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Natural Resources and Human Welfare in Central Asia

Ira Pawlowski (ed.)

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CONTENT

INTRODUCTION

IRA PAWLOWSKI

This book summarizes the main findings of the multidisciplinary research and post-graduate education project "Land use, ecosystem services, and human welfare in Central Asia (LUCA)" (2010-2014) conducted by Giessen University and its partners in Germany and Central Asia[1], funded by VolkswagenStiftung. The project combined research activity and scientific education with emphasis on the intrinsic interaction of people and their environment in the vulnerable region of Central Asia. The principal theme of the project has been the interrelation between ecosystems, land use, and human activity. Ecosystems provide supporting, provisioning, regulating, and cultural services that sustain human wellbeing but that are in turn also affected by human activity. The issue of land use and its natural and socio-economic drivers is of particular scientific interest when analysing the region of Central Asia with its extremely diverse ecosystems and with its societies and systems in transition. The increasing scarcity of natural resources – particularly water and fertile soil – together with conflicts over their use endanger the welfare of the people in the region and potentially could lead to political conflict.

With these issues in mind, a multidisciplinary and cross-national approach has been chosen by Giessen University and its partners to investigate this broad topic while in particular utilizing and enhancing the research capacity of the region. Within several subprojects young academics from Kyrgyzstan, Kazakhstan, Uzbekistan, and Tajikistan have concentrated their PhD research activities on the assessment of past and current land use structures and their interrelation with physical processes of the biogeosphere, economic development, and human welfare. Senior researchers from Germany and Central Asia have guided the research of the PhD students. Capacity building has therefore been an integral component of the LUCA project targeting three areas: the improvement of the methodological expertise of the young researchers, the promotion of multidisciplinary thinking and transnational cooperation, and the (re)connection with the international scientific community. Alongside the

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1 Partner institutions of the project have been: Marburg University, Dept. of Geography (Germany); Helmholtz-Centre Potsdam GFZ, German Research Centre for Geosciences (Germany); Central Asian Institute of Applied Geosciences (CAIAG), Bishkek (Kyrgyzstan); Hydrometeorological Research Institute (NIGMI), Tashkent (Uzbekistan); Academy of Sciences, Institute of Economy and Demography, Dushanbe (Tajikistan); Scientific Information Center of Interstate Coordination Water Commission (SIC ICWC), Tashkent (Uzbekistan); National Space Agency, National Center of Space Researches and Technologies, Almaty (Kazakhstan); Scientific Research Institute of Ecology and Climate, Almaty (Kazakhstan); Agricultural University, Tajik Agricultural Economics Institute, Dushanbe (Tajikistan).

research activities, the project has focussed on education and has conducted summer schools, training courses, a conference, and has facilitated the presentation of research outcomes in international symposia and publications.

This book, organized in two parts, presents abstracts of the research of the subprojects. The first part focuses on dimensions of earth and environmental sciences and demonstrates on how and to what extent (man-made) changes of biogeographic conditions have occurred and how they will influence land use in the future. The study of Duishonakunov/King on a mountain range of Southern Kyrgyzstan measures substantial glacier retreat of more than twenty percent on average as well as changes in permafrost due to climate change over a period of 45 years. This has serious implications for natural hazards and the economic development of the region. Another natural disaster is described in the work of Aslanov et al: the drama of the anthropogenic desertification process of the former Aral Sea. The authors have studied spatial and temporal ways of dust deposition, the composition of the deposited material containing pesticides, heavy metals and salt, and its potential impacts on arable land and human health. The research of Teshebayeva et al deals with the hazard of earthquakes and landslides. The researchers developed a special remote sensing technique for the analysis of such surface displacements in Southern Kyrgyzstan in order to help in the understanding of active tectonic processes and their spatio-temporal consequences. The improvement of irrigation and drainage systems in order to minimize water loss and return flow is the underlying idea of the work of Kenjabaev et al. By modifying a special hydrological model, they were able to predict and compare groundwater levels for various crops in the Fergana province of Uzbekistan and thus assess the efficiency of local irrigation and drainage management practices.

The second part of the book describes project research on socio-economic and institutional aspects of land use and their interrelation with human wellbeing. The working group of Khakimov et al evaluated the macroeconomic drivers of the agricultural sector of Tajikistan and explained that current income growth in the country, mainly caused by a continuously high inflow of remittances, will translate only marginally into an increase in domestic production but will lead to an increase in food imports. The case study of Gojenko et al investigated food consumption in two districts of Eastern Uzbekistan and revealed a considerable level of food insecurity, amounting to forty percent of surveyed households. This showed a direct relationship between the area of household plots, the number and variety of crops cultivated, the number of household members, and the education level of the head of the household. The contribution of Zhunusova/Herrmann investigated the impact of both direct agricultural policies and changing macroeconomic conditions on agricultural incentives in Kyrgyzstan. The authors found out that the production of food crops was preferred over tradable agricultural products due to food self-sufficiency needs, a lack of market access for export products, and a protected home market for importable goods such as energy sources and machinery. A different type of research has been undertaken by the working group of Sabitova et al who looked at the implementation of the Kyoto Protocol in Kazakhstan and its legal implications for land-use, land-use change, and forestry (LULUCF). The argument of the authors is that a domestic emissions trading scheme together with participation in Joint Implementation projects may be employed for Kazakhstan's quantified emissions limitation and reduction commitment under the Kyoto Protocol. The final contribution of Avazov et al looks at the issue of efficient pasture management in Tajikistan's mountains. Applying a bio-economic, linear programming model the authors determine the economic impact of various grazing management strategies. They show how a concentrated pricing will impact on the system by improving inventories over the season and promoting the production of fodder crops to reduce pressure on pastures.

