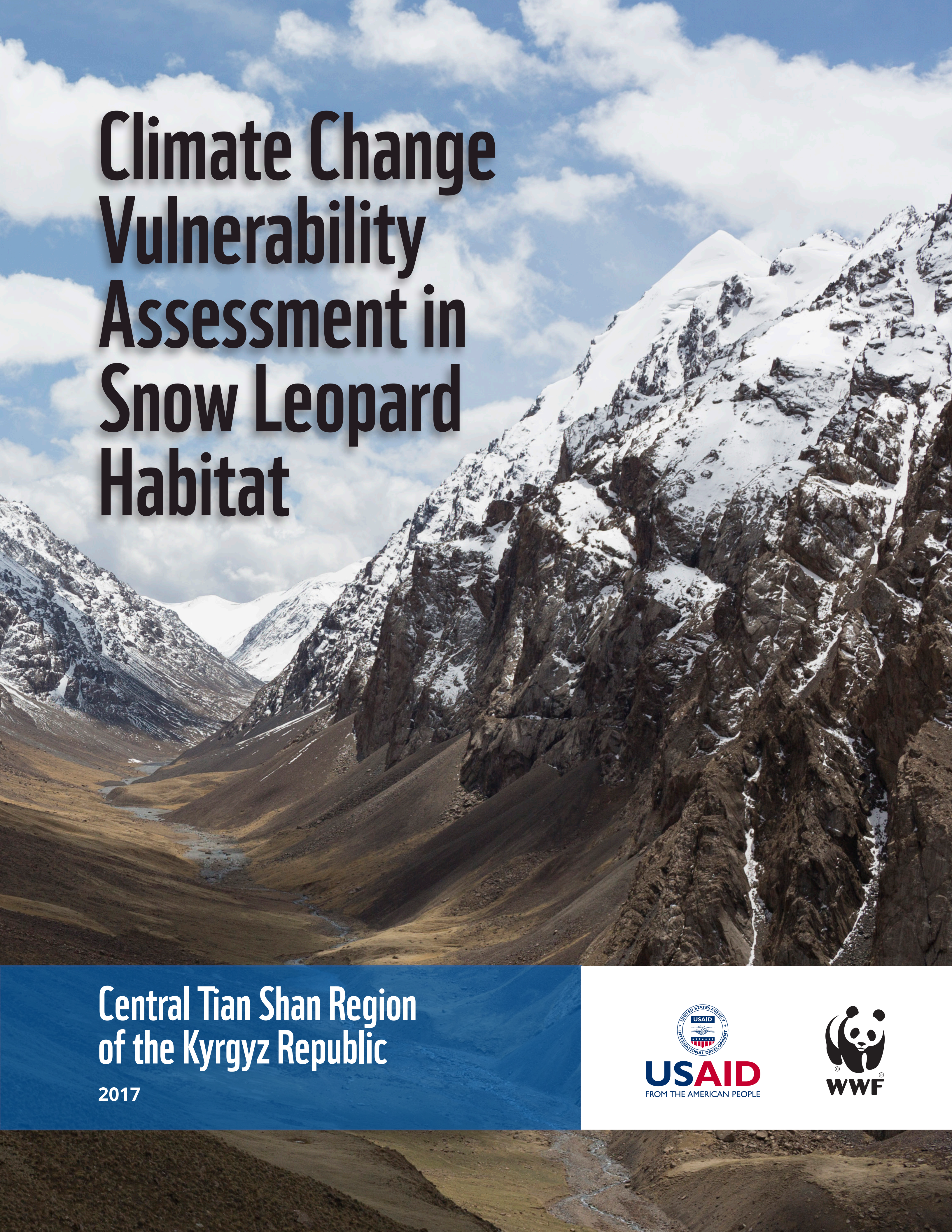

Climate Change Vulnerability Assessment in Snow Leopard Habitat

Central Tian Shan Region of the Kyrgyz Republic

2017

USAID
FROM THE AMERICAN PEOPLE

WWF

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Cover Photo: Kakshaal Range, Central Tian Shan, Kyrgyz Republic. © Andy Isaacson/WWF.

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LIST OF ACRONYMS

AHM	WWF Asia High Mountains Project
ASF	Atmospheric Stabilization Framework
AO	Aiyl Okmotu (Village Cluster)
CBD	Convention on Biological Diversity
ES	Emergency Situation
FAO	UN Food and Agricultural Organization
GLOF	Glacial Lake Outburst Flood
IPCC	Intergovernmental Panel on Climate Change
kW	Kilowatt
MW	Megawatt
PA	Protected Area
RCP	Representative Concentration Pathways
SLT	Snow Leopard Trust
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNFCC	United Nations Framework Convention on Climate Change
USAID	United States agency for International Development
USD	United States Dollar
WWF	World Wildlife Fund

1. NATURAL FEATURES OF THE CENTRAL TIAN SHAN

Khan Tengri (middle left) and Peak Pobeda (middle right), Central Tian Shan Mountains. © WWF.

1.1 Introduction

The Central Tian Shan region overlaps parts of the Kyrgyz Republic, Kazakhstan, and China and is considered to be geographically distinct from the adjacent Western and Eastern Tian Shan regions. In the Kyrgyz Republic, most of the Central Tian Shan region is situated at elevations over 3000 m, with the highest point being Peak Pobeda at 7439 m. In addition, there are six peaks over 6000 m in the Kyrgyz Central Tian Shan, the most well-known of which is the 6995 m high Khan Tengri, the most sacred mountain in Central Asia (see photo above). The lowest point in the Kyrgyz Central Tian Shan region is about 2500 m on the floodplain of the Sary-Jaz River on the border with China. The total area of the Central Tian Shan region within the Kyrgyz Republic is about 13,000 km^2 covering an area roughly 180 km in length and 70 km in width. Ecosystems are primarily various types of high-altitude grasslands, although limited shrub and forest cover also occurs. Within this mountainous region, there are a significant number of rare and endemic species of flora and fauna, perhaps the most notable of which is the snow leopard. Although remote, the region is sparsely populated by people who mainly subsist through family-run semi-nomadic livestock herding operations that for the most part specialize in sheep.

The Kyrgyz Central Tian Shan region can be divided into three distinct geographic units, the Khan Tengri, Sary-Jaz, and Ak-Shyrak sub-regions, based on altitudinal gradient, degree of glaciation, climatic features, and their varied patchwork of ecosystems (Fig. 1). The biological make-up of these sub-regions is greatly influenced by abiotic factors such as mountain

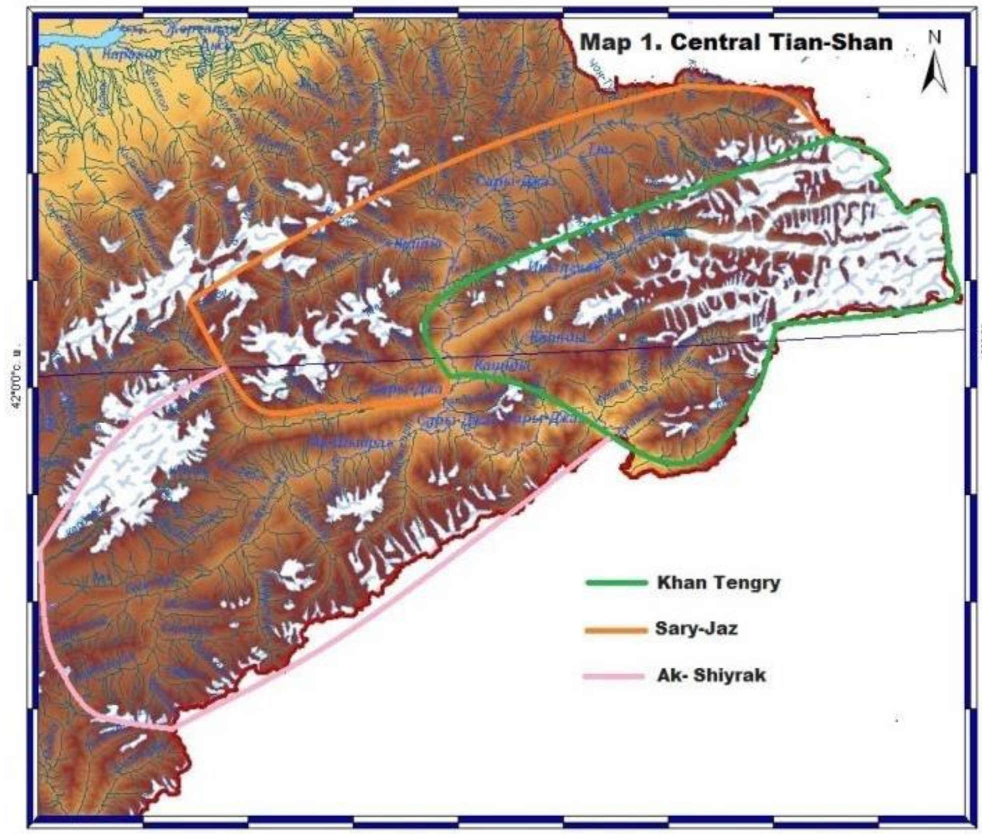

Figure 1. Sub-regions of the Central Tian Shan in the Kyrgyz Republic.

geomorphology and seasonal slope phenomena including, avalanches, mudflows, and landslides. Glaciation and permafrost have played particularly large roles in the evolution of the stream network and soil development in all three sub-regions. Human activities such as livestock grazing have also had a large influence in determining the current make-up of ecosystems throughout the Kyrgyz Central Tian Shan.

The impacts of climate change in the Kyrgyz Central Tian Shan vary widely depending on local geography and ecosystems, and further studies are needed to better understand climate impacts on the region's glaciers, permafrost, hydrology, flora and fauna. At the same time, it is also necessary to determine the ecological impact of human activities on this fragile mountain region, particularly livestock grazing and mining, since anthropogenic impacts are likely to be further exacerbated by climate change impacts. Consequently, improved natural resource management will be a high priority for any climate adaptation work in this region.

1.2 Geomorphology and Natural Hazards

The Central Tian Shan region consists of numerous distinct predominantly steep mountain ranges with narrow intermountain valleys, including the Kokshaal, Terskey, Akshyrak, Coyle, Engilchek, and Saryjaz Ranges. The higher areas of the Central Tian Shan region have typical glacial geomorphology that includes various valleys formed during ancient glacial periods, such as the Coyle, Coy-Cap, Terekty, Uch-Kul, Engilchek, and Saryjaz Valleys. These valleys are now the location of modern glaciers ranging from 2-50 km in length. Downstream, these valleys gradually deepen into gorges that can be hundreds of meters deep. At lower altitudes, all traces of ancient glaciation have, for the most part, been eroded away.

Avalanches regularly occur each year in the glacier and snowfield areas of the Central Tian Shan and pose a large hazard. For example, the Coyle River valley is lined with 15 avalanche chutes while there are 43 distinct avalanche zones on the south side of the Engilchek Glacier. Mudflows are also a large hazard in the Central Tian Shan and are triggered when heavy rains flood steep mountain ravines and gorges. Extreme summer rainfall and meltwater also regularly trigger landslides in this region, particularly in saturated glacial sediment deposits on steep, moist north-facing slopes, although earthquakes can also trigger landslides. At times, landslides in the Central Tian Shan destroy houses and roads and block river channels, which can result in catastrophic flash floods when landslide dams burst.

1.3 Ecosystems and Vegetation

The distribution of ecosystems and vegetation cover in the Central Tian Shan is largely a function of altitude, although there are a number of ecosystems that occur over a wide altitudinal range in these mountains, such as montane saline wetland, wet meadow, and floodplain ecosystems. However, the characteristic feature of ecosystems in the Central Tian Shan is vertical zonation, as highlighted by various authors (e.g. see Kaulbars, 1875; Abolin and Sovetkina, 1930; Sovetkina, 1930; Sovetkina, 1938; Vyhodtsev, 1945; Vyhodtsev, 1956; Golovkova, 1959; Kozhevnikova, 1960; Lunin, 1962; Mamytov, 1963; Popova, 1970; Orozgozhoev, 1981; Vyrypaev, 1983). These authors emphasize that, depending on slope exposure, moisture conditions, and other climatic factors, the structure of the vertical zonation of vegetation and soil differs significantly. This makes the boundaries between these zones highly site specific, and various researchers have defined the altitudinal limits of vegetation zones quite differently. Nevertheless, a very generalized overview of vegetation zones in the Kyrgyz Central Tian Shan is provided in Table 1 while a distribution map of Central Tian Shan ecosystems is provided in Figure 2.

Across these vegetation zones, ecosystems are predominantly different types of steppe grasslands. On the highest plateau areas, syrt ecosystems occur, which consist of sparse-growing, permafrost-controlled grasslands with characteristic cushion plants (Glazovskaya, 1953). Limited meadows and shrubland ecosystems also occur, but are generally limited to riparian corridors and areas with extensive seepage. Nationwide, forests cover only 6.8 percent of Kyrgyz territory. In the Central Tian Shan region forests are even more restricted in area and consist predominantly of Schrenk's spruce (*Picea schrenkiana*), which is endemic to the Tian Shan. However, these forests are of great importance in terms of biological diversity, and are home to a number of rare and endemic species. There are a number of locally and regionally rare and endemic species of vascular plants in the Central Tian Shan which are listed in Table 2,

Table 1. Vegetation zones of the Kyrgyz Central Tian Shan Region

Vegetation Zone	Elevation Range (m)	Ecosystem Types
High Mountain Desert Steppe	2500–2900	Desert, Semi-desert, High Altitude Syrt
Steppe and High Mountain Forest Meadow Steppe	2500–3900	High Altitude Dry Steppe, High Altitude Meadow Steppe, Forest, Shrublands
Subalpine Meadow Steppe	2800–3600	Cryophilic Meadow Steppe, Cryophilic Shrublands
Alpine Meadow Steppe	3400–4300	Cryophilic Meadows, Cryophilic Fenland Hummocks, Moor, Alpine Petrophytic Vegetation

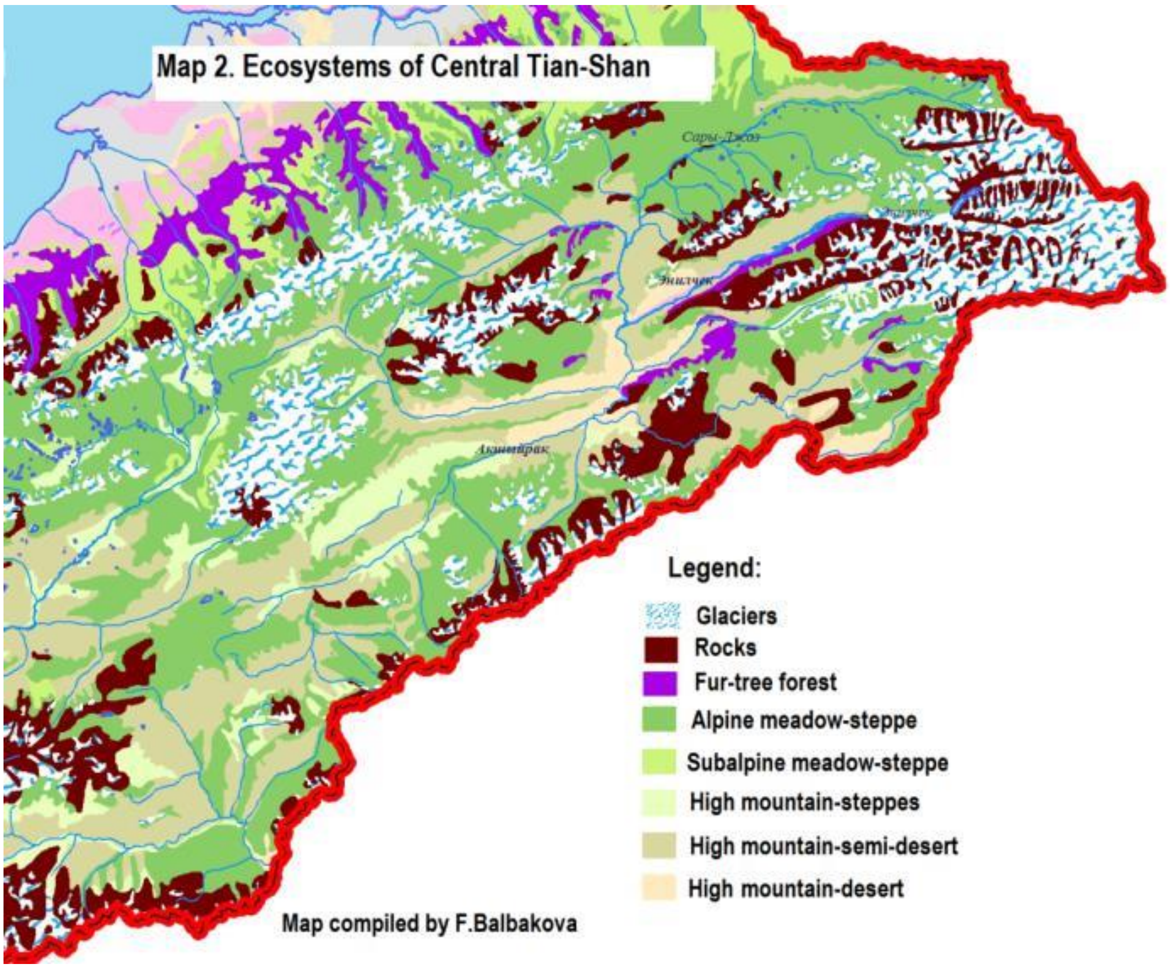

Figure. 2. Distribution of ecosystems in the Kyrgyz Central Tian-Shan.

below (Sultanova, 1998; Lazkov, 2002; Gov. of Kyr. Rep. 2006; Umralina et al., 2007; Lazkov and Umralina, 2015).

