unequal in magnitude, may appear either simultaneously or overlap with each other in mountain social-ecological systems. Moreover, vulnerability is highly dynamic, as climate impacts sometimes occur instantaneously, and at other times become apparent only through their cumulative effect over a period of many years (Devisscher et al., 2011; Vogel and O'Brien, 2004).

While the fuzzy nature of vulnerability is acknowledged, efforts are ongoing to more clearly define our understanding of the boundaries of a vulnerable system. The social sciences typically search to understand inherent social and economic characteristics that may limit the abilities of communities in developing countries to cope with external pressures (Xenarios et al., 2016). For instance, poverty analysis may draw attention to aspects of vulnerability of an agrarian community in the Pamir mountains of CA that is hampered by extensive and annually recurring droughts and floods. The natural or biophysical disciplines, on the other hand, more often emphasize the physical effects of climatic conditions – and less the socio-economic aspects, or impacts.

While the vulnerability of socio-ecological systems to climate change is a function of the exposure and *sensitivity* of people and communities (and environmental resources) to newly emerging weather conditions including extreme events, this also can be mediated by people's adaptive capacities to respond in ways that reduce the impact of changed (or changing) climatic conditions (Ripple et al., 2017). In other words, greater exposure or sensitivity to climate change increases vulnerability while greater adaptive capacity reduces overall vulnerability. In mathematical terms, vulnerability can be expressed as a simple function of exposure, sensitivity and adaptive capacity (Deressa et al., 2008; Fellmann, 2012):

$$V = f(A-(E+S)) \qquad \text{(Eq. 1)}$$

where V = Vulnerability, A= Adaptive Capacity, E = Exposure, S= Sensitivity

In turn, the *adaptive capacity* of a social-ecological system is determined by its *robustness* and its *resilience* to cope with the effects of climatic changes. The robustness of a system is its ability to withstand pressures and forces, and resilience is its ability to return to a prior state or ''bounce back'' after having been impacted and modified by external forces (Anderies et al., 2004). However, there remain considerable limitations in our understanding of the climate system as a whole, and also in the precision and even accuracy of our measures of biophysical parameters, especially at regional level. This is even more pronounced in the case of developing countries where the availability of biophysical indicators (climate data) is limited, and what data is collected may not be well characterized and may even be unreliable.

Adaptation measures are context-specific, and anticipated results may vary depending on location. For example, while in one context growing more drought-resistant crops could be an appropriate adaptive response, in other circumstances migration to a new area with better water conditions could be a more promising avenue to pursue (Appadurai et al., 2015). Adaptation activities should be flexible in the face of changing needs, and with uncertainty about the future (Jones et al., 2012).

Maladaptation also can result when local social or ecological contexts are ignored. For instance, using incremental adaptation strategies when transformational strategies are more suitable could in the end be detrimental to people's wellbeing (e.g. building higher dams against river flooding, which are prone to collapse, instead of reducing the flood risk itself through riverbed widening or reducing upstream land degradation).

The following set of aggregated prioritization criteria can be helpful in the selection of adaptation measures (GoT Nepal, 2010):

i. potential to reduce adverse impact of climate change
ii. potential to support local livelihoods
iii. synergy with national priorities
iv. level of people's participation
v. cross-sectoral benefits
vi. cost-effectiveness
vii. ease of implementation

A wide range of adaptation measures that positively enhance human well-being (in addition to mitigating direct climate change impacts) has been introduced in mountainous regions of many developing countries, with the aim to offset some of the negative impacts of climate change (Al-Nammari and Alzaghal, 2015; Begum et al., 2014; Bradt et al., 2015; Field et al., 2014; Manandhar et al., 2013; Reid, 2016). This study focuses specifically on the vulnerability and adaptive capacities of mountain societies in CA in the context of climate change, in order to enhance our understanding and contribute to a strengthening of the communities now encountering increasingly adverse weather conditions.

3. Mountain societies and climate vulnerability in Central Asia

The majority of mountain societies of Central Asia reside in the Pamir and Tien Shan mountainous ranges. The Pamir mountains culminate in the complex *Pamir Knot* (Fig.1) which centered in the southeast region of Tajikistan in Gorno-Badakhsan Autonomous Oblast (province). The northern part of the Pamirs connects with the Tien Shan mountains of Kyrgyzstan, while in the south connects with the Hindu Kush mountains in Afghanistan and Pakistan, which in turn are an extension of the Himalayan orogenic belt. The eastern part of the Pamirs lies in far western China, while the western part extends into northeastern Afghanistan. The Pamir region includes some of the highest peaks in the world, with summits over 7,000 masl, and an average elevation between 4,000-5,000 masl. Glaciers in the Pamirs cover an area of approximately 10,500 km^2 (Alford et al., 2015)

The Tien Shan mountains principally lie in Kyrgyzstan and China, forming one of the longest mountain ranges in the world (2,800 Km). The western portion of the Tien Shan mountain range is situated in Kyrgyzstan and also the Kazakh-Kyrgyz border region, while the eastern ramparts transect much of Xinjiang Uygur Autonomous Region (province), China. Elevations are lower than those of the Pamirs, with the majority of sub-ranges situated at 3-4,000 masl. Glaciers cover approximately 2,300 km^2, starting from around 3,000 masl (Farinotti et al., 2015).

The Pamir and Tien Shan ranges and their societies are subject to a unique set of environmental, social, political and economic conditions that play out and combine at multiple temporal and spatial scales – including floods, droughts, poor irrigation practices, rapid institutional changes, population growth, economic inequality (Freedman and Neuzil, 2015; Lioubimtseva and Henebry, 2009). The majority of mountainous communities are engaged in subsistence farming, livestock activities while there is a large emigration wave mainly of young generations to Russia.

Fig. 1. Mountainous areas in Central Asia, Source: Alford et al., 2015

The vulnerability of mountain societies in Central Asia already has been acknowledged in several recent regional research and development studies (CAREC, 2011, 2013; Christmann, 2011; Fritzsche et al., 2011; Hall, 2014; Qi et al., 2012; Thomas, 2008).

Unpredictable climatic conditions have further aggravated their overall vulnerability with increased frequency and intensity of sudden (e.g. floods) and sustained (e.g. erosion) hazards. Climate variability in the Pamirs and the Tien Shan mountains also is expected to greatly affect lowland areas of Tajikistan and Kyrgyzstan – mainly through the occurrence of extreme hydro-meteorological hazards (EHHs), as presented in following sections.

A recent multi-country vulnerability study has assigned some of the highest rankings to four of the five post-Soviet Central Asian countries, among 28 nations of Europe, Caucasus and Central Asia (Fay and Patel, 2008; Fig. 2). Tajikistan and Kyrgyzstan are ranked amongst the top three most climate-vulnerable countries largely due to their exposure to risks and hazards, induced by both natural and anthropogenic factors.