Although each subproject has been very specific in its research question, the overall observation is that land use has been continuously changing in Central Asia, being influenced by and influencing human welfare. Understanding the extent and the drivers of that change is crucial for the further development of the region. The LUCA project has been contributing to this analytical process through its research. Probably the most important outcome of the project has been, however, the enhanced personal and institutional scientific relationships that will sustain further investigations in the future.

The editor thanks the contributors for presenting their research, VolkswagenStiftung for funding the project including this book, and the team of the Center for International Development and Environmental Research (ZEU) at Giessen University for its assistance in publishing.

Giessen, in July 2014

Part I:
Natural Resources and Environment

CLIMATE CHANGES IN THE NARYN CATCHMENTS: CONSEQUENCES FOR GLACIERS, PERMAFROST AND THE ECONOMIC DEVELOPMENT IN KYRGYZSTAN

M. DUISHONAKUNOV and L. KING

0 ABSTRACT

The recent glacier conditions in the Naryn catchments were investigated using topographic maps and satellite imagery. The results show, that during the 45-year period 1965–2010, the glacier area decreased in the mountain ranges by 17 to 29%. The glacier shrinkage will affect not only irrigation water availability during summer but also the potential of hydropower stations once numerous smaller glaciers will have disappeared. In addition massive ground ice in permafrost may also melt in a warming climate. This will create natural hazards, especially slope instabilities. Glacier changes may lead to catastrophic glacier lake outburst floods, a common phenomenon in Kyrgyzstan. The effects of climate change on water resources are of paramount importance because of the high dependency of Kyrgyzstan on fluvial water originating from the mountains. Monitoring water resources and planning water use at a balance between water use and water resources belong to the most important issue in this region. In spite of this well-known imbalance, water demand may increase in the future due to food- and energy-security concerns in the region, and this might even lead to severe conflicts among nation states.

1 CLIMATE CHANGE AND WATER AVAILABILITY IN KYRGYZSTAN, AN INTRODUCTION

Naryn basin has the largest river catchment area in Kyrgyz Republic and many mountain glaciers. It is a huge “water tower” for the Kyrgyz Republic and Uzbekistan. Thus, the glacier conditions in the Naryn catchment have a large impact on the available water resources for the arid flat plains below. They provide water for residents, irrigation, and energy in the Kyrgyz Republic but also other parts of Central Asia.

Scientific discussions suggest that, regardless of whether climate change has natural or anthropogenic causes, it will have strong effects on glacier recession, regional hydrological balance, and economic sustainability in arid and semi-arid regions of Central Asia (Alamanov et al., 2006; Fujita et al., 2011). The probable potential effects of climate change on water resources are of paramount importance because of the high dependency on fluvial water originating from mountains. Monitoring water resources and planning water use and the balance between water use and water resources are very important issues in this region because the majority of the water supplied from Central Asian mountains is used within the irrigation zones of the arid flat plains (Report of Eurasian Development Bank, 2009; Agrawala et al., 2001). This study therefore intends to deliver valuable data for estimating the magnitude of glaciological changes and their future effects for the water availability in this region.

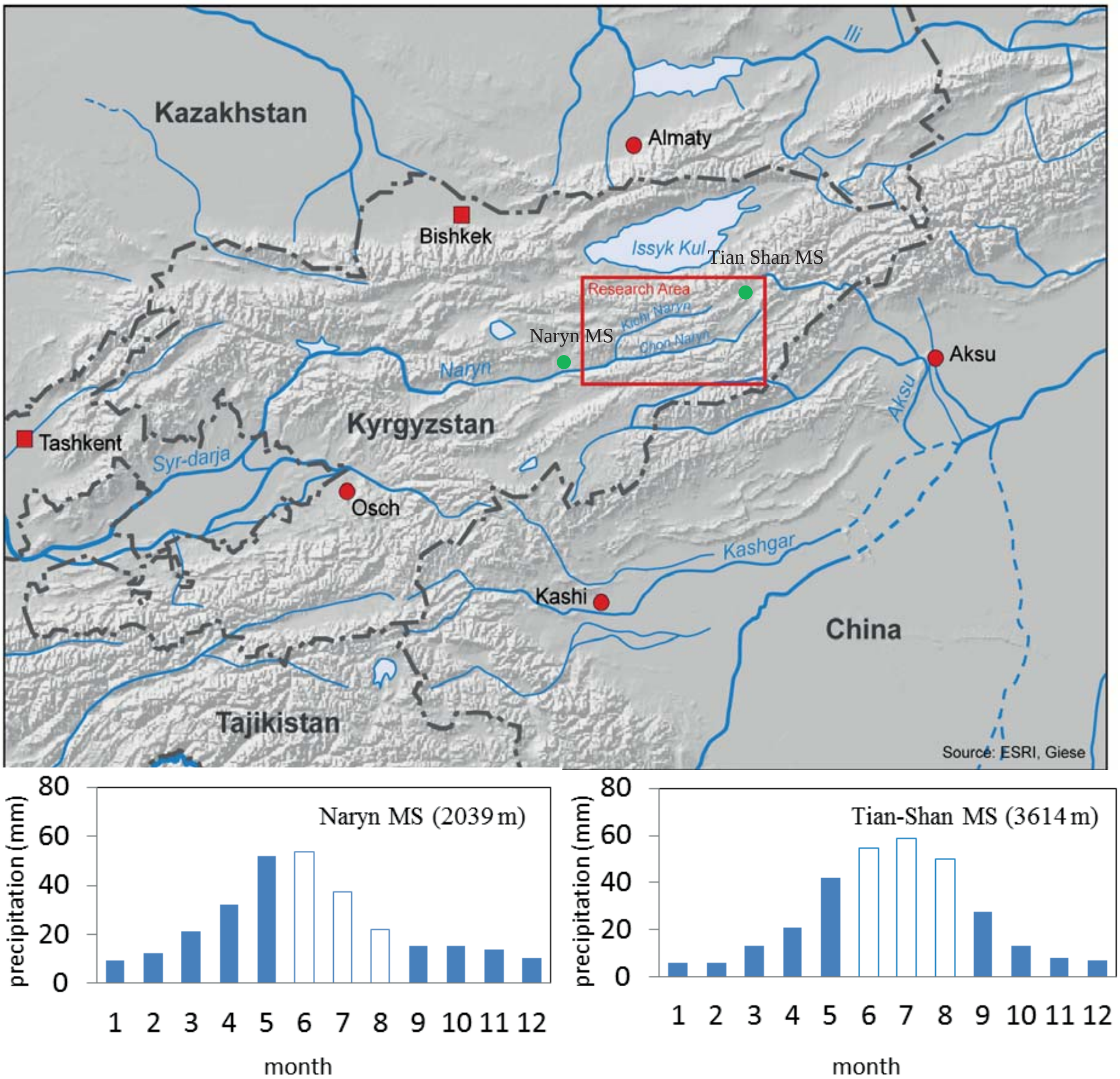
In addition to the glaciological study, the extent of frozen ground and its characteristics are also researched, as the occurrences of widespread massive ground ice in permafrost has to be assumed. This ground ice will melt in a warming climate and thus not only contribute to the water balance. More important, it will create hazards as e.g. slope instabilities by many thawing and freezing (periglacial) processes. At the same time, also glacier changes may create hazards, as e.g. catastrophic glacier lake outburst floods (GLOFs) that are very common and dangerous in Kyrgyzstan. Glacier changes (glaciology) and changes in the periglacial environment (geocryology) are therefore strongly connected by many interrelations. The hazards involved may influence and hinder the development of Kyrgyzstan. Selected glaciological and periglacial aspects will be presented in this paper.