Table 2. Rare and endemic plant species of the Central Tian Shan

Species	Status
*Allium semenovii**	Endemic to the Tian Shan
*Anemone obtusiloba**	Rare
*Berberis kaschgarica**	Sub-endemic
*Zygophyllum kaschgaricum**	Sub-endemic
*Tianschaniella umbellulifera**	Sub-endemic
*Compositae Giseke**	Sub-endemic
*Pyrethrum leontopodium**	Rare
Hedysarum kirghisorum	Endemic to the Tian Shan
Seseli pelliotii	Sub-endemic
Saussurea karaartscha	Endemic to the Tian Shan
Artemisia saposhnikovii	Endemic to the Central Tian Shan
Asterothamnus schischkinii	Endemic to the Tian Shan
Acantholimon bracteatum	Sub-endemic
Oxytropis chantengriensis	Sub-endemic
Cancrinia tripinnatifida	Sub-endemic
Achnatherum caragana	Sub-endemic

* Indicates a species listed in the 2006 Kyrgyz Red Book of Endangered Species (Gov. of Kyr Rep., 2006).

1.4 Fauna

The Central Tian Shan provides ideal habitat for the endangered snow leopard (*Panthera uncia*) (Kashkarev, 1989). Snow leopards generally live in high mountain areas between elevations of about 3000–5400 m where ecosystems are predominantly alpine grasslands and climatic conditions are harsh. In the Central Tian Shan, this cold open high-altitude habitat supports a number of snow leopard prey species, including argali (*Ovis Ammon*, IUCN status: near threatened), Siberian ibex (*Capra sibirica*), grey marmot (*Marmota baibacina*), and tolai hare (*Lepus tolai*)(Kashkarev, 1983; Vyrypaev, 1983). In addition, the Central Tian Shan is also home to a number of other generally rare carnivores, such as the Himalayan brown bear (*Ursus arctos isabellinus*), lynx (*Lynx lynx*), Pallas's cat (*Felis manul*, IUCN status: near threatened), and stone marten (*Martes foina*)(Tarasov, 1961; Vorobiev, 1975; Zhumabai and Shukurov, 2005).

Avifauna, in the Central Tian Shan includes a number of locally rare species such as the ibisbill (*Ibidorhyncha struthersii*), saker falcon (*Falco cherrug*, IUCN status: endangered), lammergeier (*Gypaetus barbatus*, IUCN status: near threatened), Himalayan griffon (*Gyps himalayensis*, IUCN status: near threatened), griffon vulture (*Gyps fulvus*), cinereous vulture (*Aegypius monachus*, IUCN status: near threatened), golden eagle (*Aquila chrysaetos*), great spotted woodpecker (*Dendrocopos major*), demoiselle crane (*Anthropoides virgo*), steppe eagle (*Aquila nipalensis*, IUCN status: endangered), imperial eagle (*Aquila heliaca*, IUCN status: vulnerable), short-toed snake-eagle (*Circaetus gallicus*) and the red-fronted rosefinch (*Carpodacus punicea*)(Tarasov, 1961; Kydyraliev, 1973; Shukurov, 2010).

There are 31 species of endemic invertebrates in the Central Tian Shan, including two butterflies, *Parnassius apollo merzbacher* and *Parnassius loxias tashkorensis*, and an endemic species of ant, *Leptothorax longipilosus*. The impressive total species diversity of the Central Tian Shan, including an abundance of endemic species and high-mountain morphs, demonstrates the importance of this region for biodiversity in Central Asia.

Tables 3, 4 and 5, below, summarize the present status and distribution of plants, mammals and birds that are typical indicator species for various ecosystem types in the Central Tian Shan. As such, monitoring the distribution and population status of these species can serve as a gauge for determining overall changes in biodiversity and the degree to which climate change impacts, such as changes in temperature and precipitation, are affecting the region. Of course, use of indicator species for this purpose will also have to consider the impact of human activities on these species.

Table 3. Status and distribution of indicator plant species in the Kyrgyz Central Tian Shan

Species	**Ecosystem Type**	**Vegetation Zone***	**Status and Estimated Percent Cover**
Kalidium foliatum	Halophytic/ Salt-worthy	1	Satisfactory Estimated Cover: 3–7%
Reaumuria songarica	*Reaumuria* communities	1	Satisfactory Estimated Cover: 5–7%
Sympegma regelii	*Sympegma* communities	1	Satisfactory Estimated Cover: 10–15%
Krascheninnikovia ceratoides	*Ceratoides* communities	1	Rare Estimated Cover: 5–7%
Saussurea pygmaea	Widely distributed in all types of communities	1	Subdominant
Artemisia rhodantha	Cold, saline	1	Very widely distributed Estimated Cover: 10–12%
Artemisia congesta	Wormwood, non-saline	1	Rare Estimated Cover: 7–12%
Artemisia saposhnikovii	Foothills of slopes, up to the level of 2700 m	1	Rare in low reaches of the Saryjaz River Estimated Cover: 10–17%
Ephedra intermedia	Ephedra, on steep slopes	1	Rare Estimated Cover: 10–12%
Artemisia rutifolia	On cliffs	1	Rare Estimated Cover: 12–15%
Stipa caucasica	*Stipa glareosa* communities, on steep slopes	1	Common Estimated Cover: 10–14%
Stipa krylovii	Dry syrt steppes below 2800 m	2	Common Estimated Cover: 17–25%
Stipa subsessiliflora	Saline dry steppes at high altitude	2	Common Estimated Cover: 20–30%
Festúca valesiáca	*Festuca* steppes below 3300 m	2	Common Estimated Cover: 25–30%
Festuca kryloviana	*Festuca* steppes above 3300 m	2 and 3	Common Estimated Cover: 20–30%
Festuca coelestis	Saline dry steppes at high altitudes	2 and 3	Rare Estimated Cover: 10–30%
Ptylagrostis purpurea	Dry steppes of watershed divides	2	Rare Estimated Cover: 20–30%

Table 3. (continued)

Species	**Ecosystem Type**	**Vegetation Zone***	**Status and Estimated Percent Cover**
Leucopoa olgae	Dry and meadow steppes of steep slopes along Akshyrak and Saryjaz River valleys	2, 3, 4	Widely distributed Estimated Cover: 17–35%
Helictotrichon tianschanicum	*Helictotrichon* meadow-steppes above dry rocky slopes	2	Rare Estimated Cover: 12–20%
Artemisia pamirica	Wormwood meadow-steppes	2	Rare From 2800–3900 m
Hordeum turkestanicum	Barley meadow steppes, rocky slopes	2	Widely distributed Estimated Cover: 30–80%
Cobresia capilliformis	*Cobresia* meadow-steppes on moderate slopes	2, 3, 4	Widely distributed; Estimated Cover: 60–65%
Picea schrenkiana subsp. tianschanica	Spruce and open woodland forests	2	Rare open stand of trees
Salix alatavica	Birch and willow communities along rivers	2	Rare River Floodplains
Lonicera simulatrix	Shrubs in river valleys	2	Rare River Floodplains
Caragana jubata	Shrubs of sub-alpine zone	3	Common in dense shrubs
Kobresia humilis	Wet sedge meadows	3 and 4	Common at *Festuca rubra* locations
Carex melanocephala	Alpine wet meadows	4	Common in Alpine Wetlands and Peatlands
Dryadanthe tetrandra	Alpine cushion plant formations	4 and 5	Rare Estimated Cover: 12–15%
Saxifraga hirculus	Alpine barren grounds	4	Common
Saxifrága oppositifólia	Barren grounds on the border of glaciers	4 and 5	Rare Cushion Plant Formations
Kobresia stenocarpa	Marshes and lakeshores	1–4	Rare Lakeshores
Potentilla biflora	Alpine barren grounds	4 and 5	Cushion Plant Formations

*Notes: Vegetation zone codes are as follows: 1 = High Mountain Desert Steppe, 2 = Steppe and High Mountain Forest Meadow-Steppe, 3 = Subalpine Meadow-Steppe, 4 = Alpine Meadow-Steppe, 5 = Glacial Nival.

Table 4. Status and distribution of indicator mammal species in the Kyrgyz Central Tian Shan

Species	**Ecosystem Type**	**Vegetation Zone***	**Status**
Tolai Hare *Lepus tolai*	Desert steppes, meadow-steppes, and meadows	1–3	Common
Grey Marmot *Marmota baibacina*	Dry steppes and meadow-steppes	1–4	Common
Red Fox *Vulpes vulpes*	Desert steppes, meadow-steppes, and meadows (Same ecosystems as for Tolai Hare)	1–3	Common
Narrow-headed Vole *Microtus gregalis*	Meadow-steppes, meadows, wet meadows	2–3	Numerous
Eurasian Badger *Meles meles*	Forests and shrubs in river valleys	2	Comparatively rare
Stoat *Mustela erminea*	Rocky meadow-steppes and floodplain shrubs	2–3	Numerous
Northern Mole Vole *Ellobius talpinus*	Meadow-steppes and meadows	2–3	Common
Silvery Mountain Vole *Alticola argentatus*	Rockslide areas on mountain slopes	2–3	Common

*Notes: Vegetation zone codes are as follows: 1 = High Mountain Desert Steppe, 2 = Steppe and High Mountain Forest Meadow-Steppe, 3 = Subalpine Meadow-Steppe, 4 = Alpine Meadow-Steppe, 5 = Glacial Nival.

Table 5. Status and distribution of indicator bird species in the Central Tian Shan

Species	High Mountain Plant Ecosystems	Vegetation Zone*	Status
Isabelline Wheatear *Oenanthe isabellina*	Deserts and semi-deserts, dry steppes	1–3	Common
Horned Lark *Eremophila alpestris*	Desert steppes and meadow-steppes	1–3	Common
Chukar Partridge *Alectoris chukar*	Rocky steppes with rockslides up to 3000 m	2	Common
Yellow-browed Warbler *Phylloscopus inornatus*	Forests and shrubs in river valleys	2	Numerous
Rock Pigeon *Columba livia*	Rocky meadows and meadow-steppes	2–3	Common
Plain Mountain Finch *Leucosticte nemoricola*	Rocky meadow steppes and subalpine meadows	2–3	Common
White-winged Snowfinch *Montifringilla nivalis*	Meadow steppes	3–4	Numerous
Himalayan Snowcock *Tetraogallus himalayensis*	Craggy meadow-steppes	3–4	Common
Yellow-billed Chough *Pyrrhocorax graculus*	Craggy meadow-steppes	3–4	Numerous
Brandt's Mountain Finch *Leucosticte brandti*	Alpine meadows	4	Locally Common
White-winged Redstart *Phoenicurus erythrogaster*	Rocky meadows	4–5	Uncommon

*Notes: Vegetation zone codes are as follows: 1 = High Mountain Desert Steppe, 2 = Steppe and High Mountain Forest Meadow-Steppe, 3 = Subalpine Meadow-Steppe, 4 = Alpine Meadow-Steppe, 5 = Glacial Nival.

1.5 Climate Change and Biodiversity Conservation

Climate change, above all, alters environmental conditions (IPCC, 2013). The resilience of ecosystems to climate change depends upon their ability to maintain both their structure and function. Inability to do so may spur the development of new ecosystems that are better adapted to changed climatic conditions but which may not support local fauna and livelihoods. Some components will react quickly (animals) and others more slowly (soils). Thus, climate change impacts ecosystem services by altering both biodiversity and productivity. The links between biodiversity and climate change are bilateral in nature: climate change threatens biodiversity while resilient biodiversity can partially mitigate the impacts of climate change.

To date, natural community composition and structure of ecosystems in the Central Tian Shan remain close to their original state at the onset of rapid climatic warming in the late 1970s. Thus, at present, these ecosystems are providing the opportunity to flexibly preserve the heterogeneity of the mountain environment and persist in spite of climatic fluctuations. Various pasture types dominate the ecosystems of the Central Tian Shan and are composed of seasonally changing groups of plant communities, a cycle which could be disrupted by the introduction of homogeneous non-native plant communities. Primary biomass in grasslands ecosystems is the basis of an important sector of the economy, namely livestock herding, that a large part of the Central Tian Shan region's human population depends for their wellbeing. At the same time, healthy mountain grassland ecosystems also prevent the loss of the thin fertile soil layer on mountain slopes and helps prevent the formation of destructive floods and landslides that annually cause millions of dollars in damage to the region's infrastructure. Therefore, healthy natural ecosystems in the Kyrgyz Tian Shan make important contributions to the ecological stability of these mountains.

The impact of climate change on biodiversity has manifested itself in the following ways:

- Changes in species distribution
- Accelerating incidence of extinction
- Changing reproduction patterns
- Lengthening of annual plant growth periods
- Changes in plant and animal phenology such as migrations and hibernation periods

Typically, species that are already endangered are particularly vulnerable to the impacts of climate change, as natural conditions are altered and habitat degraded. One such species is the snow leopard. The high mountain ecosystems of the Kyrgyz Republic form extensive snow leopard habitat, however, the country may have as few as 300 snow leopards remaining (Snow Leopard Network, 2014). Projected increases in temperature and the melting of glaciers may reduce the extent and quality of the snow leopard's alpine habitat as lower elevation ecosystems shift upward. Snow leopards could also be threatened by increasing aridity in this region, which will threaten the survival of prey species such as argali. Another climatic threat to snow leopards could be increasing snowfall in winter, which would contribute to the die-off of prey species and hinder the snow leopard's ability to hunt.

At the same time, the staff of the Sarychat-Ertash State Reserve in the Central Tian Shan have recorded the appearance or increase in number of several noteworthy species, although these reports require further confirmation. These species were as follows:

- The number of polecats, which had previously been relatively rare in the Central Tian Shan, has increased. The reason for their population growth will require detailed analysis. The contribution of climate change cannot be excluded, as it affects the distribution and abundance of small rodents and ground-nesting birds, the main prey of polecats. In turn, the abundance of polecats may be a reason for the decline in the regions marmot populations, which polecats eat in winter when marmots hibernate.

- In the Jaman Suu area of the Sarychat-Ertash State Reserve, a small but relatively stable population of frogs has recently been recorded for the first time. The exact species and reasons for their appearance need to be explored. It is possible that climate change has contributed to making habitat and migration routes for amphibians in the reserve more favorable.

- Since 2012, a small herd of wild boar has been regularly recorded in the upper reaches of the Sarychat River for the first time. It is assumed that the animals migrated from the Coyle valley to the east, where the climate is relatively milder and winters are warmer. These boar likely found the current climatic conditions of the Sarychat River valley to be increasingly acceptable.

- A recent increase in the number of jackals has been recorded in the Jety-Oguz District of the Central Tian Shan. In previous years, only a small number of jackals occurred in the Ak-Suu District, where the climate is milder.

- An increase in the numbers of brown bears and golden eagles in the Central Tian Shan has also been recorded.

Natural plant and animal communities play a crucial role in the formation of an environment suitable for life in difficult mountainous conditions. On the plains, ecosystem boundaries may extend for hundreds of kilometers and fluctuations in biological communities caused by climate change occur over vast areas. However, in the mountainous Kyrgyz Republic, desert, steppe, alpine meadow, and forest ecosystems occur in close proximity to each other and ecosystem patches are sometimes only several kilometers across. This high degree of biodiversity across such small areas can only continue to survive if these contrasting ecosystems remains healthy and resilient (Balbakova and Shukurov, 2002). The formation and preservation of soils, retention of rainfall, continuous surface water flows and purification, and even gas composition of the atmosphere depend on the functioning of natural ecosystems. Once highland ecosystems are lost, they cannot be effectively replaced by other ecosystems. Thus, preserving the heterogeneity of mountain ecosystems will need to be a critical part of the response to climate variability.

The plant species listed in the Kyrgyz Red Book as rare, endemic, or have declining habitat and thus are the most vulnerable to global climate change (Gov. of Kyr. Rep., 2003). In the Kyrgyz Republic, climate change will cause a significant shift in ecosystem boundaries due to the expansion of the desert and steppe ecosystems, including the transformation of meadows into steppe ecosystems. Yet no catastrophic changes in species composition in the nation are expected over the coming decades. Many species in the region are already characterized by having natural, adaptive capabilities to migrate to areas with more favorable conditions. However, it is likely that the altitudinal distribution of species will change with many species shifting up slope causing declines in the most vulnerable species found at higher elevations, including many rare and endemic species. A second climate-related threat to some ecosystems in the Tian Shan is the recent increase in the incidence of wild fires resulting from increasing aridity, which pose a particularly large danger as they can cause permanent loss of forests and other ecosystems.

