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Rural Sustainability and Management of Natural Resources in Tian Shan Region, Central Asia

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Abstract

The research examines aspects of natural and cultural heritage and environmental management in Tian Shan region, Central Asia. This region is outstanding for the richness of natural resources, landscapes and ecosystems. Natural resources of Tian Shan are exceptional: the ecosystems include numerous protected and rare species, endemics, unique coniferous forests, rich biodiversity. However, nowadays the ecosystems experience environmental and anthropogenic impacts. After the disintegration of the Soviet Union (1990s), there is a clear shift of the Central Asian society back to the subsistence agriculture with recovered traditional style of life: private land use and cattle grazing on mountain pastures. Therefore, the anthropogenic impacts are presented by the livestock husbandry and nomadic pastures, since the majority of the local population now maintain traditional style of life. The livestock is increased, and strong grazing pressure become transform to overgrazing. This leads to unsustainable agriculture and overgrazing caused by cattle herds, and affects sustainability in mountainous landscapes. Given the unique ecology of the region, special measures should be taken to maintain ecosystems' sustainability. The sustainable management of natural resources in this unique region needs stimulating balanced co-existence of man and nature, and requires quality insights and acquaintanceship. Nevertheless, the information about Tian Shan environment is the least available comparing to other Eurasian mountains, and there is lack of regular environmental monitoring programmes cooperated at the cross-country level. This research contributes to regional monitoring of Tian Shan, providing analysis of its environmental situation and examining ways for the sustainable use of natural resources

Keywords: *Tian Shan, natural resources, rural sustainability, environment, monitoring*

Introduction

Tian Shan, or the 'Celestial Mountains', is one of the largest world high mountain systems, covering 800 000 km². Region of Tian Shan has unique geopolitical location in Central Asia (**Fig.1**): it crosses five densely populated countries: China, Kazakhstan, Kyrgyzstan, Uzbekistan, and Tajikistan.

Figure 1 *Tian Shan mountain range*

In the past decades the environment of the Tian Shan faced environmental challenges and potential threats of natural and anthropogenic origin, which cause changes in the landscape structure of mountainous environment. The climate change mainly impacts glacier areas in the Tian Shan region triggering ice sheet melting, retreat of glaciers and decrease of snow coverage in high mountains. According to the numerous reports (e.g., Bolch, 2007; Giese and Mossig, 2004; Narama et al., 2006; Niederer et al., 2008; Solomina et al., 2004), in the last decades the Tian Shan glaciers are affected by the overall increase of the temperatures, which is caused by global climate warming.

As a consequence, the glaciers reduce in their size drastically. As reported by Aizen et al. (1997), the decrease in snow resources occurred almost everywhere in the Tian Shan, and detected since past 60 years. The maximum snow thickness and snow duration have decreased on average 10 cm and 9 days, respectively.

Another existing problem has man-made character. Unsustainable agriculture, and rising land use pressure since past 1990s lead to the over-use of natural resources. The fall of the USSR triggered changes in life style of local population. Nowadays people tend to maintain traditional style of life which implies intense agrarian and agricultural activities. Example of this is increasing overgrazing and expansion of pastures into the adjacent walnut-fruit forests on the slopes of Tian Shan. The landscapes change also due to the natural ecological reasons, which includes wildfires and plant succession and encroaching. For instance, meadows in Aksu-Jabagly Nature Reserve, South Kazakhstan are being replaced by juniper woodlands (Wagner, 2009). Examples of other negative environmental consequences include, for example, flood hazards from montane rivers and glaciers (Jansky et al., 2010).

1. Natural resources

1.1 Mountainous landscapes

Natural landscapes of Tian Shan include various reserves of both mineral and non-mineral resources, as well as reserves of oil and natural gas. Deposits of Tian Shan include tin, tungsten, polymetallic ores, copper, cobalt, etc. Geologically, Tien Shan mountains form a part of the Ural-Mongolian geosynclinal folded belts, formed in Paleozoic Era and composed of crystalline and sedimentary rocks (Shultz, 1948). Traditionally, Tian Shan is divided into Northern, Central and Southern regions due to the regional differences of geologic origin and development during the mountain-building period. The Northern Tian Shan is the oldest region, formed during Caledonian folding, and Southern Tian Shan is the youngest, formed in Hercynian folding.