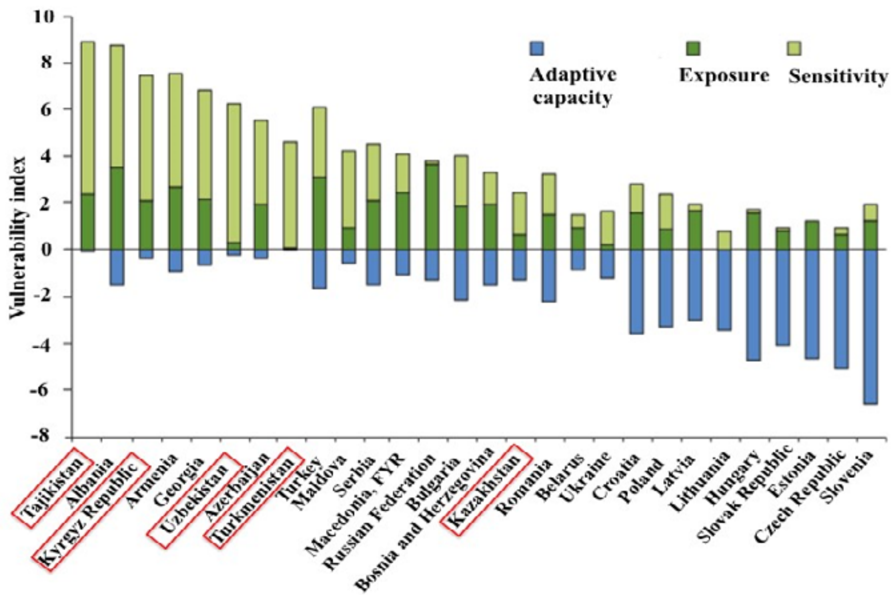

Fig. 2 Vulnerability index of countries in Eastern Europe and Central Asia
(Source: Fay and Patel, 2008)

4. Regional climate trends and predictions in Central Asia

Climate change projections as well as mitigation and adaptation measures have been developed for the CA region as a whole, and for each country separately. Recently, advanced climatic models have been used to downscale regional climate predictions to national levels, including their mountainous terrains. Overall, the climate in Central Asia is characterized by high ‘’continentality’’ with a wide range of diurnal and seasonal temperatures and limited precipitation. Increasing temperatures and mixed precipitation trends were observed in all Central Asia countries as shown in Fig. 3 and Fig. 4. A distinct increase in air temperature also has been noted in desert areas, whereas such increase was less pronounced in mountainous areas (CAREC, 2011).

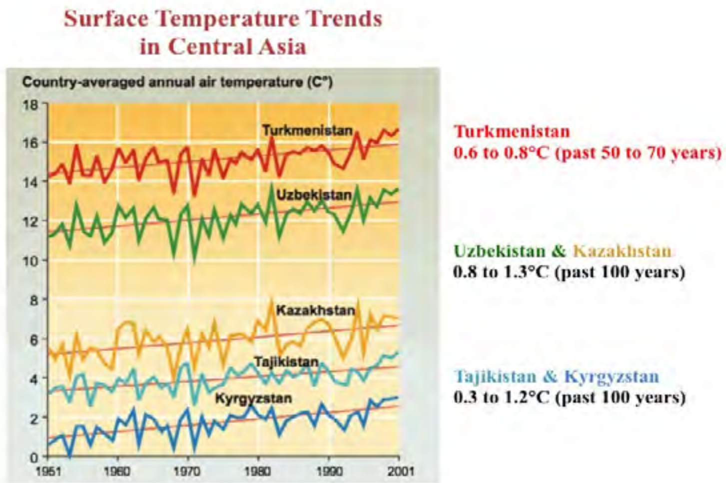

Fig. 3 Observed trends in surface temperature changes in Central Asia
(Source: Zoï Environment Network, 2009)

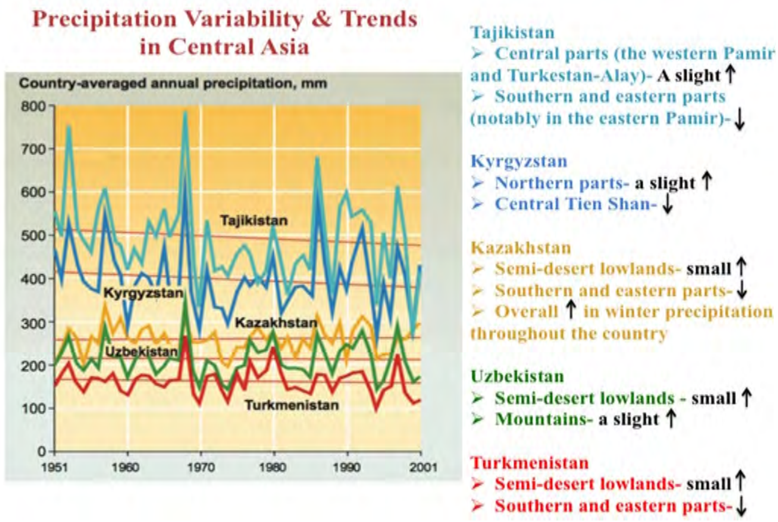

Fig. 4 Observed variability and trends in precipitation changes in Central Asia,
(Source: Zoï Environment Network, 2009)

Climate trends also varied significantly between and within countries. Table 2 synthesizes the main observed trends in recent decades for each Central Asian country. It should be mentioned, however, that different time scales have been used for each national assessment, which renders it difficult to systematically or accurately compare the climate change trends across countries at regional level.

Table 2. Observed (reported) climate trends in different countries of Central Asia

Country	Temperature change	Precipitation change
Kyrgyzstan	• Average annual temperature in 20th Century rose by 1.6°C	• Annual precipitation increased in all regions except in Inner Tien Shan
Tajikistan	• Temperature rose at average rate of 0.1 to 0.2°C /decade in plain areas, 0.2 to 0.4°C /decade in highland areas (above 2500 m), and 0.3 to 0.5°C /decade in mountain districts – with the exception of several districts where the trends were less pronounced	• Annual precipitation increased by 5 to 10% between 1940 and 2012 • A slight increase in central parts (the Western Pamir, Turkestan-Alay) but decrease in the Eastern Pamir
Kazakhstan	• Annual average air temperature increased by 0.2°C /decade • Regionally differentiated, the air temperature increase was 0.3 to 0.3°C /decade in the north, west and south of the country, and 0.2 to 0.2°C /decade in the remaining regions	• Annual precipitation decreased by 0.5mm /decade • Winter precipitation increased by 1.7mm /decade throughout country • Spring, summer and autumn rainfall decreased by 1mm /decade
Uzbekistan	• Rate of warming for maximum temperature averages 0.2°C /decade, while for minimum temperature it is 0.3°C /decade (since 1951). • The Aral Sea presents a notable exception, maximum temperatures are very high, low minimum temperatures remain almost unchanged	• Increases in precipitation are barely noticeable in Uzbekistan • Small increases are noted in semi-desert lowlands and in mountains
Turkmenistan	• Temperature increased by 0.6 to 0.8°C over the past 50 to 70 years	• Annual precipitation increased only slightly across the country (1931-1995), with the greatest increase in winter season

(Source: Kazakhstan- Ministry of Environment and Water Protection of the Republic of Kazakhstan, 2013; Kyrgyzstan- Ministry of Ecology and Emergencies of the Kyrgyz Republic, 2003; Tajikistan- Government of the Republic of Tajikistan, 2014; Turkmenistan- Ministry of Nature Protection, 2000; Uzbekistan- Centre of Hydro-meteorological Service under the Cabinet of Ministers of the Republic of Uzbekistan, 2008; Zoï environment network, 2009)

Several scenarios have been developed by different scientific teams on the projected climatic trends in CA. Global circulations models (GCMs) based on thermodynamic and energy principles have been introduced to predict future temperature and precipitation changes regionally. The 5th Assessment Report of the Intergovernmental Panel on Climate Change (IPPC AR5, 2014) – the most widely acknowledged report on climate change matters – has employed 21 global models to predict future climate trends both globally and in CA.

Climate projections developed by IPPC AR5 are based on the four accepted scenarios, more commonly known as Representative Concentration Pathways (RCPs). The RCPs reflect the former A (1-2 and subdivisions) and B (1-2 and subdivisions) scenarios of IPCC's previous report, AR4. The RCPs express the most likely greenhouse gas concentration trajectories (not emissions trajectories) and these are used for climate modeling purposes, and consequently for predictions. The ensemble of these models suggests that the average temperature in Central Asia is expected to increase by 3.7°C by the end of the twenty-first century. The peak increases are expected to occur in the winter months of December, January and February (DJF). Precipitation estimates in most models also show an increase during DJF and a decrease in other periods.