Table 6. Growth of the Kyrgyz Republic's protected area network by type, 1990-2013

Type of Protected Area	Total Area of Protected Area Types by Year (hectares)					
Year	**1990**	**1995**	**2000**	**2005**	**2010**	**2013**
Nature Reserves	164,857	236,937	236,937	354,760	460,887	537,925
National Parks	11,172	13,458	238,697	259,197	294,801	297,052
Natural Monuments	100	100	100	100	100	100
Wildlife Sanctuaries	288,900	288,900	36,176	291,017	287,193	289,060
Nature Reserve Buffer Zones	—	—	—	—	139,5867	77,1867
Botanical and Zoological Gardens	150.7	150.7	150.7	150.7	150.7	150.7
Total	**465,179**	**539,545**	**512,060**	**905,224**	**1,182,718**	**1,201,474**
Percent of National Territory	**2.3**	**2.7**	**2.5**	**4.5**	**6.0**	**6.1**

Source: Balbakova, 2013.

Given the predicted future climatic changes in the Central Tian Shan region, the most effective way to protect the region's natural systems against these change is through preservation of species and communities in their natural state, particularly through the establishment of protected areas (PAs). At present, the Kyrgyz Republic has a network of 87 protected areas covering a total area of 1,201,474 hectares, or about 6.1 percent of national territory (Table 6, Fig. 3 and 4). These protected areas are fully or partially withdrawn from economic use and are of paramount importance for the conservation of the nation's biological and landscape diversity.

At the time of this writing, the only functioning protected area in the Kyrgyz Central Tian Shan is the Sarychat-Ertash State Reserve (Fig. 4). This high-altitude nature reserve was established in 1995 with an area of 72,080 hectares and expanded in 2013 to cover a total area of 149,117 hectares. The reserve is notable for having the largest snow leopard, argali, and ibex populations in the Kyrgyz Republic and for protecting a large tract of fragile high-altitude syrt grassland ecosystem. Other notable mammal species found in the reserve include Himalayan brown bear, Pallas's cat, wolf, fox, grey marmot, and tolai hare and stone marten (Alamanov et al. 2013b). Notable birds found in the reserve include saker falcon, golden eagle, Himalayan Griffon, cinereous vulture, griffon vulture lammergeier, common kestrel (*Falco tinnunculus*), Eurasian eagle owl (*Bubo bubo*) and ibisbill. Two notable rare plants found at Sarychat-Ertash are Kashgar barberry (*Berberis kaschgarica*) and snow lotus (*Saussurea involucrata*).

In 2016, the 278,500 hectare Khan Tengri National Nature Park was established as the second protected area in the Kyrgyz Central Tian Shan. This park has now supplanted the Sarychat-Ertash State Reserve as the Kyrgyz Republic's largest protected area. This new park will soon protect a vast swath of important snow leopard habitat in the Central Tian Shan, but the process of setting up a park administration is still currently underway.

Figure 3. Protected areas of the Kyrgyz Republic. Source: Balbakova, 2013.

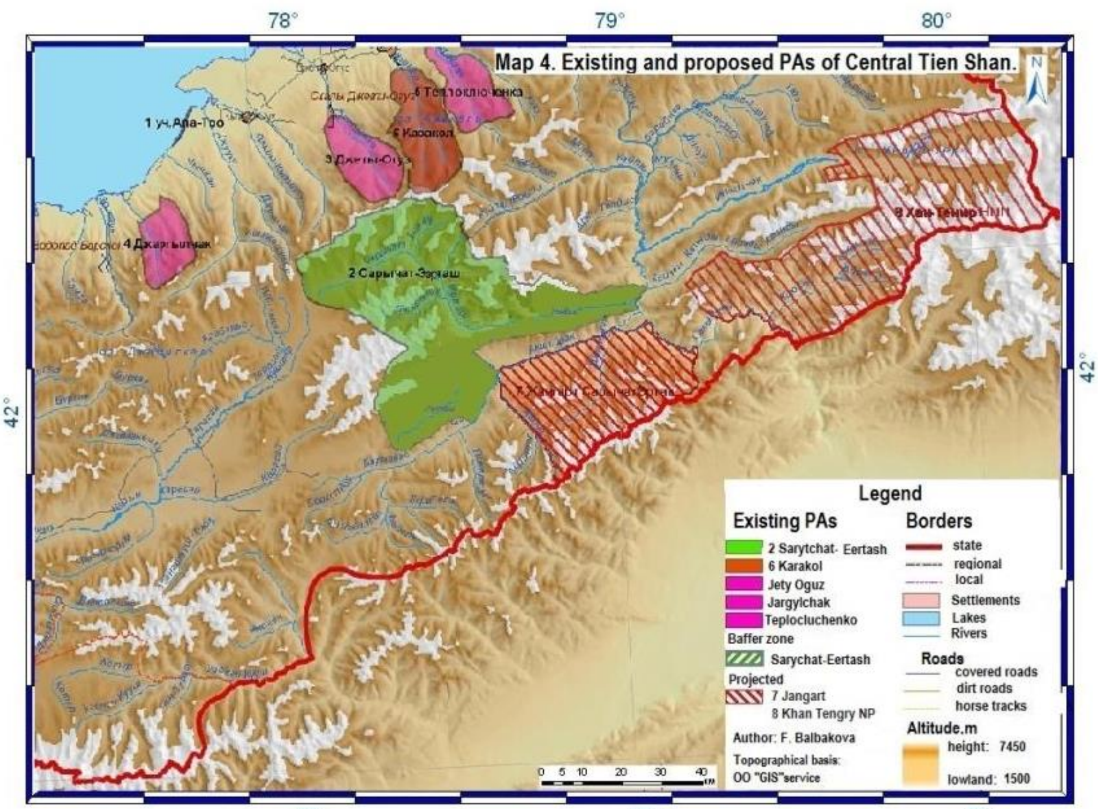

Figure 4. Map of showing the location of protected areas of the Central Tian Shan and northern Terskey Range, Issyk Kul Province, Kyrgyz Republic. Source: Balbakova, 2013.

2. CLIMATE CHANGE IMPACTS

2.1 Climatic Regions of the Kyrgyz Republic

The Central Tian Shan is located at the junction of three major geographic regions, the Central-Asia, Turan and Central Kazakh Steppe regions and is influenced by three high elevation air currents, the southern (dry), western (wet) and northern (cold) air currents (Alamanov et al. 2013a). The circulation processes that determine the climate of the Central Tian Shan occur on a geographically large scale. The Kyrgyz Republic itself has four distinct climatic regions (Fig. 5). These are:

- The Northwestern Region, which includes the Chuy and Talas Valleys and surrounding mountain ranges. This region is characterized by a moderately warm climate and sufficient moisture with maximum rainfall in spring.

- The Northeastern Region, which includes the Issyk-Kul Lake basin and its surroundings. It is characterized by maximum precipitation in summer, with the ice-free water mass of the lake providing a moderating influence on the climate of the region.

- The Southwestern Region, which includes the Ferghana, Alai, and Chatkal Valleys and surrounding mountain ranges. These are the warmest and most humid areas where, unlike the other regions, a significant amount of precipitation falls during the cold season.

- The Central and Inner Tian Shan lie in the Southeastern Region, which is characterized by a cold and dry climate with low temperatures and low evaporation. Maximum precipitation in this region occurs from May to and July (Gov. of Kyr. Rep., 2009).

2.2 Lakes

Lakes in the Central Tian Shan are found in the upper part of the Tuz River basin, between the Adir-Tor and Sary-Jaz Rivers, along the Ashu-Tor River and adjacent to or even on glaciers. The largest lake of ancient glacial origin is located in the Bash-Kul River valley. Six ancient glacial lakes, with a total area of 1.3 km^2 are located in the upper part of the Akshyrak River basin, between the southwestern slopes of the Akshyrak Range and the northeastern slopes of the Borkoldoi Range. The largest of these is Lake Batyr-Beshik, which has an area of 1.1 km^2 and is over 700 m in length and 200–220 m in width. The remaining lakes are small and range in length from 60–100 m and are 30–70 m in width. The deepest of these are only about 3–4 m in depth (Shnitnikov, 1975). The bottoms of the deepest lake basins are covered in gray mud, although beds of shallow areas are predominantly glacial drift and small boulders. At present, these lakes are shrinking, as evidenced by the presence of swampy mud and sedge marsh meadows along the

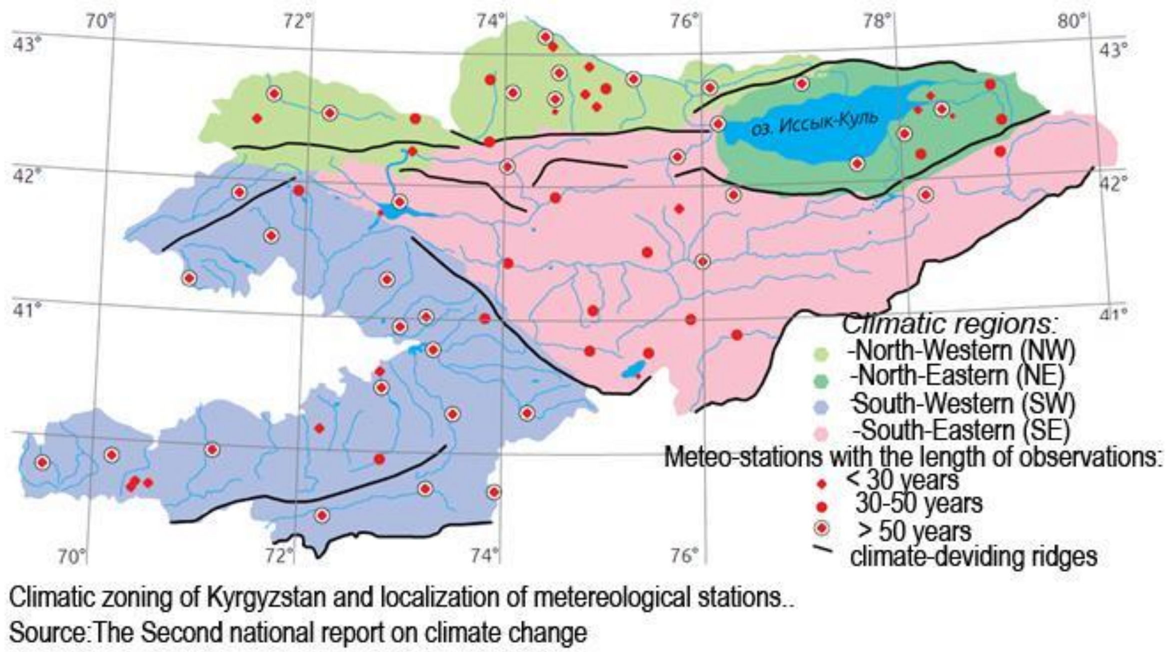

Figure 5. Map of climatic regions of the Kyrgyz Republic with locations of hydro-meteorological stations. Source: Government of the Kyrgyz Republic, 2009.

banks at distances of 80–100 m from the shore. In addition, evaporation in summer and a lack of spring floods is leading to a negative water balance that will eventually lead to their drying up.

2.3 Permafrost

In high-altitude areas of the Central Tian Shan, both continuous and island permafrost occur. Permafrost extends to lower elevations on north-facing slopes than on south-facing slopes, with the 3000 m contour forming the approximate boundary between island and continuous permafrost on north-facing slopes and the lower limit of all permafrost on south-facing slopes. However, permafrost distribution varies with slope aspect, slope steepness, geology, climate, snow cover, vegetation, soil moisture, and altitude. For example, on the north-facing slopes of the Engilchek Range north of the Kandzhayloo River, permafrost was found at an altitude of 2900 m and a depth of 1.36 m, but on the south-facing side of the same valley, permafrost was absent even at a depth of 1.80 m.

Precise data on permafrost thickness in the Central Tian Shan is not available, but fragmentary reports indicate that permafrost in the region is directly dependent on altitude and climatic conditions. In general, the thickness of the permafrost layer increases with increasing altitude, but this pattern is often dependent on slope aspect. According to A.P. Gorbunov (1967, 1970), who analyzed all available information on permafrost thickness in the Tian Shan, permafrost can reach depths of 20–25 m at an altitude of about 3000 m, 50–60 m at 3100–3200 m, 100–110 m at

3300–3400 m, 150–160 m at 3500–3600 m, 200 m at 4000 m, and several hundred meters at altitudes of 5000–6000 m.

Summer thawing is indicative of the temperature regime of the permafrost active layer, with average thawing reaching a maximum depth of 119.8 cm over an average thawing period of 114 days. Freezing of the active layer in winter occurs, on average, in 26 days, about 4.5 times faster than thawing. The magnitude of seasonal thawing of permafrost in spring is strongly influenced by vegetation. The melt horizon of the permafrost layer under sparse alpine desert vegetation at altitudes of 3800–4000 m is typically 60–80 cm, while it ranges from just 5 to 35 cm under the dense sod of *Kobresia* sedge meadows.

Permafrost in the Central Tian Shan has a great diversity of forms, including frozen soil, frozen rocky-sandy sediments, and ground ice. Ground ice occurs in two forms: 1) buried ice, which consists of surface ice that was subsequently buried, and 2) proper ice formed in situ underground. Buried ice ranges in thicknesses from 30 to 150 m. Basin-type subsidence in Pleistocene moraines of the Central Tian Shan indicates past melting of buried ice blocks. Permafrost geomorphology is characterized by cryogenic landforms that alter the usual appearance of the highland landscapes, and include dense networks of frost mounds, multiple polygonal banded microforms, frost cracks, and surface solifluction.

Permafrost impedes infiltration and reduces soil temperature and hence reduces soil and ground water temperature, even in summer. This in turn reduces evaporation from the soil surface and even small amounts of precipitation runoff have low volatility and persist in surface pools longer than expected. This results in the formation of high altitude wetlands in areas such as the upper reaches of the Saryjaz River. The disappearance of permafrost on syrt lands in the Central Tian Shan would therefore cause the disappearance of many wetlands and a reduce the area of highly productive meadow ecosystems. From this perspective, the presence of permafrost in the highlands is a positive phenomenon. On the other hand, the existence of persistent surface water combined with intense evaporation can lead to soil salinization.

2.4 Glaciers

About 45 percent of all glaciers in Central Asia are located in the Kyrgyz Republic, where there are 8200 glaciers with a total area of 8169 km^2. These glaciers cover 4.2 percent of Kyrgyz territory and have an estimated volume of 650 km^3 (Gov. of Kyr. Rep., 2012a; Alamanov et al., 2006). Glaciers and snowmelt in the Kyrgyz Tian Shan are of great importance in the regulation of regional water supplies, especially during hot dry summers, and the future of these glaciers under a warming climate is of particular concern (e.g. see Podrezov et al. 2003). Rivers emanating from the Central Tian Shan and its glaciers provide water resources for almost one-third of the Kyrgyz Republic as well as for vast areas of neighboring countries, and this region is often referred to as the water tower of Central Asia.

In the history of Central Asia's glaciers, there have been several periods of advance and retreat. Following the Little Ice Age (1450–1850), glaciers in the Tian Shan and Pamir-Alai have generally been in retreat with short periods of advance (Imbrie and Imbrie, 1988). The current warming trend in Central Asia began in the mid-20th Century. Global warming is most apparent in surface air temperature changes. Warming, combined with unpredictable changes in precipitation in the alpine zone (which will either decrease or remain within the climatic norm), will cause a steady reduction in coverage of contemporary glaciers. Despite regional differences in climatic conditions, baseline climate characteristics are similar across the Central Asian Region, and the general trend of glacial degradation will continue across these mountain ranges.

Precipitation is one of the most variable climate elements. Long-term fluctuations in precipitation are largely related to the variability of processes in a given year. Despite the fact that the same processes cover a large area, precipitation changes in the Tian Shan are not the same everywhere due to varying topography, orography, and hypsometry. Variation in temperature and precipitation in turn affect the locations where glaciers form and are maintained. Moreover, glacier shape and size can change in relatively short time intervals as a result of their advance or retreat. But significantly, climatic conditions are similar for all internal areas of the Tian Shan, with glacial meltwater from these ranges forming runoff that feeds the two largest rivers of the Tian Shan, the Naryn and Saryjaz Rivers.

The largest glacier fields in the Tian Shan are concentrated in the area of the Peak Pobeda and Peak Khan Tengri (Osmonov, 1974). In the eastern Saryjaz River basin, glaciers cover 2000 km^2 of a total area of 11,200 km^2. In comparison, total glacier cover in the Altai Mountains was just 910 km^2 in the mid-20th Century while in the Caucasus, glaciers have a total area of 1400 km^2 spread over a total area of about 440,000 km^2 (Tronov, 1949; Ivankov, 1959).

2.5 Glacier Retreat

Inner Tian Shan

Analysis of 39 glaciers in the Akshyrak Range in the upper reaches of the Naryn River found that the average rate of retreat during the 1943–1977 period was 1.5–2 m/year faster on the south-facing Kara-Sai River side of the range than in the north facing Taragay River side. In general, retreat of the 39 glaciers in the upper part of the Naryn River during this 34 year period averaged 6.5 m/year (Table 7)(Kuzmichonok, 1986).

On the southern slope of the Terskey Range, ten glaciers retreated at relatively slowly rate of 2–4 m/year from the mid-19th Century until 1943. From 1943–1956, the average rate of retreat increased significantly and reached 14–17 m/year. Over the next 20 years glaciers continued to retreat, but the rate of decline decreased slightly to 8–10 m/year. Beginning in the late 1970s the rate of glacier retreat rate steadily increased in the Inner Tian Shan and from 1990–2006, the average rate of glacial retreat was the highest in the last 150 years at 18–20 m/year (Kutuzov, 2009).

