Mandych A.F.[1]

CONDITIONS AND TRENDS IN NATURAL SYSTEMS OF THE ALTAI-SAYAN ECOREGION

1. FOREWORD

National governments, governmental institutions and corporate organizations now increasingly understand the necessity of conservation of biodiversity, natural ecosystems and biosphere services in the Altai-Sayan ecoregion (ASER). These organizations recognize more and more the significance of natural ecosystems, their resources and services for the development of human well-being, whereas their condition is assessed as a necessary prerequisite for sustainable development. Meanwhile, human-induced transformation of the environment in the region still continues, and there still exist driving forces decreasing biological diversity.

2. INTRODUCTION

For the last five years, WWF Russia together with WWF Mongolia carries out ecoregional program on long-term biodiversity conservation in the Altai-Sayan ecoregion. Since 2001 WWF in co-operation with UNDP and some other international organizations initiated projects for ecoregional biodiversity conservation in the Altai-Sayan, which is the main value of the ecosystems and their services. The projects are, as follows:

- Ensuring Long-term Conservation of Biodiversity in Altai-Sayan ecoregion, four-year WWF Russia projects (1998-2002), which was to a great extent focused on biodiversity inventory and assessment in the ecoregion. One of its results was the first version of the ecoregional GIS providing a comprehensive basis for the further works;
- The PDF B phase of UNDP/GEF project “Biodiversity Conservation in the Altai-Sayan Montane ecoregion” initiated by WWF Russia;
- UNDP/GEF project “Conservation and Sustainable Use of Biodiversity in the Altai-Sayan ecoregion in Mongolia” initiated by WWF Mongolia.
- Project of WWF Russia, conceived for the use of the potential of protected areas in the southern territory of the Altai Republic for the social and economic development of the region.

The implementation of the Projects has revealed that the state of biodiversity in the ecoregion and its future depend not only on an impact of local population and economy on natural ecosystems but also on a number of social, economic and political factors, which are often originated geographically far abroad (e.g. due globalization processes). It became obvious now that the biodiversity conservation in ASER cannot be approached outside appropriate concepts or strategies of sustainable development its population, economy and nature as parts of holistic unity, integrated regional ecosystem. The situation seems even more intricate if someone will take into account that the ecoregion belongs to four states, which follow their own development strategies and treat nature in accordance with their economic, resource and other potentialities.

Realistic concepts of ASER sustainable development cannot be elaborated without careful, sometimes very fine analysis of the interaction between natural ecosystems and society at different scales. Such goals were set up in the Millennium Ecosystem Assessment Program, which WWF Russia and WWF Mongolia decided to join to in 2002. As a result the project: “Millennium

[1] Institute of Geography, Russian Academy of Sciences. a.f.mandych@igras.ru

Ecosystem Assessment: Altai-Sayan ecoregion" was established in 2003. Work on the project commenced in August 2003. It was carried out by efforts of Russian and Mongolian WWF. Since the beginning of the project the preliminary review and assessment of key selected ecosystems namely forest and grazing ecosystems were completed. The basin of the Katun River, which drains the central part of the Altai Mountains (as an inland freshwater ecosystems and water services), and ecologically oriented behavior of rural householders in the ecoregion were assessed too.

3. ALTAI-SAYAN ECOREGION: GENERAL CHARACTERISTICS

3.1. Geographic Scope

The Altai-Sayan ecoregion (total area of 1 065 thousand km^2) is situated in the intermediate zone between the boreal forest belt of the Northern hemisphere, mountain ranges of Altai and Sayan and semi-deserts and deserts of China and Mongolia. Its area belongs to the territory of Russia (62%), Mongolia (29%), Kazakhstan (5%) and China (4%) (Figure 3.1). Great latitudinal and longitudinal extents of the ecoregion, significant variance in the height and landscapes, and its location in the centre of Asia on the border between sub-continental divides of the basins of the Arctic Ocean and closed drainage depressions of Central Asia, cause considerable spatial and temporal gradients in climate and ecological conditions. This peculiar combination of conditions and the complex geological structure of the Region underpinned the origin of a rich diversity of natural ecosystems and their ways of functioning caused a great variety of ecosystem services provided by the biodiversity of the ecoregion at local, regional, national and sub-global levels.

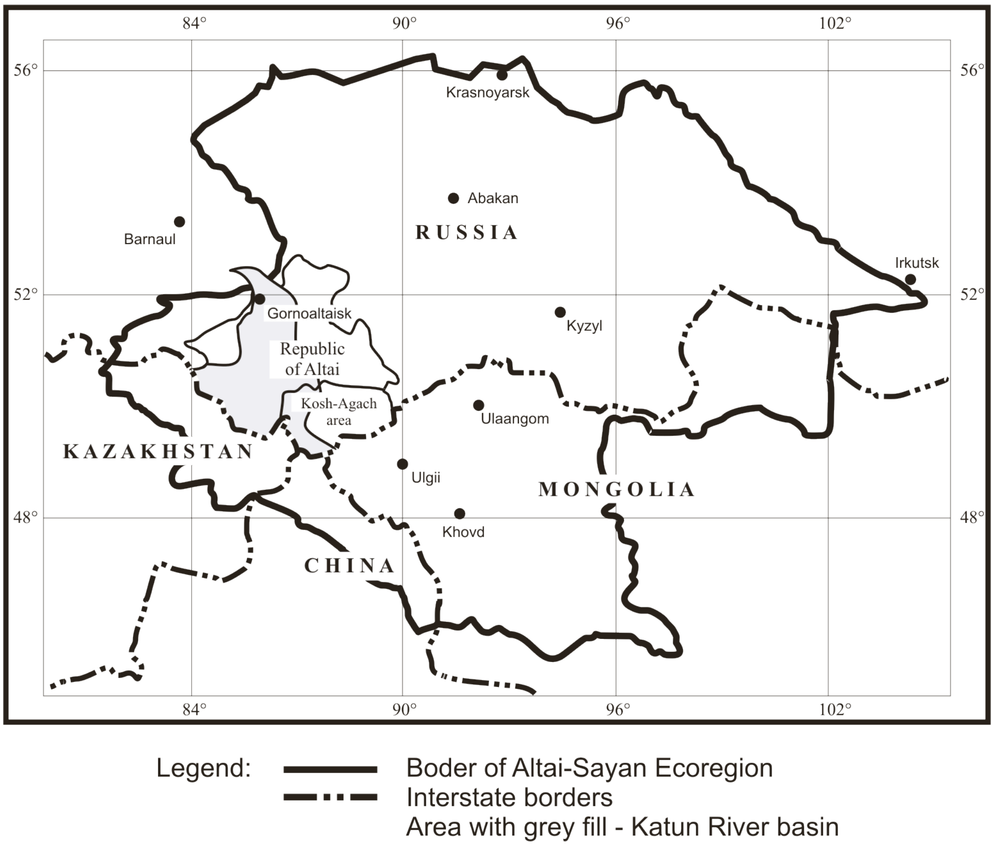

Figure 1. Location of Altai-Sayan ecoregion and study areas.

3.2. Biosphere and Biodiversity

The Altai-Sayan is one of the key WWF Global 200 ecoregions. Its biological, landscape, historical and cultural diversity is considered very unique. The ecoregion is one of the most distinctive examples of a conglomeration of the world's diverse habitats. Its ecosystems are known to be among the richest in the North Eurasia in terms of biodiversity. Moreover, the region represents the most complete sequence of altitude vegetation zones in Siberia. The area contains geographically distinct biomes, consisting of high mountain taiga, mountain tundra, a mix of forests, desert and semi-deserts, steppes and wetlands that share a large number of species, dynamics and environmental conditions (Kupriyanov 2003; Shvarts, Shestakov 2000).

Forest ecosystems occupy half of the entire territory of the ecoregion; steppe and highlands occupy 24 and 22%, correspondingly, whereas semi-desert and desert make up 4% (Table 3.1).

Table 1: Landscapes of the Altai-Sayan ecoregion

Name	Area, thou. km^2	Area, %
Forest	535	50
Steppe	249	24
Highlands, including	234	22
mountain tundra	175	16
alpine and sub alpine meadows	59	6
Desert	47	4

This ecoregion gives life to two of the world's ten largest rivers: the Ob' and the Yenisei, with a total watershed of over 5.5 million square km. The ecoregion also contributes to the drainage of Lake Baikal, while in Mongolia, the Altai Mountains drain into the closed water system of the Great Lake Basin. Water quality and runoff of the largest Siberian river basins over an area equal to Europe in size depend on the future preservation of ecological processes in the Altai-Sayan ecoregion. The "health" of the Altai-Sayan ecoregion is crucial to the health of freshwater ecosystems that stretch far outside the immediate area.

Forests in the Altai-Sayan ecoregion are of crucial global importance. They contain the world's largest unbroken stretches of Siberian Pine forests (some trees are up to 700 years old) of the highest quality and dark coniferous taiga. This taiga consists mainly of endemic Siberian fir forests that have many relict and endemic vascular plants and mosses. Siberian larch and birch represent the remaining forest areas. Siberian forests occupy more than 535 thousand km^2. Approximately 26% of the forests in the ecoregion are located in the protected areas of IUCN I-IV categories.

As a natural dividing line between the Siberian boreal forests and the Central Asian deserts, the ecoregion hosts a unique species diversity of mammals, birds, vascular plants and mosses.

Vertical climatic variations and the isolation of various intermountain depressions determine the richness of the Altai-Sayan flora (3726 species). More than 10% of plant species are endemics and 76 species are listed in the Red data Book (Kupriyanov 2003). Altai-Sayan ecoregion is defined by the WWF/IUCN Centres of Plant Diversity project as one of the world's centres of plant diversity (The Secretariat… 2001).

There are 691 species of vertebrate animals in the region, 49 of them are listed as rare and endangered (Kupriyanov 2003). The Altai-Sayan ecoregion forms the world's northernmost habitat of the Snow Leopard, locally called Irbis (*Uncia uncia*) and the Argali (*Ovis ammon ammon*), the world's largest species of wild sheep. Other mammals include Mongolian saiga antelope, Siberian maral, Asiatic ibex, manul, musk deer, Siberian mountain goat, reindeer, sable, marmot and others. The Altai-Sayan ecoregion is home to more than 400 bird species, including several rare ones, such as the Altai ular, cenerous vulture, golden eagle, Dalmatian pelican, great bustard, and demoiselle crane, among others. The ecoregion is also an important habitat for endemic fish species, such as the Altai ide, Mongolian grayling, and Siberian catfish.

3.3. Ethnical and cultural diversity

For many centuries the region has been at the crossroads of European and Asian civilizations, and thus is home to great historical treasures. The ancient history of the region is so unique that many historians and archaeologists call it "*the cradle of civilization*". The ancient historic monuments are integrated into the natural landscape in such a way that it forms a harmonious and inseparable unity. Thousands of petroglyphs, cave paintings, antique burial mounds, menhirs, steles, tumuli and other ancient monuments are found in the area, some even as ancient as the Egyptian pyramids. One of the oldest sites, Malaya Syya in Khakasia, dates back to 35,000 BC.

More than 20 different indigenous ethnic groups that have lived together for centuries inhabit the Altai-Sayan ecoregion. Various ancient cultures (Scythian, Turkic, Ugro-Finnish, Iranian, Chinese and others) "merged" together in the region. A variety of languages of the Slavic, Turkic, and Mongolian families are spoken today. Different nationalities including Russians, Mongolians, Chinese, Kazakhs, Uighurs, Uzbeks, Altainians, Tuvinians, Buryats, Shores, Khakasians, Teleuts, Soyots and others live in the region making it really multicultural.

The lifestyle and traditional occupations have much in common through the region and are based on the traditions of nomadic cattle-raising tribes. Nowadays, old traditions connected with pagan customs and shamanism, national holidays and traditional art (e.g. the unique musical art of throat singing) are being revived.

The population consists of approximately 1.5 million people, with the majority still living in rural areas. Most of the territory still remains scarcely populated. The average density is among the lowest in Eurasia. In general, people in the Altai-Sayan ecoregion rely heavily upon local natural resources for their livelihood. Most of the inhabitants of the Mongolian part of the region are herdsmen whose economic activities are based on livestock and pasture management. People in the Russian part are engaged mainly in farming, cattle breeding, and mining, and many people earn a living by hunting and using variety of forest resources. Most of the Altai-Sayan region remains among the least economically developed regions of all four countries of the ecoregion. Poverty, widespread unemployment and a lack of alternative economic activities are serious socio-economic problems that could have a negative impact on both natural resources and the biodiversity of the ecoregion.

Exploitation and strain on natural resources are increasing rapidly in the ecoregion. Protection of Altai-Sayan biodiversity depends in many ways on the ability of the local communities to preserve traditional land use patterns. Such patterns do not only ensure the sustainable use of nature, but also ensure that particular natural sites, towards which local people hold a sacred attitude and special value, will remain respected and undisturbed.