Several other climate projections also have been developed by national agencies, research institutes and international organizations based on GCMs and preliminary research, as presented in Table 3.

Table 3. Future climate projections in different countries of Central Asia

Country	Model	Temperature change (°C)	Precipitation change (%)
Kyrgyzstan	HadCM-2 model, UKTR model and CSIRO2-EQ model (IS92a and IS92C scenarios) (Ministry of ecology and emergencies of the Kyrgyz Republic, 2003)	• By 2100, the overall range of warming scenarios is from 1.8 to 4.4°C rise in average annual temperature and 1.3 to 4.8°C rise in temperature in different seasons	• By 2100, overall range of moistening scenarios will vary from annual precipitation reduction by 6% to its increase by 54%; seasonal scenarios in general vary from 20% reduction to 84% increase
	A multi-model downscaled ensemble (n=63) of CIMP5 Earth System Models (ESM) applied across four RCPs (Zomer et al., 2015)	• Mean annual temperature is projected to increase by 2.8°C by 2050, when averaged across the four Representative Concentration Pathways (RCPs)	• Mean annual precipitation is projected to increase by 30 mm by 2050, when averaged across the four RCPs
Tajikistan	CCSM3, CHAM5 and CSIRO models (A1B, A2 and B1 scenarios) (Government of the Republic of Tajikistan, 2014)	• By the end of 21st century warming may have become especially significant exceeding 5°C in southern districts of the country as well as in mountains of central Tajikistan and western Pamir	• Annual amount of precipitation is likely to decrease in southern Tajikistan and neighboring areas, including Afghanistan and mountainous parts of the country • The amount of precipitation is likely to increase during summer and winter and may reduce in spring and autumn
	A multi-model downscaled ensemble (n=63) of CIMP5 Earth System Models (ESM) applied across four RCPs (Zomer et al., 2015)	• Mean annual temperature is projected to increase by 2.9°C by 2050, averaged across the four RCPs	• Mean annual precipitation is projected to increase by 2050, averaged across the four RCPs
Kazakhstan	A model ensemble (15 models) of the new generation CMIP3 project (A2, A1B and B1 scenarios) (Ministry of Environment and water resources of the Republic of Kazakhstan, 2013)	• By 2030, according to the A2, B1 and A1B scenarios, temperature will increase between 1.6 and 1.8°C in relation to the base period (from 1961 to 1990) • By 2050, according to the A2 scenario, temperature will increase between 3.0 and 3.5°C in relation to the base period • By 2085, temperature will increase between 2.5 and 3.0°C according to the B1 scenario and between 3.5 and 5.6°C according to the A2 scenario in relation to the base period	• Annual precipitation increases in all scenarios of climate change, though with some seasonal fluctuations
	A multi-model downscaled ensemble (n=63) of CIMP5 Earth System Models (ESM) applied across four RCPs (Zomer et al., 2015)	• Mean annual temperature is projected to increase by 3.2°C by 2050, averaged across the four RCPs	• Mean annual precipitation is projected to increase by 2050, averaged across the four RCPs

Table 3. Future climate projections in different countries of Central Asia (continued)

Country	Model	Temperature change (°C)	Precipitation change (%)
Uzbekistan	CGCM1-TR, CSIRO-TR, ECHAM4, HadCM3, CCSR-NIES, GFDL-TR Models (A1B, A2, B1, B2 scenarios) (Centre of Hydro-meteorological Service under the Cabinet of Ministers of the Republic of Uzbekistan, 2008)	• By 2030, according to B2 and A2 scenarios, temperature will increase in the range of 1.3 to 1.7°C and 1.1 to 1.3°C, respectively • By 2050, according to B2 and A2 scenarios, temperature will increase in the range of 2.0 to 2.5°C and 1.9 to 2.4°C, respectively • By 2080, according to B2 and A2 scenarios, temperature will increase in the range of 2.9 to 3.5°C and 3.7 to 4.3°C, respectively	• According to B2 and A2 scenarios, precipitation will increase in the range 104% to 117% between 2030 and 2080
	A multi-model downscaled ensemble (n=63) of CIMP5 Earth System Models (ESM) applied across four RCPs (Zomer et al., 2015)	• Mean annual temperature is projected to increase by 2.7°C by 2050, averaged across the four RCPs	• Mean annual precipitation is projected to increase by the year 2050, averaged across the four RCPs
Turkmenistan	GISS, GFDL, UK89, CCC and GFDL-T (Ministry of nature protection, 2000)	• By 20250, maximum warming of 6.10°C is projected by the CCC model under doubling CO_2 conditions • Minimum warming of 4.2°C is projected under the GDFL model scenario • Other models predict a warming between 4.6 to 5.5°C	• Precipitation decrease by 15% is projected by CCC model under doubling CO_2 conditions • The annual overall precipitation is projected to remain constant • Decrease of precipitation by 17 to 56% is projected by the other models
	A multi-model downscaled ensemble (n=63) of CIMP5 Earth System Models (ESM) applied across four RCPs (Zomer et al., 2015)	• Mean annual temperature is projected to increase by 2.6°C by 2050, averaged across the four RCPs	• Mean annual precipitation is projected to increase slightly by 2050, averaged across the four RCPs

However, climate change processes in mountain areas of CA have proven to be more complex than initially anticipated. Geophysical, social, historic and institutional factors make climatic predictions and the introduction of adaptation measures a challenging task, requiring thorough and in-depth analysis. The currently available climate prediction models also are afflicted with uncertainties that often exceed the predicted magnitudes of change, especially at the local level, where adaptation measures rely critically on precise information.

5. Microclimates in Central Asian mountain regions

The prediction of climatic trends in mountainous areas is a complicated task demanding extensive knowledge of water and energy nexus, and of the interactions between topography and the atmosphere (Aus der Beek, 2011; Mountain Research Initiative, 2015; Narama et al., 2010; Stucker et al., 2012; Tebaldi et al., 2006). The situation is further complicated by the presence of glaciers, which are highly susceptible to climatic variabilities (Hag et al., 2013a; Gan et al., 2015; Kriegel et al., 2013). The melting of glaciers resulting from rising temperatures may amplify the occurrence and intensity of natural disasters in mountainous CA and increase the vulnerability of local populations.

A brief introduction to glaciers may help clarify their significance for climate change studies, and their contribution to risks and hazards associated with the disturbance of the hydrological cycle. A glacier can be defined as "a natural ice body made out of snow consolidated under its own weight and large enough to 'flow' under gravity either in a spreading pattern from an elevated center towards the edges (dome-shaped ice sheets and ice caps), or downward (mountain glaciers)" (Savoskul and Smakhtin, 2013). Snow accumulated in a glacier is partially released to hydrological basins, mostly in the warmer seasons, while the rest is converted to ice. However, temperature increase due to climate change is likely to increase the release of the snow to hydrological basins, simultaneously reducing ice accumulation and hence limiting the replenishment of glacier mass.

It is important also to note that the processes of ice melting in a glacier due to temperature increase are not yet well understood. Additionally, glaciers in polar regions are completely different in this respect from glaciers in mountains of the temperate or subtropical zones. An example of the melting and accumulation of ice in glaciers, and the role played by precipitation in these processes, help to elucidate the mechanisms at work. The case of the Karakoram mountains south of the Pamirs, which resemble the Pamirs and Tien Shan mountains with respect to topography, is presented in Fig. 5.