Central Tian Shan

This region is dominated by the Saryjaz River basin, where the basin's 195 glaciers were retreating at an average speed of 7.1 m/year over a 34-year period from 1943 to 1977. However,

Table 7. Average retreat of glaciers in the upper Naryn River basin, 1943-1977.

River Basin	Number of Glaciers	Average Total Retreat 1943–1977 (m)	Average Rate of Retreat 1943-1977 (m/year)
Taragai River basin			
Terskey Range: Southern Slopes	8	193	5.7
Akshyrak Range: North and Northwestern Slopes	18	204	6.0
Karasai River basin			
Akshyrak Range: South and Southwestern Slopes	13	262	7.7
Total	**39**	**221**	**6.5**

Source: Kuzmichonok, 1986.

rates of retreat varied widely in the basin, ranging from a low of 3.3 m/year in the Big and Small Taldy-Suu River area on the southern slopes of the Koëlyu-Too Range to 10.1 m/year on the southern slopes of the Koëlyu-Too Range in the Uch-Kul River basin (Table 8)(Alamanov et al. 2013). Geography appears to be the primary factor determining glacier retreat rates in the Saryjaz basin, with glaciers on south facing slopes in both the eastern and western halves of the basin retreating at significantly faster rates than glaciers on the basin's north-facing slopes.

The largest dendritic glaciers of the Tian Shan are located in the Saryjaz River basin. Fluctuations in dendritic glaciers of the Tian Shan have been investigated in detail by E.K. Bakov (1975). Along with climatic factors, these fluctuations are affected dynamically by the relative tendency of a glacier to surge. Surging glaciers periodically pulsate and advance but this action is often not consistent with the current climatic conditions of the area.

Glacial fluctuations can be very erratic. Semenov's Glacier in the upper reaches of Saryjaz River retreated 1.7 km from 1943 to 1963, with an average rate of 85 m/year. From 1963 to 1968 the glacier was almost stable. In 1970, average annual retreat was 27 m/year. According to Dyurgerov et al., (1995), Semenov's Glacier periodically surges, then rapidly retreats for long periods at an average rate of 20 m/year.

Mushketov's Glacier is a typical pulsing glacier in the Central Tian Shan. From 1943 to 1956 it retreated by 2 km with an average rate of 143 m/year. In 1956 and 1957 the glacier suddenly retreated by 4.5 km (Bondarev and Zabirov, 1964). After 1967, the glacier gradually receded by an average of 8–15 m/year (Dikikh et al., 1991). North Engilchek Glacier retreated 3.2 km from 1943 to 1981 with an average rate of 84 m/year and from 1981 to 1990 another 1 km, accelerating to an average rate of retreat of 111 m/year (Kuzmichonok, 1986). However, between 1993 and 1997 the glacier rapidly advanced more than 4 km. As a result, it almost completely displaced Lake Verhnee from its basin, regaining the lenght that it had had in 1943. After 1997,

Table 8. Average retreat of glaciers in the the Saryjaz River basin, 1943 to 1977.

River basin	Number of Glaciers	Average Total Retreat (m)	Average Rate of Retreat (m/year)
Koëlyu River basin			
Southern slopes of the Terskey Range	29	313	9.2
Northern slopes of the Koëlyu-Too Range	24	243	7.1
Uch-Kul River			
Southern slopes of the Koëlyu-Too Range	10	343	10.1
Southern slopes of the Terskey Range	41	192	5.6
North-northeastern slope of the Akshyrak Range	40	198	5.8
Other Rivers			
Big and Small Taldy-Suu Rivers and Kaiyndy-Bulak (southern slopes of the Koëlyu-Too Range)	8	111	3.3
Terekty River (southern slopes of the Koëlyu-Too Range)	20	279	8.2
Akshyrak River (South-southeastern slopes of the Akshyrak Range)	12	293	8.6
Upper reaches of Saryjaz River	7	273	8.0
Enylchek and Kaiyndy Rivers	4	211	6.2
Total	**195**	**240**	**7.1**

Source: Alamanov et al., 2013a.

the glacier again began to retreat intensely and the area of Lake Verhnee increased again. One reason for the rapid glacial movement is the dynamic nature of the floating glacier tongue. On the other hand, the tongue of the South Engilchek Glacier descends to 2800 m, yet the glacier is relatively stable. The reason for this comparative stability is a large, 14 km long moraine that blocks the end of the glacier (Mavlyudov, 1988).

Information about the fluctuations of the Kaiyndy Glacier is very limited. From 1932 through 1943, the length of the glacier decreased by 300 m at rate of 25 m/year. In the period from 1943 to 1960, the glacier retreated 1.3 km. Yet over the period from 1850-1965 the glacier retreated a net distance of only 500 m, with a mean rate of about 5 m/year (Bakov, 1975). Despite the weak correlation with climate change, the largest dendritic glaciers of the Tian Shan are generally retreating. However, the rate of retreat of dendritic glaciers is low compared with other types of glaciers.

Table 9. Average rate of retreat of glaciers in the Kyrgyz Tian Shan from 1943–1999.

Region	Range of Minimum Retreat (m/year)	Range of Maximum Retreat (m/year)
Western Tian Shan	< 2.7–3.0	4.5–6.0
Northern Tian Shan	4.0–6.7	8.5–11.8
Issyk-Kul Basin	2.0–4.9	5.4–6.0
Inner Tian Shan	5.6	7.7
Central Tian Shan	3.3–4.3	8.3–9.5
Dendritic Glaciers	0–5	10–27

Source: Alamanov et al., 2013a.

In the Tian Shan, the fastest rates of retreat, up to 9.7 m/year, have been observed in valley and hanging-valley glaciers with southern, southwestern, and southeastern exposure for more than 3 km of their length. Slowest rates of retreat, 3–5 m/year, occur in cirque-hanging glaciers with northern and northeastern orientation that have lengths of less than 1–2 km while flat top glaciers have even slower rates of retreat of less than 1.3 m/year. Nevertheless, on the southern slopes of the Terskey Range in the Taragay and Uch-Ceol River basins, some glaciers actually have average rates of retreat that are lower than glaciers with northern, northeastern, and northwestern exposures.

Although taken from a number of different time periods, observations of glacier fluctuation throughout the Kyrgyz Tian Shan from 1943-1999 reveal distinct regional differences (Table 9) (Alamanov et al. 2013a). However, in general the rate of glacier retreat increased during this period. While the rate of glacier retreat slowed in the first half of the 1960s and mid-1970s, when there were even cases of brief growth, these were insignificant compared to the general pattern of retreat and can be explained by briefly favorable climatic conditions. After the late 1970s, glaciers again began steady retreat. During the 1943-1999 period, minimum rates of retreat were noted in the ranges of the Western Tian Shan and Issyk-Kul basin (2.0–6.0 m/year), while maximum rates of retreat were observed in the Northern Tian Shan Range (8.5–11.8 m/year). As the overall decline of glaciers continues, rates of retreat will vary in intensity (Alamanov et al., 2013a).

2.6 Change in Glacier Area and Volume

The mountain ranges of the Tian Shan are surrounded by arid plains with sparse summer precipitation, where glacier and snowmelt-fed rivers are the primary source of fresh water in summer (Sorg et al., 2012). Therefore, precise information about glacial ice cover is very important for assessing water resources available for agriculture, industry, and drinking water.

Despite its dry continental climate, the Tian Shan has a very high concentration of glaciers compared to all other mountainous regions in Eurasia (Kotlyakov et al., 2012).

Most information on change in glacier area in the Tian Shan comes from observations of individual mountain ranges and river basins of the Northern Tian Shan, Inner Tian Shan, and the Lake Issyk-Kul basin, as well as other glaciated areas of the Tian Shan. In general, though, the total area of glacier cover in the Tian Shan is decreasing as glaciers retreat as evidenced by comparison of historical maps and satellite imagery as well as long-term field measurements. The valley glaciers of the Tian Shan experienced the greatest decline in area during the second half of the 20th Century although smaller mountain slope glaciers lost 10–20 percent more total area than valley glaciers, with some melting away completely.

Inner and Central Tian Shan

Of 178 glaciers in the Akshyrak Range, 149 glaciers decreased in area during the period from 1943 to 1977, while the area for 22 glaciers was virtually unchanged and 7 glaciers increased in area. In total, the area of glaciers in the Inner and Central Tian Shan decreased by 14.4 km^2, or 3.4 percent overall during this period, with an average annual decrease in area of 0.424 km^2. The greatest decreases in area were observed for glaciers of the eastern, southern, and northern peripheries of the range (Table 10)(Kuzmichonok, 1989). However, total decrease in glacial area in the Akshyrak Range was less than in the Northern Tian Shan. Table 11 shows the reduction of glacier area (S) and glacier volume (V) of the glaciers in the Akshyrak Range over three different time periods from 1943 to 2003.

On the southern slopes of the Terskey Range, which lie in both the Inner and Central Tian Shan Regions, total glacial area decreased 19 percent over the previous 150 years up to 2003, from a total of 404 km^2 to 328 km^2. By 2003, the total number of glaciers on the southern slopes of the Terskey Range had increased to 335 from 297 during the Little Ice Age due to the break-up of large valley glaciers. The number of valley glaciers has increased from 47 in the middle of the 19th Century to 71 in 2003, while 16 small glaciers completely melted away during the 20th Century. Glaciers larger than 10 km^2 have lost an average of 10 percent of their area, with the largest glaciers having lost even more. Glaciers smaller than 1 km^2 lost on average about 30 percent of their area. Between 1990 and 2003, the highest rate of decrease was recorded in glaciers situated on flat mountaintops, which lost an average of 0.6 percent of their areas annually (Kutuzov, 2009).

Table 10. Average decline in area of glaciers in the Akshyrak Range, 1943 to 1977.

Glacier Group	Total Glacier Area by Group in 1943 (km^2)	Decrease in Glacier Area by 1977 (km^2)	Percent Decrease	Average Rate of Decrease (km^2/year)
Northern periphery	62.3	3.3	5.3	0.10
Jaman-Suu River basin	57.2	1.7	3.0	0.05
Eastern Periphery	16.7	1.2	7.2	0.04
Koëndu River basin	60.9	2.1	3.4	0.06
Southern Periphery	14.5	1.0	6.9	0.03
Karasai River basin	86.7	2.0	2.3	0.06
Western Periphery	50.4	2.1	4.2	0.06
Petrov's Glacier System	77.4	1.0	1.3	0.03
Total	**426.1**	**14.4**	**3.4**	**0.424**

Source: Kuzmichonok, 1989.

Table 11. Changes in area and volume of glaciers of the Akshyrak mountain group from 1943–2003.

1943–1977			1977–2003			1943–2003		
S (km^2)	S (%)	V (km^3)	S (km^2)	S (%)	V (km^3)	S (km^2)	S (%)	V (km^3)
-17.95	-4.2	-3.6	-35.5	-8.7	-6.1	-53.10	-12.5	-9.7

Source: Kutuzov and Shahedanova, 2009.

2.7 Advancing Glaciers

Based on a study of satellite images from 1990 to 2010, 10 glaciers were discovered whose area had increased from 0.4–13.0 percent (average 3.9 percent). Growth was observed mainly in large glaciers, with growth in small and medium-sized glaciers being extremely rare. In the eastern Saryjaz River basin, increases in area of three glaciers area were minimal and they should be considered stable glaciers, with the two largest increases having been just 2.9 percent and 6.8 percent of total area during this period (Alamanov et al., 2013a).

The greatest increase in area of a glacier in the Inner and Central Tian Shan Region was 5.8–6.5 km^2, or 13 percent, observed for Glacier Number 377, located in the southern sector on a slope with a northwestern exposure (Fig. 6). A detailed analysis of this glacier revealed that it initially retreated by 450 m in length, or 0.5 percent, between 1990 and 1998. Then, during the

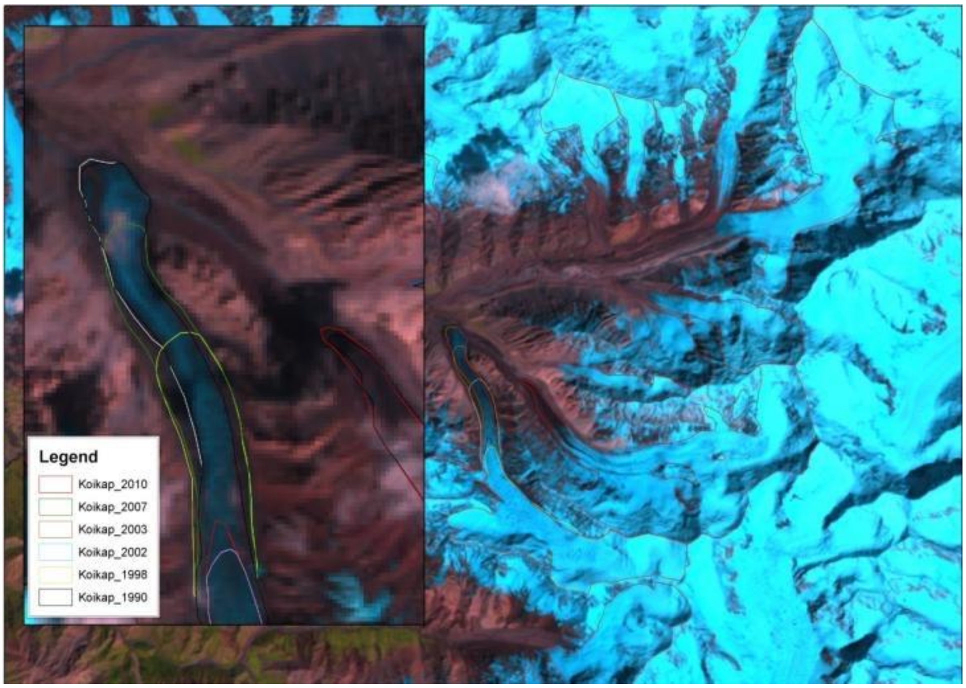

Figure 6. Changes of Glacier 377, 1990–2010. Source: Alamanov et al., 2013a.

1999–2002 period, the area of the glacier increased by 5.8–6.4 km^2, or 11.5 percent, and the glacier itself surged 3200 m, a 10.7 percent increase in length. In 2003 alone, the glacier advanced 850 m and at the same time expanded. In 2007, this glacier narrowed and increased in length, while its total area decreased by 1 percent from 6.6 km^2 to 6.5 km^2. Overall, from 1990 to 2010, the area of Glacier Number 377 increased by 13 percent and increased in length by 3 km, at the same time increasing in debris cover (Alamanov et al., 2013a).

2.8 Glaciers in the Saryjaz River Basin

Understanding the dynamics of meltwater originating in the Saryjaz River basin is of great importance for understanding contemporary changes in water availability in the Tarim Basin in Xinjiang, China. The Tarim River, which is the main source of fresh water in the northern Taklamakan Desert, receives 75 percent of its water from the Saryjaz basin (Dikikh et al., 1991; Sorg et al., 2012). To study the dynamics of glaciers in the Saryjaz River basin, which occupies a large part of the Central Tian Shan, data were obtained on the dynamics of glaciers across the whole basin for the 1990-2010 period (Table 12)(Alamanov, 2013a).

A total of 1310 glaciers with areas larger than 0.1 km^2 were counted in the Saryjaz River basin, which had a total area of 2055 ± 41.1 km^2 and covered 18 percent of the basin in 1990 (Table 12). From 1990 to 2010, the area of these glaciers decreased by 77.1 ± 57.1 km^2, or 3.7 ± 2.7 percent. The smallest decreases (1.5-2.7 percent) were observed in the eastern part of the Saryjaz River basin. This is where the largest glacial area is located as well as the highest peak in the

Table 12. Changes in area of glacier groups in the Saryjaz River basin from 1990-2010.

Glacier Group	River Sub-basin	Sub-basin Area (km^2)	Number of Glaciers	Total Glacier Area (km^2)		Changes in Total Glacier Area (1990–2010)	
				1990	2010	Absolute (km^2)	Relative (%)
Northern	Koëlyu, upper Saryjaz River	2818.9	348	487.4 ± 9.7	455.8 ± 9.1	-31.6 ± 13.4	6.5 ± 2.7
Eastern	Engilchek, Kaiyndy	2329.8	318	926.8 ± 18.5	912.8 ± 18.3	-14.0 ± 26.0	1.5 ± 2.7
Southern	Lower Dzhangart, Dzhangart, Jaman-Suu, Taldy-Bulak Uch-Chat, Koykap	1662.9	146	130.1 ± 2.6	124.1 ± 2.5	-6.0 ± 3.6	3.4 ± 2.7
Western	Ak-Shyyrak, Uch-Kul, Terekty, Kichi-Terekty.	4389.8	498	510.7 ± 10.2	485.2 ± 9.7	-25.5 ± 14.1	5.0 ± 2.7
Total		**11,201.4**	**1310**	**2055 ± 41.1**	**1977.9 ± 39.6**	**-77.1 ± 57.0**	**3.7 ± 2.7**

Source: Osmonov, 2013.

Tian Shan, Peak Pobeda. Comparisons of glaciers of similar size showed that those covered by debris melted more rapidly than those that were debris-free.