The geologic development in Mesozoic and Cenozoic Era at Northern and Central Tian Shan differs from that of the Southern Tian Shan. Accordingly, there are differences in geologic structure of Northern and Southern parts of Tian Shan. Thus, Northern and Central regions underwent intense folding during the early Paleozoic Era. Uplift and erosion formed a platform with a thin cover layer of continental clastic sediments. In western Tian Shan there are gold and quartz deposits. Natural gas and oil are discovered in Ferghana and Tajik valleys. Finally, there are numerous deposits of non-metallic mineral resources: marble, limestone, gypsum, etc. Southern Tian Shan, on the contrary, mainly consists of sedimentary marine, continental and lagoonal deposits, fluvial, lacustrine and moraine sediments in the intermontane basins, but also intrusive, volcanic and metamorphosed rocks. The regional differences are also noticeable in orography of the Tian Shan. Hence, folded structures in the north generally extend in sub-latitudinal and north-western direction, while the southern faults are mostly sub-latitudinal narrowing eastwards.

On the south the folds of southern Tian Shan are constrained by the Afghan-Tajik and Tarim Precambrian massifs (Fig. 2). In brief description of the geomorphological settings of Tian Shan mountains, a review of the regional characteristics and most important geomorphic structures of Tian Shan is performed, according to the regional orographic structure: Western, Northern, Central and Eastern Tian Shan. The geomorphology of Tian Shan is represented by a complex system of mountain ranges,

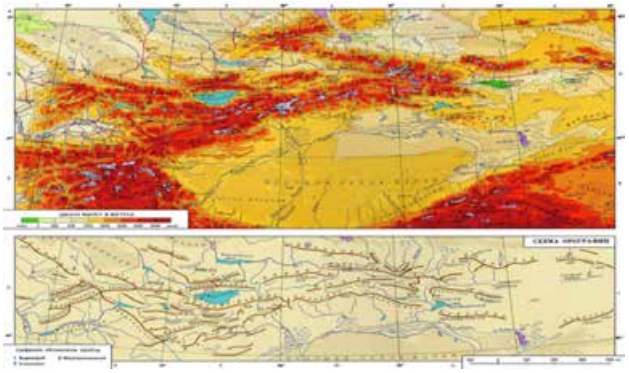

Figure 2 *Orographic structure of Tian Shan. Source: Great Soviet Encyclopedia*

steep slopes, river valleys and basins (Ferghana, Naryn, Issyk-Kul, Turfan). The majority of Tian Shan ranges extends in west-east direction with the exception of Fergana Kyrka Mountains (Fig.2) which extends from southeast to northwest direction, splitting Central Tian Shan from the Western and Southern regions. The geomorphic structure of Tian Shan varies in western and eastern parts, as well as in external and internal parts of the Tien-Shan, according to the orographic structure. In the inner regions, the typical are high plateaux with smooth relief and the largest glaciers. Northern and western Tien-Shan ranges have alpine relief with well-formed valleys (Bondarev et al., 1997).

1.2 Regional patterns

The favourable conditions for extensive pasture in Tian Shan region are created by the specific mountainous topography (Fig.4). Western Tian Shan is geographically located in Kyrgyzstan. In general, the terrain relief of the Western Tian Shan is very rugged which causes local climatic differences, depending on the altitude and topographic exposition. The altitudinal zonation in western Tian Shan is clearly expressed (Gvozdetsky and Mikhailov, 1978). The main mountain range of Western Tian Shan is Talas Alatau (Fig.2), a narrow cliffy ridge which spreads in westward direction in the western part of Kyrgyzstan dividing watersheds of Talas and Chirchiq rivers. The Talas Alatau is connected to the smaller ranges: Chatkal Range framing Ferghana valley on the north; Sandalysh; Maidan-Tal; Pskem Mountain Range, which serves as a natural border between Kyrgyzstan and Uzbekistan; Ugam and Karjantau Mountain Range (Chupakhin, 1964). These ranges are sub-divided into several ridges.