2 THE STUDY AREA

The Naryn basin flow runs from east to west across the territory of Kyrgyzstan, and its length, before merging with the Syr-Darya, is more than 700 kilometers. The major water resources of the Naryn basin are fluvial water from rain and snow and glacier melt in the upstream area. There are 654 identified glaciers in the Naryn basin (Glacier Inventory of USSR, 1973, 1977). We investigated the recent condition of glaciers in the Chon Naryn and Kichi Naryn river catchments in the eastern part of the Naryn basin (Figure 1). These catchments include 69% of the glacier area in the Naryn basin, including 607.9 km2 (10.8% of the basin) in the Chon Naryn and 344.7 km2 (8.9% of the basin) in the Kichi Naryn. The catchments include eight mountain ranges: the Akshyirak, Borkoldoy, Naryn, Sook, Jetim, Jetimbel, Terskey, and Uchemchek.

Two meteorological stations are shown in Figure 1, along with the seasonal variation in monthly precipitation for 1930–2010 for selected stations. The climatic conditions in the upper Naryn basin are very severe, and all locations within it show an average annual air temperature below freezing point. In the lower part of the upper Naryn basin, annual precipitations are 292 mm at the Naryn meteorological station (2039 m) and 311 mm at the Tian Shan meteorological station located at an altitude of 3614 meters (Figure 1, cp. Figure 10 for climate values).

Figure 1: Location of the Naryn basin. The red rectangle shows the study area. Green dots show the locations of the two meteorological stations. Figures at the bottom show the seasonal variation in monthly precipitation for 1930–2010 for selected stations (white bar: JJA).



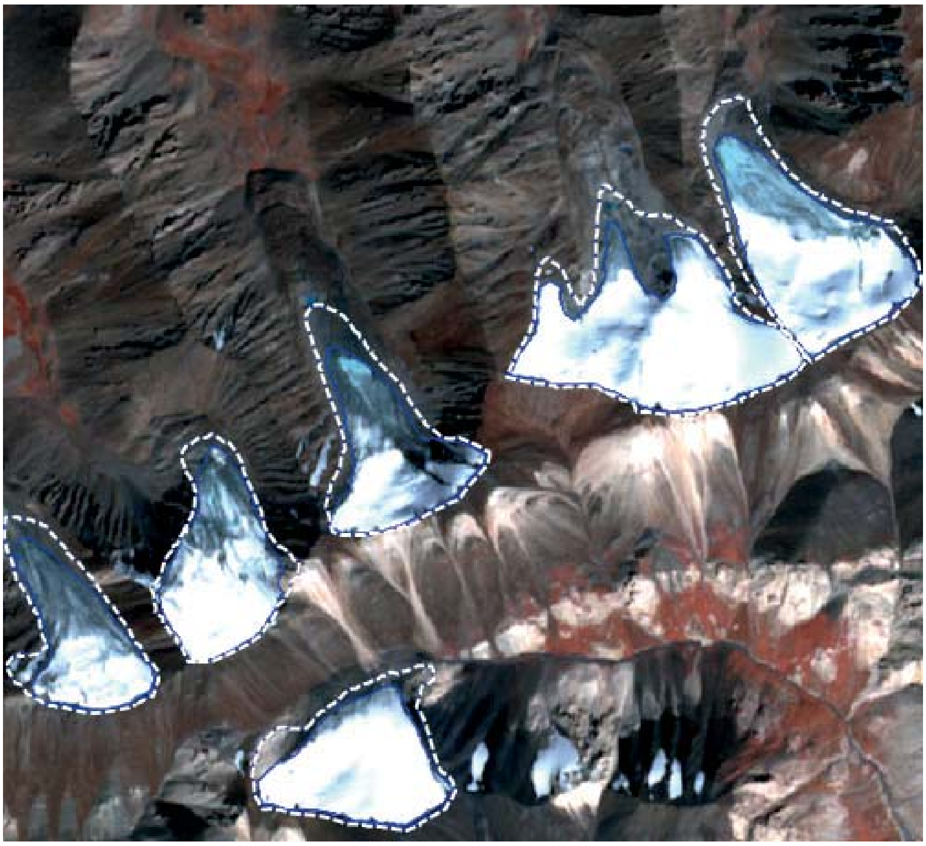
Annual precipitation is low, and the maximum precipitation occurs during summer (May to August) because of the topographical complexity of the Tian Shan Mountains and the complex interactions between the Westerlies and the Siberian High that affect the precipitation in the Tian Shan Mountains (e.g., Aizen et al., 1995, 1997). The basin has clear cloudless weather with little precipitation during winter, and this allows the use of the Arabel Kumtor, and Chon Naryn catchments as winter pastures. In this paper, local Kyrgyz geographic names are used according to Barataliev (2004) and Barataliev et al. (2004).