4. DRIVERS OF CHANGE

4.1. International and Political

From the viewpoint of administrative division, the Altai-Sayan ecoregion is a complex formation situated on the borders between four states: Kazakhstan, China, Mongolia and Russia. The Russian part of the ecoregion belongs to 8 large administrative territories of the Russian Federation.

Within the previous two decades, problems of effective use of resources and the environmental potential of ecosystems experienced radical changes in the geopolitical space. Until the late 1980's, motives for social and economic development within the larger part of the ecoregion were dominated by ideological doctrines characteristic for the development type based on extensive exploitation of natural resources and neglect to nature protection constraints.

The disintegration of the Soviet Union resulted in the appearance of new states, Kazakhstan and Russian Federation, and states including the ASER territory clearly demonstrated the tendency to establish priorities of their development, starting from their own interests. Over recent years, states of the ecoregion have faced a number of problems including consequences of unpractical industrial development, underdeveloped economic infrastructure and increasing deterioration of environment. It becomes evident that a number of acute problems can only be resolved on the base of efficient use of resources and services of natural ecosystems, and conservation of rich natural biodiversity. Given the division of the ecoregion by national borders, international cooperation is clearly the main prerequisite to overcome handicaps existing on the way to sustainable social, economic and environmentally favourable development of the Altai-Sayan ecoregion.

Regional administrations of the countries included in the ecoregion increasingly understand the necessity of joint action targeted on biodiversity conservation and efficient use of ecosystem resources and services. This understanding had an effect on a number of international and inter-regional treaties. The most important of these include the following documents.

In 1998, representatives of Kazakhstan, China, Mongolia and Russia met in Urumqi (China) to agree on the organization of a trans-boundary strict nature reserve and launch joint programs to conserve biodiversity. These intentions make provision for development of land tenure systems that consider ecological requirements and traditions of local people, generation of environmentally friendly power systems and transportation infrastructure, development of tourism and trans-boundary communications of local population, collaboration in the field of protection of natural matters of cultural, historic and religious heritage.

In 1998, the Republics of Tuva, Khakassia and Altai in the Russian Federation signed an agreement on the protection of the environment. All parties expressed their commitments to develop a package of urgent measures to conserve biological and landscape diversity within the territories of the participants of the Agreement, to develop national strategies for conservation of the snow leopard and Altai argali sheep as key components of ecosystems in the ecoregion and to create an ecological framework of strictly protected natural territories.

In 1999, an international forum held at the initiative of the WWF in Belokurikha (Russia) adopted the Altai-Sayan Initiative for the Next Millennium, which was signed by leaders of the governments of the Republic of Altai (Russia), the Republic of Tuva (Russia), the Republic of Khakassia (Russia), governors of Krasnoyarsk Region (Russia), the Aimaks of Bayan-Ulgii, Khovd, Khuvsugul and Uvs, and also by the directors of the Mongolian and Russian WWF offices. Kemerovo Region and Eastern Kazakhstan Region joined the treaty later. Participants of the Initiative recognize the existence of a tight correlation between protection of natural processes and economic development. They stated that conservation of natural processes should be the main goal of regional development.

In March 2003, organizations representing state governments of Altai Region (Russia), Bayan-Ulgii Aimak (Mongolia), Eastern Kazakhstan Region (Kazakhstan), the Republic of Altai (Russia), Xingjian Uygur Autonomous Region (China) and Khovd Aimak (Mongolia) resolved to establish an International Steering Board called “Altai, Our Common Home” in agreement with a resolution of the International Forum of the same name. The main aim of the Board is to unite efforts of state bodies, businessmen, scientists and representatives of public organizations to create optimum conditions for the development of all parts of Altai Region.

The main challenge faced by the population of the Altai-Sayan ecoregion, irrespective of states and nations, is the necessity to realize the idea of long-term sustainable development. It is necessary to schedule the framework and conditions that would allow natural ecosystems (including biological diversity) and the community represented by local people to form mutually supplementary and supporting parts of the ecosystem of the ASER as a whole developing unit. An important step towards this goal would be integrated assessment of the natural environment of the ecoregion. The assessment will help to shape the current condition and trends in the change of ecosystems, determine their true social and biosphere value, recognize key driving forces causing unfavourable changes and, what is most important, to develop recommendations for decision makers of all levels on due practical measures to achieve sustainable and environmentally friendly social and economic development of the Region.

4.2. Social and economic

The population of the Altai-Sayan ecoregion is 5.5 million. Territories of different countries are significantly diverse in population density (Table 2). This probably acts as a driving force of spatial differentiation of human impact on ecosystems within the region.

Multinational composition of the population is characteristic of the ecoregion. Representatives of 40 nationalities inhabit the Russian part of the Region, whereas the Mongolian part is inhabited by 2 nationalities, the Chinese part by 13, and Kazakh part by 11. The Altai-Sayan ecoregion is home to many indigenous peoples, totalling 1.5 million persons (Climatic Passport 2001) united in approximately 20 ethnic groups. The origin of their ethnic and cultural peculiarities is rooted in the early ages. Harmonious coexistence with nature, and feeling a part of it, are clearly expressed characteristics of these people.

Table 2: Population of ASER

Region	Population		Population density, persons per km^2
	Thousand persons	%	
Kazakhstan	373	6.8	6.2
China	590	10.7	13.7
Mongolia	556	10.1	1.2
Russia	3987	72.4	2.4

From the early 1990's, the transition from a centralized to a market economy started in Kazakhstan, Mongolia and Russia, causing a dramatic economic decline, which has not yet been overcome. The main consequence of this decline was a significant decrease in living standards of the population, which in turn intensified previously existing environmental problems and awoke new threats to biodiversity conservation. Although details of this process differ in Kazakhstan, Mongolia and Russia, its consequences for people and nature were very much the same.

A profound decrease and deterioration of former agricultural enterprises in Kazakhstan moved local people to subsistence farming conditions. Cattle breeding, agricultural work and exploitation of natural ecosystem biological resources became major income sources for most of the people. The level of income of the population decreased to critically low rates and amounts to just a few US dollars a month.

Livestock privatisation, increase in herder household numbers and the increase in goats within the herd structure in Mongolia became primary driving forces causing rapid pasture decay over large territories. Significant loss of cattle due to particularly severe winters and summer droughts considerably aggravated the economic situation over the last three years. As a result, around 40% of the Mongolian part of the ecoregion is below the official poverty line (WWF 2002). Budgets of all somons situated in this area are subsidized by the state (Enkhtsetseg et al. 2002).

Industrial and agricultural activities of state enterprises have almost completely stopped in the Russian part of the ecoregion, resulting in a virtually zero economy level. Thus, for instance, the Republic of Tuva is currently subsidized from the federal budget at a rate of 96%, and the Republic of Altai by 90%. In this situation, the population's income almost solely depends on subsistence farming and exploitation of any available resources of natural ecosystems.

Other driving forces also contributed to a stronger human impact on ecosystems of the ecoregion. These forces include a low technological level of industries working in the Region, dominating primary processing of natural resources, low effectiveness of resource and power utilization and a lack of ecological considerations. Moreover, the Region is deprived of opportunity to financially support conservation activities. State control over exploitation of natural resources is weak.

The low level of social and economic human well-being in the ecoregion promoted an increase of human impact on natural ecosystems. This impact is expressed in forest reduction, pasture overgrazing, mass poaching, and excessively intensive exploitation of ecosystem resources by local people, redundant recreation, etc.

Direct human influence on ecosystems provoked action of secondary, yet powerful forces causing ecosystem transformation. These include forest fires, habitat loss, fragmentation of landscapes, pollution of environment, and violation of regimes in strictly protected natural territories. All this occurred along with the weakening of the system of state management in economy and the environment under new economic conditions.

4.3. Climate change

The present-day climate of the Altai-Sayan ecoregion is characterized by significant spatial contrasts in the magnitude and rate of changes (Kharlamova 2000, 2002; Revyakin and Kharlamova 2003).

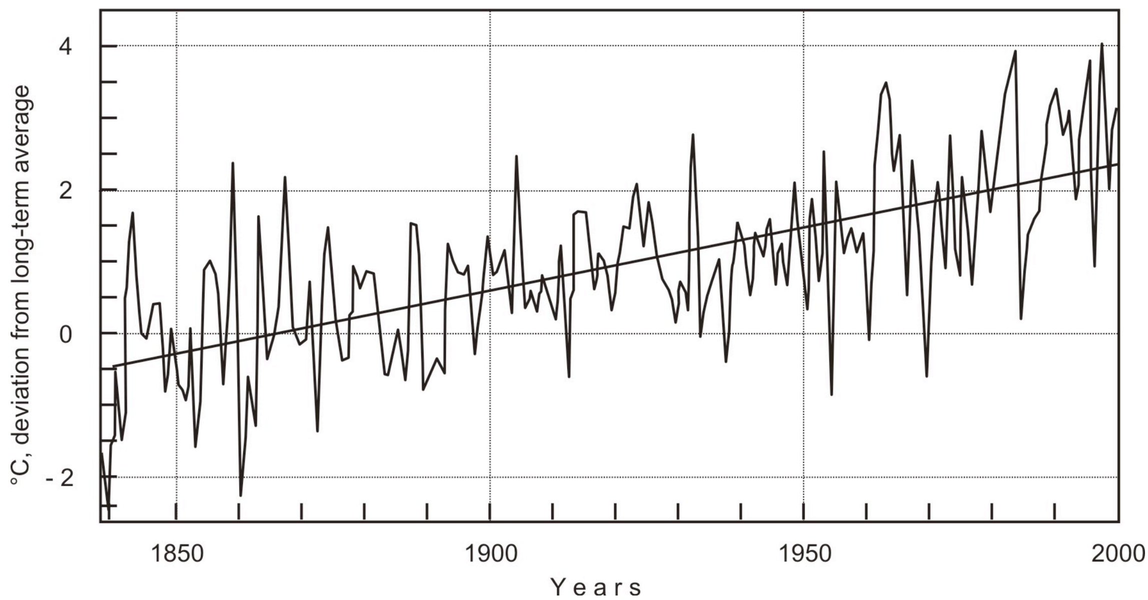

Figure 2. Deviation of mean annual air temperature at Barnaul meteorological station. Source: Kharlamova 2000.

Meteorological observation in the Altai-Sayan ecoregion indicates progressive warming. Kharlamova (2000) has analyzed air temperature variations at the Barnaul meteorological station located northwest of the region and ascertained the clear trend of increasing the mean annual air temperature – 2.8°C for the past half century (Figure 2). The increase of air temperature differs by seasons. It is 3.4°C from November to March and much lower in the warm period – 2.3°C.

The analysis of the mean annual, seasonal and monthly air temperatures of the Altai Mountains indicates that the ecoregion is in the area of their rising, which particularly strengthened since the 1970's. Intensive increase of the mean annual temperature is observed in all altitudinal belts.

However the change of temperature differs in meteorological stations. The mean air temperature trends in altitudinal belts of the Altai Mountains by seasons for 60 years (1935-1994), 50 years (1945-1994), 40 years (1955-1994), 30 years (1965-1994) are shown in Table 3 (Paromov 1999).

Table 3. Characteristic values of the trend (°C per 10 years) for the areas of the Upper Ob basin classified by this indicator

Period (years)	Season	Areas of close values of the trend parameter			
		High mountain	Intermountain depressions	Low mountains	Lower Katun
60	Year	0.23	0.40	0.27	0.42
	Winter	0.27	0.55	0.33	0.51
	Spring	no	0.16	no	0.24
	Summer	no	0.10	no	0.14
	Autumn	no	no	-0.12	no
50	Year	0.27	0.45	0.32	0.54
	Winter	0.40	0.71	0.52	0.73
	Spring	no	no	no	no
	Summer	no	0.11	no	0.18
	Autumn	no	no	-0.14	no
40	Year	0.33	0.52	0.49	0.68
	Winter	0.34	0.67	0.54	0.69
	Spring	no	no	0.28	0.38
	Summer	no	0.14	no	0.20
	Autumn	no	no	no	0.23
30	Year	0.54	0.69	0.81	1.07
	Winter	0.58	0.72	0.84	1.10
	Spring	no	no	no	0.29
	Summer	no	no	no	0.23
	Autumn	no	no	no	no

As a whole the mountain part of the Altai is characterized by deceleration the increase of the mean annual and seasonal air temperature with height. If in the high-mountain and middle-mountain belts (outside intermountain depressions) the rise of mean annual temperature was 0.23°C per decade for 60 year and it was only due to increase of winter temperature (0.27°C per decade), in the foothills the temperature growth occurred in all seasons, excluding autumn (Table 3).

Faster warming is observed in the intermountain depressions and the lower Katun basin, in the foothills, where the rate of temperature increase comprises 0.40°C and 0.42°C per decade, respectively. The contrast between temperatures in the valleys and surrounding mountain slopes gets lower, indicating climate softening.

Despite air temperature, annual precipitation change is not so clearly pronounced. The curve of annual precipitation of the Barnaul meteorological station (Figure 3) shows that the increase is within normal annual fluctuations for the past decades.