Rate of Glacier retreat in the Saryjaz basin was much slower than in other valleys of the Tian Shan. This phenomenon is explained by the internal plateau location of the basin’s glaciers relative to other ridges in the peripheral areas on the outer edges of the Tian Shan mountain belt. Another possible explanation for differences in melting rates could simply be differences in measurement techniques used between earlier aerial photos and more recent satellite images. These differences require revaluation of glacier sizes obtained from the Soviet-era glacier catalog (Alamanov et al. 2013a).

Individual glaciers in the Saryjaz River basin are melting differently and at different rates. Most glaciers retreated slowly (large glaciers) or at rates fairly typical for the region (small and medium-sized glaciers). Only a small number experienced rapid melting (mostly small glaciers). In addition, several advancing glaciers were observed, which exhibited typical behavior of surging glaciers. The dynamics of any glacier is dependent on its size and on many local conditions, including microrelief, slope exposure, and terrain. Varied glacier melting rates were observed in other regions of the Tian Shan, but, in general, glacier melting in these other regions occurred at a higher rate than in the Saryjaz River basin.

Two variables, air temperature and precipitation, were used to analyze climate change in the Saryjaz River basin based on data from the Tian Shan hydro-meteorological station for the 80-year period from 1930–2009. The average annual temperature in the Saryjaz River basin increased during this period, but brief periods of cooling did occur. Periods of change were described as cold, stable, and warm. During the cold period, which was occurred from 1930 until 1950, temperature showed a mainly decreasing trend. The second period from 1955–1970, had comparatively stable temperatures, with positive and negative trends repeated with almost the same frequency that ultimately balanced each other. This period was characterized by smooth fluctuations in temperature. Beginning in the 1970s, average temperatures began to rise faster than in previous periods, continuing up to 2009 (Fig. 7 A1, B1, C1).

Total precipitation, on the other hand, decreased in the Saryjaz River basin, except during the periods 1930–1940 and 1950–1960. Since 1967, rainfall has declined continuously, a trend that intensified after 1989, as rainfall was reduced from 257.8 to 96.7 mm/year by 1997. Data for 1998 and 1999 are missing from the Tian Shan meteorological station, but in the subsequent period, 2000–2009, the amount of rainfall at the site was more than in the previous seven recorded years (Fig. 7 A2, B2, C2). On average, these data show that air temperature has increased and rainfall has decreased during the last 20 years in the Saryjaz River basin, and that climatic conditions have changed significantly (Alamanov, 2013a).

The mountain ranges and valleys in the eastern Saryjaz River basin have a general increase in altitude from west to east which creates favorable conditions for increasing snow cover from west to east. The intensity of glaciation and extent of glacial ice are negatively correlated with the distance to the longitudinal ridge centered on Peak Pobeda, with glaciers that are closer to this ridge being larger (Osmonov, 1974). Practically all known types of mountain glaciers can be found in the study area, from dendritic glaciers with areas of several hundred square kilometers, to very small glaciers no larger than 0.1 km^2. The Saryjaz River basin hosts the largest glaciers in the Tian Shan, with 21 glaciers longer than 5 km, seven glaciers stretching for more than 10 km, and five glaciers over 20 km long (Osmonov, 2013). The glaciers of the Saryjaz River basin can be differentiated according to their areas. Small glaciers (<0.5 km^2) and medium-sized glaciers, (0.5–1.0 km^2) are the most numerous. Glaciers exceeding 1 km^2 are uncommon. A similar pattern was found for the Northern Tian Shan (Tokmagambetov, 1976).

Slope exposure greatly influences the intensity of glaciation. As a rule, most of the valley glaciers in the Saryjaz River basin are located on north-facing slopes, where conditions are most favorable for their existence. Here, the snow line is lower, annual duration of ablation is shorter, and glaciers have the most favorable orientation with respect to receiving moisture-bearing air flow (Osmonov, 2013). On south-facing slopes (e.g. the Postysheva and Mai-Bash Ranges), there are either no glaciers or they are significantly less developed than glaciers on north-facing slopes. Some tributaries of valley glaciers and isolated glaciers located on the south-facing slopes, are poorly situated for the development and maintenance of glacial ice because of intense solar radiation hitting glacier surfaces, contributing to snow and ice melt. This effect is especially pronounced in the upper reaches of the Saryjaz River. However, in the eastern Saryjaz River basin, where the Northern and Southern Engilchek and Kaiyndy Glaciers are situated, the impact of slope exposure is mitigated by the high-altitude location of these glaciers (Osmonov, 2013). Nevertheless, throughout the Tian Shan, glaciers are concentrated mainly on northern slopes (69.9 percent), while only 18.0 percent are located on southern slopes, with 7.2 percent and 4.9 percent found on western and eastern exposures, respectively (Dikikh et al., 2007).

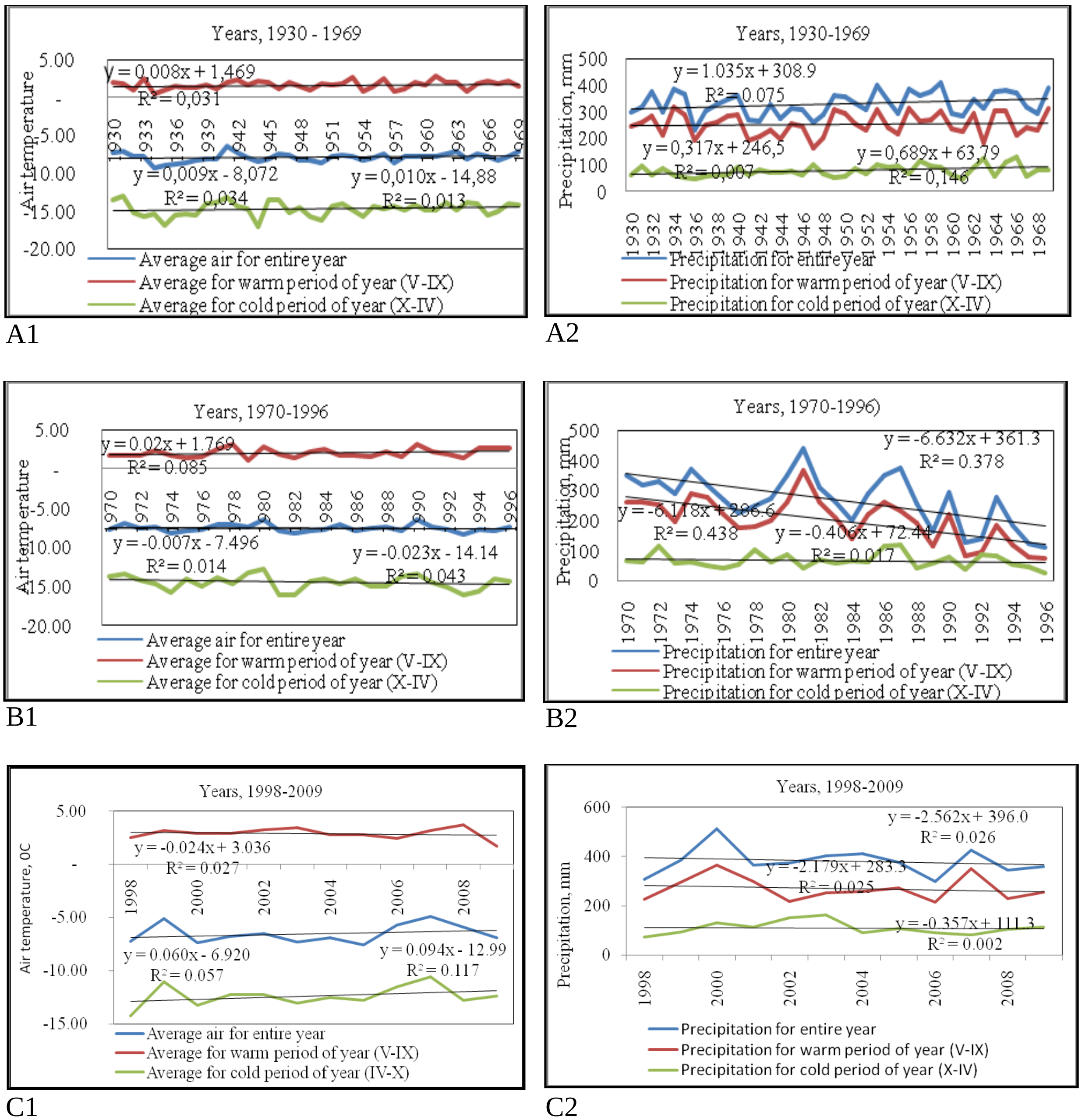

Figure 7. Changes in air temperature (A1, B1, C1) and precipitation (A2, B2, C2) from the Tian Shan meteorological station over three periods: 1930–1969 (A1, A2), 1970–1996 (B1, B2), 1998–2009 (C1, C2). Source: Alamanov et al., 2013.

The eastern Saryjaz River basin has the largest concentration of glaciers. This area is a part of the ice massif of Khan Tengri and Peak Pobeda. Conditions here, namely low temperature and large amounts of snow, are very favorable for glacier formation. Glaciers here are melting more slowly than in other areas, and three glaciers of different sizes are in a stable condition. In the eastern Saryjaz River basin, rugged terrain combined with altitudes reaching over 7000 m are especially important factors for the development and maintenance of glaciers (Osmonov, 2013).

The mountains of Central Asia receive most of their precipitation, 75 percent, during summer from air masses of Atlantic Ocean origin that contain abundant moisture. These air masses move from west to east, reaching the Tian Shan where they are stopped by the highest ranges of the Khan Tengri Region. These include the Saryjaz Range and its highest mountain, Peak Semenov (5816 m). Here, this moisture is released, mainly in the form of snow (Osmonov, 2013). Large masses of snow accumulate in the upper zone of the glaciers, accumulation of which outpaces melting (Bakov, 1975).

In winter, the Tian Shan receives much less precipitation (25 percent of annual total). The Siberian anticyclone extends from the northeast and prevents western Atlantic moist air masses from reaching the Tian Shan. As a result, the annual glacial accumulation period occurs predominantly in summer (Dikikh et al., 1991). Precipitation in the Tian Shan increases with altitude, with totals reaching 1000 mm/year at altitudes over 5100 m. Glaciers of the eastern Saryjaz River basin are located mainly between 2950 and 7400 m, with 89 percent located between 3800 and 7400 m. However, the eastern region is characterized by relatively dry conditions compared to the upper Saryjaz basin. The Saryjaz Range has an average elevation of 4830 m, which blocks the main moisture-rich air masses coming from the Lake Issyk-Kul basin. These lake air masses release most of their moisture as precipitation in the Saryjaz Range, and only a small portion penetrates into the eastern Saryjaz basin (Osmonov, 2013).

Summary of Saryjaz Basin Glaciers

To summarize, the area of glaciers in the Saryjaz River basin have significantly decreased since the first half of the 20th Century, particularly from 1990–2010, due to general trends of rising air temperature and reduced rainfall. At the same time, different glaciers reacted differently to changes in climatic conditions, with some even advancing. In general, however, the following trends of glacial change in the Saryjaz River basin were observed by Alamanov et al. (2013a).

Glacial Distribution

Glacial distribution is very uneven in the Saryjaz basin. The eastern section of the Saryjaz has the greatest numbers of glaciers and the most favorable conditions for their preservation, namely low temperature and large amounts of snow. Another reason for the relatively small loss of ice is the extensive debris cover on many glaciers. Both north and northwestern-facing slopes and areas of rugged terrain have more developed glaciation than south-facing slopes.

Melting of Glaciers

- The Saryjaz River basin has a total of 1310 glaciers with areas ranging from 0.5 to > 5.0 km^2. In 1990, total glacier area was 2055 ± 41.1 km^2, which covered about 18 percent of the basin. Glacier retreat by 2010 was relatively small: 57.1 to 77.1 km^2 (2.7 to 3.7 percent). Glaciers of the Saryjaz basin declined much more slowly than was observed in other ranges of the Tian Shan.

- The smallest glacial retreat (1.5 ± 2.7 percent) was observed in the eastern sector of the basin, where the largest glaciers and the highest peaks are concentrated. The most intense melting was observed in the northern and western sectors (6.5 ± 2.7 percent and 5.0 ± 2.7 percent, respectively).

- Glaciers with thick debris cover melted much more slowly than glaciers with exposed surfaces. Debris cover, depending on its depth can strongly restrict glacial retreat, allowing the largest glacier, the Southern Engilchek Glacier, to retain its original area for a long time.

- Small (<0.5 km^2) and medium-sized glaciers (0.5–1.0 km^2) were more sensitive to climate change, while larger glaciers (>1 km^2) retreated more slowly.

- At present, most glaciers are melting, and large glaciers have disintegrated into several smaller ones (Alamanov et al. 2013a).

Glacier Expansion and Surges

- In the Saryjaz River basin, glacial expansion was observed predominantly for large glaciers, and was extremely rare for small and medium-sized glaciers.

- Most (9 of 10) advancing glaciers were on northern exposures.

- Glacier surges were recorded in Glacier Number 377 (southern section) and on some tributaries of the Mushketov Glacier (northern section) (Alamanov et al. 2013a).

Climate change

- From 1930 to 2010, the climate became generally warmer and drier. However, from 1990 to 2010, an increase in both average winter temperature and precipitation was observed in the Saryjaz basin.

- Clearly, the general trend of air temperature increase contributes to the melting of glaciers. Temperature during the melt season (July–August) increased only slightly, but duration of the melt season has increased into September throughout Central Asia. At the same time, the volume of precipitation significantly decreased in the high mountains of the internal ranges of the Tian Shan. Apparently, this is the main reason for the retreat of glaciers in the Saryjaz River basin (Alamanov et al. 2013a).

2.9 Climate-Related Emergencies

High altitude areas of the Tian Shan that experience glaciation and tectonic activity are extremely susceptible to landslides, avalanches, rockfalls, floods, earthquakes, glacial lake outburst floods (GLOFs), permafrost melt, and other hazards. Table 13 lists climate-related

Table 13. Climate Related Emergencies in the Kyrgyz Republic, 2007-2012.

Type of emergency	**2007**	**2008**	**2009**	**2010**	**2011**
Mudflows	70	83	93	131	61
Landslides	5	2	13	40	12
Avalanches	14	25	35	63	22
Earthquakes	18	44	22	22	31
Flooding	4	26	1	12	3
Rain shower	3	1	7	3	—
Serious fires	42	38	10	50	73
Infections, invasions	14	24	7	7	—
Industrial disasters, serious road traffic incidents	26	26	15	61	15
Tornadoes	5	34	14	36	24
Hailstorms	3	1	3	1	—
Heavy snow, ice blockage	—	5	4	11	14
Rock fall	5	2	2	1	—
Others	—	1	1	—	—
Total emergencies	**209**	**312**	**277**	**439**	**255**

Source: Government of the Kyrgyz Republic, 2012a.

emergencies for 2007-2011 from the Emergency Ministry's 2012 Kyrgyz National Report (Gov. of Kyr Rep, 2012a).

During the 2007–2011 period in the Kyrgyz Republic, the greatest number of emergency situations (ES) were registered in 2010 (439), the least in 2007 (209). In 2011 there were 255 emergencies. Most were natural and climate-related emergencies: mudflows, floods, landslides, avalanches, flooding, wind, hail, snow, and rain (Fig. 8). Giant avalanches, landslides, and firn ice falls are not unusual in the mountain regions. Their volumes reach up to 2.2 million m^3 in the Engilchek River basin. The greatest economic damage in the Kyrgyz Central Tian Shan Region is caused by avalanches on the Karakol–Engilchek road.