3 DATA AND METHODOLOGY FOR GLACIER AND PERMAFROST STUDIES

3.1 Available data and data processing

To clarify recent glacier changes in the two catchments, glacier boundaries were delineated on 1:25,000 topographic maps based on aerial photography collected in the 1960s and with “Advanced Land Observing Satellite” and “Advanced Visible and Near Infrared Radiometer type 2” satellite datasets acquired during 2008–2010. This ALOS/AVNIR-2 (70 × 70 km) data used consists of four bands, three visible (0.42–0.69 µm) and one near infrared (0.76–0.89 µm), and have a spatial resolution of 10 m (JAXA, 2009). We used orthorectified ALOS/AVNIR-2 products by JAXA in this study. To reduce the potential uncertainty in glacier mapping with satellite data, we selected satellite imagery acquired during the glacier ablation period that had minimal cloud cover or nearly cloud-free conditions. The topographic maps were scanned at 700 dpi and were projected by georeference on ArcGIS 9.2.

Figure 2: Extraction of glacier outlines in the Borkoldoy range from ALOS/AVNIR satellite images and topographic maps (1:25,000). Dark-blue glacier outlines of 2010, and white dotted outlines of 1965.



3.2 Glacier outline extraction

The outlines of glaciers were extracted manually by visual interpretation of the 2008–2010 ALOS/AVNIR-2 images (Figure 2). The areas of the extracted glacier polygons were computed using ArcGIS 9.2, with omission of glacier areas smaller than 0.1 km2. We added the glacier polygon data to attribute data such as mean altitude, minimum altitude, maximum altitude, area, and aspect in each glacier-area class. Changes in the terminus position of some glaciers were observed and measured during fieldwork from 2010 to 2012 using GPS instruments.

3.3 Permafrost research methodology

In addition to the glacier studies, we also investigated the conditions of Permafrost and ground ice. In Kyrgyzstan, only a few researchers are currently dealing with this topic. However it is studied here, as the melting of massive ground ice and perennial snow patches (as indicators for actual permafrost conditions) may contribute to the regional water balance in a much greater magnitude than assumed today.

For the current study we investigated frozen ground upon upstream Naryn catchments, during August 2010 to August 2013. We measured near-surface ground temperatures in 18 locations at different altitudes and slopes. The objectives of this study are to estimate the distribution of permafrost, and its active layer, and to discuss the permafrost environment in the upstream Naryn catchments. The general features of mountain permafrost such as permafrost distribution and temperatures, active layer thicknesses within the upstream Naryn catchments, Tian Shan Mountains are described. The area of permafrost studies in the Naryn basin is located within the two upstream river basins (Chon Naryn and Kichi Naryn). The mountain permafrost zone in our study area belongs to the Asian mountain permafrost area, the largest in the world.

In the field we used steel rods and a hammer to knock holes up to 1.5 m deep in order to install our thermistor strings, thus measuring continuously ground temperature profiles for the coming study years. Ground temperature measurements were carried out in 18 locations between altitudes 3007 and 4043 meters. These measurements were performed using wireless mini thermistor sensors and loggers (M-Log5W). They have a high memory capacity (2048kB), a very low energy consumption and a waterproof cover (Figure 3). The temperature sensor has a high resolution of 0.01°C and an overall accuracy of ± 0.1°C. This thermistor can work more than 5 years without changing batteries depending on temperature conditions of the logger instrument and the batteries. The temperature recording started in August 2010 at an hourly interval. At all locations the observation period was up to end of August 2013.

Figure 3: M-Log5W wireless mini data logger

(http://www.geoprecision.com/)

4 GLACIOLOGY OF THE NARYN CATCHMENTS

4.1 General glacier characteristics

A total of 654 glaciers were studied in the two researched catchments: 15 glaciers in the Akshyirak massif, 126 in the Borkoldoy range, 130 in the Jetim range, 89 in the Jetimbel range, 80 in the Naryn range, 41 in the Sook range, 95 in the Terskey range (south slope glaciers), and 78 in the Uchemchek range (Table 2). Of these, 513 glaciers (435.2 km2) in the northwest, north, and northeast sectors of the eight mountain ranges account for 74.3% of the total glacial area. The characteristics of the glacier distribution in the study area were analyzed in relation to the statistical relations among topographic parameters of the attribute data (mean altitude, minimum altitude, maximum altitude, area, and aspect in each size class; Tables 1 and 2).