Many small rivers originate in the glaciers and snowfields on the plateaux and ranges in this region, flow down the slopes and feed two major flows of the western Tien Shan-Chatkal and Pskem rivers. In the south-eastern slopes of the ridge Chatkal many rivers flow to the Ferghana Valley into Syr Darya river. However, their waters are mostly taken for irrigation. There are only few mountain lakes in the western Tian Shan with the most known lake Sary-Chelek. Small-sized lakes of landslide or moraine origin are located in the valleys of the small rivers. Ranges of Eastern Tian Shan are almost entirely located in western China, Xinjiang Uygur Autonomous Region. The city of Urumqi is situated between the ranges Bogda and Uken. The Borokhoro Range, the westernmost extremity in the Kazakhstan, the Avral-Ula and the Narat Range form three 'fork tines' which gradually merge in eastward direction from 80°E (Fig.2). The Barkol Tagh Range is the easternmost part of Tian Shan bordering on Dzhungar Gobi desert zone (Gvozdetsky and Mikhailov, 1978). The Eastern region of Tian Shan has the most extreme topography in Tian Shan system. Since both the highest and the lowest points of Tian Shan are located on the east, the differences in altitude elevations exceed 7,000 m. The tallest peak in Tian Shan is Victory Peak located on the Chinese-Kyrgyz border, reaching 7,439 m. This region is notable for inaccessible gorges, typical alpine steep slopes with glaciers. Another notable mountain peak is Khan Tangri Peak, the highest point in Kazakhstan, with 6,995 m. The lowest altitude of Tian Shan and the lowest point in the Central Asia, is Turfan Depression (China), with depth of -154 m from the sea level. Northern Tian Shan occupies relatively small part in Kazakhstan from the total area of Tian Shan system. The Issyk Kul Lake naturally divides Northern Tian Shan from the Central and Southern regions. Main orographic mountain ridges of the Northern Tian Shan are Kungey

Figure 3 *Landscapes of Altyn-Emel National Natural Park (Kazakhstan). Source: altyn-emel.kz*

Alatau and Zailysky Alatau. They form the geomorphic basis of the northern region. Outer important chains of the northern Tien Shan, isolated apart from the main massif, are Ketmen Range and a Kyrgys Range (Svarichevskaya, 1965). Central (or Inner) Tian Shan includes Terskey Alatau Range with heights raising up to 5300 m, which forms a natural arch surrounding Issyk Kul lake (Fig.2). To the south of Issyk Kul Lake, the geomorphic structure is presented by the wide river valleys, plateaus, and peripheral mountain ranges (Zlotin, 1978). This region is formed by complex of alternating short mountain ranges and valleys extending westwards. The most important ranges of the Central Tian Shan are Borkoldoy, Dzhetym, At-Bashy, and the Kakshaal Ranges; the highest point is Dankova Peak reaching 5,982 m.

The mountain heights increases from southern to the north-eastern direction, with highest peaks of Khan Tangri Peak and Victory Peak in the east. The southernmost ranges of Tian Shan include Alay and Zeravshan, adjoining the Pamir Mountains.

2. Environmental settings

2.1 Vegetation coverage

The region of Tian Shan mountains has unique biota structure, generally divided into two large groups: humid, typical for forest, and arid, i.e. located in deserts (Zlotin, 1978). The arid ecosystems are dominating in steppe areas and deserts of Tian Shan.

They include many endemic species, typical for desert arid areas. For humid regions of Tian Shan typical are arctic and boreal species that area characteristic for humid ecosystems (meadows) and tundras.