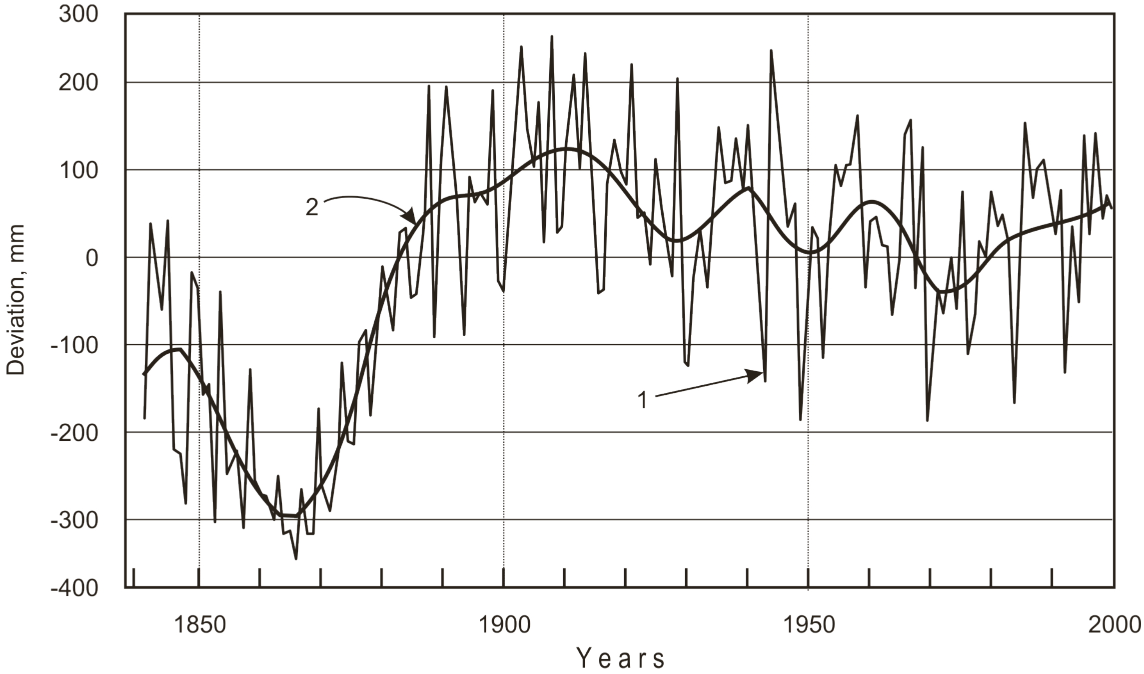

Figure 3. Deviation of annual precipitation from long-term average at Barnaul meteorological station: 1 - true deviations, 2 - deviations curve smoothed by low frequency filter. Source: Revyakin and Kharlamova 2003.

The examination of seasonal precipitation over the same period of observation has no single meaning as temperature of the surface air layer. Winter precipitation decrease is seen at meteorological stations of foothills, low altitudinal belt and intermountain depressions. There is no an appreciable tendency in precipitation change of this season in the middle and high mountain belts. On the whole the total precipitation in spring and autumn is stable at all altitudes of the Northern Altai, excluding high mountains where it increases in spring and, during recent years, in autumn. Summer precipitation has decreased in all altitudinal belts, but the change of sign of tendency occurred during the past 30 years. However that increase did not evolve into a steady trend. The annual precipitation in the foothills, low mountains and intermountain depressions decreases, and is stable at middle altitudes. It increases, mainly due to growth of spring precipitation, on watersheds of high mountains, which slopes are exposed to moisture-laden western air masses.

Climate warming is also observed throughout West Mongolia while the rate is different in its various parts. The general estimation of increasing the mean annual air temperature in Mongolia (Batima 2002) corresponds to the data of the Barnaul meteorological station (Figure 4).

5. FOREST ECOSYSTEMS

Analysis of condition and trends of forest ecosystems in ASER has been carried out at three spatial scales: for the whole Russian part of the ecoregion, for the Republic Altai and its Kosh-Agach area (Figure 1). Hence the forests were characterized at regional, sub regional and local scales . The assessment of forest ecosystems of the Russian Altai-Sayan ecoregion in general (national scale) is approximate.

5.1 Ecosystem outline

Forests of the Altai-Sayan ecoregion constitute certain integrity according to geobotanic, floristic and silvicultural attributes. They are classified as a single complex of boreal South-Siberian-

Mongolian forests (Polikarpov et al. 1986). Forests in the region mostly exist in the form of mountain altitudinal belts. If the topography of the region is plain, there would be zonal vegetation types such as steppe and forest-steppe. Only a small part in the northern ecoregion lies at a latitude of taiga.

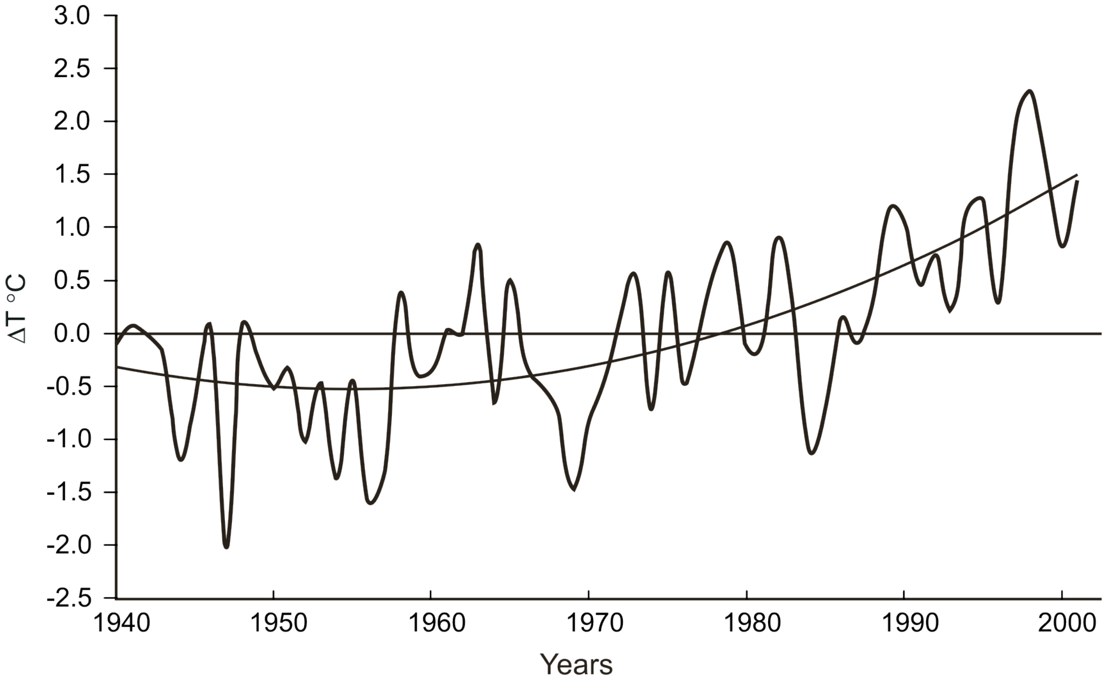

Figure 4. Standard deviation of normalized air temperature in 1940-2001. Source: Batima 2002.

The mountain topography of the most part of the region, considerable latitudinal and longitudinal extension, diverse lithologic and edaphic factors predetermine very high spatial inhomogeneity of forest habitats in the Russian ecoregion. As a result the forest cover has a very complex structure. It is characterized by the clear hierarchic structure of forest biogeocenoses and their complexes sketchily shown in table 4.

Objects of ecosystem analysis can be forest types considered as integrated forest communities and conditions, which regularly recur within certain areas with relatively homogeneous zonal conditions of climate and soil (Smagin et al. 1980). Forest types originate hierarchically dependent landscapes of different size. There is a zonal-provincial complex of forest types (ZPC) and altitudinal complex of forest types (AC).

ZPC is a set of forest types classified by similar climatic and soil conditions of a natural zone for plain topography. The size of such spatial objects is enough for mapping at 1: 10 000 000 – 1:20 000 000 scales.

AC prevails in the Altai-Sayan ecoregion. It is a set of forest types classified by similar zonal-provincial and altitudinal conditions of climate and soil of an altitudinal belt for mountain topography. Such spatial objects can be mapped at 1:100 000 – 1:1 000 000 scales. Every AC is different from upper and lower ones in heat and moisture supply and the specific composition of lower layers of forest stand.

Such classification units as class or formation of forest types, which combine all forest types with one tree species, are also used to visualize spatial distribution of forest types and their components for more suitable analysis. Figure 1 is a reduced copy of the map of forest type formations of the Altai-Sayan ecoregion, which are classified by dominant tree species.

Simple and well-known characteristics of forest cover and ecosystems were used for the preliminary assessment of the state and trends of forest ecosystems described in the report. They consist of the attributes, as follows:

- Size of forest cover, tree species, burnt-up and cut areas; it takes the form of the percentage of the total area or hectares or square kilometers
- Timber resource per area; it takes the form of m^3/ha
- Rate of changing the timber resource per unit of time; it takes the form of m^3/ha a year
- Forest stand productivity index. It is represented in marks.
- Forest regeneration; it takes the form of qualitative wordy scores: poor, fair, good, etc.

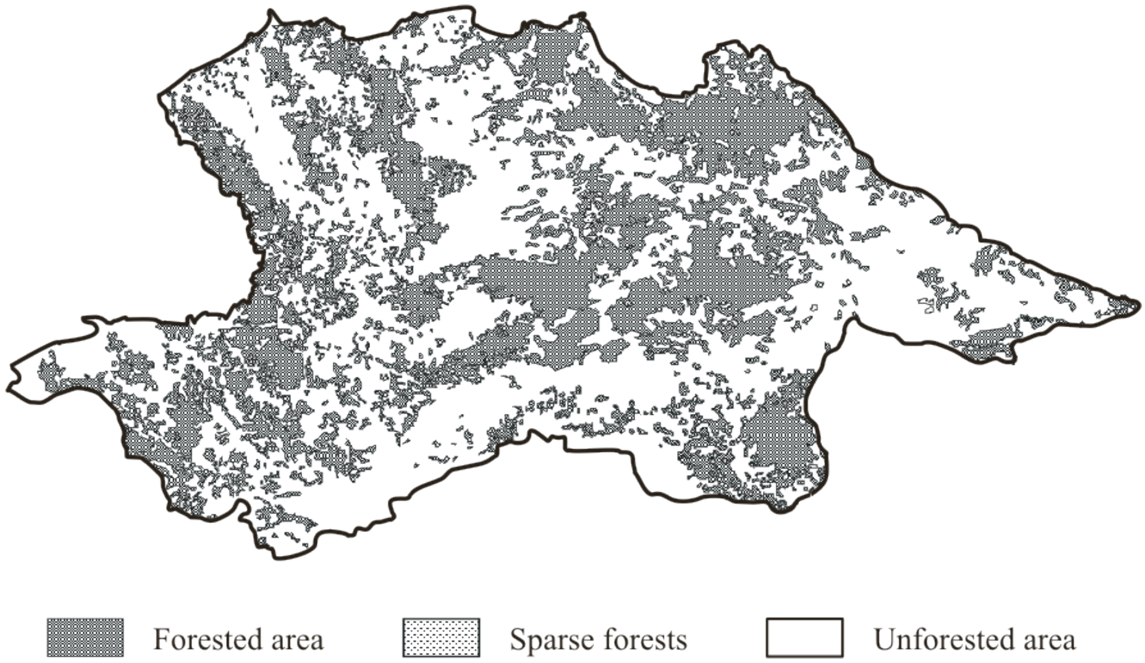

Figure 5. Forest cover of Russian part of ASER

The Republic of Altai of 92.9 thousand km^2 occupies the highest part of the Central Altai and the northern foothills. It is entirely located in the Ob River basin. The southern border runs from west to east along the ranges of Kholzun, Listvyaga and partially Katunskiy, Yuzhno-Altayskiy and Saylyugemskiy. The ranges exceed 2000 m, reaching in some areas 3500 m. He highest point of the Altai Mountains is Mount Belukha (4506 m) in the Katunskiy Range.

The eastern border of the Republic of Altai coincides with the divide between the Ob and Yenisey basins. It runs from north to south along the ranges of Poskay, partially Abakanskiy, Shapshalskiy and Chikhachev to the joint with the eastern offshoots of the Saylyugemskiy Range. The ranges reach 3000-4000 m.

The western border coincides with the border of the Altai-Sayan ecoregion, the northern one runs along the crest of the Niyskaya Griva Range.

The Republic of Altai is a mountain country, consisting of a set of ranges going radially from the highest part of the Central Altai. Narrow river valleys or vast intermountain depressions divide the ranges.

The Kosh-Agach area is located in the southwestern part of the Republic of Altai and borders Mongolia, China and Kazakhstan (Figure 1). The forest area totals 308.6 thousand ha, including 186.6 thousand ha of the forest-covered area (Gunya et al. 2002). All the forests belong to Group 1.