Table 1: Basic information on investigated glaciers (1965)

Class (km^2)	Number	Total area (km^2)	Total area (%)	Minimum elevation (m)	Maximum elevation (m)	Mean elevation (m)
0.1 – 0.5	395	98.1	16.8	3580	4960	4187
0.5 – 1	177	186.6	31.9	3510	4960	4214
1 – 2	40	70.9	12.1	3580	5020	4232
2 – 5	30	120.6	20.6	3720	4880	4222
5 >	12	109.2	18.6	3600	5170	4258
Total	654	585.4	100	3510	5170	4223

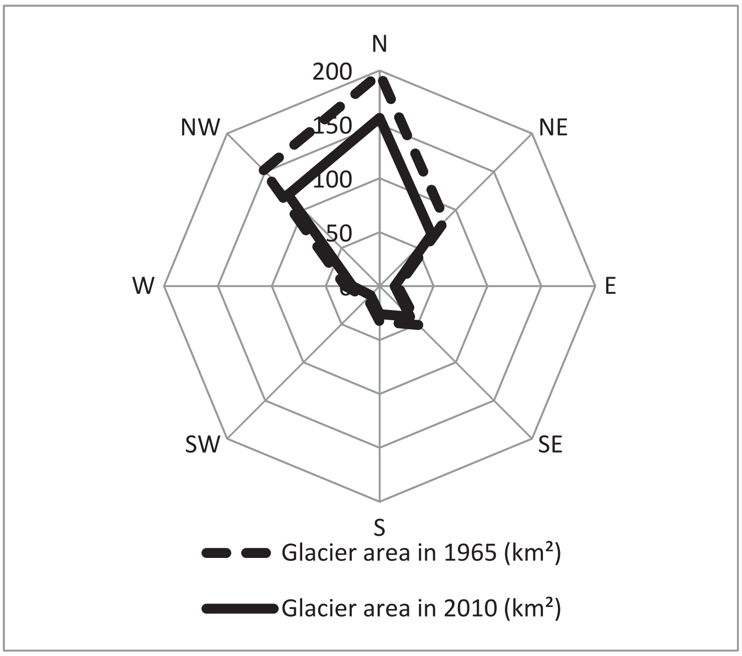
Table 2: Derived glacier parameters (~2010) for eight mountain ranges

	range	Akshyirak	Borkoldoy	Jetim	Jetimbel	Naryn	Sook	Terskey	Uchemchek
Area (%)	0.1 – 0.5 (km2)	2	11	15	**24**	**46**	14	18	19
	0.5 – 1 (km2)	10	**27**	**30**	**54**	**38**	72	**22**	**30**
	1 – 2 (km2)	18	14	6	17	0	14	8	**24**
	2 – 5 (km2)	**23**	**26**	**29**	5	16	0	**24**	13
	5 > (km2)	**47**	**22**	**20**	0	0	0	**28**	14
Aspect (%)	N	2	**32**	**48**	**55**	**39**	**58**	3	40
	NE	0	**20**	15	16	**33**	16	7	12
	E	0	0	2	6	4	6	9	0
	SE	0	5	5	0	0	4	**39**	0
	S	0	2	1	0	0	0	**32**	0
	SW	9	2	3	1	0	6	3	0
	W	9	8	2	2	6	4	2	14
	NW	**80**	**31**	**24**	**20**	18	6	5	**34**
Total glaciers measured		15	126	130	89	80	41	95	78

A majority of the parameters clearly showed evidence of changes in the regional characteristics of the glacier distribution. Figure 4 shows that the relationship between glacier area and aspect, indicating that large glaciers are concentrated on northern aspects. A majority (74.3%) of the total area is located in the sectors northwest, north, and northeast. Table 2 shows the distribution of glaciers classified according to area class (0.1–0.5 km2, 0.5–1 km2, 1–2 km2, 2–5 km2, and >5 km2) for the eight mountain ranges. In three mountain ranges, the distributions of glacier size classes are similar: glaciers with areas of less than 1 km2 occupy 78% in the Jetimbel range, 86% in the Naryn range, and 84% in the Sook range.

There are there are no glaciers larger than 5 km2 in these ranges. In the Akshyirak massif, small glaciers of less than 1 km2 occupy 11.5%, and larger glaciers of more than 5 km2 occupy 48%. In the other (Borkoldoy, Jetim, Terskey, and Uchemchek) ranges, the distribution of glacier size classes is different; glaciers with areas of less than 1 km2 occupy 39–50% and those larger than 5 km2 occupy 14–28%. The glacier termini altitudes in these four mountain ranges are quite different: 5170 m in the Borkoldoy range, 4840 m in the Terskey range, 4825 m in the Jetim range, and 3510 m in the Uchemchek range. The average glacier termini altitude in the study area is 4223 meters.