Figure 4 *Sheep herds in Kyrgyzstan mountains. Source: boorsok.ru*

Such unique, complex and mixed ecosystem structure is formed by complex migration and colonisation processes of vegetation and animal elements in Pleistocene epoch of Quaternary. As a result, the ecosystems of Tian Shan region have unique biodiversity phytogeographic composition which includes many endemics and rare species introduced from several phytogeographical groups: Middle Asian, Irano-Turanian and Pontic-Siberian, as well as northern (Siberian) and Eurasian species (Wagner, 2009). About 70% of species (both animal and plants) have specific south Asian distribution, mostly typical for steppe and desert

ecosystems (Zlotin, 1978). To support and preserve such unique natural ecosystems, several Natural Research Parks were created in Tian Shan area, of which five the most important are acknowledged by the United Nations Educational, Scientific and Cultural Organisation (UNESCO), developed to protect unique environment: 1) Issyk-Kul Biosphere Reserve (Kyrgyzstan), UNESCO 'Man and the Biosphere' programme; 2) State Kazakhstan National Natural Park 'Altyn-Emel', a UNESCO World Heritage object (Fig.3); 3) Aksu-Zhabagly National Park (Kazakhstan); 4) Sary-Chelek Nature Reserve (Kyrgyzstan), a World Biosphere reserve designated by UNESCO; 5) Ugam-Chatkal National Park (Uzbekistan), a UNESCO World Biosphere reserve. These National reserves maintain thousands of hectares of precious forests, meadows, and other natural reservoirs (for example, unique ancient rock carvings dated 1-2 millennia B.C. are found in Chatkal Biosphere Reserve, Uzbekistan).

Table 1 Land Use Statistics in Central Asia. Source: FAO, 2006.

Country	Total Land Area (million ha)	Rainfed	Irrigated	**Pastures and Rangelands**
Kazakhstan	269,970	18,994	2,312	185,098
Kyrgyzstan	19,180	0,238	1,072	9,365
Uzbekistan	42,540	0,419	4,281	22,219
Tajikistan	13,996	0,208	0,722	3,198
Turkmenistan	46,993	0,400	1,800	30,700
Total	**392,679**	**20,259**	**10,187**	**250,580**

The endemic flora of National Parks in Tian Shan region counts to thousands of rare and unique species typical to this region and not found elsewhere. The climatic settings of Tian Shan in general are typical continental. However, there are local climatic differences formed in various geographic conditions: the most extremely cold and dry climate is in inner parts of mountains on the high plateaux, while northern and western slopes of Tien-Shan are characterised by more temperate climate. Thus, the mean summer temperature is 3.7ºC at the altitude of the Equilibrium Line Altitude (ELA) in the western regions and -8.1ºC in the east; the annual precipitation is 1500-2000 mm in the west and 200–400 mm in the east, respectively (Bondarev et al., 1997). The northern slopes of Tian Shan, such as Kyrgyz Alatau and Zailinsky Alatau, have major influence of cyclonic activity. Precipitation in Tian

Figure 5 *Schrenk forests in Tian Shan. Source: Forest library*

Shan reaches its maximal level in spring and summer seasons, which coincides with the ice and snow melt. In winter the Siberian anticyclone prevents much precipitation in this area (Aizen et al., 1996). In general, the precipitation also increases with altitude. According to the moisture conditions, i.e. precipitation and evaporation, the alpine zone in Tian Shan ranges is similar to the zonal ecosystems of other mountain vegetation alpine zones in boreal and subboreal palearctic regions (Zlotin, 1978).

2.2 Landscape Types

The landscape structure and vegetation coverage in Tian-Shan vary significantly on different altitudes and in external and internal regions (Bondarev et al., 1997). The inner parts of Tian Shan ranges have scarce and poor vegetation coverage comparing to the valleys of the northern and western slopes. Similar to other mountain ranges, Tian Shan ecosystems can be divided into vegetation belts. The highest altitudinal belts include nival which starts at 4400 m AMSL, and sub-nival at heights 4000 to 4400m. The largest area, occupying area of 30%-40% from the total, is represented by the alpine vegetational belt, located above the tree line at heights 3000 to 4000m. The alpine belt has complex structure and is separated into several sub-divisions. These include tundra plant community, moist meadows, steppe meadows, cold steppes, dry steppes, semi-deserts and deserts (Zlotin, 1978). The slopes of the mountains at altitudes 2000 to 3000m are mostly covered by precious coniferous forests of Schrenk's Spruce (Picea schrenkiana), recorded in the International Union for Conservation of Nature (IUCN) Red List of Threatened Species.