Avalanches in the Kyrgyz Republic threaten 53 percent of terrain. Within 779 avalanche areas, more than 30,000 avalanche sites have been described and about 1000 of these pose a severe threat. Avalanches are observed almost everywhere that steep slopes and snow cover of sufficient depth exists. In the Kyrgyz Republic, avalanche season lasts for three to four months

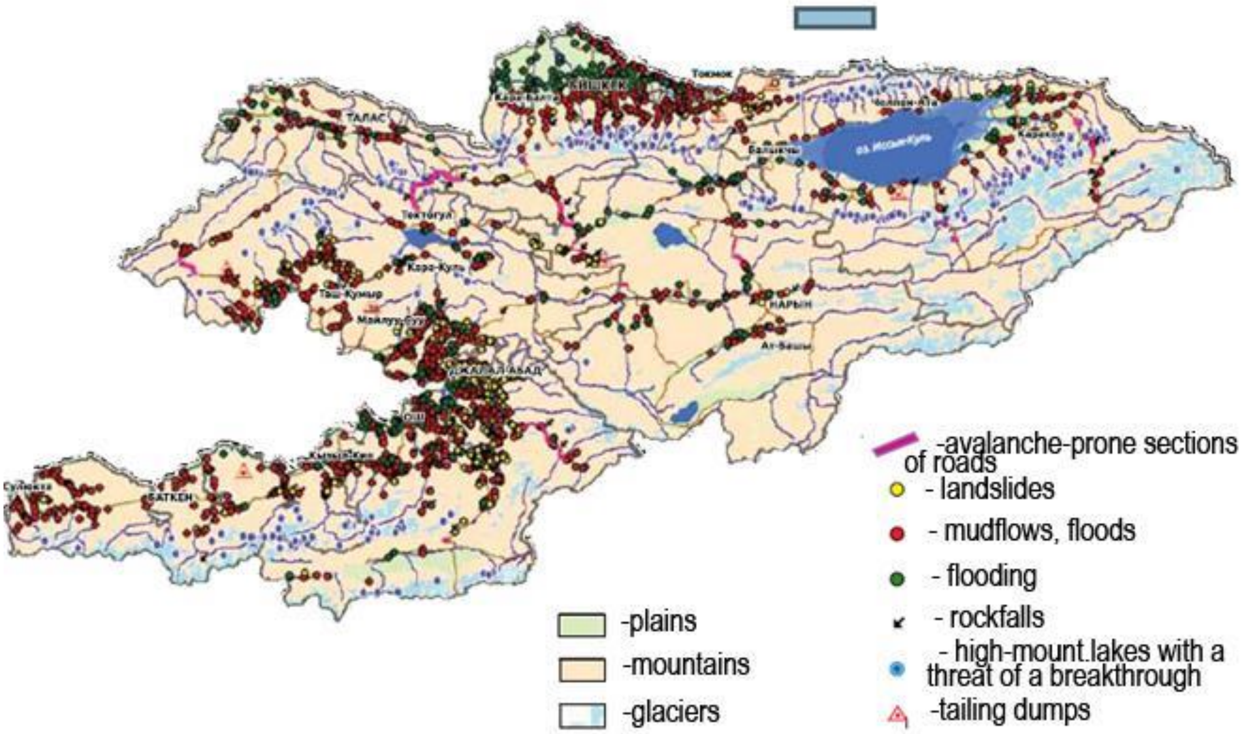

Figure 8. Areas prone to avalanches, landslides, floods, mudflows, and rockfalls. Source: Government of the Kyrgyz Republic, 2012a.

annually in the Western Tian Shan, and a full 10 to 12 months annually in the Central Tian Shan. Most avalanches (63 percent) that damage roads in the Kyrgyz Tian Shan consistently occur in February and March. Only 16 percent are registered in January, 13 percent in April, 4 percent in December, 1.5 percent in November, and 2.5 percent in May. The greatest amount of snow displaced by avalanches is typically in March (52.6 percent). Most avalanches occur on north and northwestern-facing slopes. During the 2000–2011 period, the largest number of emergencies caused by avalanches occurred in Jalal-Abad Province (4 percent of the total number of emergencies in the Kyrgyz Republic), Osh Province (1.9 percent), Naryn Province (1.6 percent), and Issyk-Kul Province (1.6 percent) (Gov. of Kyr. Rep., 2012a). Figures 9–14 show an increasing trend in climate-related emergencies in the Kyrgyz Republic from 1990-2010 (Ilyasov et al., 2013).

In the 21st Century, climatic changes in the Kyrgyz Republic are representative of climate trends elsewhere in mountainous Central Asia. These mountain regions have experienced greater temperature increases over the last 100 years than much of the Earth as a whole, with some regions warming by 2.5°C (Gov. of Kyr. Rep., 2012a). Overall precipitation has changed little, with considerable inter-annual variability. All of this illustrates the heterogeneity of local responses to global and regional climate change and the need for practical assessments of local climate change in the Central Tian Shan (Gov. of Kyr. Rep., 2012a).

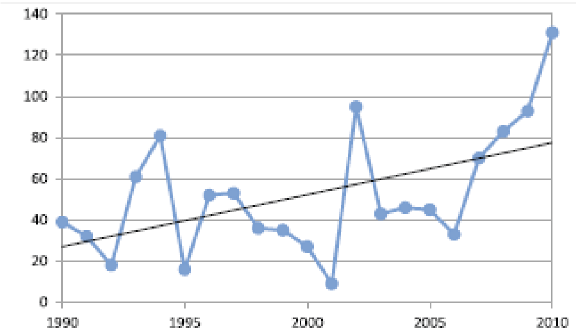

Figure 9. Number of mudflows in the Kyrgyz Republic, 1990-2010. Source: Ilyasov et al., 2013.

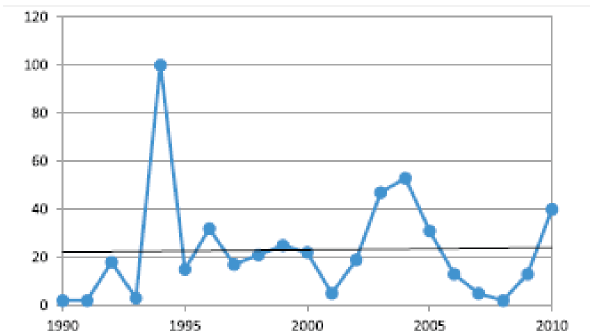

Figure 10. Number of landslides in the Kyrgyz Republic, 1990-2010. Source: Ilyasov et al., 2013.

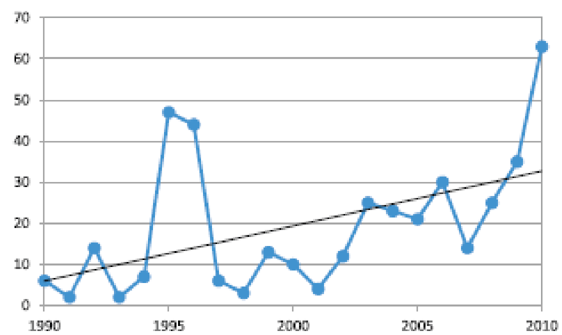

Figure 11. Number of avalanches in the Kyrgyz Republic, 1990-2010. Source: Ilyasov et al., 2013.

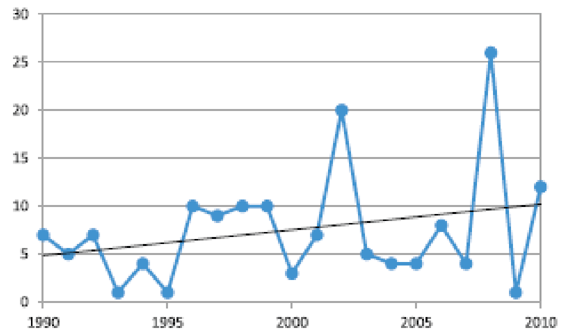

Figure 12. Number of floods in the Kyrgyz Republic, 1990-2010. Source: Ilyasov et al., 2013.

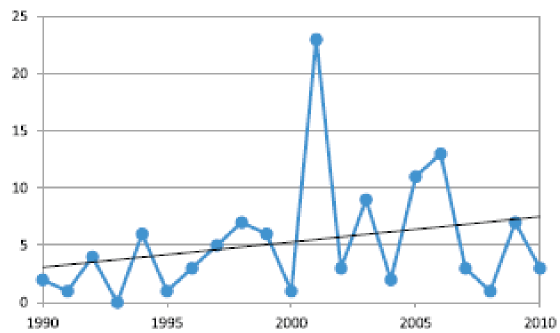

Figure 13. Number of severe rainstorms in the Kyrgyz Republic, 1990-2010. Source: Ilyasov et al., 2013.

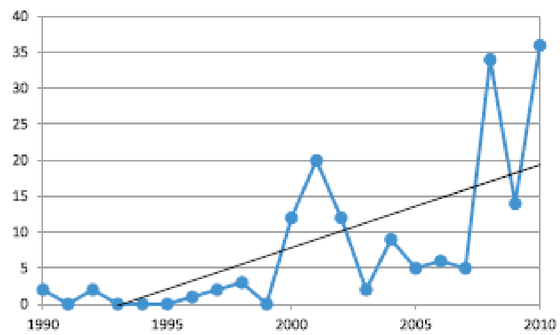

Figure 14. Number of tornadoes in the Kyrgyz Republic, 1990-2010. Source: Ilyasov et al., 2013.

3. FUTURE CLIMATE SCENARIOS

Global warming is expected to increase average annual temperature throughout Central Asia (Katsov et.al., 2008). There is no doubt that the largest resulting climate-related problem that could affect hundreds of millions of people is the lack of food and fresh water. For large parts of Asia, severe droughts are not expected as they are for vast areas of Africa, America, and the Mediterranean. But the western part of Central Asia and its mountainous areas may be affected, especially by the projected reduction in precipitation, which will in turn cause the disappearance of glaciers that accumulate precipitation and gradually release it over time in the form of river flow. With the application of modern agricultural techniques and new varieties of crops, food problems in Asia can be avoided, but the costs will be large.

For the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), experts from the Main Geophysical Observatory produced a model of temperature dynamics for a number of regions, including the Kyrgyz Republic, for the B1, A1B, and A2 climate scenarios for the beginning, middle, and end of this century (Table 14)(Katsov et.al., 2008; IPCC, 2007). The Second National Communication of the Kyrgyz Republic to the Parties of the UN Framework Convention on Climate Change (UNFCC) also provided a detailed description of projected climatic changes for the Kyrgyz Republic with simulations carried out in accordance with the scenarios described in the 4th IPCC Assessment Report (Gov. of Kyr. Rep., 2009; IPCC 2007).

For agriculture, climate change will primarily alter the thermal regime (heat supply), which is one of the main factors for agro-climatic zoning. An increase in heat will substantially affect the cultivation of different crops as follows:

- In the northwest region of the Kyrgyz Republic under scenario A2-ASF at altitudes up to 1400 m, the climate will shift from very hot to moderately hot by the year 2100. Under scenario B2-MESSAGE, such a climate will occur at an altitude of 1200 m. The frost-free period under scenario A2-ASF will last 264 days per year at an altitude of 600 m, and 120 days per year at an altitude of 3000 m. Under scenario B2-MESSAGE, the frost-free period will last 246 days per year at an altitude of 600 m, and 103 days per year at an altitude of 3000 m.

- In the northeastern region of the Kyrgyz Republic under scenario A2-ASF, a moderately hot climate will exist in the lakeshore shore area of Lake Issyk-Kul up to an altitude of 1800 m by the year 2100. Under scenario B2-MESSAGE, there will be no hot climate in the lake basin. The frost-free period under scenario A2-ASF will last 304 days per year at an altitude of 1600 m and 102 days per year at an altitude of 3000 m. Under scenario B2-MESSAGE, the frost-free period will last 255 days per year at an altitude of 1600 m, and 73 days per year at an altitude of 3000 m.

Table 14. Increases in annual mean surface air temperature (ºC) with respect to the 1980-1999 baseline period. Standard deviations given provide a measure of intermodel scatter.

Time Period	**2011-2030**			**2041-2060**			**2080-2099**		
Scenario	**B1**	**A1B**	**A2**	**B1**	**A1B**	**A2**	**B1**	**A1B**	**A2**
Central Asia	1.2±0.4	1.0±0.5	1.0±0.4	1.8±0.5	2.5±0.5	2.2±0.5	2.6±0.7	4.0±0.9	4.7±0.9
Kyrgyzstan	1.2±0.5	1.1±0.4	1.2±0.3	1.8±0.4	2.6±0.5	2.3±0.4	2.7±0.7	4.0±0.8	4.7±0.8

Source: Katsov et.al., 2008.

Table 15. Increases in annual mean precipitation (%) with respect to the 1980-1999 baseline period. Standard deviations given provide a measure of intermodel scatter.

Period	**2011-2030**			**2041-2060**			**2080-2099**		
Scenario	**B1**	**A1B**	**A2**	**B1**	**A1B**	**A2**	**B1**	**A1B**	**A2**
Central Asia	3.0±3.6	3.7±4.2	3.7±4.1	4.9±4.4	3.3±5.4	3.9±4.4	6.2±5.9	6.2±7.5	3.7±3.6
Kyrgyzstan	1.1±5.1	2.4±5.6	1.6±5.7	3.9±5.3	1.2±7.2	0.9±6.6	4.1±7.2	2.7±8.8	0.1±3.3

Source: Katsov et.al., 2008.

- In the Inner Tian Shan region under scenario A2-ASF, a moderately hot climate will exist at an altitude of 1800 m by the year 2100. Under scenario B2-MESSAGE, there will be no hot climate areas in the Inner Tian Shan.

- In the southwestern region of the Kyrgyz Republic under scenario A2-ASF, the climate will be very hot to moderately hot at altitudes up to 2000 m by the year 2100. Under scenario B2-MESSAGE, such a climate will be typical at altitudes up to 1600 m. The frost-free period under scenario A2-ASF will last for 294 days per year at an altitude of 600 m and 161 days per year at an altitude of 3000 m. Under scenario B2-MESSAGE, it will last 276 days per year at an altitude of 600 m and 144 days per year at an altitude of 3000 m (Gov. of Kyr. Rep., 2008).

In general, areas of the Kyrgyz Republic with variation in thermal regimes will increase, and areas with cumulative temperature increases >4000°C will more than double by the year 2100 (Gov. of Kyr. Rep., 2009). Along with a general increase in temperature, the number of frost days is expected to decrease by the end of the 21st Century in the Kyrgyz Republic to just 30–35 days per year. At the same time, the duration of heat waves (days with the maximum temperature) will increase, with valley areas being more susceptible to heat waves than mountainous terrain (Katsov et.al., 2008).

Changes in the amount of precipitation for the Kyrgyz Republic vary significantly under different scenarios and with considerable uncertainty due to annual variability (Table 15)(Katsov et.al., 2008). The mildest scenario, B1, in which the amount of precipitation will increase as concentration of CO_2 in the atmosphere exceeds normal levels, should no longer be considered. A slight increase in rainfall, which is expected under a moderate scenario, would be quite varied both from year to year, and for different parts of the country. In any case, the valleys and lower slopes of the mountains will experience increased aridity.

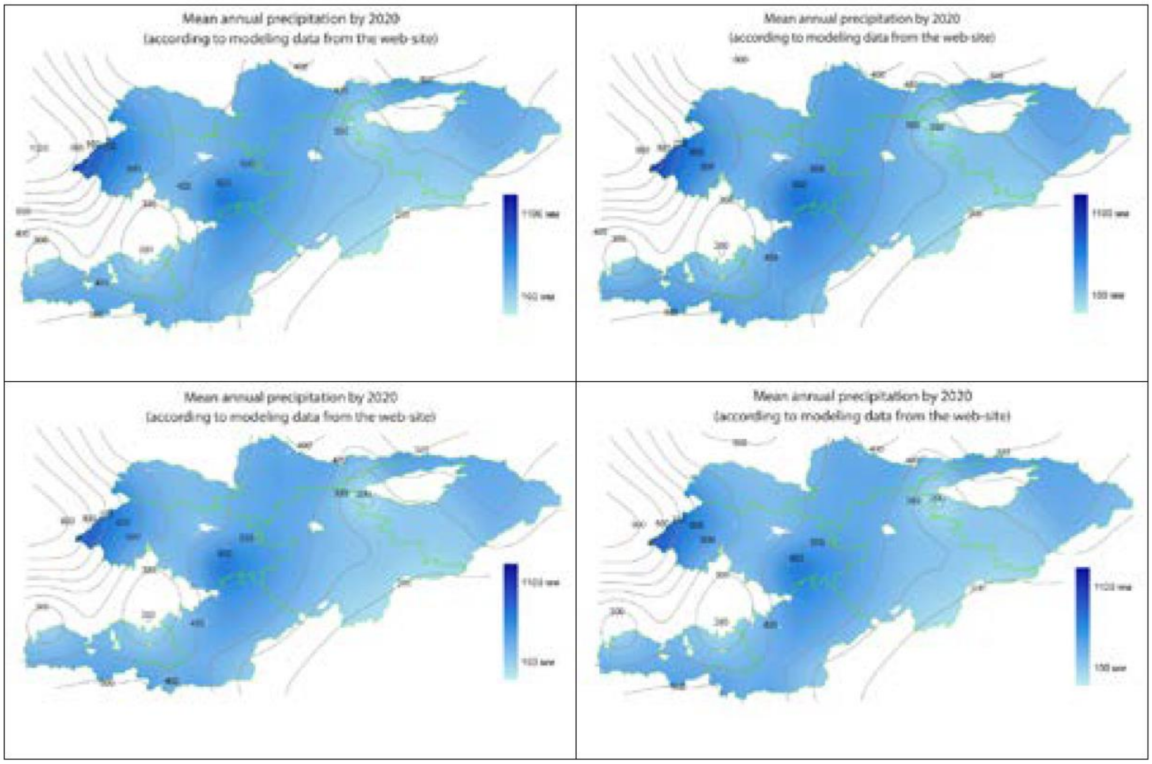

Figure 15. Mean annual precipitation by 2020 (top left), 2050 (top right), 2080 (lower left), and 2100 (lower right). Source: Ilyasov et al., 2013.