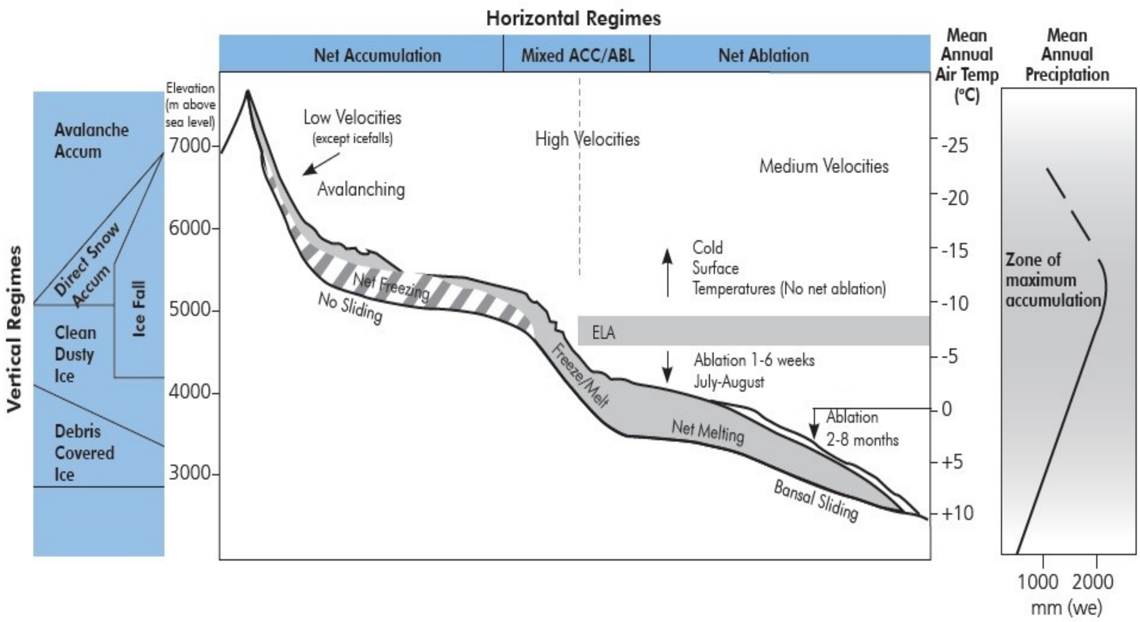

Fig. 5. Mass balance in a Karakoram glacier, with illustration of freezing and melting processes (Source: Hewitt, 2007)

As shown in Fig. 5, a glacier may be divided in two major zones, the upper "accumulation zone" and the lower "ablation zone." Glacier surface accumulation processes include snow and ice from direct precipitation, avalanches, and windblown snow, which contribute to the mass accumulation (Alford et al., 2012). Ablation processes encompass surface melt, surface meltwater runoff, sublimation, avalanching, and windblown snow (Davies, 2017). The Equilibrium Line Altitude (ELA) marks the point where ablation equals accumulation and where the freezing/melt balance equals zero (Benn and Evans, 1998).

The Equilibrium Line Altitude (ELA) of the Karakoram glacier shown in Fig. 5 is located at about 5,000 masl, which is similar to the Pamirs and higher than in the Tien Shan mountains (~4,000 masl).

In the accumulation zone, the temperature is below freezing point (0 °C) with low precipitation intake resulting in snow accumulation. In the ablation zone, the temperatures are above zero with higher precipitations in the form of snow and rainfall. The snow volume in the ablation zone is decreasing (melting) at a variable pace; with faster melting at lower elevations.

Photo 3. Mountain range in Kyrgyzstan (credit: Marc Foggin)

Climate change in the Pamirs and Tien Shan is understood to have shifted the ELA level upward, thus increasing the area in which ablation occurs relative to the area of accumulation, consequently leading to a reduction of overall glacier mass. Estimating ELA and glacier mass evolution over the course of years demands extensive monitoring. Energy exchange from solar radiation through short- and long-wave energy sources is a major determinant of glacier mass balance and needs especially to be measured and monitored with greater precision (Alford et al., 2015). The intensity of short-wave solar energy – the prevalent driver of net ablation on glaciers – depends on altitude, slope, cloudiness, and ice reflectivity; yet the interplay of these factors remains largely underexplored. The long-wave radiation derived by water evaporation in lower altitudes also has not been studied in the Pamir and Tien Shan mountains.

The variability of precipitation trends in CA mountains may also be a factor in moving ELA upwards and increasing the ablation zone, but, again, little research has been conducted in this regard. An example can be drawn from the Indian Himalayas (Shrivastava, 2011) where precipitation and temperature seem to interact intensively in the ice melting process. A times series analysis of temperature records between 1950 and 1991 in the Indian Himalayas shows an upward trend in the winter season, but less pronounced increases in the spring and summer. During the same time period, precipitation appears to have decreased in summer, but has increased progressively in the spring season. Some early observations are now also suggesting that glacial retreat in the Indian Himalayas may be due to fluctuations in precipitation patterns, rather than to temperature increase (Bahuguna et al., 2014).

It should be additionally mentioned that the precipitation-temperature interaction at high altitudes (i.e., above 3,000 masl) is fraught with uncertainty (Alford et al., 2012). Due to the scarcity of high altitude weather stations, the temperature record relies largely on measurements taken in lowland stations and extrapolated to adjacent areas. Air temperature for glaciated zones is inferred through different technical proxies which may entail a deviation of up to 50% from actual temperatures (Savoskul and Smakhtin, 2013). In the case of precipitation measurements, a statistical error of up to 30% of actual intake should be incorporated in analyses.

Such uncertainties obviously prevent the development accurate modelling and predictions at regional level (Wagner and Hoelzle, 2010). Uncertainty is even more pronounced in the mountains of Central Asia where the glacier monitoring and on-site assessments declined drastically following the dissolution of the Soviet regime – with few weather monitoring stations remaining, almost no long-term field studies, and only occasional expeditions taking place. Designing adaptation tools or approaches for the amelioration of climate change impacts in mountainous CA in the face of such data deficiency should therefore be approached with considerable care (Sorg et al., 2012).

6. Climate change adaptation initiatives in Kyrgyzstan and Tajikistan

6.1 Adaptation initiatives in collaboration with international agencies

Kyrgyzstan and Tajikistan are already engaged in several adaptation initiatives with donors and international organizations. A number of completed and ongoing projects and programs funded by multiple donors are presented in Fig. 6. The Pilot Progam for Climate Resilience (PPCR, 2016) funded by various agencies is one of the largest ongoing projects in Tajikistan (US$47.8 million), aiming to pilot and demonstrate ways in which climate risk and resilience may be integrated into core development planning and implementation. The preparations for a similar PPCR programme were approved for Kyrgyzstan in May 2015. Also, Kyrgyzstan and Tajikistan are part of broader projects involving other countries from Central and Eastern Europe.

State agencies in Kyrgyzstan and Tajikistan execute various projects and programs with the support of multiple donor agencies (BMZ, World Bank, UNDP, GEF, ADB, etc.). Projects focus on issues such as forest and pasture management, water management, agricultural productivity and nutrition improvement, disaster mitigation, climate risk management, energy efficiency, environmental and land management, and rural livelihoods. Appendix 1 provides a list of projects related to CCA in Kyrgyzstan and Tajikistan.