The unique coniferous pine Shrenk forests play important role in the ecosystems of the Tian Shan, being hot spots of biodiversity, rich in species and resources (Fig.5). Besides, they serve as a buffer belt against flooding and low-water runoff. The lower slopes are covered by mixed forests of wild Persian walnut (Juglans regia), wild fruits and apple (Malus domestica). Other examples of species presented in Tian Shan wood and shrubland include, e.g., maple (Acer turkestanicum), Turkestan juniper (Juniperus), Oriental plane (Platanus orientalis), pomegranate (Punica granatum), Caucasian persimmon, or date-plum, (Diospyros lotus), rowan (Sorbus) (Wagner, 2009). Montane grass-forb (mixed grasses) meadows are typical for the steppe alpine belt. The south-western region of Tian Shan is an exceptional area with respect to the biodiversity and species richness, e.g., growing walnut and fruit forests, grasslands rich in endemics and unique Euro-siberian species.

3. Overgrazing Effects on Mountainous Slopes

The anthropogenic influence in Tian Shan mountains is mainly presented by the livestock husbandry and nomadic pastures, since the majority of the local population maintain traditional style of life (Fig.6). Grazing of herds on mountain pastures is a typical activity practiced by the local population (**Tab.1**). For example, in Kyrgyzstan livestock husbandry occupies in total 85% of the total agricultural area, which also includes arable land: legume feed, lucerne, barley, and crop by-products such as hay and straw (Wilson, 1997). The livestock grazing activity has been kept by local population for centuries until middle of XX century, when the economic and land use structure was forced to state farms and sedentary lifestyle.

However, after the disintegration of the Soviet Union, since 1990s, there is a clear shift of the Central Asian society back to the subsistence agriculture with recovered traditional style of life: private land use and cattle grazing on mountain pastures. Consequently, the livestock numbers are increased, and corresponding strong grazing pressure become more intense up to overgrazing (Borchardt et al., 2011). This causes detrimental effect on Tian Shan landscapes, affecting species composition and structure of plant communities, e.g. decreasing relic and endemic species.

As a result, rare Euro-Siberian and Middle Asian species, which include several endemic plants, are now became endangered, due to the increased overgrazing (Borchardt et al., 2010). Furthermore, cattle trampling cause soil erosion and degradation of shrubland and vulnerable habitats. Another characteristics of unsustainable grazing is geographic unbalance in grazing areas. The nomadism has seasonal character, with intensive grazing in the summer months in high altitudes and migration downwards in winter.

The grazing routes are determined by the geographic location of the pastures: those near the settlements are over-utilised, whereas remotely located pastures are frequently abandoned (Ludi, 2003). These factors of high anthropogenic pressure and non-sustainable grazing pose major threats to the local environment and may have severe negative impacts on sensitive mountain ecosystems.

Currently, about 50 million hectares of pastures in Kazakhstan are declined and gradually degrading. This was announced in 2012 by the deputies of the Kazakh Parliament. To deal with problem, a draft law "On pastures" was discussed and reported by the Tengrinews.kz. The main aim of the current environmental issue is to analyse current state of the prevailing practice of pasture resources in Kazakhstan and to maintain environmental stability. Thus, according to the World Resources Institute, grazing land in the country is covered 188 million hectares, or 70 percent of the entire area. Of these, the degraded land covers more than 48 million hectares, or 26 percent of the total area, which is more than one fourth, i.e. a significant part of the territory. In view of this, it is intended at the governmental level of Kazakhstan to create sustainable, modern and effective ways of the rational land use of pastures in Tian Shan. The main current aim of the environmental policy in Kazakhstan is to improve the infrastructure of pastures, to prevent further degradation of pasture lands, as well as to maintain and increase the conservation of the ecological integrity of the ecosystems in the environment. The improvement will address issues of pasture management, the conditions governing the legal status of the pastures, and the maintain further sustainable way of use of pastures, as a basis for the development of livestock in Kazakhstan.