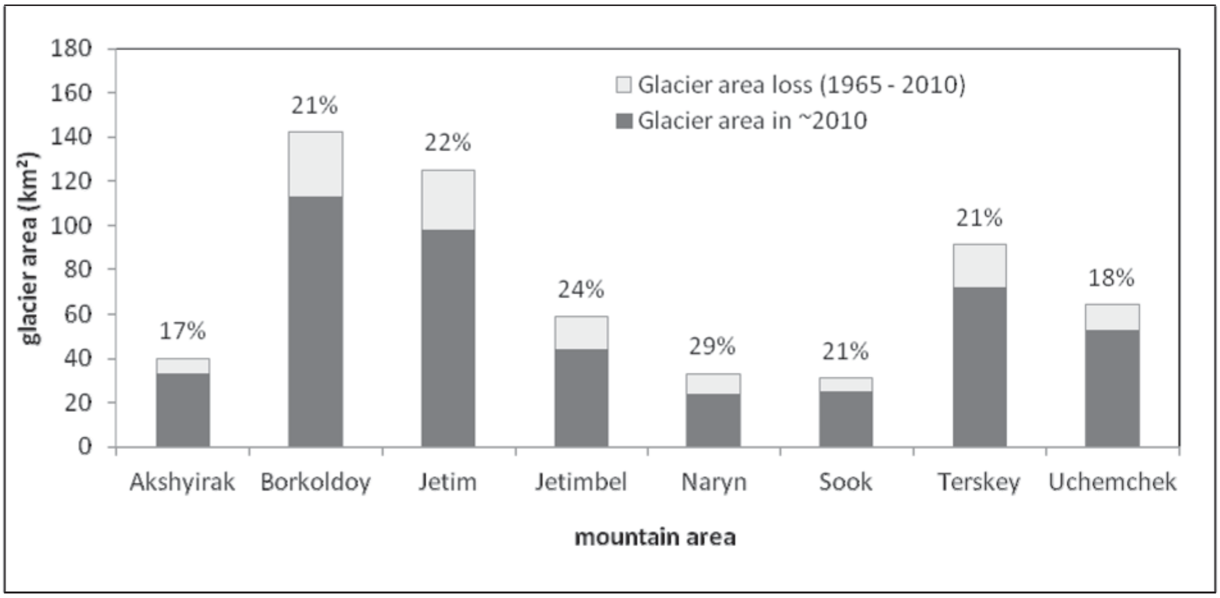
Figure 4: Distribution and area change of glaciers with different aspects.



4.2 Glacier area changes from 1965 to 2010

We investigated the glacier shrinkage in the two catchments using 1:25,000 topographic maps (~1965) and ALOS AVNIR-2 satellite data (~2010). The total area of the 654 studied glaciers decreased by 21.3% (from 585.4 km² to 460.5 km2) during the period 1965 to 2010 (Table 3). The glacier area decreased by 17.4% in the Akshyirak massif, 20.8% in the Borkoldoy range, 21.9% in the Jetim range, 24.6% in the Jetimbel range, 28.9% in the Naryn range (north slope), 20.8% in the Sook range, 20.9% in the Terskey range (south slope), and 17.8% in the Uchemchek ranges (Figure 5). The greatest area reductions occurred in the Naryn (28.9%), Jetimbel (24.6%), and Jetim ranges (21.9%).

Figure 5: Changes in total glacier area in eight mountain regions for the period ~1965 and ~2010



Additionally, the percentages of glacier loss in the different size classes were investigated. Small glacier areas are sensitive to local climate changes and local glaciological factors (Johannesson et al., 1989; Kuhn, 1995; Nesje and Dahl, 2000). The relative abundances of glaciers in the different size classes strongly affected the total glacier-area loss percentage. The regions dominated by small glaciers are more sensitive to change because of the shorter response time of small glaciers to climate variability (Bahr et al., 1998). In the study area, 89% of glaciers have an area of less than 1 km2. A comparison of glacier size class distributions and glacier shrinkage amounts revealed that the Naryn range with its many small glaciers (<1 km2) experienced large glacier shrinkage (28.9%), whereas, the Akshyirak massif with its large glaciers (>5 km2) had less shrinkage (17.4%; Tables 2 and 3). Figures 6 and 7 show specific glacier changes related to the glacier size class. There were also dramatic change differences between glaciers located on northern and southern slopes. On northern slopes, 513 glaciers decreased by 19.7%, but on southern slopes, 78 glaciers were reduced by 24.1%.

Figure 6: Specific glacier changes related to the glacier size class (Akshyirak, Borkoldoy, Naryn and Sook mountain ranges)