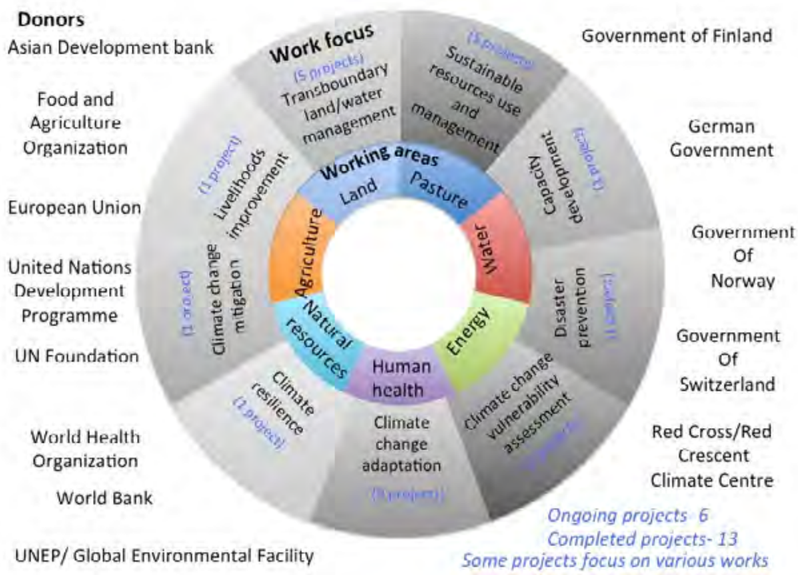

Fig. 6 Summary of completed and ongoing projects on climate change in Central Asia (as of December 2015)

Various regional organizations and programmes such as the Interstate Commission for Water Coordination of Central Asia (ICWC), Central Asia Regional Economic Cooperation (CAREC), Regional Environmental Centre for Central Asia, Central Asia Energy-Water Development Program (CAEWDP), Shanghai Cooperation Organization (SCO), and International Fund for Saving Aral Sea have been formed in Central Asia to promote regional cooperation in addressing environmental problems, managing resources, and accelerating economic growth and poverty reduction. Other initiatives such as the Global Snow Leopard & Ecosystem Protection Program (GSLEP) are focused on the protection and sustainable use of high mountain ecosystems and habitats, including the introduction of adaptation measures (UNDP, 2016).

Projects focusing explicitly on CCA and mountain regions have also been initiated in partnership with national governments and international agencies. For example, the International Climate Initiative (IKI), launched the *Ecosystem-based Adaptation (EbA) to climate change in the high mountain areas of Central Asia* in 2015. It aims to assess EbA options in selected high mountain regions of Kyrgyzstan and Tajikistan and to identify institutional, administrative, economic, technical and informational challenges to their implementation (IKI, 2016).

6.2 National initiatives and engagement in international treaties

The governments of Kyrgyzstan and Tajikistan have also developed various strategies, laws and plans to support climate change mitigation and adaptation as well as environmental protection (see Appendix 2). Both countries have reached their first milestones in CCA processes by preparing and submitting their respective National Communication to the United Nations Framework Convention on Climate Change (UNFCCC). These documents provide an opportunity for countries to assess their vulnerabilities and suggest measures to improve adaptive capacities. Furthermore, both countries have focused on developing national adaptation strategies and mainstreaming CCA into sectoral policies. Both Kyrgyzstan and Tajikistan are now developing national CCA strategies and Kyrgyzstan is also specifically preparing an adaptation plan that targets its health sector.

The governments of Kyrgyzstan and Tajikistan have already identified agriculture and food security, water resources, human health, biodiversity and forestry, and extreme weather events, as five priority areas for CCA actions. Several studies and reports including communication documents by the national governments of Kyrgyzstan and Tajikistan have highlighted a range of adaptation measures selected to reduce vulnerability within priority areas or sectors (CAREC, 2013; Fay et al., 2010; Government of the Kyrgyz Republic, 2009; Government of the Republic of Tajikistan, 2014).

In the case of the agricultural sector, technological improvements (e.g. improvement of crop and livestock varieties, more efficient irrigation technologies, weather forecasting and early warning systems), economic mechanisms (e.g. crop insurance, investment in agricultural equities and futures, diversification of income sources) and institutional support (e.g. assistance related to seed improvement and cattle breeding, incentive programs for peasant farmers) have been identified as the most important focal areas for climate change adaptation measures.

Overall, the Governments of Kyrgyzstan and Tajikistan have developed laws, strategies, programs, plans, and documents; signed a variety of conventions; and implemented various programs and projects to support CCA, mitigation, disaster risk reduction, and environmental protection.

7. Gap analysis of CCA initiatives in Tajikistan and Kyrgyzstan

The current national initiatives and internationally-funded projects offer a baseline to advance climate change adaptation policies and practices in Tajikistan and Kyrgyzstan. There are however many institutional, socio-economic and technical challenges that must be met for a more profound implementation of adaptation strategies at the national level. Below, we provide a synopsis of the major areas where more substantive action still needs to be taken.

Policy, institution and governance gaps: There is still no robust or comprehensive CCA strategy in Kyrgyzstan and Tajikistan. Adaptation programs and projects are not clearly linked to existing development and sectoral policies in either country. There is a lack of collaboration between local communities, policy makers and scientists in various fields. At the local level, lack of relevant information, and insufficient short- and mid-term economic incentives to undertake adaptation measures are strong barriers to CCA .

Economic and financial gaps: There is limited knowledge of economic losses due to climate change and related disasters. Financial literacy is limited, and regulatory frameworks to support CCA and Disaster Risk Reduction (DRR) and affiliated services (e.g., micro-credits, micro-savings, micro-insurance) are underutilized. The governments have insufficient funding for disaster risk mitigation investments. Economic and policy incentives also are insufficient for improving water efficiency, diversifying incomes, and promoting agribusiness industries. At the local level, communities do not have easy access to different financial tools and limited opportunities for income diversification.

Education and capacity building gaps: The public as well as some government officials are not yet adequately aware of climate change, climate-related disasters, and potential adaptation measures. Therefore, awareness programs are needed at various levels. Climate change education has yet to be integrated into national curricula, and public schools and universities do not offer courses or programs on climate change issues. Education and health professionals also have limited options to learn about climate change and related impacts on public health and other sectors. Overall, there are limited training opportunities on CCA and DRR for community members, local government authorities, and education, health and other professionals.

Photo 4. Pastoralism – a livelihood opportunity in the mountains of Central Asia (credit: Marc Foggin)

Knowledge sharing: Sharing of available data is still in its infancy, although some noteworthy attempts have been made. A search engine known as ‘‘K-Link’’ accesses documents and data from several knowledge platforms including UCA, CAREC, Kyrgyz State Agency for Environmental Protection and Forestry, GIZ and a few local NGOs, but it has not yet been adopted regionally. Additionally, there are sector specific developments in regional data sharing and knowledge management in Central Asia, most notably FAO's Pastoralist Knowledge Hub and the GIZ-supported Regional Pasture Network (RPN), which brings together pastoralists and other actors working with them – both seeking to create synergies for dialogue and pastoralist development. Generally, though, more effort at multiple levels is still needed to significantly improve data sharing and knowledge management across a range of sectors in Central Asia.

Technologies, methodologies, practice, and infrastructure gaps: Kyrgyzstan and Tajikistan do not have adequate weather and climate data monitoring systems, as will be presented in more detail in the following section. Their abilities to undertake large-scale vulnerability assessments are limited and they have no clear means to evaluate either past or current adaptation practices. Governments generally are slow to implement new adaptation approaches, such as climate-smart agriculture, climate smart disaster risk management, ecosystem-based adaptation (EbA), etc. Risk information and hazard maps also are not readily available to communities and there is a lack of adequate infrastructure to prevent climate-related hazards such as landslides, mudslides, flood, and drought. At local level, communities are still unaware of potential adaptation measures (e.g. new agricultural technologies, new seed varieties, improved farming practices) to adapt to climate change and related disasters.

Science-based information and data gaps: There is a huge demand for scientifically sound and actionable information and knowledge in Tajikistan and Kyrgyzstan. Climate services that include the timely production, translation, and delivery of useful climate data, information and knowledge for individual and societal decision-making should be underpinned by research in climate and related sciences, along with research on sectoral applications (e.g. agriculture, water, health, energy, disasters) (Vaughan et al., 2016). Climate change research is slowly gaining momentum, but is still at an early stage of development. In Kyrgyzstan and Tajikistan, little scientific research is carried out and limited information exists on climate change (both past and future trends), vulnerability, and potential risk and impacts in relation to various sectors and livelihoods (agriculture, livestock, forest, pasture, water resources, etc.). Potential adaptation approaches and measures also remain largely understudied. Additionally, there is poor communication and information sharing on climate change, its potential risks and potential adaptation measures at the local level, and communities are mostly unaware of scientific facts and findings.