4. Conclusion

The effective solving of the existing environmental problems in mountainous regions of Tian Shan has a common basis in all its sub-regions. For example, the use of pastures in the border areas and grazing leading to land degradation is the same for Tajikistan, Kyrgyzstan and Uzbekistan. Not sustainable way of land use and inadequate agriculture management in the fields of Tian Shan valleys are another example of a common environmental problem for all Central Asian republics. The problem of deforestation in Tajikistan and Kyrgyzstan is one of the major causes of soil erosion on the mountain slopes, which not only leads to desertification of mountain areas, but also causes silting of debris from the rivers and lakes. Other anthropogenic effects include, for instance, mining Industry. The mining industrial sector of the republics of Tajikistan, Kyrgyzstan and Uzbekistan worked in close collaboration during the Soviet era. Therefore, many ecological problems became deeply interconnected and triggered related problems. In addition, many mining and processing enterprises are located in famous Fergana Valley, which is a part of all the three Central Asian republics of Tian Shan basin. Regardless of the exact location, the business activities in Fergana valley are causing water and air pollution, as well as soil degradation which affect neighbouring countries as well. Construction and exploitation of roads in mountainous areas of Tian Shan is not only a difficult engineering task, but also a significant factor in changing the landscape and the natural ecosystem boundaries, leading to habitat change and environmental degradation. Single mountain system of the Central Asian republics, determines the identity of the origin and occurrence of natural disasters (earthquakes, landslides, etc). The overgrazing, degradation of pasture and lack of effective management in agriculture are the most important factors that affect the sustainable

Figure 6 *Kyrgyzstan. Son-Kuul Pasture. Source: quad-offroad.com*

conditions of the mountainous ecosystems of Tian Shan, together with other factors (e.g., such as construction of roads, natural cataclysms, Illegal logging, mining industry).

Dealing with environmental problems of this unique region is only possible in close cooperation of all neighbouring countries and with support of intensive monitoring of the region. The history of Tian Shan monitoring is relatively young. The exploration, regular observations and descriptions of Tian Shan mountains began since the middle of the XIX century, organised as hydro-meteorological network, by Russian Main Geophysical Observatory. By 1991, in total about 2000 Russian scientific hydro-meteorological stations were organised in locations at 700-3500 m altitude (Aizen et al., 2006). However, Tian Shan mountains and surrounding region are the least known to the European researchers, comparing to other highland areas in Eurasia (Himalayas, Alps, Caucasus, Pyrenees). It is mostly explained by the hardly possible access to this region. The hydro-meteorological data from these stations provide key information about hydrological regime and meteorological conditions of this region. Using these data, changes in climatic conditions in Tian Shan have been detected (e.g., Aizen et al., 2006; Kutuzov and Shahgedanova, 2009; Bazhev et al., 1975). Nowadays, the region of Tian Shan still remains hardly accessible for regular research fieldwork. There is still limited availability of knowledge in very specific areas of Tian Shan studies. Thus, for example, it is noticed (Borchardt et al., 2011) that there is no information on plant communities in mountain pastures in Tian Shan, and their relationships with the environment. Also it is difficult to obtain reliable information on the exact amount of current cattle livestock grazing in the mountain pastures. Since direct environmental analysis and observations are very limited in this region, the advantages of the usage of modern monitoring methods, such as remotely sensed data and GPS tools become evident. Therefore, the perspectives of monitoring of Tian Shan pastures are deeply connected to the application of remotely sensed data (e.g. satellite multi-spectral and hyper-spectral imagery, aerial imagery from the Google Earth), usage of cutting-edge GIS technologies and close collaboration of governmental and scientific research communities.

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