The dominant species is larch. All the forests grow under extreme conditions at altitudes over 1200-1400 m above the sea level. The timber reserve totals 28.4 million m^3, the reserve of mature and over mature forests is 15.2 million m^3.

The share of forests is lowest in Mountain Altai – 7.5%. However the value of forests of the Kosh-Agach area is very high, mainly due to their water-control and erosion-control functions.

5.2 Conditions and trends

The drivers of the present-day dynamics of forest ecosystems in the Altai-Sayan ecoregion are

Table 4. Some hierarchic organizational levels of the forest cover of the Altai-Sayan ecoregion

Classification categories	Scale of occurrence (mapping)	Brief characteristic
Types of forest, biogeocenosis or ecosystem	1:10 thou – 1:100 thou	Object of ecosystem analysis of the lowest rank
Groups of forest types	1:10 thou – 1:100 thou	Genetically close forest types with one dominant tree species and with similar composition of low vegetation layers and soils of the same type or subtype
Ecogenetic or landscape rows of forest types	1:10 thou – 1:100 thou	Set of groups of forest types with the same row of soil formation
Zonal-provincial complex of forest types (ZPC)	1:10 thou – 1:20 thou	Combination of forest types with similar climate and soil within a part of a province of a natural zone
Altitudinal complexes of forest types (AC)	1:100 thou – 1:1 thou	Combination of forest types of an altitudinal belt with similar zonal-provisional and altitudinal features of climate and soil
Formations of forest types (ZPC or AC classes)	1:1 thou – 1:20 thou	Set of all forest types with one tree species

natural regeneration and succession processes, fire, climate change, logging and grazing. The analysis of existing data of inventorying the ecoregion's forest shows that no significant changes have been observed either within the whole ecoregion or the Republic of Altai for the past 30 years. There are several causes for the explanation.

Thirty years are a short period for forest, close to a phase of succession dynamics. No significant changes of forests occur during such a period that can be observed by the standard inventory. One of the leading drivers of forest ecosystem change is forest fire. According to the contemporary standards, the rate of forest fire in the ecoregion is fair (Furyaev 2002). The potential of fire is different in various parts of the ecoregion owing to natural and climatic conditions. The very high rate of forest fire is characteristic of the Republic of Tyva where the annual number of fire ranged from 12 to 24 per 1 million ha in 1997-2001 and the burnt-up area totaled about 350 km^2.

The comparatively low rate of forest fire in the Republic of Altai is caused by prevailing coniferous forests of low inflammability and high precipitation in the warm period. However about 250 forest fires occurred in an area of about 80 km^2 for 1997-2001.

The total number of forest fire in the Altai-Sayan ecoregion in 1997-2001 was 1630 and the area of burnt-up forests was about 500 km^2. In other words, fire is a permanent factor of forest change in the ecoregion, which annually affects about 0.09% of the forest-covered area. It is evident that the influence cannot cause substantial change of the forest cover in the ecoregion.

During the past years forest ecosystem change caused by climate warming is discussed in some publications. It is argued that the upper timberline in the Chuya depression (Kosh-Agach area) has raised much toward the alpine and mountain-tundra belts (Modina et al. 2002; Ovchinnikov et al. 2002). It is noted that the upper timberline in the Central Altai has risen since the middle of the 19th century (Adamenko 1985).

The mean annual air temperature increases in the Altai part of the ecoregion during the past decade (Kharlamova 2000, Revyakin and Kharlamova 2003). It is characterized by considerable spatial irregularity of warming and the increase of the mean annual air temperature caused by dominating increase of winter temperature and nearly non-changing summer temperature. Hence there is a doubt that the response of forest ecosystems to increasing mean annual air temperature can occur under the lower increase of mean temperature of the vegetation period. One of the factors of fluctuation the upper timberline may be natural biogenic dynamics (Polyakov and Semechkin 2001, Ovchinnikov et al. 2002). There are no publications about explorations made by methods that are specially designed for revealing changes of the upper timberline in the Altai-Sayan ecoregion induced by climate warming. Moreover forest transformation near the upper timberline can be induced not only by climatic factors and can occur not only as the extension of trees upward. Tree species can simultaneously migrate at opposite directions or stay in the same place (Leak and Graber 1974). It is a fact that the change of the upper timberline upward is observed only in several places, its magnitude is low and we cannot say about considerable redistribution of altitudinal forest belts.

Economic activities have little influence on forest ecosystems at a scale of the Altai-Sayan ecoregion or Republic of Altai. The main human-induced factors affecting forest ecosystems are logging and fire. The logging area much reduced for the past decade. It totally accounts for less than 1% of the forest-covered area of the Altai-Sayan ecoregion and less than 0.1% of the Republic of Altai. Logging is not practiced, at least legally, in the Kosh-Agach area.

The general assessment of the state and trends of the most important forest ecosystem resources and services in the Russian Altai-Sayan ecoregion, Republic of Altai and Kosh-Agach area is presented in table 5. It indicates the situation at three scales, i.e. national (regional), sub regional and local. The analysis of table 5 reveals some features of the assessment of ecosystem resources and services.

First, there is obvious dependence between the natural potential of ecosystem services and the score. For example, score “poor” for timber and firewood in the Kosh-Agach area means limited natural capacity of ecosystems to provide these resources and so little influence of human-being and economy in absolute expression but comparatively high effect. Thus score “good” for timber and firewood first indicates high natural capacity of these resources. On this background, significant changes of forest ecosystems caused by fire, logging, pests or other factors seem to be insignificant.

Second, table 5 shows much difference between scores of different scales. Scores for the same resources and services are particularly contrast between the Kosh-Agach area and Altai-Sayan-ecoregion in general. It is expected because the natural potential of forest ecosystems, land use and economic effects are different in the area and ecoregion. There is a question how objects for assessment at a local scale are chosen in order to make multiscale assessment for the ecoregion as a whole most effective or informative. It is an objective of further works within the Altai-Sayan Sub global Project.

5.3 Plausible future

The existing different and often not very correct data on the forest ecosystem behavior in various locations under outer impacts indicate that their future depends on fire, human activities, climate change and pests. Now fire is a leading driver by an effect on ecosystems. Its role will increase in the nearest future owing to human activities and climate change.

The contemporary wood harvest in the region is not a factor of irreversible transformation of the forest cover in the nearest decades. Even if it is considerably increased, if logging distribution is specially designed, the forest cover of ASER will keep its resource and environment-forming potential.

One of the likely and appreciable effects of climate change on forest ecosystems will be not the change of the upper timberline but the increase of the fire rate. The climatic factor may also spur pests.

The above judgments are based, as shown above, on diverse, unsystematic and specially unanalyzed information. Scenarios for forest ecosystems in ASER for nearest 30-50 years are targets for the following stage of the study.

5.4 Summary

The present-day state of the main resource of forest ecosystems, timber and firewood, in the Altai-Sayan ecoregion as a whole is estimated good. However the score is reduced to fair or even poor in some localities that are under human or economic impact or where logging is practiced.

In the visible future, forest ecosystems of the region will continue providing people and economy with demanded resources and carry on environment-forming functions. However it will be possible only in case of keeping on the state control of forest resources use at least at the contemporary level.

The leading driver of changing forest ecosystems in the ecoregion in the nearest decades is fire. Its impact will increase owing to human being, economy, climate change and pests.

The existing data and outputs of exploration are not enough to reply to the question about an impact of climate change on forest ecosystems and the consequences. It is urgent to conduct a special study concerning an impact of climate change on forest ecosystems of the ecoregion.

Table 5. Forest ecosystems' services in the Russia part of Altai-Sayan Ecoregion: current state and trends of change

Goods / services	Kosh-Agach area		Republic of Altai		Russian Altai-Sayan
	Importance for local population	State and trends	Importance for local population	State and trends	State and trends
Timber and firewood	Low	Poor ➘	High	Normal ➔	Good ➔
Meat and fur of wild animals	Low	Fair ➔	Medium	Fair ➘	Fair ➔
Biodiversity	Medium	Fair ➚	High	Normal ➔	Normal ➘
Medicinal plants	High	Poor ➘	High	Fair ➘	Fair ➘
Habitat of harvested animals and plants	Medium	Fair ➘	High	Fair ➘	Poor ➘
Territories of indigenous people living	High	Normal ➚	High	Normal ➚	Fair ➘
Chain of hydrologic cycle; flood control	Medium	Fair ➘	High	Normal ➔	Normal ➔
Cultural, historical, aesthetic, religious values	Medium	Fair ➘	Medium	Fair ➘	Normal ➔

Legend for trend: ➔ - no changes; ➘ - worsening, decreasing; ➚ - improving, increasing.

6. GRAZING ECOSYSTEMS

6.1. Ecosystem outline

The Mongolian part of the Altai-Sayan Ecosystem (hereinafter referred to as Western Mongolia) is 304 thousand km^2, or about 20% of the country. It is administratively divided into 87 soums of six western aimags (Table 6).

The population of the region is about 537 thousand people with the mean density of 1.3 persons per km^2. The inhabitants are irregularly distributed. It is 2 persons per km^2 in Bayan-Ulgii Aimag while it is 0.5 persons per km^2 in the Gobi-Altai Aimag.

Western Mongolia is characterized by the diversity of natural landscapes. Alpine meadows, forest-steppe and desert-steppe, which form the grazing resources, cover about 59% of the area. The other part is occupied by barren deserts, rocks, waters and nival and glacial landscapes.

Steppe landscapes prevail in western Mongolia, accounting for more than 46% of the area. They occupy planes, depression bottoms, terraces of big river valleys, as well as mountain slopes up to 2300 m above the sea level and up to 2550 m on favorable expositions of slopes (Chistyakov and Seliverstov 1999).

Steppe ecosystems in the region are classified into two main groups. The first one presents communities of perennial xerophylous turf grass resistant to low temperature in winter. Such steppe landscapes occur in the northern part of the region.

Table 6. Population and administrative units (Statistical Yearbook 2002)

Aimags	Number of soums	Area in ASER, km^2	Percentage of total area	Population in 1999, thousand persons
Bayan Ulgii	12	45 861	98.8	100.0
Khovd	16	75 547	73.8	94.5
Uvs	19	63 765	99.4	98.4
Zavkhan	14	28 234	56.0	104.0
Gobi-Altai	14	47 118	63.5	74.1
Khuvsgul	12	43 491	66.8	65.6
Total	**87**	**303 836**		**536.6**

Desert-steppe landscapes prevail in the southern part. They exist under low precipitation, very high heat supply in a warm period and usually under unfavorable soil and lithological conditions, such as sand, salt ground, etc.

Term “grazing ecosystems” is used in the paper to accentuate one of the most important features of the ecosystems of Western Mongolia, i.e. permanent use by wild and domestic animals for grazing. Actually the category includes quite different ecosystems, such as Alpine meadows and tundra, forest-steppe, steppe and semi desert. The floristic composition of these ecosystems, their productivity, feed value and resistance to different impacts range much.

The population of the region and its main activities are mostly found in steppe landscapes.

6.2. Conditions and trends

The overview of the present-day conditions and trends of changing main ecosystem services in West Mongolia is shown in eable 7. Eight basic ecosystem services of four ecosystem types were assessed.

Table 7. Grazing ecosystems' services in the Mongolian Altai-Sayan Ecoregion: current state and trend of change

Goods / services	Type of natural landscape			
	Alpine meadow and tundra	Forest-steppe	Steppe	Desert-steppe
Fodder	Good ➘	Fair ➔	Poor ➘	Poor ➘
Firewood and timber	Not assessed	Fair ➔	Poor ➘	Poor ➘
Meat and fur of wild animal	Poor ➘	Poor ➘	Poor ➘	Poor ➘
Biodiversity	Fair ➔	Fair ➘	Poor ➘	Poor ➘
Medicinal plants	Not assessed	Fair ➔	Fair ➔	Fair ➔
Habitat of harvested animals and plants	Fair ➘	Fair ➘	Fair ➘	Fair ➘
Area of nomadic style of living	Fair ➘	Good ➘	Fair ➘	Fair ➘
Cultural, historical, aesthetic, religious values	Not assessed	Fair ➔	Good ➔	Good ➔

Legend for trend: ➔ - no changes; ➘ - worsening, decreasing; ➚ - improving, increasing.

Animal husbandry is a basic economy of the region. It makes up about 70% of GDP, being the basis of the social and economic development of rural areas and well-being. Hence the feed resources provided by natural ecosystems play a key role in the people well-being.

According to Table 6.2, a supply of feed from steppe ecosystems, which are potential for the economic development of West Mongolia, is inadequate. A supply of wood, meet and fur of wild animals, and biodiversity has the same value. The state of medicinal plants and habitats of wild animals and plants is little better. This indicates a poor state of grazing ecosystems. The contemporary changes of the ecosystem services show continuing degradation.

The transition of Mongolia to the market economy started in the beginning of the 1990's triggered changes. The most important ones are shown in Figure 6.