8. Data and knowledge climate adaptation constraints in mountain regions of Central Asia

The design and development of adaptation measures in mountain regions of Tajikistan and Kyrgyzstan demands even further research. Fortunately, CCA research on mountain areas of CA is slowly gaining momentum (Aus der Beek et al., 2011; Bobojonov and Aw-Hassan, 2014; Christmann and Aw-Hassan, 2011; Feng, 2013; Hag et al., 2013b; Lioubimtseva and Henebry, 2009; Malsy et al., 2012; Oberhansli et al., 2011; Qi et al., 2012; Reyer et al., 2015; Savitskiy et al., 2008; Sommer et al., 2013; Thomas, 2008). However, there is still limited evidence on climate-glacier-water-land interactions and their relations to risks and hazards, mainly due to the poor weather, climate and hydrological monitoring services in Tajikistan and Kyrgyzstan. Most equipment is obsolete and maintenance is inadequate due to the lack of spare parts. Until the end of the Soviet era in 1991, there was a fairly extensive network of meteorological and hydrological stations and other facilities, but most are now out of service (see Table 4).

Table 4. Declining Hydro-meteorological Observation Networks in Kyrgyzstan and Tajikistan 1985-2008.

Component parts of climate observation network	Kyrgyz Republic		Republic of Tajikistan	
	Number in 2008	Reduction from 1985 (%)	Number in 2008	Reduction from 1985 (%)
Meteorological stations	32	62	57	22
Hydrological stations and posts	76	48	81	41
Upper Air	0[a]	100	0[b]	100
Meteorological Radars	0[c]	100	1	75
Agromet observation stations	31	55	37	46

[A] There were 3 operational upper air stations in Kyrgyz Republic in 1985; [B] There were 4 operational upper air stations in Republic of Tajikistan in 1985; [C] One radar was in pilot operation in Kyrgyz Republic in 1985.

Source: World Bank (2016a), modified by S. Xenarios

Meteorological stations have reduced in Kyrgyzstan by 62% since 1985, while the hydrological stations in both Kyrgyzstan and Tajikistan have been reduced by half. Wind measurements, for their part, were halted completely after the dissolution of the Soviet Union, and the snow surveys that occurred prior to the 1990s have also ceased. Currently the weather and forecasting facilities and related capacities in both countries cannot meet the operational standards of the World Meteorological Organization. An overhaul of the hardware system is necessary. The situation is even more drastic at high altitudes (above 3,000 masl) where the few stations that had been operating before the 1990s have now fallen into disrepair and can no longer provide reliable information.

Photo 5. Debris (mud) flow in south Tajikistan (credit: Nikolai Ischuk)

The hazards associated with glacier melting are difficult to manage due to the absence of weather and hydrological monitoring devices in the Pamir and Tien Shan mountains. A recent study on the improvement of weather, climate and hydrological services in CA has emphasized that this would be necessary, as both Kyrgyzstan and Tajikistan are suffering from Extreme Hydro-meteorological Hazards (EHHs). According to this study, “Meteorological, agrometeorological, and hydrological events are classed as EHHs when by intensity, territorial coverage (more than 30 percent of the region’s territory), or duration they could cause or have caused significant damage to the economy and population and could result or have resulted in a disaster” (World Bank, 2016).

Table 5 presents the average annual frequency of EHHs in both countries and the relevant costs interpreted in monetary terms (US$). As revealed in the table, floods and mudslides are the most frequent hazard types, burdening both Kyrgyzstan and Tajikistan. Most of these hazards occur in mountainous regions, devastating economic and living conditions of local societies and endangering human lives.

Though the occurrence of droughts may be less frequent, their economic impacts are disproportionally high – attributed mostly to losses in agricultural production. Other hazards met frequently in the highlands of CA are rainstorms, snowstorms, windstorms, and avalanches. While the accumulated economic impact of these latter hazards may be significantly lower on a national level than that of floods and mudslides, locally the occurrence of avalanches (for instance) has repeatedly threatened human security in mountain regions by damaging vital infrastructure such as roads and bridges.

Table 5. Average Annual Frequency of Occurrence of Major EHHs in 2008, and their Annual Average Economic Losses (US Dollars in 2006 prices)

Type of Event	Kyrgyzstan		Tajikistan	
	Frequency of occurrence (annual)	Average annual economics losses (M US$)	Frequency of occurrence (annual)	Average annual economics losses (M US$)
Floods and Mudslides	43	11	42	11.7
Drought	0.5	7.3	0.12	7.6
Spring and autumn frosts	2	7.5	n/a	n/a
Severe Storms	n/a	n/a	1.1	0.4
Rainstorms	5.6	0.4	3	1.5
Hail	1.6	0.5	7.7	1.6
Snowstorms	2.6	0.2	3	0.6
Avalanches	15.1	0.3	26.6	0.8
Windstorms	4.5	0.1	8.1	0.8

Source: World Bank, 2016a

Most of the hazards presented in Table 5 are related to the hydrological regime of mountainous areas. Some preliminary assessments have been carried out on the cause-effect relation of snow and glacier melt in river basins, but with limited success (Aizen et al., 2007; Dixon and Wilby, 2015; Hagg et al., 2013a, 2013b; Gan et al., 2015; Kure et al., 2013; Mergili et al., 2013; Salamat et al., 2015; Stucker et al., 2012; Wang et al., 2013; White et al., 2014).

The estimation of snowmelt and glacier discharge into river basins is a very challenging task which requires analysis of precipitation intake in mountainous areas together with discharge amounts in river basins. It is generally difficult to monitor water resources, and especially to assess how precipitation is received – whether “immediate runoff as quick flow, [or] seasonal storage as snow and ground water or long-term storage in perennial snow fields and glaciers” (Alford et al., 2012).

In the case of the Pamirs and Tien Shan mountains, the extensive, complex network of river basins in Tajikistan and Kyrgyzstan renders it particularly challenging to estimate water runoff due to significant differences in the contribution of snow and glacier melting to various stream outlets (Hock, 2005). The abandonment of the few gauging stations in the highlands after the dissolution of the Soviet Union has made it almost unattainable to precisely measure the water runoff into the basins of CA rivers. New isotope techniques recently introduced for the tracing and differentiation between snow and ice-melt components could help provide better results, but in many cases this approach has thus far proven inadequate (Singh and Singh, 2001).

Poor data collection and poor quality of data on precipitation and discharge has restrained the development of reliable hydrological models that could more effectively predict the effects of ice and snow melting and contribute to improved understanding of the occurrence of hazards. Most of the hydrological models applied in CA basins rely on “rainfall–runoff” or “black box” correlation modeling, where the precipitation input is correlated with streamflow output for the estimation of water volume and its fluctuations on a basin level (Alford et al., 2015). These models, however, generally fail to identify whether precipitation input is derived from rain, snow, or glacier melt. To partially overcome such data limitation, different remote sources are now used such as satellite images, global databases, and global circulation models, to better assess precipitation features on a local/regional level. Still, even these sources cannot accurately calculate precipitation amounts and thus can entail misinterpretations about the possible hazards generated from hydrological causes.