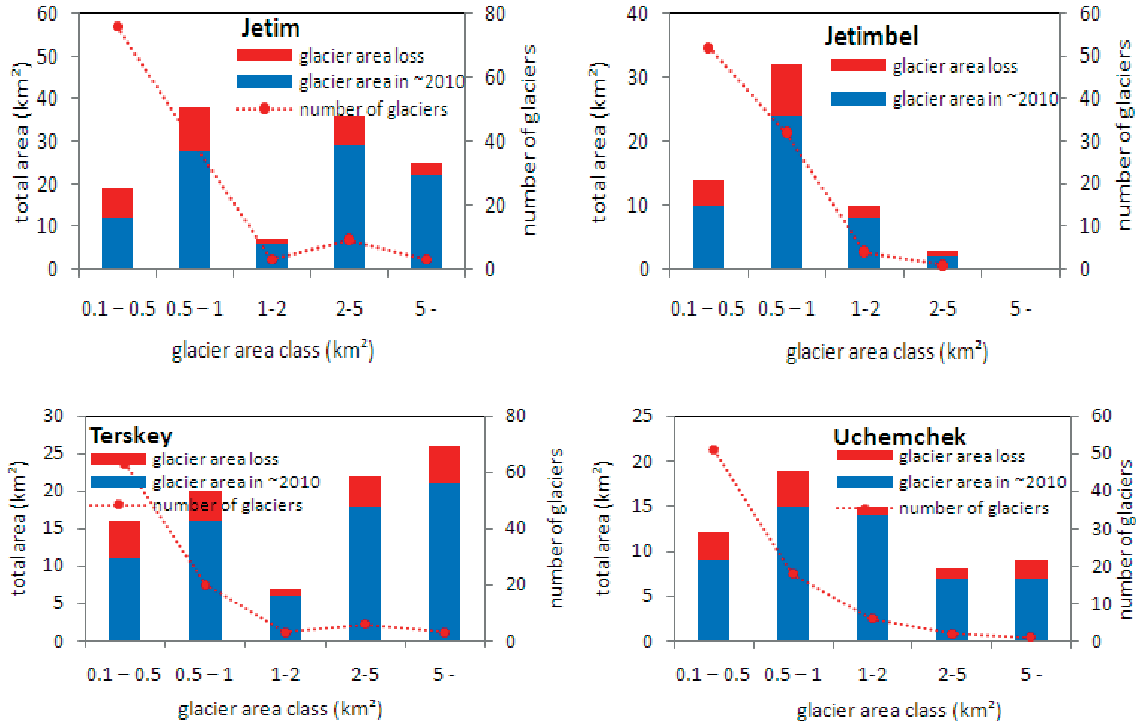


Figure 7: Specific glacier changes related to the glacier size class (Jetim, Jetimbel, Terskey and Uchemchek mountain ranges)

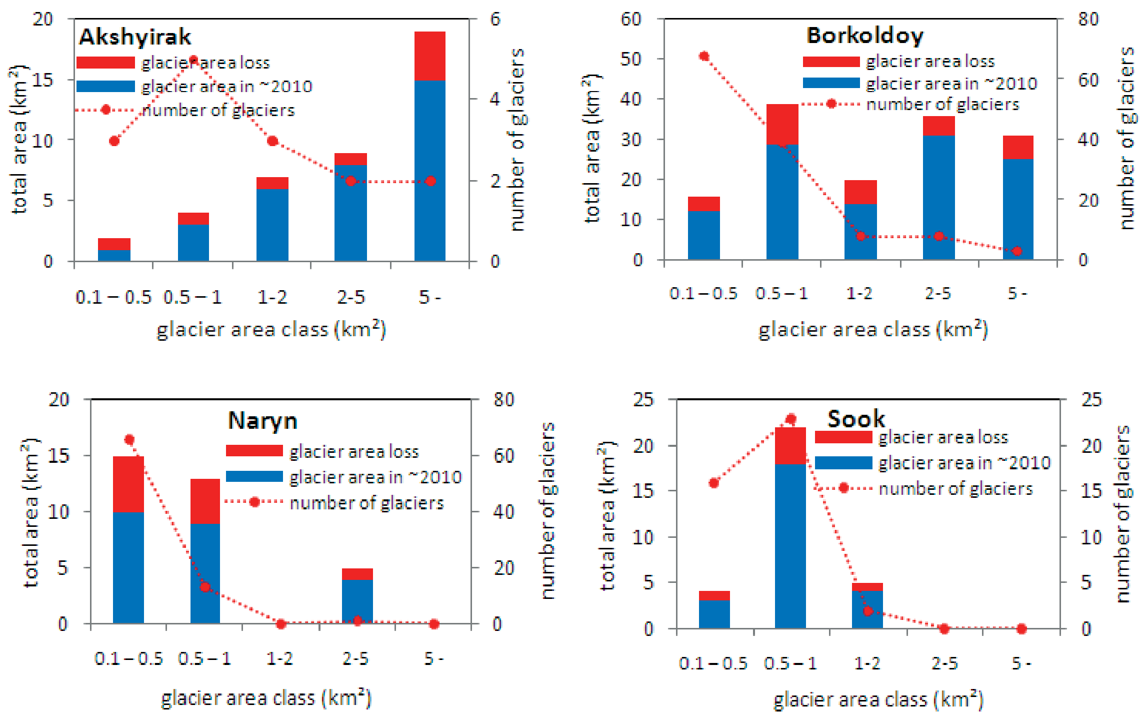


Table 3: Summary of glacier area change in eight mountain ranges

Mountain area	Average area (km^2)	Area (km^2) 1965	Area (km^2) 2010	Area change (%) (1965 - 2010)
Akshyirak	2.66	39.9	32.96	- 17.4
Borkoldoy	1.13	142.0	112.50	- 20.8
Jetim	0.96	125.1	97.75	- 21.9
Jetimbel	0.66	58.7	44.25	- 24.6
Naryn	0.42	33.3	23.65	- 28.9
Sook	0.76	31.4	24.86	- 20.8
Terskey	0.96	91.0	71.96	- 20.9
Uchemchek	0.82	64.0	52.61	- 17.8
Total	0.90	585.4	460.54	- 21.3

5 IMPACTS OF GLACIER CHANGES ON WATER RESOURCES

The total area of glaciers of the Chon Naryn and Kichi Naryn catchments of the Naryn basin decreased significantly between about 1965 and 2010, with a total glacier retreat of 21.3%. This is due to increasing summer temperatures and decreasing precipitation. This glacier shrinkage varied with regional climate and differed among glaciers of different sizes and according to altitude. The largest amount of glacier shrinkage occurred in the Naryn range (28.9%) because of the dominance of small-scale glaciers on north-facing slopes. Strong glacier retreat can produce large quantities of water in a short time period, which may cause hazards in downstream areas. Continuing glacier shrinkage will result in water and energy deficiencies in the region. The present state of these glaciers needs to be evaluated and monitored scientifically for reasonable development and use of regional water resources and water cycle models, and for regional economic planning.