Nomadic herding practiced in West Mongolia for millennia has a significant effect on the structure and floristic composition of grazing ecosystems. However the effect was similar to wild herbivorous animals in intact landscapes. Hence nomadic herding in West Mongolia was more or less harmonized with the internal interactions and processes of these ecosystems. That is why ecosystems under grazing balanced with their natural carrying capacity are recognized as nearly intact. However we should note that on the way to such state of regional ecosystems, wild herbivorous animals were extinguished or at least their number was reduced (Kozlov 1948)

The primary factor controlling the magnitude of changes in grazing ecosystems for the last 13 years is abolishment of herding collectives and privatization of the most part of the state livestock. It has caused a series of sequential aftermaths that have a great impact on grazing ecosystems, environment of the region and human well-being. The most important ones are, as follows:

1) After the abolishment of herding collectives, herders themselves became taking decisions on all issues of husbandry – from grazing to marketing. The number of herding farms and livestock has increased for a short period (Table 7). Herders immediately face the problem of selling finished products. The earlier facilities were not intended for the considerable increase of animal production. Under new conditions many functions of the state became ineffective or stopped. Hence herders started roaming closer to cities and big inhabited areas where they could sell their products. As a result, a great number of livestock is concentrated within limited areas around big settlements, pastures are overgrazed and even some of them are irretrievably destroyed.

Table 7. Total livestock population trend, in million heads (Ecoregion Conservation 2002)

Year	1930	1960	1995	1990	1999	2000	2001
Million heads	23.6	23.0	25.9	28.6	33.6	30.2	26.1

2) The privatization does not touch the pasture irrigation system, which was established in the pre-perestroika years and which mostly consists of wells. Most of them is ownerless and destroys. The number of active wells decreased 40% till 2000 compared with the late 1980's. It reinforced an impact on accessible grazing lands, overgrazing and partial degradation.

3) Since the early 1990's the price of goat wool (cashmere) considerably increased. It became a trigger for increasing goat number from 30% to 60%, i.e. twice from 1990 to 1999. This, in turn, resulted in more intensive overgrazing.

4) The ownership of grazing lands is not legally regulated yet. Most of them are still public lands. Overgrazing in many areas and lack of grazing resources are causes of conflicts between herders. This finally reinforces an impact of nomadic herding on grazing ecosystems.

For millennia Mongolia has developed a specific traditional approach to the use of grazing areas. It includes the formation of a particular species ratio composition of livestock consisting of combination of camels, horses, cattle, goats and sheep. The specific percentage of each species in the livestock leads to the most uniform grazing of the whole range of grazing species, which differ much in nutrition value. Such practice makes the efficiency of the use of pasture areas higher, normally preventing them from overgrazing.

5) The uneven development of herding for the past decade has increased the magnitude of irrational use of grazing lands. It partially depends on the involvement of new, young herders who are not experienced in nomadic herding. It is also caused by weakening the state management of grazing lands and poor control of their proper use. So control of such pests of grazing lands as white mouse is nearly stopped. The growth of the number of this pest considerably decreased feed resources. As the earlier described cases, it makes an impact on grazing lands higher.

Climate warming will result in more intensive aridization of Western Mongolia. This will have an unfavorable impact on the productivity of grazing ecosystems and, by the opinion of some Mongolian scientists, already does. Thus climate change has decreased the productivity of grazing lands by 20% to 30% for past 40 years (Batima 2002). The changes correspond to increasing air temperature but the effects are transformed by the landscape structure where they occur. It is seen in the case of considerable decrease of the productivity of grazing lands in the Gobi-Altai (Erdenemandal) while north (Ulgii) the change is moderate (Figure 7). Climate warming will also increase biomass produced by grazing ecosystems in high mountains that is already found by experimental field observation (Batima 2002).

6.3. Likely future

Based on the assessment of the contemporary state of grazing ecosystems and their trends in the region, the most important analyses of their likely future were chosen. They are, as follow.

1) The contemporary trend of the socio-economic development of the region. The scenario is aimed at searching instruments to re-direct the process to sustainable development when the human use of grazing ecosystems is in compliance with their actual productivity rather than determining dates and details of the collapse of the “pasture – human population and livestock” system.

2) Future grazing ecosystems under the rational use of their resources. The scenario is aimed at analyzing means (social, economic, technological, legal, etc.) for long-term self-sustaining functioning of grazing ecosystems. The reality of achieving the scenario’s goals is assessed as well.

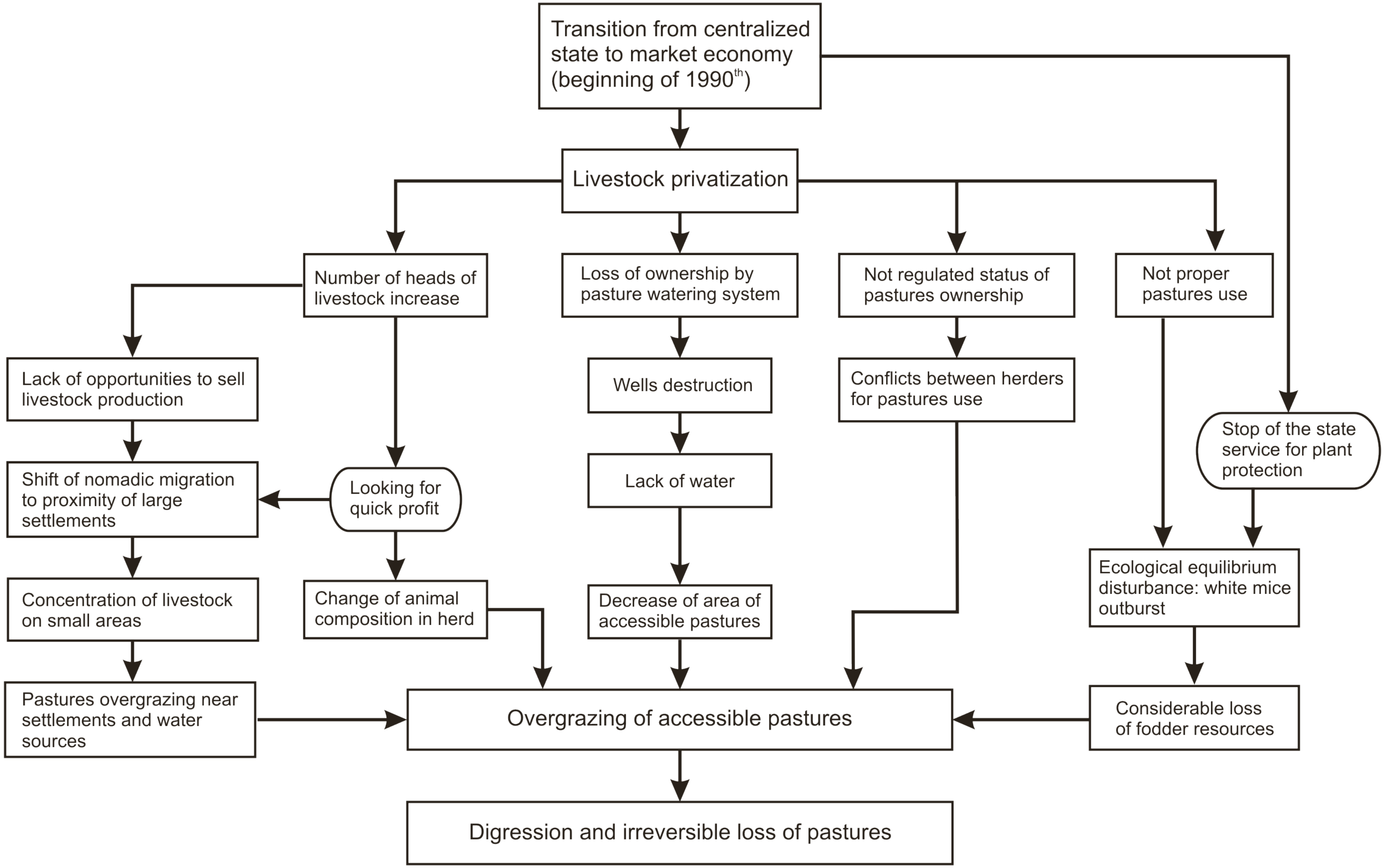

Figure 6. Some processes of grazing ecosystems change in the Western Mongolia during last decade

3) Future grazing ecosystems of West Mongolia under considerable climate warming. The scenario is aimed at describing the spatial heterogeneity of climate warming effects for grazing ecosystems and determining possible measures to resist adverse effects.

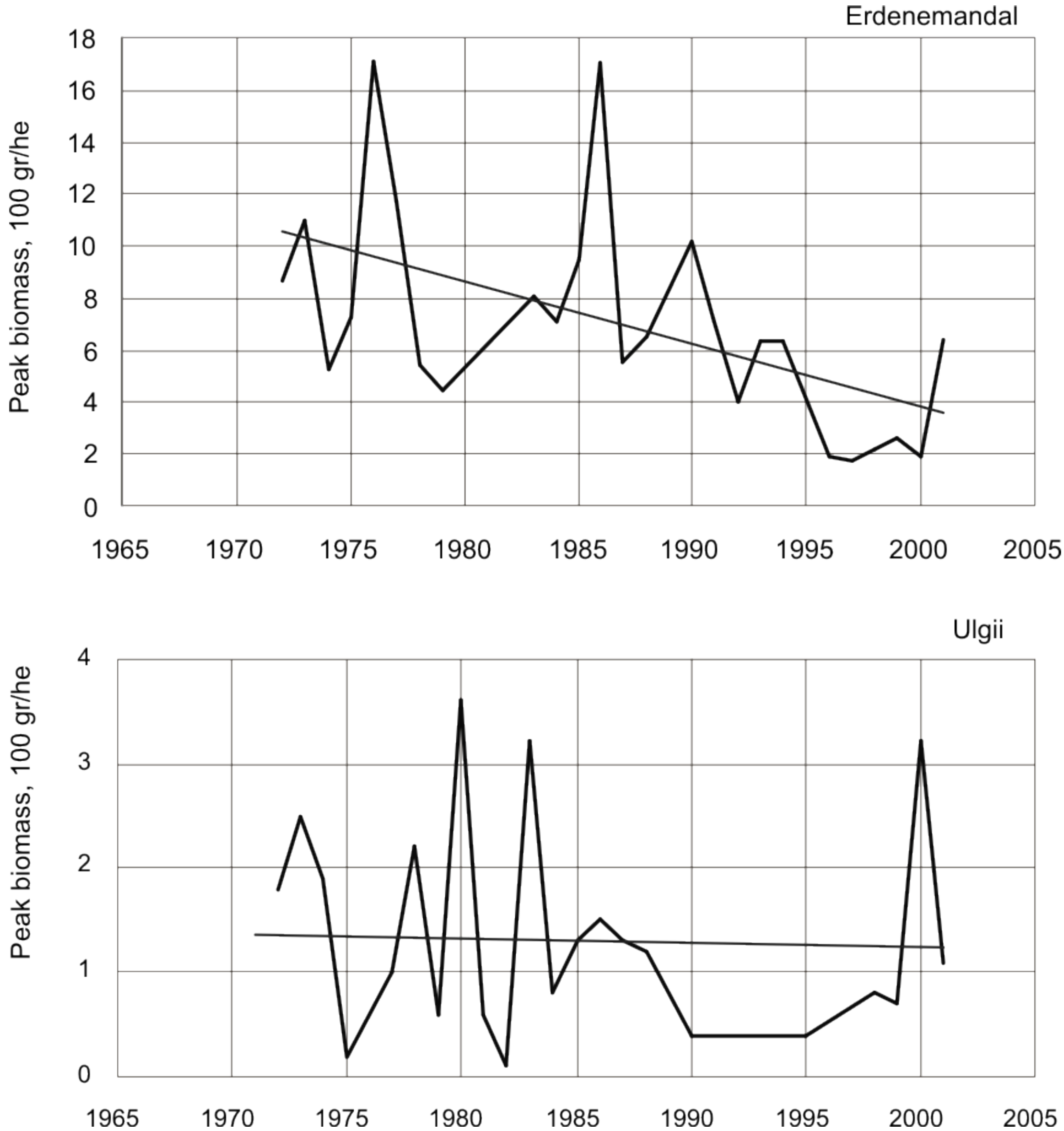

Figure 7. Peak biomass trend (Batima 2002).

6.4. Responses

Based on the assessment of the state and trends of grazing ecosystems, it is possible to define priorities in assessing the social response to the present-day situation and future development. It is obvious that the transition to the market economy caused the loss of some functions of the state, which were important at any economic systems. They are the development of elements of a social strategy related to the use of natural resources and sustainable nature management. Decision making on the use of grazing ecosystems at the present-day conditions and in future was passed from the national to the local level. It is clear that decision making at this level cannot adequately take into account many factors of regional and national levels.

The detailed analysis of the social response to the use of grazing ecosystem services is made in 2004 and 2005.

6.5. Summary

Overgrazing and over harvesting of natural resources in West Mongolia is a result of the impoverishment of country population who has very few facilities for surviving and who much depends on natural resources.