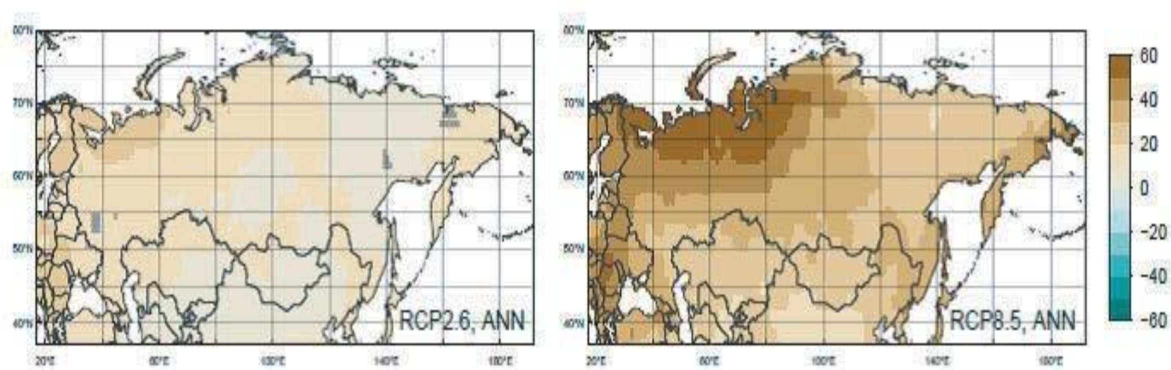

Figure 16. Projected changes in the values of evapotranspiration from 2071–2099 with respect to the 1951–1981 reference period under scenario RCP2.6 (2°C) on the left, and RCP8.5 (4°C) on the right. Source: Shah et al., 2013.

In the climate profile in Figure 15, model forecasts of future average annual precipitation are shown which indicate a lack of any significant trend (Ilyasov et al. 2013). If precipitation decreases, the areas of arid and semi-arid semi-desert zones in the Kyrgyz Republic could increase from approximately 15 percent of national territory in 2000 to between 23.3 percent and 49.7 percent in 2100. The area and productivity of alpine pastures in syrt ecosystems of the Tian

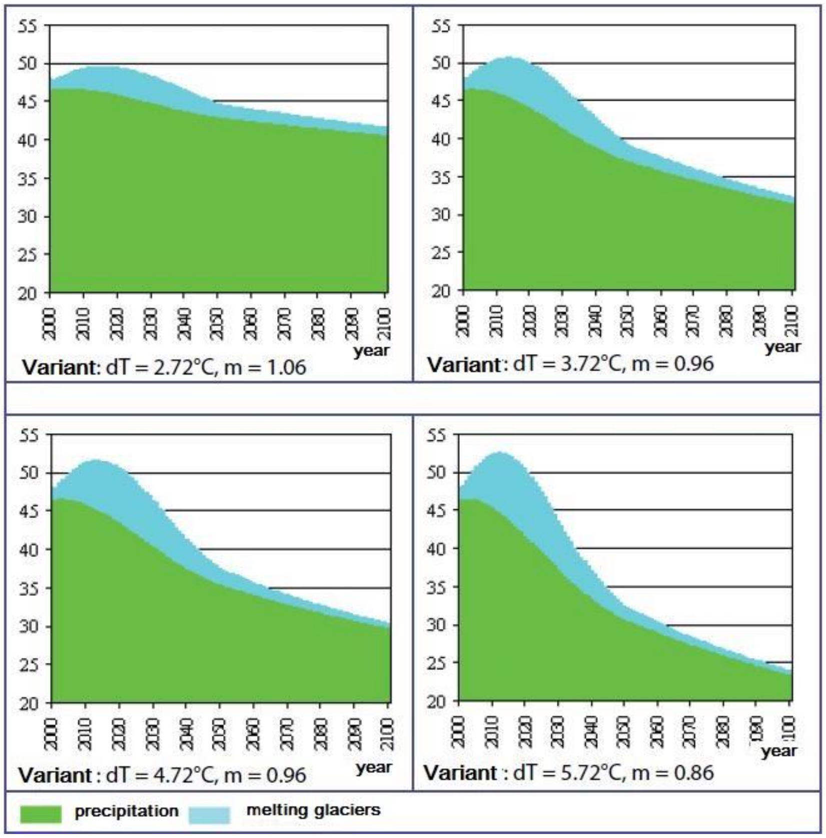

Figure 17. Future scenarios for runoff originating from precipitation (Shown in Green) and glacier melt (Shown in Blue) for the 2000-2100 period. X-axis: Year, Y-axis: Runoff in km^3, dT = average annual temperature change in °C, m = annual total precipitation in relation to the base period. Source: Government of the Kyrgyz Republic, 2009.

Shan, including the Ak-Sai and Alai Valleys, could be significantly reduced (Gov. of Kyr. Rep., 2009). A World Bank report provides projections of changes in evapotranspiration from 2071–2099 with respect to the 1951–1981 reference period (Fig. 16) (Shah et al. 2013).

River flow is directly related to rainfall amount and temperature, since glacier melt plays an important role in the dynamics of runoff and water availability in the Kyrgyz Republic. Most scenarios show an increase in runoff until about 2015 due to increasing glacial melt with sharp declines thereafter (Gov. of Kyr. Rep., 2009). Figure 17 presents four projected scenarios for runoff from precipitation and glacier melt (Gov. of Kyr. Rep., 2009).

With funding from the WWF Asia High Mountains (AHM) Project, Peters et al. (2016) developed future temperature and precipitation projections specifically for the Kyrgyz Central Tian Shan Region for the 2011-2040 and 2041-2070 time periods using the 1980-2005 reference period as a baseline. This was done using a series of 21 climate models and the IPCC's RCP 4.5 and RCP 8.5 future climate scenarios (IPCC 2013). Under these scenarios, models project an annual mean temperature increase for the region of 0.9˚C to 1.5˚C above the baseline temperature by 2011 to 2040 and 1.9˚C to 3.2˚C by the 2041 to 2070. Increasing temperature trends are fairly consistent throughout the year, however, warmer months are projected to see temperatures rise slightly more than the colder months. The largest increases in temperature are projected to occur in August, with predicted average monthly temperature increases of 1.1˚C to 2.1˚C by 2011-2040, and 2.3˚C to 4.1˚C by 2041-2070 (Peters et al., 2016).

Projections for precipitation predict an increase in annual mean precipitation of up to 17 percent by 2011-2040 and an increase of 6 to 23 percent by 2041-2070. However, the various climate models show great discrepancies for projected precipitation in July, at the height of the summer rainy season, with models predicting anywhere from a 14 percent decrease in July rainfall to a 9 percent increase by 2041-2070. The driest months of the year, December to February, are projected to have increases in precipitation of 15 to 59 percent by 2041-2070, but given the low baseline precipitation for these months, these increases will not significantly increase total annual mean precipitation. These future changes in temperature and precipitation may ultimately result in earlier snow melt, changes in seasonal vegetation patterns, increased risk for flooding and landslides, habitat shifts, changes in food availability, and increased human-wildlife conflict (Peters et al., 2016)

4. CLIMATE CHANGE VULNERABILITY

4.1 Hydropower

A reduction in glaciation due to climate change would affect the Kyrgyz Republic's energy security. Glaciers of the Central Tian Shan are a major source of runoff for the main "energy-artery" of the country, the Naryn River, which has a length of 807 km and a basin area of 59,900 km^2. The river is formed at the confluence of the Taragai and Karasai Rivers which originate from the glaciers of the Central Tian Shan. All major hydroelectric power stations (HPS) in the Kyrgyz Republic are concentrated on this river. The Toktogul HPS network, which includes six existing and one projected station, are situated in the lower reaches of the Naryn and have a power capacity as shown in Table 16. Construction of four hydropower stations on the Upper-Naryn cascade with a total planned capacity of 237.7 MW is ongoing.

Table 16. Operating and planned hydroelectric power stations on the lower and upper Naryn River in the Kyrgyz Republic.

Hydroelectric Power Station	Power Generating Capacity (MW)
Toktogul	1200
Kurpsai	800
Tashkumyr	450
Shamaldysaiya	240
Uchkurgan	180
Kambaratinskaya 1	1860 (Planned)
Kambaratinskaya 2	120 (Operating) 360 (Planned)
Upper Naryn River 1-4	237.7

4.2 Natural Hazards

Given that the mountainous Kyrgyz Republic is highly prone to natural hazards, its future vulnerability to such disaster emergencies risk was summarized using statistical models as detailed below (Gov. of Kyr. Rep., 2009):

- More than 5000 landslide prone areas exist on the territory of the Kyrgyz Republic.

- Nearly the entire territory of the country is threatened by mudflows, floods, and GLOFs, since more than 95 percent of the nation's settlements and population centers are located in close proximity to water sources, mainly along rivers. More than 90 percent of all lakes are in mountainous areas and 200 of these pose a high threat for catastrophic GLOF events.

- Avalanches occur in the steep mountains of the country when unstable, deep snow cover forms due to heavy precipitation.

A national-level vulnerability assessment for the Kyrgyz Republic was carried out for the country’s three main regions (central, northern, and southern) that are traditionally identified for the monitoring and analysis of emergencies. Mudflows, floods, and GLOFs are combined into one category because outburst floods are very rare and difficult to model separately. Estimates are given for the expected changes in climatic parameters under two climate scenarios. The results for the period up to 2100 led to the following conclusions (Gov. of Kyr. Rep., 2009):

- For the southern region, under the A2-ASF scenario, the likelihood of landslides will not change much, but under scenario B2-MESSAGE, it will increase slightly. The probability of mudflows, floods, and GLOFs under both scenarios A2-ASF and B2-MESSAGE will increase several fold. For both scenarios, the likelihood of avalanches will increase in the Chatkal area and significantly decrease in the Toktogul region.

- For the central region, under scenarios A2-ASF and B2-MESSAGE, the likelihood of mudslides, floods, and GLOFs will be significantly reduced. Under both scenarios, the probability of avalanches will increase slightly.

- For the northern region, under scenarios A2-ASF and B2-MESSAGE, the likelihood of mudslides, floods, and GLOFs will be significantly reduced. Under both scenarios, the probability of avalanches will increase significantly.

4.3 Glaciers

According to projections, the degradation of glaciers will continue. Vulnerability assessments for ice volume and surface runoff were made using complex digital elevation models and moisture condition models developed at the Institute of Water Problems and Hydropower of the Kyrgyz National Academy of Sciences. The projected state of glaciers up to the year 2100 is given in the Table 17. Figure 18 provides an overview of the decline in the area of glaciers in the Altai-Sayan Region, Pamirs, and Tian Shan from the 1960s to 2008 as determined by satellite image analysis.

4.4 Runoff

Projected changes in surface runoff under various climate scenarios are provided in Table 18. Projection results indicate that a significant decrease in surface runoff in the long-term can be expected under all the most probable scenarios. During the period up to 2020–2025, an increase in the surface runoff is expected due to an increasing contribution from glacial melt. By 2100, a decrease of 43.6–88.4 percent in total flow with respect to the year 2000 is predicted. The

Table 17. Projected decreases in glacier parameters in the Kyrgyz Republic under various climate scenarios.

	dT (°C)	**2.96**		**3.96**		**4.96**		**5.96**	
m	**Year**	**2050**	**2100**	**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
1.16	Number			2803	1446				
	Area (km^2)			3573.02	2320.74				
	Volume (km^3)			233.487	161.772				
	Thickness (m)			65.35	69.71				
1.06	Number	3097	1484	1958	721	1276	378	897	227
	Area (km^2)	3861.63	2428.06	2901.73	1529.93	2214.80	1039.11	1716.25	741.98
	Volume (km^3)	251,056	169,654	197,236	115,389	157,143	83,151	126,872	61,889
	Thickness (m)	65.01	69.87	67.97	75.42	70.95	80.02	73.92	83.41
0.96	Number			1442	397	988	238	651	142
	Area (km^2)			2395.21	1092.01	1861.05	783.32	1453.63	571.54
	Volume (km^3)			168,889	87,522	136,439	65,445	111,234	49,250
	Thickness (m)			70.51	80.15	73.31	83.55	76.52	86.17
0.86	Number			1071	251	741	152	508	87
	Area (km^2)			2014.70	826.97	1573.22	609.03	1258.77	452.33
	Volume, (km^3)			146,630	69,183	119,369	52,472	99,064	39,754
	Thickness (m)			72.78	83.66	75.88	86.16	78.7	87.89
0.76	Number							402	59
	Area (km^2)							1104.55	362.41
	Volume, (km^3)							89,061	32,207
	Thickness (m)							80.63	88.87

Note: dT = change in mean annual temperature in °C, m = the ratio of annual precipitation in relation to the base period. Source: Government of the Kyrgyz Republic, 2009.

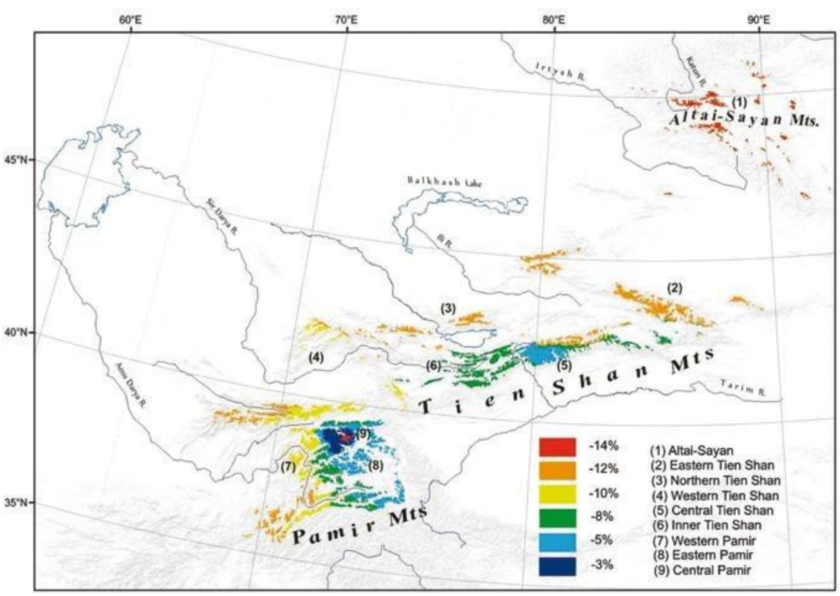

Figure 18. Decline in the area of glaciers in the Altai-Sayan Region, Pamirs, and Tian Shan from the 1960s to 2008 as determined by satellite image analysis. Source: IPCC, 2014.

consequences of such a significant decrease in the projected surface runoff will undoubtedly have a negative impact on living conditions and economic activities in the Kyrgyz Republic, as well as in neighboring states. Risks in the areas of water use and water allocation will undoubtedly increase if preventive measures are not taken.

In most probable future climate scenarios, a reduction of water input from glacier melt will have a significant impact on river flow, substantially reducing high flow in the summer while also shifting peak glacier melt flow to earlier in the year. Glaciers accumulate solid precipitation almost year-round giving back most moisture during summer, a critical time for agriculture, increasing river flow in both hot and dry years. According to models, this natural potential for flow regulation will be weakened as glaciers decline with rising temperatures. Without appropriate adaptive measures, loss of glaciers will significantly affect water resource availability in the Kyrgyz Republic and neighboring countries.

Table 18. Projected total annual surface runoff in the Kyrgyz Republic under various climate scenarios (km^3).

dT (°C)	**2.72**		**3.72**		**4.72**		**5.72**	
m	**2050**	**2100**	**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
1.16					43.776	42.421		
1.06	43.679	41.311	41.671	38.436	39.860	36.170		
0.96			37.739	32.187	36.149	30.453	34.753	29.036
0.86					32.650	25.221	31.449	24.099
0.76					29.357	20.434		

Note: dT = change in mean annual temperature in °C, m = the ratio of annual precipitation in relation to the base period. Source: Government of the Kyrgyz Republic, 2009.

4.5 Lakes

Climate change may also have a significant impact on lakes in the Kyrgyz Republic. For example, the area of Lake Issyk-Kul is expected to decrease anywhere from 232-1049 km^2, while the lakes' depth is expected to decrease by 5.1-27.5 m in comparison with 2000. It was found that, under all the most probable future climate scenarios, Lake Chatyr-Kul will exist only seasonally as a relatively small water body (Gov. of Kyr. Rep., 2009).

4.6 Human Health

Projected future climate conditions will have a particularly severe impact on agriculture, and it may require a large increase in expenditures to provide food for populations. The following human health and demographic indicators were also modeled for the Kyrgyz Republic under future climate scenarios:

- Contagious infections, e.g. acute intestinal infections, for all regions of the country.

- Noncommunicable diseases, e.g. cardio-circulatory diseases, for the population of Bishkek.

- Deaths by cause, location, sex, and age.

- Details of deaths due to cardiovascular diseases for Jalalabad and Chui Provinces and Bishkek.

Results show a significant relationship between medical/demographic indicators and climate change:

- A serious increase in incidence of acute intestinal infections is expected by 2100. The expected values under scenario A2-ASF are 57.0 cases per 100 thousand people by the year 2100 and, for scenario B2-MESSAGE, 54.4 cases per 100 thousand people, an increase of 15.9 and 10.6 percent, respectively, with respect to the 2005 baseline.

- The incidence of diseases of the cardio-circulatory system will substantially increase in relation to the 2005 baseline, in Chui Province by 69.6 percent or 45.6 percent for the A2-ASF and B2-MESSAGE, respectively; in Issyk-Kul Province by 13.5 percent or 8.3 percent for the A2-ASF and B2-MESSAGE, respectively; and in Jalalabad Province by 73.2 percent or 37.6 percent for the A2-ASF and B2-MESSAGE, respectively. The increase in the incidence of diseases in the northern and southern regions of the country is expected to be approximately the same. A smaller increase in morbidity, or even a slight decrease, under the B2-MESSAGE scenario in Issyk-Kul Province is expected due to the temperature-moderating effects of Lake Issyk-Kul.