On the other hand, the vulnerability of local communities cannot be ascribed only to hazards, as has been done in some studies and development projects in mountainous CA (Diagne et al., 2014; Broka et al., 2016a, b). It is a complicated, multi-dimensional process to distinguish between the contributions of pre-existing social deprivations and climate-induced hazards to community vulnerability. The livelihoods of Central Asian mountain societies are precarious not only because of climatic factors. Current welfare conditions and inequalities in rural communities and lack of access to basic amenities are still a fact of life in many parts of CA due to an interplay of many factors, of which climate is only one (Mogilevski et al., 2017). Climate change, however, is likely to aggravate existing vulnerabilities which are caused by a wide range of climatic and non-climatic drivers (Wu et al., 2017). A detailed assessment of vulnerabilities would require a comprehensive technical and social analysis, which so far has not been conducted in many hazard risk, vulnerability, and climate adaptation studies. The interplay of climatic and non-climatic drivers should be further investigated in order to better evaluate the effect of climate and weather extremes on the mountain societies of CA.

Only limited research has been done assessing the effectiveness and outcome of climate change adaptation programming in CA at the local level. One study by Ashley et al. (2015) has documented a CCA program implemented in Kyrgyzstan by an NGO (MSDSP) aiming to build local adaptive capacity among agro-pastoral villages in remote mountain areas. This research found the programme has contributed to increased adaptive capacity related to the asset base, knowledge and information, and flexible foresighted decision-making. Changes in the characteristics of institutions, and transformations in terms of entitlements and innovations were much less obvious.

9. Emerging opportunities for CCA research/action in Central Asia

In this section, we propose several research and development initiatives that aim to better understand climate change processes and enhance adaptive capacities of mountain communities in CA. Table 6 clusters suggested research, development interventions, and policy initiatives, into the following four broad categories: monitoring and assessment, climatic processes and hazards, vulnerability and adaptive capacity, and governance and economy. The classification of the above categories was inferred by the activities needed to be taken according to literature review and project findings in Kyrgyzstan and Tajikistan.

As mentioned earlier, glacier monitoring with a denser network of hydro-meteorological stations is essential for a better comprehension of the microclimate features in the Pamir and Tien Shan mountains. Further assessment through remote sensing and modeling would complement the primary data inputs from the monitoring stations. Capacity building initiatives for communities and other local stakeholders in data collection and monitoring also need to be established. The monitoring data should then be entered in inventories and data/knowledge repositories, largely available as open access and disseminated as appropriate.

Regional climatic scenarios should also be developed to gain better understanding of climate trends at smaller (local) scales. These scenarios should help us to understand climate-glacier-water-land interactions as well as the hazards induced by high or increasing climatic variabilities at regional level. Hydrological modelling analysis should be further enriched with more precise estimations of precipitation amounts, the forms of precipitation, and the energy exchanged between glaciers and downstream portions of regional river basins. Better evidence and probabilistic forecasting arising from regional climate scenarios and hydrological models could significantly assist development practitioners and decision-makers in the formulation of community-based early warning systems and communication systems for the mitigation of hazard impacts.

The vulnerability status of communities also should be assessed in more depth by distinguishing between climatic and non-climatic factors, or drivers, that determine vulnerability. Significant knowledge derived from existing traditional practices for alleviating the negative effects of weather extremes also could be leveraged to decrease the vulnerability of local communities. Community-led initiatives such as the introduction of more resilient crops or better livestock and rangeland management regimes also could be enhanced, based on purposeful, strategic fusion of traditional knowledge and modern scientific investigations. Recent projects in CA have already demonstrated the effectiveness of multi-purpose projects that include the development or strengthening climate resilient farming, improving overall market accessibility, and building connections with available micro-finance schemes (e.g. MIAD project, 2017).

Knowledge about the institutional aspects of natural resource governance and management and the roles of local communities in decision-making processes is essential to design better adaptation strategies in the mountain regions of CA. Many climate adaptation projects have resulted in limited success, often due to their key interventions being designed with inadequate consultation with local communities and other stakeholders or designed on the basis of mainly foreign contexts. Overall, communications should be improved across stakeholder groups in order to create a more relevant and substantial science-policy-practice interface. Economic mechanisms and tools for establishing (co-creating) better adaptation strategies should also be shared and understood by communities, providing a basis for longer-term development partnerships and solutions.

Table 6. Suggested interventions for improving Climate Adaptation in the mountain regions of CA

Research, Development and Policy-Making Initiatives

Monitoring and assessment	**Processes and hazards**	**Vulnerability and capacity**	**Governance and Economy**
Glacier monitoring through direct measurements, remote sensing, modeling	Downscale climate scenarios, uncertainty analysis	Vulnerability assessment at various spatial levels	Natural resource governance and community role in decision processes
Hydro-meteorological stations in high altitudes (>3,00 masl), denser network of stations	Hydrological modelling and precipitation amounts, forms, energy inputs	Climate vs non-climate drivers and institutional analysis	Review programs and policies for CCA and DRR
Technical upgrade of existing observation networks	Climate-glacier-water-land interactions and hazards	Traditional knowledge on CCA and climate-related DRR	Communication approaches for science-policy-practice interface
Capacity building to support data collection by local stakeholders	Risk and hazard mapping under different CC scenarios	Climate smart agriculture and livestock-pasture management	Economic and finance tools for promotion CCA and DRR
Inventory of glacier features (e.g. topography, gradient, ELA);	Community-based early warning and communication systems	Farming and pastoral market knowledge	Economic mechanisms and value chain knowledge
Data-sharing framework through web and other media		High-impact market interventions, multipurpose projects (e.g. MIAD,2017)	

Concluding remarks

Mountain societies in developing countries are often characterized by higher levels of economic and climate vulnerability than people living in lowland areas. The degree of climate vulnerability in the mountain societies of the Pamirs and Tien Shan mountains is still difficult to comprehend due to a variety of technical and socioeconomic constraints. The microclimatic processes in glaciated zones of the Pamir and Tien Shan mountains remain poorly explored, and the effects of ice and snow melt on the hydrological cycles of major river basins are still unclear. Pre-existing social deprivations and their linkages with climatic drivers also are poorly understood. Additionally, the consequences of the scientific and infrastructural vacuum that has emerged since the end of the Soviet era in 1991 are difficult to assess.

Adaptation strategies aiming to increase the adaptive capacity and resilience to CC of mountain societies in CA should be carefully designed based on sound scientific understanding of the natural and social environments. Evidence-based and coherent policies should be developed in collaboration with local communities. While there is no single blueprint available for CCA frameworks and approaches, adaptation initiatives targeting the mountains of CA should be harmonized with the experiences and findings of governmental and non-governmental agencies, international organizations, academia, and civil society, in order to avoid fragmented or contradictory activities and incoherent policies.

The adaptation initiatives depend on sound and reliable climate change information, therefore, there is a pronounced need for better knowledge dissemination to all stakeholders. Further, there is also the need for perceptive (Mukherjee et al. 2016) and practical adaptation knowledge reaped from and co-generated with local adapting communities. Such information is crucial for mainstreaming adaptation into various sectors as well as for promoting climate smart investments.

Research institutes and other partners can fill many of the knowledge and information gaps in areas of monitoring and assessment, climatic processes and hazards, vulnerability and adaptive capacity, and governance and economic aspects of sustainable mountain development. This study has attempted to identify the priority areas for climate change and adaptation research, and thus to support development initiatives aiming to improve the livelihoods and wellbeing of mountain societies in Central Asia through adaptation, in the face of observed and predicted climate change and related environmental and socioeconomic vulnerabilities.