It is important to understand the impact of glacier shrinkage on water resources in lowland arid areas. Any change in the glacier regime has a severe impact on Naryn River tributary water entering the Syr-Darya, which is important for Kyrgyzstan and Uzbekistan. Hagg et al. (2007) estimated significant changes in seasonal runoff volume related to glacier area loss in the Tian Shan using a special CO2 scenario from 2050 to 2075. Decreased glacier area leads to a decrease in summer glacier-melt discharge. The distribution of glaciers among the main tributaries of the Naryn basin is extremely uneven, and the contribution of glacier water to the total runoff also varies among the tributaries. In this paper, based on identified regularity of spatial distribution of rainfall, relations of melting ice and snow on the temperature (Dikih, 1999) determined the volume of glacial runoff in the Chon and Kichi Naryn rivers. Table 4 contains the values of runoff norm. The share of glacier melt water is analyzed using Dikih's method. The contribution of glacier runoff to the summer discharge is large in both catchments.

Table 4: Total and glacier runoff of the Chon Naryn and Kichi Naryn catchments

Hydrological station	Average annual discharge, 1930-2010 (m^3/sec)	Runoff volume (mln m^3)	Glacier runoff (mln m^3)			Share of glaciers in total runoff (%)	Share of glaciers in summer runoff (%)
			From snow melting	From ice melting	Total		
Chon Naryn	46.5	1479	196.5	258.5	455.0	30.7	51.3
Kichi Naryn	41.1	1340	201.6	119.7	321.3	23,9	36.5

6 PERMAFROST AND GROUND ICE AS ADDITIONAL RUNOFF PARAMETERS

6.1 Permafrost

Permafrost is defined as ground that remains at or below 0°C for at least two consecutive years. Mountain permafrost regions are traditionally divided into several zones based on estimated geographic continuity in the landscape. A typical classification recognizes continuous permafrost (underlying 90-100% of the landscape); discontinuous permafrost (50-90%); and sporadic permafrost (0-50%) (www.ipa.arcticportal.org). In the Tian Shan Mountains at altitudes of more than 3300 m a.s.l. there is permanently frozen ground spread almost everywhere.

The permafrost – is the product of climate and heat-flux from the earth. Its origin and preserving is promoted by the low average annual and winter temperatures and the insignificant snow cover, which favour the cooling off in winter. Permafrost has been identified as one of the cryospheric indicators of global climate change within the monitoring framework of the WMO Global Climate Observing System (GCOS) (Harris et al., 2003 a, b; Cihlar et al., 1997; Mackay, 1972). In a permafrost area, the so-called active layer thaws in summer and freezes in winter. Accordingly, any underground ice must lie in permafrost below the depth of summer thaw. Underground ice can only persist in permafrost, but not all permafrost has underground ice, because permafrost is defined solely upon a temperatures basis (below 0 °C) and not upon the presence or absence of ice. King et al. (1992) remind the following: Whereas practically all water is frozen in permafrost material at temperatures of about -15 C, a considerable amount of water remains unfrozen at temperatures between 0 °C and -5 °C, especially in materials with high clay content. This is important when using geophysical (seismic) properties in order to find and characterize permafrost. Permafrost may exist in soils or other surficial materials (from peat or clay to boulders) or even in bedrock (King L., 1986). Mountain permafrost is known from many high altitude regions, such as the Rocky Mountains in North America (Janke, 2005), the Alps in Europe (Harris et al, 2003; King, 1990, 2000), the mountains in Scandinavia (King, 1986; King et al., 1988), the Himalaya in Asia (Jin et al, 2000).

Recent studies have reported warming of permafrost temperatures in many places of the world (e.g. Marchenko et al., 2007; Gruber et al, 2004; Ostercamp, 2003). Under climate change, the temperature increase and the distribution of permafrost in the mountain areas get more and more in the focus of the scientific community especially because of its impact on the water balance, but also concerning slope instabilities and many natural hazards involved with slope failures.

6.2 Periglacial processes and phenomena

The study of periglacial environments is very important for Kyrgyzstan with its vast mountain areas. By definition, the term “periglacial” means “the conditions, processes and landforms associated with cold, nonglacial environments”. The term was originally used to describe the climatic and geomorphic conditions of areas peripheral to Pleistocene ice sheets and glaciers. Modern usage refers, however, to a wider range of cold climatic conditions regardless of their proximity to a glacier, either in space or time. Many, but not all, periglacial environments possess permafrost; all are dominated by frost action processes. Therefore the periglacial environment does not include glacier areas, but ground ice and consequently freezing and thawing processes. This is important to understand, because ground ice in permafrost, in contrast to glacier ice, does not contribute to the annual runoff, hence the water level in the rivers (French, 2007). However, the ground is frozen, which means that the water stays frozen within these grounds. But, in the future the ground ice which is stored in permafrost can be a significant water source. That is why it´s important to study the differences between the glacial and the periglacial environment.

Periglacial processes include frost jacking, frost sorting, frost wedging, cryoturbation, and the development of cryotextures, cryostructures and cryogenic fabrics in soils. Its phenomena include landforms like seasonal and perennial frost mounds, as well as the cryotextures, and cryogenic fabrics found in soils. Special landforms exist in areas with frost, although only some indicate proofs of permafrost presence. Surface features formed under cold, nonglacial conditions are known as periglacial landforms (Washburn, 1980; French, 1996). Many researchers were fascinated by the wealth of periglacial forms, and many well illustrated textbooks on periglacial processes and “cryology” exist (e.g. Washburn, 1973; 1979).