The transition of Mongolia to the market economy caused some adverse effects. One of them related to an impact on grazing lands is caused by the cessation of seasonal grazing, which has been practiced by Mongolian nomads for millennia. Seasonal herding provided a more equal impact on all grazing lands of the region. Abandoning the traditional herding practice, long distance from sales markets and social services, hindered access to water sources at many grazing lands were accompanied by the great increase of livestock concentrated in small areas around administrative centers and near water sources. It caused considerable overgrazing or even destruction of grazing lands in some places.

7. KATUN' RIVER BASIN[2]

7.1 Introduction

The assessment of the state and trends of the hydrological regime and water resources of the Katun Basin purposes several aims. First since the Katun drains glacial watersheds of the South and Central Altai, it is possible to describe effects of climate warming observed in the Altai on the hydrological system of the river basin. Second the population and economy of the region have an growing impact on the water resources and hydrology of the Katun River. It is pronounced in direct water withdrawal from rivers and other sources, water pollution and conditions change of forming water resources. The good state of the Katun basin, its ecosystem is a prerequisite for developing economy and raising well-being of the residents. Third the Katun basin is one of two parts of the headwaters of the vast Ob River system. Hence the conditions for forming the water resources of the region, hydrological regime and water quality are of great importance for the state of downstream of the Ob, people dwelling on its banks.

7.2 Ecosystems outline

The Katun River springs from glaciers of the Altai highest mountain – Mount Belukha (Figure 8). The watershed is 60 900 km^2, the length – 688 km. The major tributaries of the Katun are the Koksa, Argut, Chuya, Ursul, Chemal, Sema, Isha and Kamenka Rivers (Semenov 1969).

The biggest tributary of the Katun is the Chuya with the watershed of 11 200 km^2, the river is 320 km long, it springs from glaciers of the Saylyugemskiy Range, crosses the Chuya and Kuray intermountain depressions and flows into the Katun River in the middle-mountain zone. The Argut (232 km long) and many other tributaries of the Katun River, with the watershed heights averaging from 2200 to 2500 m, spring from glaciers of the Central and South Altai. The greater part of their runoff is formed in the glacial and nival zones (Table 8).

The share of the glacial runoff for the rivers with the average watershed height exceeding 3000 m at sections near ice streams is 40% to 60%, while the share at the river outlets from the mountains is less than 10-15% of the annual runoff. Where the rivers flow to the Katun, the greater part of the runoff is generated from firn basins or seasonal snow cover (30 to 50%). The rain feed of the rivers accounts for less than 20% and the ground feed is 30%. The share of rainfall increased, in high-mountain intermountain depressions in particular, in the 1990's and the beginning of the present century that had an effect on the percentage of annual runoff components.

---

[2] Co-author Semenov V.A.

Table 8. Annual runoff components of the rivers with glaciers in the watersheds

River-point	Watershed, km^2	Watershed average height, m	Annual runoff components, %			
			groundwater	snow	rain	glacier
Aktru – Aktru Alpinist camp	33.4	3100	10	15	15	60
Akkem – Akkem hydrometeostation	78,9	2900	9	35	13	43
Argut (Akalakha) – Bertek hydrometeostation	602	2600	12	40	20	28
Argut – Argut	7070	2500	21	43	20	16
Katun Катунь – at mountain Belukha foothills	56.0	2700	10	27	14	49
Katun – Maly Yaloman	3680	2280	25	40	22	13
Katun – Srostki	58 400	1770	28	44	20	8
Kucherla – Kucherla	627	2300	22	30	21	27
Chagan – Kyzyl-Many	372	2800	11	32	18	39
Chuya – Bely Bom	10 900	2340	33	31	18	18

Since thermokarst processes occur in the widespread permafrost zone, the share of the ground component in the river runoff will change.

The main spatial features of precipitation and maximum snow reserves in the basin are their increase with elevation and decrease at the same elevations from periphery toward inner areas.
The total water loss for evaporation from the river basin reduces from 500 mm and more in the lower basin at an altitude of 400–600 m to 150–200 mm in high-mountain intercontinental areas and intermountain depressions at an altitude of more than 2000 m that is explained by different heat regimes of the basin high zones and lack of precipitation in high-mountain intermountain depressions.

The greatest mean annual runoff is formed in the high-mountain zone of the Katun Range in the southern Katun basin, reaching 800 to 1000 mm. The worse runoff conditions are found in intermountain depressions, e.g. it is 50 mm in the Chuya depression (Komlev 1966, Semenov 1969).

The total mean annual runoff of the Katun basin is 19.5 km^3. About half of the volume is formed in the upper basin before the Chuya mouth.

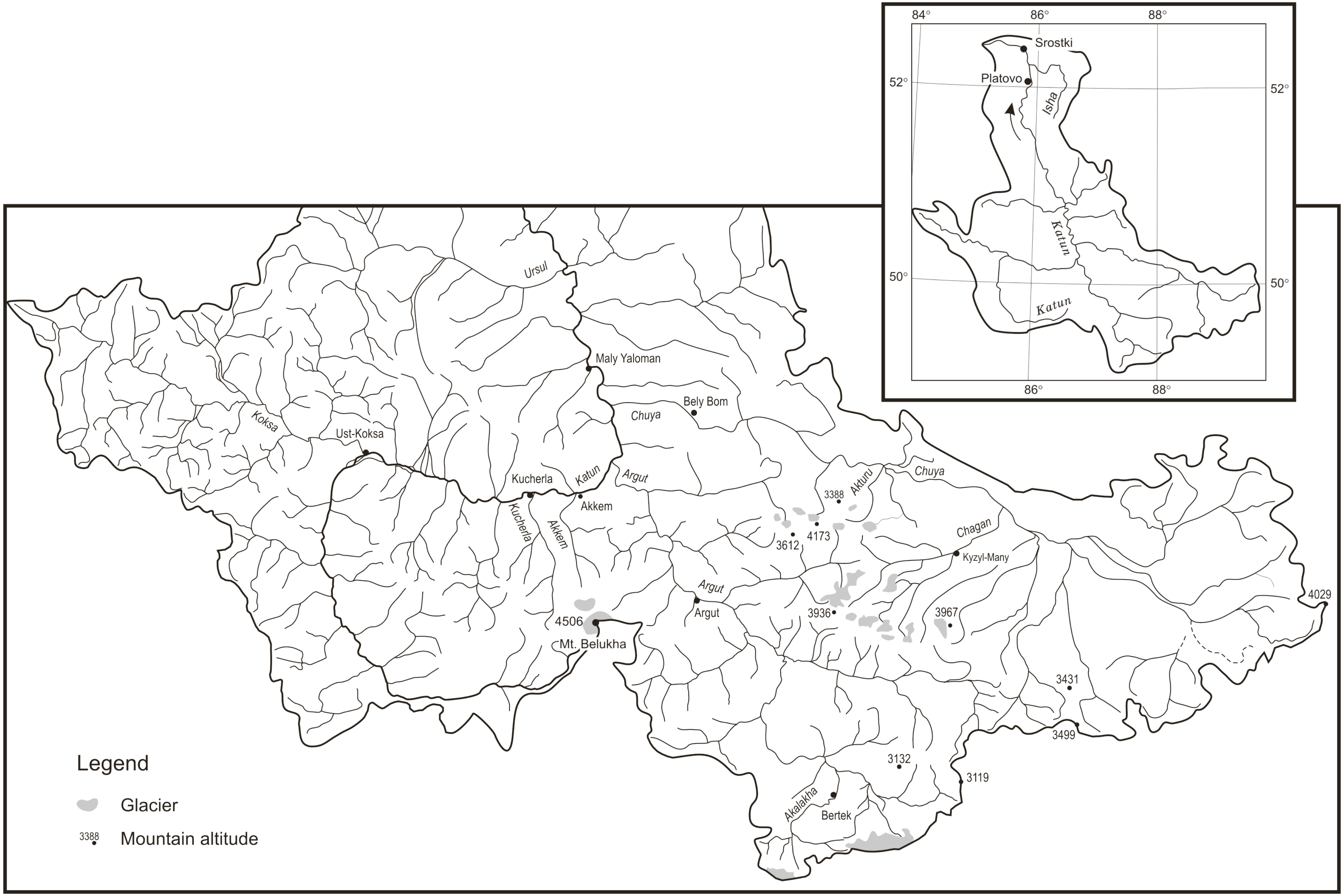

Figure 8. Katun River basin.

7.3 Conditions and trends

7.3.1 Glaciers

There were 400 glaciers, totaling 626 km^2 in the Katun basin at the beginning of 1981 (Revyakin, 1981).

The Argut River gets the most amount of water in the Katun basin. The Chuya and Upper Katun, upper the Argut mouth, provides approximately the same volume of water – some more than a quarter of 1 cubic kilometer (Galakhov 1999). The calculation of the glacial runoff of the rivers of the Central Altai shows that it is lower 10% to 15% in year with favorable conditions for glaciers and is higher 25% to 30% in year with unfavorable conditions. The ice resources of the Central Altai are 150 km^3, including 27% in glaciers, 69% in permafrost, 4% in seasonal snow cover, 0.4% in frazils (Galakhov 1999).

The observation of the Altai glaciers fluctuation has been carried out since 1835, in the past decades also by researchers of the Tomsk University. It indicates the recession of more than fifty glaciers within the Altai mountain system.

Glaciers decreased from 8 to 40% for the observation period. While decreasing, the largest glaciers come apart. Some glaciers disappear at all.

Small glaciers are more stable. It is caused by the higher location and location in shadowy kars on the northern slopes of mountain rangers.
The total number of glaciers increased 25% due to the disintegration of large glaciers for the century and a half (Narozhny 2001). The glacial area in the Katun basin decreased 25% for the period. The third of this decrease occurred after 1952. Although glaciers recess in general during the past decades, its intensity increased 1.5 times for low valley glaciers and reduced approximately the same value for high mountains glaciers.

In the alimentation areas, the surface of glaciers considerably declined that predetermines their further recession within the next 10–15 years.

7.3.2 Hydrology

The analysis of the hydrological observation for trend, with the verification of the reliability with several methods proposed by the World Meteorological Organization (Semenov et al., 1994), shows that the runoff of the Katun and Chuya rivers was characterized by negative trend from the 1930's to the middle 1970's (Table 9) while the runoff of the tributaries with the high share of ice feed (the Akkem) did not change significantly.

Table 9. Parameters of intensity (*b*) and statistical significance (*γ*) of changing flood runoff by periods

River - point	Watershed, km^2	Observation period	Whole observation period		1941-1975		1951-1975	
			b, mm	*γ*, %	*b*, mm	*γ*, %	*b*, mm	*γ*, %
Katun – Srostki	58 400	1936-1977	-1.483	99	-1.430	82	-1. 525	54
Chuya – Bely Bom	10 900	1932-1974	-0.095	93	-0.044	69	-0.277	66
Akkem – Akkem	79	1952-1975	10.113	59			10.113	59

The lower and middle Katun (at Tyungur and Srostki settlements) flood and mean annual runoff is characterized by insignificant negative change for 1951-1980. The same tendency had remained for the following period up to 2000, but with changing the negative trend to stability. The stability of the mean annual runoff is also characteristic of the middle-mountain zone (the Koksa) while the runoff of the low-mountain zone is characterized by negative tendency (Semenov 1997).

The annual runoff of low and high mountains with a considerable part of ice and snow feed is characterized by smoothing seasonal differences. The rivers of intermountain depressions show the stable annual distribution of runoff in all moisture phases (Narozhny 2001, Paromov 1999, Skotselyas 1975).

The tendency to decrease the difference between seasonal runoff in high and low mountains that is revealed by the analysis of annual seasonal runoff is confirmed by a significant increase of an coefficient of runoff self regulation during the course of an year in the rivers of those zones (Narozhny et al. 1998) and is a response of runoff to climate change, seasonal precipitation first of all. The Katun runoff remains without change owing to the combination of the opposite tendencies in the runoff of its tributaries.

Table 10. Runoff change of the Katun and Koksa Rivers from 1950 to 2000

River - point	Watershed, km^2	Mean runoff for the period, l/sec. km^2		Runoff norm before 1970, q_0, l/sec. km^2	Ratio	
		1981-2000, q	1951-1980, q_{cp}		q/q_{cp}	q/q_0
Katun – Srostki	58 400	18.6	19.4	19.6	0.96	0.95
Koksa – Ust-Koksa	5600	13.3	14.6	14.6	0.91	0.91

7.3.3 Human impact

Human-induced impacts on the Katun hydrological regime and water resources of the basin are diverse. Impacts are induced in the process of direct water use or are indirectly pronounced, e.g. under the change of the hydrological cycle caused by logging. The main economic activities in the river basin that have an impact on the condition of natural waters are, as follow:

- Communal water supply, agriculture and industry
- Waste discharge into water bodies
- Water use for power generation
- Irrigation
- Forestry
- Water transport
- Recreation

The water consumption in the Katun basin accounts for an insignificant percentage of the mean annual runoff (about 0.18% in 1992). Hence an impact of water withdrawal on the hydrological regime is extremely low. It is notable that water use considerably decreased for the past decade that is caused by the deep economic crisis (Table 11).