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Appendix 1. National projects in Kyrgyzstan and Tajikistan contributing to CCA

National Projects in Kyrgyzstan	National Projects in Tajikistan	Donor
• Conserving biodiversity and reducing poverty through improved management of forests and pasture (2014-2018, active)	• Adaptation to climate change through sustainable forest management (2013-2018, active)	BMZ
• Disaster hazard mitigation project (Completed) • Integrated Forest Ecosystem Management (2015-2021, active) • National water resources management project- Phase 1(Water resource management and rural services and infrastructure development) (2014-2017, active) • Agriculture productivity and nutrition improvement project (Active) • Pasture and livestock management improvement project (Active) • Second on-farm irrigation Project (Active) • Pilot program for climate resilience (approved in 2015)	• Additional Financing- Ferghana Valley water resources management project (Completed) • Emergency flood assistance project (Completed) • Community agriculture and watershed management (Competed) • Environmental Land Management and Rural Livelihoods- additional financing (Active) • Pilot program for climate resilience- Tajikistan (Active)	World Bank
• Naryn Area-Based Development Programme [Naryn Oblast (30 villages) Socio-economic development] (2014-2015, completed) • Climate Risk Management in Kyrgyzstan [Suusamyr valley, Chui Province] (2010-2014, Completed)	• Disaster Risk Management in Tajikistan (2010-2015, completed) • Sustaining agricultural biodiversity in the face of climate change in Tajikistan (2010-2015, completed) • Enabling Activities for the Preparation of Tajikistan's Third National Communication (TNC) to the United Nations Framework Convention on Climate Change (2010-2014, completed) • Climate Risk Management (2010-2015, completed)	UNDP
• Enabling Kyrgyz Republic to Prepare its First National Communication in Response to its Commitments to UNFCCC (Active) • Climate Change Enabling Activities Expedited Financing (Phase II)- (In Pipeline CEO approved) • Improving Energy Efficiency in Buildings (Completed) • Small Hydro Power Development (Active) • Promoting Climate Resiliency of Water Supplies in Kyrgyzstan (Pipeline CEO Endorsed)	• Enabling the Republic of Tajikistan to Prepare its First National Communication in Response to its Commitments to the UNFCCC (Active) • Climate Change Enabling Activity (Additional Financing for Capacity Building in Priority Areas) (Approved) • Increasing Climate Resilience through Drinking Water Rehabilitation in North Tajikistan (Pipeline CEO Endorsed)	GEF
	• Water resources Management in Pyanj River Basin (Proposed) • Building Climate Resilience in the Pyanj River Basin (Completed) • Khatlon Province Flood Management Project (Completed) • Climate resilience for Natural Resources Investments (Completed) • Community participatory flood management (Completed)	ADB

Source: ADB, 2016; GIZ, 2016; GEF, 2016; World Bank, 2016b; UNDP, 2016

Appendix 2. Government actions for CCA, mitigation, disaster risk reduction and environment and nature protection in Kyrgyzstan and Tajikistan

	KYRGYZSTAN	TAJIKISTAN
Government strategies, programs, plans and documents	***Climate Change Adaptation (CCA)***	
	• 1st National communication to the UNFCCC (2003) • National climate change committee established (2005) • 2nd National communication to the UNFCCC (2009) • Working group on CCA in the health sector of the Kyrgyz Republic established (2009) • CCA plan for health sector (in development process) • Programme for the public health sector of the Kyrgyz Republic in CCA over the period 2011-2015 (2011) • National strategy of the Kyrgyz Republic on CCA until 2020 (in development process) • Priorities for adaptation to climate change in the Kyrgyz Republic until 2017 (2013) • Climate change platform for dialogue established (July 2014) • Pilot programme on adaptation to climate change (2015) • Climate Action Network of Kyrgyzstan established (2009)	• 1st National communication to the UNFCCC (2002) • 2nd National communication to the UNFCCC (2008) • Pilot programme on adaptation to climate change (2010) • National report on human development: Tajikistan-poverty in the context of climate change (2012) • 3rd National communication to the UNFCCC (2014) • National strategy of the Tajikistan on CCA (in development process)
	Climate change mitigation	
	• National action plan for climate change mitigation • Intended Nationally Determined Contributions (INDCs)- Kyrgyzstan (2015)	• National action plan for climate change mitigation (2003) • Intended Nationally Determined Contributions (INDCs)- Tajikistan (2015)
	Disaster Risk Reduction	
	• Kyrgyzstan: Resolution on the Inter-Agency Commission on Emergency Situations (2006) • Kyrgyzstan: Enhancing coordination for disaster preparedness and response (2010) • Tajikistan: National action plan (2008) • Statement of common understanding: rapid emergency assessment and coordination team- Tajikistan (2008) • Tajikistan: National disaster risk management strategy (2010) • National strategy of the Republic of Tajikistan on the management of hazards risk from 2010 to 2015 (2010)	

	KYRGYZSTAN	TAJIKISTAN
	Environment/Nature protection and others	
Government strategies, programs, plans and documents	• Action plan of the national forest programme 2005-2015 (2004) • National energy programme of Kyrgyzstan 2006-2010 (2005) • State program on utilization of industrial and municipal waste (2005) • National development strategy for the period 2007-2010 (2007) • Program for energy conservation (2009) • Ozone and climate change center established (previously ozone center) (February 2011) • National sustainable development strategy for the period 2013-2017 (2013)	• State program on environmental awareness-raising and education of the population of Tajikistan until 2000 and 2010 (1996) • National action plan for hygiene of the environment (2000) • National action program to combat desertification (2001) • State program on development of forestry and hunting for 2006-2015 (2005) • National action plan for environmental protection (2006) • National development strategy of the Republic of Tajikistan for the period to 2015 (2007) • Complex program on use of the renewable energy sources in Tajikistan for 2007-2015 (2007) • Issues of climate change risks incorporated in third poverty reduction strategy (PRS) 2010-2012 • Living standards improvement strategy for 2013-2015 • National report on implementation of the Aarhus Convention (2013)
Relevant Laws	• Law on energy saving (1998) • Law on environmental protection (1999) • Law on the forest code of the Kyrgyz Republic (1999) • Law on air pollution (1999) • Law on industrial and municipal wastes (2001) • Law on environmental assessment (2003) • Law on the protection of an ozone layer (2006) • Law on state regulation and policy towards GHG emission and capture (2007) • Law “General Technical Regulation on environmental safety” (2009) • Law on the energy efficiency of buildings (2011) • Law of the Kyrgyz Republic on renewable energy sources (2008)	• Law on nature protection (1994) • Law on atmospheric air protection (1996) • Law of the Republic of Tajikistan on protection of atmosphere (1996) • Law of the Republic of Tajikistan on energy (2000) • Law of the Republic of Tajikistan on transport (2000) • Law of the Republic of Tajikistan on environmental education (2010) • Law of the Republic of Tajikistan on the use of renewable energy sources (2010) • Law of the Republic of Tajikistan on environmental protection (2011) • Law of the Republic of Tajikistan on environmental information (2011) • Law of the Republic of Tajikistan on ecological expertise (2012) • Law of the Republic of Tajikistan on energy saving and energy efficiency (2013)

	KYRGYZSTAN	TAJIKISTAN
UNFCCC signatory	• Bonn convention on the conservation of migratory species of wild animals (1979) • UN convention on biological diversity (1996) • UN convention to combat desertification (1997) • Vienna Convention for the protection of ozone layer (2000) • UN framework convention on climate change (2001) • Montreal Protocol on substances that deplete the ozone layer (2000) • Aarhus Convention on access to information, public participation in decision making and access to justice in environmental matters (2001) • Ramsar Convention on wetlands of international importance (2002) • Kyoto Protocol (2003)	• Vienna Convention for the protection of ozone layer (1996) • Montreal Protocol on substances that deplete the ozone layer (1997), and amendments • UN Convention on biological diversity (1997) • UN Convention to combat desertification (1997) • UN Framework Convention on climate change (1998) • Ramsar Convention on wetlands of international importance (2000) • Bonn Convention on the conservation of migratory species of wild animals (2000) • Aarhus Convention on access to information, public participation in decision making and access to justice in environmental matters (2001) • Kyoto Protocol (2008)

Group of tourist at Ala Archa National Park going up to the Upper Ala-Arche ski resort (3410m), led by Simon Charre. (Qobiljon Shokirov, 2014)