- The incidence of cancer in women is forecast to increase approximately 7 percent with respect to the year 2000 while decreasing in men.

- A substantial increase mortality from cardiovascular diseases is expected by 2100 compared to 2005, in Bishkek by 50.6 percent or 39.4 percent for the A2-ASF and B2-MESSAGE, respectively; in Chui Province by 54.4 percent or 42.9 percent for the A2-ASF and B2-MESSAGE, respectively; and in the Jalalabad Province by 75.3 percent and 54.3 percent for the A2-ASF and B2-MESSAGE, respectively (Ilyasov et al. 2013).

Unfortunately, the dynamics of natural focal infectious diseases was not considered in the Second National Communication. Nevertheless, diseases transmitted by other organisms such as insects, ticks, and rodents, are affected by climate change. Both transmitters and hosts of parasites react to changing environmental conditions. Carriers of some infections are becoming more active and/or more widely distributed, often migrating northward as temperature rises.

Table 19. Incidence of various infectious and parasitic diseases reported in the Kyrgyz Republic, 2008-2012.

Year	**2008**	**2009**	**2010**	**2011**	**2012**
Zoonotic Diseases					
Brucellosis	3825	3629	3977	4412	2296
Pediculosis	271	230	293	137	131
Siberian Plague	46	11	28	12	6
Malaria	18	4	2	44	3
Parasitic Diseases					
Lumbricosis	8491	9339	9304	10,483	11,302
Enterobiasis	17,472	17,150	15,477	11,403	11,844
Echinococcosis	812	813	785	926	930

Source: Ilyasov et al. 2013

Of course, the climate does not create new diseases directly, but warmer weather promotes the development of pathogens while aridization can improve containment of infectious diseases. When permafrost thaws, Siberian scabies foci may activate. Climate change can spur the emergence of new strains of diseases such as plague. It should be noted that in 2013, for the first time in over 30 years, the death of a teenager was recorded after he visited a natural source of plague in the Central Tian Shan and made contact with a marmot, the main carrier of the plague.

One of the most dangerous natural focal diseases is tick-borne encephalitis. There are currently 10 natural foci of tick-borne encephalitis in Kyrgyzstan. Over the past 10 years, cases of the taiga tick bite have doubled, up to 16 cases per year. The number of people who apply for medical services for all tick bites is also increasing every year. In 2011, 639 cases were reported, and in 2012, 851 cases. The duration of the dangerous tick season has increased in recent years and it is no longer limited to April–June when the aggressiveness of blood-sucking insects is at its highest, with more tick bites now being reported from August–October.

Epidemiologists have even introduced the concept of a second peak in tick activity, with about the same number of individual cases of infection now occurring in both July and November. A further increase in the length of the tick activity period is expected due to an earlier exit from hibernation in spring and later onset of hibernation in autumn (Ilyasov et al. 2013). However, a clear relationship between climate change and the incidence of tick-borne encephalitis has not been proven. Although ticks have become much more numerous in some areas, only a small number are infected with the encephalitis-causing virus. However, the connection between climate change and the increase in the duration of the tick season due to an increase in mean annual temperature and lengthening of the frost-free period appears undeniable.

Malaria is also recorded in the Kyrgyz Republic and its distribution correlates well to climatic conditions (Ilyasov et al., 2013). Similarly, the cases of Siberian scabies disease among wild animals have become more frequent, being transferred through the food chain from prey to predators, including the snow leopard. Reports of other infectious diseases in the Kyrgyz Republic from 2008-2012 are shown in Table 19, above.

4.7 Summary

In general, anticipated changes in the climate of the Central Tian Shan under most scenarios will be detrimental for both natural ecosystems, human health, and the economy. Measures aimed at reducing greenhouse gas emissions and adapting to climate change are urgently needed. According to Shah et al. (2013), the Kyrgyz Republic is the third most vulnerable to climate change impacts amongst the countries of Eastern Europe and Central Asia (Fig. 19).

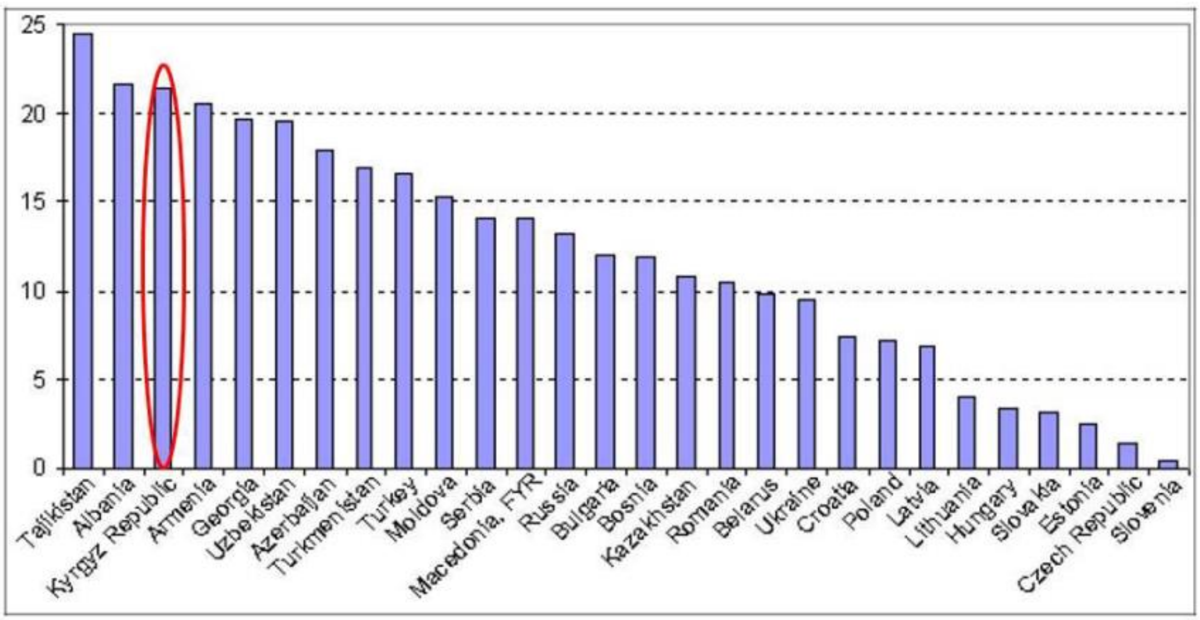

Figure 19. Ranking of vulnerability to climate change in Europe and Central Asia, by country. Source: Shah et al. 2013

The Kyrgz Republic recognizes the urgent need for developing adaptation actions, but currently poverty alleviation and human well-being are the primary focus of development initiatives. At the national level, the sectors most vulnerable to climate change in the Kyrgyz Republic have been identified as follows (Gov. of Kyr. Rep., 2009):

- Water resources (vulnerability indicators: glaciers parameter, surface runoff, lake area and depth).

- Human health (vulnerability indicators: morbidity).

- Agriculture (vulnerability indicator: heat supply, crop yield and pasture productivity).

- Climate-related emergencies (vulnerability indicators: frequency of floods, landslides, GLOFs and avalanches).

5. CLIMATE CHANGE ADAPTATION

At the national-level, intensive climate adaptation efforts in the Kyrgyz Republic will need to be made in a wide variety of areas, including in the fields of water resources, agriculture, healthcare, and natural hazard mitigation, as discussed below.

5.1 Adaptation for Water Resources

Formulation of adaptation strategies for water resources in will need to be region-specific, but in general should address:

- More effective and careful management of irrigation systems to conserve and better utilize water.
- Regulation of surface runoff and water storage in reservoirs.
- Use of more modern and efficient systems for water distribution that reduce systemic losses.
- Promotion of more efficient use of available water resources through the introduction of water usage fees.

5.2 Adaptation for Agriculture

Climate adaptation strategies for agriculture will need to address the following:

- Technological improvement for traditional agricultural practices.
- Economic mechanisms to encourage individual farmers to adopt climate-smart production practices.
- Delineation of ways state support for agriculture can be improved.

5.3 Adaptation for Healthcare

Climate adaptation strategies for the healthcare sector will need to address the following:

- Expansion of research into the negative impact of climate change on human health in the country.

- Development of science-based forecasts on possible climate-related deterioration of public health and preparation of a prevention strategy.

- Regular preparation of national reports assessing the impact of climate change on the human health.

- Raising of public awareness about climate change impacts on health through special publications, periodicals, and brochure, and the media.

- Improving the system of education and training of public health specialists on epidemiological monitoring.

- Development of a national action plan on the prevention and reduction of the negative impacts of climate change on human health of the Kyrgyz Republic.

5.4 Adaptation for Natural Hazards

To reduce risks from climate-related natural hazards, measures to improve risk prevention will be important, in part by the reasonable reallocation of funds to prevent emergencies in the most vulnerable areas. Thus, a climate adaptation strategy for natural hazard risk prevention will need to address the following:

- Spatial planning for all natural disasters in order to identify high-risk areas and design methods to reduce human activities in these zones. This should be based on the current and projected probability of emergencies, taking into consideration the impact of climate change.

- Engineering measures aimed at eliminating natural hazards.

- Legislative measures defining rules and regulations that provide the basis for spatial planning and engineering activities for risk prevention.

- Public awareness raising and education on the expected increase in natural hazard risks resulting from climate change and methods for avoidance.

5.5 Adaptation for Biodiversity

The conservation of biological diversity in the face of climate change was not considered in the adaptation measures prepared for the Second National Communication to the UNFCCC (Gov. of Kyr. Rep. 2009). However, ecosystem resilience to climate change can be improved and the risk of damage to anthropogenic and natural ecosystems can be reduced through the adoption of adaptation strategies that take into account the conservation and sustainable use of biodiversity. The IPCC recommends implementing adaptation actions for natural or anthropogenic systems that address negative impacts or make use of positive opportunities resulting from climate change (IPCC, 2014).

At the state level, the major tool for conserving biodiversity under changing climatic conditions is establishment of an effective protected area (PA) system. This in itself is an adaptation measure for the conservation of rare species and ecosystems. The removal of anthropogenic pressure from protected areas allows biota to respond flexibly and adapt to new conditions, reducing the risk of extinction of the most vulnerable species. Therefore, although the Second National Communication does not consider biodiversity conservation, the expansion of the protected area system in the Kyrgyz Republic is a direct adaptation measure that is being taken for the conservation of the nation's natural heritage.

5.6 WWF Asia High Mountains Project Adaptation Actions

Implementation of the USAID-funded WWF Conservation and Adaptation in Asia's High Mountain (AHM) Landscapes and Communities Project in the Kyrgyz Republic focuses on the highland areas of the Central Tian Shan and links to the priorities of the National Medium-Term Development Program. This program confirms that highland areas form the core of the nation's biodiversity and emphasizes that protected areas play a key role in the conservation and management of biodiversity (Gov. of Kyr. Rep., 2012b). The need to preserve the biodiversity of the Tian Shan is set as a high national priority in the Fourth National Report of the Kyrgyz Republic under the Convention on Biological Diversity (CBD)(Gov. of Kyr. Rep., 2008). This report recommends prioritizing expansion of the national protected area system to cover 8 percent of the Kyrgyz Republic's territory as part of achieving sustainable development goals for the country. The AHM Project also supports implementation of the national Action Plan for Implementation of Biodiversity Conservation Priorities, and provides assistance to the Kyrgyz Republic in the implementation of relevant aspects of the CBD program (Gov. of Kyr. Rep. 2013).

The AHM Project has also developed a number of proposals for improving the resilience of ecosystems to climate change impacts. Currently, WWF is preparing a review and analysis of data collected on pasture use in the Central Tian Shan where the primary livelihood activity is livestock herding. In order to develop adaptation measures and sustainable pasture use practices, a series of workshops was conducted that was devoted to the impact of climate change on alpine communities, improving traditional livelihoods, and the development of new livelihood options. The seminar was attended by representatives of local governments and pasture committees. The use of pastures, stocking rates, and grazing pressure regulations were discussed, with notable findings being:

- In Aksu District, 12 aiyl okmotu (AO, village clusters) have the right to pastures covering 207,888 hectares of grasslands that have a stocking rate of 1.8 head of livestock per hectare of pasture.

- In Jeti-Oguz District, 10 AO have the right to pastures covering 351,923 hectares of grasslands that have a stocking rate 1.6 head of livestock per hectare of pasture.

These discussions identified the following issues:

- When planning the use of pastures, calculated optimal stocking rates for ecosystem preservation are are not taken into account.

- The impacts of climate change, particularly the negative impact of reduced rainfall on the yield of forage grasses, were not evaluated because of the absence of meteorological stations in the Central Tian Shan.

- The maintenance cost of livestock is increasing every year because of the increasing price of hay, purchase of which is necessary due to a decrease in rainfall during the forage crop growing season and lack of irrigation water for these crops. For example, one bale of hay cost 80 soms in 2012, 100 soms in 2013, and 300 soms in 2014 (Note: the exchange rate in February 2015 was USD 1.00 = 60 Kyrgyz Soms).

- In the project area there are two AOs, Engilchek and Akshyrak, which have no fixed grazing areas, and are forced to rent land from other AOs located in the Lake Issyk Kul basin. During the Soviet era, both of these villages were created for mining development and they did not receive grassland allocations, creating a serious problem for these villages today.

With the collapse of the Soviet Union, mining ceased and the populations of Engilchek and Akshyrak Villages lost their livelihoods. Some residents started to breed yaks and sheep, however, much of the local population engaged in wildlife poaching that included hunting and selling of argali and ibex for meat, marmots and martens for skins, and hunting of other animals as well. At the beginning of the WWF's work in the region in 2009, almost 80 percent of the inhabitants of these villages were engaged in poaching. Thanks to the activities of the WWF AHM project and the Snow Leopard Trust's (SLT) Snow Leopard Enterprises Project, very little poaching is occurring in these villages today, and anti-poaching patrols are now only recording two to three cases of poaching per year.

In order to solve problems related to climate change, training sessions were organized for the representatives of local communities to create revolving micro-finance funds that promote sustainable use of pastures and alternative income-generating activities. Subsequently, Akshyrak and Engilchek Villages both created such local development funds. WWF has allocated USD

10,000 (USD 5000 per village) in seed money, and local residents have put up USD 3000 in co-financing. Funding groups were organized to develop projects and receive money from the local development fund at a 10 percent annual interest rate (by way of comparison, bank loans in the Kyrgyz Republic typically charge interest rates of 26-40 percent per year).

Thus, when looking for ways to help the poorest adapt to climate change, priority should be given to protecting biodiversity, an element that is often not taken into account in many existing strategies. As climate-related precipitation decline and water shortages affect local populations more and more each year, it will be necessary to find alternative sources of income for the local population that will permit a reduction in the number of livestock and a reduction in grazing pressure without decreasing the standard of living. Current WWF AHM Project adaptation actions in the Kyrgyz Central Tian Shan include:

- Yak breeding: The AHM Project provides assistance in the development of yak breeding as a climate-smart alternative to traditional sheep breeding, as yaks do not require additional feeding and are better adapted than sheep to the harsh climatic conditions of high mountains. Raising yaks also helps protect native biodiversity since they are kept in smaller numbers than sheep, providing more space for wild ungulates. Yak breeding does not require a large financial investment and allows the production of ecologically sustainable meat that has a higher market value than mutton.

- Development of alternative income sources: Women are being trained on production of felt handicrafts and souvenirs in order to develop a climate-smart alternative source of income to heavily climate-dependent livestock herding. The AHM Project assists with marketing of felt products produced by supporting participation of women from high-mountain communities in the annual Oimo traditional handicraft fair at the tourist resort town of Cholpon-Ata on Lake Issyk Kul.

- Ecotourism: Ecotourism is a promising direction for livelihood development in the Central Tian Shan, as the region is famous for Peak Pobeda (7439 m) and Peak Khan Tengri (6995 m) as well as for a variety of alpine sports and tourism sites, including Merzbacher Lake on the Engilchek Glacier. In general, the development of ecotourism in the Central Tian Shan has the potential to benefit at least 50 families in local communities, who can provide services for tourists, including accommodation, meals, horses, guides, porters, and souvenirs. This will boost employment in the central Tian Shan where each job is critically important. In recent years, scientific and educational tourism in the Sarychat-Ertash State Reserve has become more popular and there are now plans to train local people on the basics of ecotourism and involve them in this growing economic sector.

- Promotion of renewable energy sources: Wind generators with capacities of 1.5 and 2 W were installed to power lighting at two ranger stations in the Sarychat-Ertash State Reserve that are located 18 to 20 km from the power grid. There are now plans to install renewable energy generators at other reserve ranger stations.

Implementation of these measures is helping the local population in the Kyrgyz Central Tian Shan adapt their lifestyle to the changing climate and will reduce human pressure on and build resilience of local ecosystems and snow leopard habitat to climate change impacts, preserving the unique natural heritage of this region. At the same time, many of the most important climate adaptation measures will need to be implemented by the national and provincial governments, including construction of engineering works to safeguard against natural hazards, improving the quality of medical care, and expanding the protected area network. A combination of local citizen initiatives and government programs will be the best way to implement climate change adaptation strategies and solve the persistent problem of poverty in the Kyrgyz Central Tian Shan.

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