Human-induced impacts on natural waters are most pronounced through pollution. It is caused by waste discharge into water bodies, fertilizer and chemicals discharge from arable lands, traffic, poor treatment of used water, etc. In general the river water quality in the basin is close to natural. The main characteristics of the water chemical composition at the lower Katun (near Platovo village) in 2002 were, as follows: salt content 88.2-186.9 mg/dm^3, pH -7.2-7.5, COD – 3.2-6.9 mgO/dm^3, BOD_5 – 0.31-1.99 mgO/dm^3, organic matter content – 1.18-2.64 mg/dm^3, water hardness – less than 3.35 mg-equ/dm^3. The contend of dissolved oxygen in the Katun was at least 9.0 mgO_2/dm^3 in the year that indicated, together with high positive Eh values, a good oxygen regime of the river.

However the human-induced decrease of the river water quality is found in the densely populated and economically developed foothill areas and intermountain depressions. The content of some pollutants exceeds maximum permissible concentrations (MPC). Table 6 shows the content of some pollutants that exceeds MPC in the Katun water.

Table 11. Water withdrawal from surface water bodies and aquifers in 1992-2002, in mln. cub. m

Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
From surface waters	22,21	14,56	13,41	12,25	10,46	8,15	7,52	2,31	4,55	1,51	1,81
From aquifers	12,55	10,35	10,9	12,72	7,67	11,21	8,26	7,34	7,35	7,02	7,16
Total	34,76	24,91	24,31	24,97	18,13	19,36	15,78	9,65	11,9	8,53	9,05

The existing data of the surface and ground water pollution in the Katun basin show that the present-day human-induced impact on the natural waters does not deteriorate them. The chemical composition of the most rivers is determined by natural factors. However the further development of the economy and water supply in the Katun basin may cause the quick increase of the river water pollution if appropriate measures to prevent from water pollution and to treat communal, agricultural and industrial wastes are not taken.

Table 12. Content of some pollutants in the Katun water near Platovo Village in 2000 - 2002

Pollutants	Range of content, mg/dm^3			MPC, mg/dm^3	Exceeding MPC in 2002
	2000	2001	2002		
NH_4^+	0.01-0.50	0.39-1.01	0.02 - 0.56	0.39	Up to 1.4 times
NO_2^-	0.01-0.05	0.02 - 0.07	0.01-0.06	0.02	Up to 3 times
NO_3^-	0.09-1.03	0.17-0.43	1.04-10.92	9.1	Up to 1.2 times
Petroleum products	0.02 - 0.32	0.01-0.41	0.01-0.30	0.05	Up to 6 times
Phenols	0.001-0.009	0.001-0.007	0.002-0.019	0.001	Up to 19 times
SAA	0.02 - 0.33	0.01-0.25	0.05 - 0.44	0.5	–
CLA	0.00-1.50	0.00 - 0.99	0.01-0.93	3.9	–
BOD_5	0.10-1.06	0.39-2.59	0.15-1.00	3.0	–
COD	1.10-5.10	3.50 - 7.70	2.51-3.35	15.0	–
Hg^{2+} $\mu g/dm^3$	0.02 - 0.08	0.005 - 0.07	0.01-0.09	0.01	Up to 9 times

The hydropower resources of the Katun are estimated 55 billion kWh (Ryabchikov 1978). Their use began in 1934 when a low-powered hydropower plant on the Chemal River was built. It still operates at present. The construction of a hydropower plant on the Chuya near Aktash was stopped due to design mistakes. In the late 1990's the Katun Power Plant near Yeland village was designed but it was not completed. Now the small Altai Power Plant on the Katun 235 km upper the confluence of the Katun and Biya (near Yeland village) is designing. The main features of the reservoir is 10 times smaller than those of the Katun Power Plant that was projected earlier. The area of the reservoir is 12.1 km^2 and the volume is about 0.2 km^3.

An agricultural impact on the water resources of the Katun basin is comparatively low. It includes the use of river water for irrigation of intermountain depressions within the Chuya, Koksa and Ursul watersheds. The irrigated lands totaled about 8 thousand hectares in the early 1990's (Bannikova 2001). Water used for irrigation was 22.4 million m^3 or about 0.11% of the Katun mean annual runoff in 1992. This volume reduced to 0.76 million m^3 till 2001 due to economic decline.

The forest cover that played an important role in protecting and regulating the river runoff in the Katun basin was significantly reduced at the first half of the 20th century; forest in the Chuya Basin was destroyed at all that intensified desertification (Yaskov 1997). In the middle of the 20th century water bodies were suffered from the destruction of scrub and drainage of wetlands during melioration. Nowadays the main threat to forest ecosystems is fire and pests with which the combat was stopped during the economic decline. Selection felling is basically practiced.

The lower Katun up to approximately 30 km is navigable. The building of the modern navigable channel began in 1978 and requires river-training works (Berkovich et al. 2000). Till 1984 twelve straightening constructions were built on the river section 4 to 22 km from the mouth and the major bank strengthening reached 10 km. While reconstructing the natural riverbed, it was also deepened. In the early 1980's intensive extraction of sand and gravel began in the lower Katun. This made the level of the Katun lower and changed the floodplain water supply.

The inundation of the lower floodplain (0 to 2 m) in the 1980-1990's decreased 50 days compared with the previous period, middle floodplain (2 to 4 m) – 20 to 30 days, and high floodplain (4 m and above) – 3 to 6 days. Now the zone of flooding is limited by the course floodplain of 0.5 to 1 km wide. Hence the high floodplain was xerophytized that was accompanied by drying out floodplain lakes and streams, degrading wetlands and meadow. The effects of changing flooding duration are supplemented by overgrazing of floodplain meadows and clearing forest and scrub for arable lands. Cut forests do not regenerate in the floodplain owing to climate conditions.

Recreation, treatment and tourism in the high and low mountains of the Katun basin in the soviet time were mostly organized and so accountable. The annual tourist flow to the Alati was 40 to 50 thousand people at that time (Arefyeva and Chudova 1994). In 1990 about 40 thousand tourists visited Mountain Altai, then there was a decline of organized tourism. In the late 1990's it was changed by the increase of "wild" tours organized by a great number of companies in Siberian cities and independent autotourists. That is why tourist account is difficult. Unofficial estimates show that the number of tourists visited Mountain Altai in 2000 was 224 000, in 2001 – 402 780, in 2002 – 582 400, for 9 months of 2003 – 413 000.

The account of amateur tourists, autotourists in particular, is very complicated. Most of them go to the bank of the Katun and its tributaries and in forest to collect nuts of Siberian pine, berries and mushrooms. Despite organized tourists who pass over established routes, amateur tourists may do maximum damage to tree roots, shrubs and herbage. They are also local threats to water and near-water ecosystems.

7.4. Plausible future

Quite possible that climate warming will cause the further increase of annual air temperature in Mountain Altai while effects on seasonal temperature and precipitation are different. Many climatologists forecast precipitation increasing, which had to occur. Some Russian and Chinese experts substantiate its insignificant change and even decreasing in some seasons. The calculation made by the methods of Sherstyukov and Isayev (1999) shows air temperature increasing in summer and decreasing in winter and spring, precipitation decreasing in winter and increasing in summer in the region up to 2010. The annual precipitation will increase, however evaporation loss will increase too.

The change of runoff and water resources in the Katun basin caused by climate warming is indefinite because of different respond of various parts of the basin system to climate warming. This issue is an objective of further study.

A human-induced impact on the Katun basin is still temperate. However the increase of population and economy will likely cause surface water pollution.

7.5 Summary

The river network of the Katun basin drains the northern macro slope of the Altai high mountains where about 400 glaciers of more than 600 km^2 are located. Considerable climate warming is observed in the region during the past decades that results in glacier recessing and shrinking. Hence the Katun basin may be used for monitoring of the respond of a large river system and its ecosystem of a sub global scale to climate change.

The runoff change of the Katun tributaries for the past 4-5 decades had opposite trends. The compensation of the opposite runoff trends as the response to climate change was the reason that there was no trend in the Katun runoff from 1951 to 2000. However the trend is found to smooth differences between the seasonal runoff in the high and low mountains of the Katun basin. It is explained by the different responses of the rivers with runoff forming in different elevation zones to seasonal changes of air precipitation.

Water of the Katun basin is used for communal water supply, agriculture, industry, irrigation, power generation, water transport and recreation. Direct water withdrawal for economic needs is insignificant and has no noticeable impact on water bodies.

The population and economy has an impact on the water quality of the rivers and lakes. Although the general water quality remains close to natural, water pollution may be very high in some localities. The further economic development in the Katun basin may cause the quick increase of river water pollution. Appropriate measures to treat communal, agricultural and industrial wastes should be taken to prevent water from pollution.

The Katun River has large hydropower resources that are almost not used now. They should be used only through small hydropower plants whose construction and maintenance will not cause adverse environmental effects. So it will largely improve the power supply of the Republic of Altai and a part of electric power may be supplied to neighboring regions.

The most valuable resource of the Katun basin is forest, which is of high water protection value and provides high biological diversity of the region. Nowadays the main threat to forest ecosystems is forest fire and pest outburst. The role of these factors considerably increased for the past decade owing to poor fire and pest control. Drastic measures are required to neutralize these threats.

Great and diverse facilities for recreation are a feature of the Katun basin. There are facilities for alpinism, walking tourism, rafting, climatic healing, balneological treatment. The number of visitors to Mountain Altai is quickly growing. In 1990 about 40 000 tourists visited the region, in 2002 the number of tourists reached 582 400 people, for 9 months of 2003 – 413 000. The number of summer cottages, inns, hotels, motels and so on is quickly growing on rivers and lakes. The unregulated development of recreation infrastructure may be a serious factor of polluting natural waters of the river basin.

8. CONCLUSION

The main result of the initial assessment stage in the Altai-Sayan ecoregion is preliminary overview of the state of key ecosystems, which provide ecological services for local population and economy (forests, grazing ecosystems, water). Besides ecosystem assessment the initial evaluation of the population attitude towards ecosystem importance and role in the society life was conducted. This overview allows identifying necessary next steps for the more comprehensive assessment.

The key features of the ecoregion identified as the main for the further assessment and understanding of the ecosystem services are as follows:

- Assessment of the state and trends of forest and grazing ecosystems for the past 10-20 years showed the very high level of the North – South contrasts of natural, social, economic and cultural characteristics through the natural and administrative boundaries. These contrasts are outside just "transboundary" effects and could be regarded as sub global phenomenon. These interregional contrasts would cause effects which will determine the future status of the ecosystems in the ecoregion and thus need full assessment;
- Substantial part of the population in the ecoregion survives on cattle breeding using ecosystem services provided by grassland (pasture) ecosystems. Current state of grazing ecosystems in the ecoregion is at the threshold of destruction (especially in most easy access pastures) due to overexploitation during last years as a result of collapse of the centralized economic management system and elimination of the state support to the livestock producers;
- Forest ecosystems suffer from the same driving forces as grazing lands. Economic and subsequent social crisis enormously increased direct uncontrolled use (often illegal) of all type of forests resources especially those easy to derive with extensive methods (e.g. non timber biodiversity resources). However, despite these negative trends forest ecosystems of the ecoregion in general are still in good condition. At this stage overexploitation has limited scale close to and around settlements. Forests in the ecoregion are much more stable ecosystems rather than grasslands. At the same time growing timber demand and intensification of economic activities in some parts of the ecoregion pose additional threat to forests which could lead to negative biodiversity dynamics tendencies in the coming 5-10 years. Forest ecosystems could become the main source of services for local communities in the coming years;
- Meteorological stations in the Basin of Katun River show increase in temperature and trends of increasing melting of glaciers and snow. Different parts of Katun river basin show differentiated reaction on climate changes (temperature and precipitations). Despite differentiation of response in parts of the basin the river basin in general as a system is still quite stable and its general flow characteristics are maintained without changes;
- There are no proves or current research which could confirm changes in the ecosystems caused by climate change in the ecoregion;
- Transformations of political and economic systems in the countries of the ecoregion took place from the top and are clearer at national and regional levels rather then at local. New local governance structures are still under formation. Economic activities at local level were dramatically affected by political changes at national level. At the same time local resources use patterns still keep traditions practices of the previous political period. Differences in social-economic and political situation and developments in the countries

of the ecoregion determine unequal and sometimes controversial processes in the similar ecosystems;

- There are evidences of changes in attitude of local rural population (in Russian part of the ecoregion covered by sociological study) towards increase of awareness about environmental issues and interest in sustainable use of biological resources;

Initial stage of the assessment in 2003 revealed the key issues to be investigated and assessed. Those issues include:

1. Assessment of the natural water resources as a key element of the ecosystems in the ecoregion playing important role for the human wellbeing in the entire ecoregion and as a service for neighbouring (downstream) regions. This assessment will include: i) water resources quantity and quality, ii) relationships with functioning of key selected ecosystems, iii) access to water resources in the different parts of the ecoregion, iv) response on climate change, v) use in economic activities (water supply, hydro energy, water transport, recreation, medicinal use and etc.). Special emphasis will be done for the assessment of the role of wetlands in the ecosystem structure and functioning of the ecoregional biodiversity. Scale: ecoregional, national, basin and local.

2. Assessment of current status and trends of biodiversity (at indicator species and ecosystem levels). Key ecosystems include: nival-glacial systems, alpine tundra and meadows, forest, forest-steppe, steppe, desert-steppe, wetlands, agricultural ecosystem. Assessment should identify major drivers of changes and current mechanisms of changes in ecosystem goods and services. Special focus should be done on assessment of the carrying capacity (sustainability thresholds) of the ecosystems of different types and their potential to provide services and goods under different level of anthropogenic pressure. Scale: ecoregional, national and sub regional (for biodiversity status and trends) and local level (for carrying capacity and services production under pressure).

3. Investigation of social, political, institutional and legal driving forces determining responses of local communities to ecosystem changes in the ecoregion. Investigation should be focused on assessment of adequacy of the current community organization (institutional, legislative, legal, psychological aspects) as related to the character and scale of contemporary ecosystem changes. Scale: local.

4. Investigation of specific features of human well-being related to specific ecosystems (based on traditional knowledge and land use systems) for different ethnic groups and indigenous communities in the ecoregion. Assessment of potential of use of the existing traditional knowledge in the ecoregion for organization of sustainable use in the ecoregion. Scale: sub regional, local.

5. Development and analysis of scenarios. Current situation review revealed the following potential developments to be investigated:

- conditions and potential volumes of services which grazing ecosystems will provide to maintain traditional and/or current cattle breeding patterns a swell as changes in grazing system needed to ensure sustainable and comprehensive use of available pasture resources;
- conditions for the long-term balance between various resources and services and different practices of their use in forest ecosystems. Forest ecosystems under various development scenarios (intensive forestry oriented / industrial and mining development / biodiversity use oriented);

- key types of the ecosystems under climate change.

Scale: ecoregional, national, sub-regional and local.

6. Assessment of the role of current governance systems and their trends in the different parts of the ecoregion for potential changes of the resources use patterns and incorporation of ecosystem services into economic policies. This assessment will include:
   - analysis of the institutional, legal and social basis for the population reaction on the ecosystem changes. Scale: local, sub-regional, regional, national;
   - identification and analysis of socio-economic driving forces and conditions, causing ecosystem changes and determining appropriate responses of local communities. Scale: local, sub-regional, regional, national.

ACKNOWLEDGEMENTS

I wish to thank Drs. Alexander S. Shestakov and Chimed-Ochir Bazarsad for discussions various details of the study and for contribution of data and materials for it. Many thanks Drs. A. Sokolov and S. Surazakova for their essential materials as well. This study was initiated and sponsored by WWF Russia Program Office through Grant No. A240/Ru109201/GLP.

REFERENCES

1. **Adamenko**, M.F.,F., 1985: Reconstruction of thermal regime dynamics for summer months and glaciation in the Altai Highlands region in XIV-XX centuries. Theses of dissertation, Novosibirsk, 16 pp. (in Russian)
2. **Areyev,** V.E., Chudov A.V., 1994: *Tourism in the Altai*. Publ. House of the Altai State University, Barnaul, 119 p. (in Russian)
3. **Bannikova**, O.I., 2001: Assessment of Natural Resources and Environmental State of *Intermountain Depressions.* Dissertation thesis, Kaluga, 25 p. (in Russian)
4. **Batima**, P., 2002: Living with Climate Change. 1st draft of unpublished Synthesis Report within framework of the ongoing project "*Potential Impacts of Climate Change and Vulnerability and Adaptation Assessment for Grassland Ecosystem and Livestock Sector in Mongolia*" financed by GEF, implemented by Global System for Analysis, Research and Training (START), Third World Academy of Sciences (TWAS), United Nations Environment Programme (UNEP), 91 pp.
5. **Berkovich,** K.M., Chalov R.S., Chernov A.V., 2000: *Ecological Channel Science*. GEOS, Moscow, 332 p. (in Russian)
6. **Biological** Resources and Natural Conditions of Mongolia. Joint Russian-Mongolian Interdisciplinary Biological Expedition. 1995. Vol. XXXIX, Ecosystems of Mongolia: Distribution and Current State. Moscow, "Nauka", 224 p. (in Russian)
7. **Chistyakov**, K.V. and Yu.P. Seliverstov, 1999: *Regional Ecology of Little Altered Landscapes. North-West of the Inner Asia*. Sankt-Petersberg University Publishing House, 264 pp. (in Russian)
8. **Climatic Passport** of Altai-Sayan Ecoregion. Issue 1. Moscow, WWF, 2001. 26 p.
9. **Enkhtsetseg**, B. et al., 2002. Socio-economic Situation in the Altai-Sayan (Mongolia).
10. **Ensuring** Long-term Conservation of Biodiversity in Altai-Sayan ecoregion. 1999. Proposed tasks, results and activity for the project. Manuscript, WWF Russian Program Office, Document with the summary after International Forum "Altai-Sayan – XXI Century", December 1999, 62 p. (in Russian)
11. **Furyaev**, V.V., 2002: Biodiversity conservation by measures to decrease of forest fire threats in Altai-Sayan ecoregion. Manuscript, Krasnoyarsk, 34 pp. (in Russian)
12. **Galakhov,** V.P., Mukhametov R.P., 1999: *Glaciers of the Altai.* Nauka, Novosibirsk, 135 p. (in Russian)
13. **Gunya**, A.N., Drozdov, A.V., and G.S. Samoilova, 2002: Landscapes and land-use in Kosh-Agach area of the Republic of Altai. *Proceedings of the Academy of Sciences*, Geographical series, **5**, 83-90. (in Russian)

14. **Kharlamova**, N.F., 2000: Dynamics of thermal regime in the continental regions of Russia over last 160 years. *Proceedings of the Altai University,* **3(17)**, 56-58. (in Russian)

15. **Komlev,** A.M., Titova Yu.V., 1966: *Runoff Formation in the Katun Basin (Mountain Altai).* Nauka, Siberian branch, Novosibirsk, 155 p. (in Russian)

16. **Kordonsky**, S.G., 2003: Private communication on the activities of Tyungur Village community in tourist business

17. **Kuminova,** A.V. (ed.), 1982. Plant Communities of Tyva. Novosibirsk, "Nauka" – Siberian Branch, 204 p. (in Russian)

18. **Kupriyanov**, A.N. (ed), 2003. Biological diversity of Altai-Sayan ecoregion. CREOO "Irbis", Kemerovo, 156.

19. **Leak**, W.B., and R.E. Graber, 1974: A method for detecting migration of forest vegetation. *Ecology*, **55(6)**, 1425-1427.

20. **Modina**, T.D., Drachev, S.S. and M.G. Sukhova, 2002: On the global climatic change on the Mountain Altai territory. *Proceedings of regional scientific and practical conference*, Tomsk, p. 161. (in Russian)

21. **Narozhny,** Yu.K., Paromov V.V., Shantykova L.N., 1998: *Features of the Annual Runoff of the Altai River.* Transactions of Glaciological Studies, **84**, pp. 34-40 (in Russian)

22. **Narozhny,** Yu.K., Okishev P.A., 1999: Dynamics of the Altai Glaciers at the Regression Phase of the Minor Ice Age. Transactions of Glaciological Studies, **87**, pp. 119-123 (in Russian)

23. **Narozhny** Yu.K., 2001: *Resource Assessment and Tendencies of Glaciers in the Aktru Basin (Altai) for the Past Century and a Half.* Transactions of Glaciological Studies, **90,** pp. 117-125 (in Russian)

24. **Nemolyaeva** L. 2001. Ensuring Long-Term Conservation of the Altai-Sayan ecoregion. WWF Project: Achievements and Lessons Learned. WWF Russia, 17 p.

25. **Ovchinnikov**, D.V., and E.A. Vaganov, 1999: Dendrochronologic characteristics of Siberian larch (Latix sibirica L.) at the upper forest limit in the Altai Highlands. Siberian ecological journal, **2**, 145-152. (in Russian)

26. **Ovchinnikov**, D.V., Panyushkina, I.P., and M.F. Adamenko, 2002: Millennial tree-ring chronology of larch stands in the Altai Highlands and its utilization for reconstruction of summer temperature. *Geography and natural resources*, **1**, 102-108. (in Russian)

27. **Paromov**, V.V., 1999: *Water Resources of the Upper Ob: Contemporary Assessment and Tendencies.* Dissertation thesis, Institute of Geography of Siberia and the Far East, Irkutsk, 24 p. (in Russian)

28. **Polikarpov**, N.P., N.M. Chebakova, D.I. Nazimova, 1986. Climate and Mountain Forest in the Southern Siberia. Novosibirsk, "Nauka" – Siberian Branch, 226 p. (in Russian)

29. **Polyakov**, V.I., and I.V. Semechkin, 2001: Biogenic dynamics of cedar forests in the West Sayan mountains. Siberian ecological journal, **6**, 667-673. (in Russian)

30. **Revyakin,** V.S., 1981: Natural Ices of the Altai-Sayan Mountain Region. Gidrometeoizdat, Leningrad, 268 p. (in Russian)

31. **Revyakin**, V.S. and N.F. Kharlamova, 2003. Climate change in the Inner Asia in XIX-XX centuries. *Proceedings of International Symposium "Climate and Environment Change in the Central Asia"*, Ulan-Ude, 2003, pp. 57-63. (in Russian)

32. **Ryabchikov,** A.M., Gvozdetsky N.A., Konisshev V.N., Salisshev K.A., Saushkin Yu.G. (edd.), 1978: Altayskiy Kray. Atlas, vol. 1. GUGK, Moscow, Barnaul, 222 p. (in Russian)

33. **Semenov,** V.A. (ed.), 1969: Resources of Surface Waters of the USSR. Vol. 15-1: Mountain Altai and Upper Irtysh. Gidrometeoizdat, Leningrad, 318 p. (in Russian)

34. **Semenov,** V.A**.**, Alekseeva A.K., Degtyarenko T.I., 1994: Runoff Change of Rivers of Russia and Adjacent Areas in the 20th Century. Meteorology and Hydrology, **2**, 76-83 pp. (in Russian)

35. **Semenov,** V.A., Klimova O.V., 1997: Regional Distribution and Human-Induced and Climatic Change of the River Runoff of Mountain Altai. In: Natural Resources of Mountain Altai. Gorno-Altaysk, pp. 138-141 (in Russian)

36. **Sherstyukov,** B.G., Isaev A.A., 1999: Method of Multiple Cyclicity for Analyzing Time Rows and Superlong-term Forecasts in the Case of Characteristics of a Heating Period in Moscow. Meteorology and Hydrology, **8**, 24-28 pp. (in Russian)

37. **Shvarts**, E. A. Shestakov, A.S., 2000. Protected Areas and Sustainable Development: A Chance for Biodiversity or a New Self-Deception. In: Nature Conservation: Bridges between West and East. Publikation zur Tagung "Forum fur Wissen" Swiss Fed. Inst. for Forest, Snow and Landscape Research, Birmensdorf, 2000, pp. 23-29.

38. **Shvarts**, E. A., Shestakov, A.S., 2002. Protected areas: contribution to sustainable development of Russia. In: Transition to sustainable development: global, regional and local levels. Foreign experience and Russia's issues. (Series: Sustainable development: problems and prospects. Issue 1.). Moscow, KMK Publisher, pp. 287-297. (In Russian)

39. **Shvarts**, E. A., 2003. WWF Russia project "Ensuring Long-term Conservation and Sustainable Use of Biodiversity in Altai-Sayan ecoregion". Manuscript, 8 p. (in Russian)

40. **Shvarts**, E.A., 2003: Ecological and Geographical Problems of Biodiversity Conservation in Russia. Dissertation thesis, 49 p. (in Russian)

41. **Skotselyas,** I.I., 1975: Calculation of Annual Runoff Distribution for Unstudied Rivers of Mountain Altai. Transactions of the Kazakh Research Hydrometeorological Institute, **48**, 36-59 pp. (in Russian)

42. **Smagin**, V.N., S.A. Il'inskaya, D.I. Nazimova, et al. 1980. Forest Types in the Southern Siberia. Novosibirsk, "Nauka" – Siberian Branch, 336 p. (in Russian)

43. **The Secretariat** of the Convention on Biological Diversity. 2001. *Global Biodiversity Outlook*. Secretariat of the Convention on Biological Diversity, Montreal, 282 p.

44. **WWF**, 2002. Altai-Sayan Ecoregion Conservation Action Plan. Final Draft. WWF.

45. **Yaskov,** M.I., 1997: Desertification of the Chuya Steppe – State and Prospects. In: *Natural Resources of Mountain Altai*. Gorno-Altaysk, pp. 164-167 (in Russian)