Chapter 1
High-Altitude Flora and Vegetation of Kazakhstan and Climate Change Impacts

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1.1 Introduction

The Republic of Kazakhstan (55°26′–40°56′ northern latitude and 46°27′–87°18′ eastern longitude) lies between Siberian Taiga and Central Asian deserts. In the direction from west to east, the country stretches as far as 3000 km, from north to south—1650 km. Its area makes up 2724.9 km^2. The Republic is situated in the center of the Eurasian continent. Such a deep continental location determines considerably its natural conditions. Steppes occupy more than a quarter of the country's area (Ozturk et al.1996a, b), deserts take up a half of the country, and the rest of the territory is occupied by mountains, lakes, and rivers. Plain territory is divided from north to south into forest steppe, steppe, and desert nature-climatic zones; eastern and south-eastern areas of the country present mountain ridges. The highest point is the Khan Tengri Mountain (6.995 m), located on the border with China and Kyrghyzstan.

On the basis of botanical-geographic regionalization, the country is located in two botanical-geographic regions: Eurasian steppe and Sahara–Gobi desert (Rachkovskaya 2006; National Atlas 2010). The steppe portions of Kazakhstan are associated with the Black Sea–Kazakhstan subregion of the Eurasian steppe region. It has three provinces: west Siberian forest steppe and Trans-Volga–Kazakhstan steppe in plains and south Altai in the mountains. Desert portions are associated with the Iran-Turan subregion of the Sahara–Gobi desert. North Turan, south Turan, and Junggar are provinces in plains; Junggar–north Tien Shan and Central Asian Mountains are highland provinces.

The flora in general includes almost 6000 vascular plant species, 14% being endemics. On an average basis, 1000 km^2 of its area has two vascular plant species, the index ranging from 27 (Altai) up to 146 species (western Tien Shan) in the mountain regions. Latter occupy less than 9% of the country's area but represent over 60% of the plant species diversity of the country. Being floristic origin centers,

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mountainous ecosystems are characterized not only by maximum concentration of plant diversity but also by the maximum original and unique nature (National Strategy 2001) and include: the Altai, Saur, Tarbagatai, Junggar Alatau, Tien Shan (northern, western) Mountains. Different vegetation types on these habitats are preconditioned by integrated factors: zonal position of the plains that surround a mountainous system; ridge orientation; relative and absolute altitudes; climatic features; and plant cover history (Rachkovskaya et al. 2003). The lithology of rocks too is of great importance, as well as the combination of warmth and moisture and their fluctuations (climatic inversions) depending on their slope exposure and height.

In general studies on the belt, distribution of plants in the mountains is the first stage in the investigation of the mountain region vegetation structure. Altitudinal belt of the vegetation is an altitude interval in mountains that differ in its hydrothermal regime, with certain prevailing types of soils and regular combination of plant communities pertaining to one or several types of vegetation. Sub-belt is characterized with a certain structure of plant communities of the dominant vegetation type that grow on various soil subtypes (Vegetation of Kazakhstan and Middle Asia 1995). Changes of vegetation cover in sub-belts are assessed according to the structure of plant communities: a set of species life forms, composition of dominant species, interrelation of species, ecological groups (mesophytes, xerophytes, etc.), and ratio of phytocoenotic groups of species (meadowsteppe, steppe, shrub groups, etc.).

Altitudinal zonality reveals itself depending on the set of climatic, geological, and orographic features. Mountain vegetation of Kazakhstan is subdivided into four groups of altitudinal zonality types: the Altai group (in dry steppes), the Saur–Tarbagatai (in desert steppes), the Junggar–North Tien Shan (in moderate cold deserts), and the west Tien Shan group (in the southern moderate hot deserts) (Rachkovskaya 2006).

In this chapter, we will discuss the traits of the flora and vegetation, patterns of altitudinal zonality with examples from three mountain systems (Fig. 1.1): the Altai (the southern Altai ridges), the north Tien Shan (the Kyrghyz Alatau range), and the western Tien Shan (the Talass and Ugam ridges).

Fig. 1.1 Study areas

This study covering the current state of the plant cover, the traits of species and communities distribution in the mountain belts, the identification of floristic composition of the plant communities, and the typology of vegetation will allow us to reveal plant response to the climate change as well as to identify vulnerable species, predict possible ways of migration and dynamics of the mountain belts.

The research is based on the data received from the projects supported by Ministry of Education and Science of the Republic of Kazakhstan titled "Scientific Basis for Sustainable Use of Plant Cover and Plant Resources in the Southern Altai" (2006–2008) and "Botanical Diversity of Crop Wild Relatives in Kazakhstan as a Source for the Enrichment and Conservation of Agrobiological Diversity Genetic Fund for the Implementation of the Food Program" (2013–2015). Species names and plant family characteristics have been taken from Cherepanov (1995).

1.2 Natural Conditions

1.2.1 The Southern Altai

The southern Altai mountainous system is located at the junction of Kazakhstan's frontier with Russia, Mongolia, and China. The ridges are mostly of sub-latitudinal stretching (the southern Altai, Altai Tarbagatai, Sarymsakty, Narym, Kurshum, Azutau ridges), composed of metamorphic Cambro-Silurian, Silurian, and Devonian shale rocks. It is a mountainous system with folded dislocations that supposedly terminate at the Paleozoic and Mesozoic junction (Nikolaeva and Muzalevskaya 1978; Geldyeva and Egorova 1978).

1.2.2 Topography

The most typical relief forms are high-mountain alpine landscapes with abrupt steep slopes; leveled high-mountain—plateau-like uplands; erosive mid-mountain or mountain taiga; leveled mid-mountain accumulative and erosive valley; low-mountain erosive zone; accumulative and erosive low-mountain valley and valley-low mountain; erosive foothills; accumulative and erosive foothills; intermountainous accumulative and highly accumulative and erosive plains of large tectonic depressions; foothill base accumulative and erosive plains; piedmont declivous accumulative plains. The absolute altitudes of the region range from 600 to 700 m in the west and south-western foothills; and up to 4506 m above sea level (a.s.l.; the Belukha Mountain) in the north. The slopes are asymmetric: in the north they are short and steep; in the south—long and gentle. Intermountain depressions are frequent and mostly located in the lines of tectonic splits. The largest are the Markakol, Verkhnekabinskaya, Bobrovskaya, Orlovskaya, and Verkhne–Bukhtarminskaya depressions. The southern Altai Mountains are distinguished with gentle undulated plateau-like surfaces located at elevations of 1100–2000 m a.s.l.

1.2.3 Hydrography

The largest rivers are Bukhtarma, Kurchum, Kaljir, and Narym. All these rivers are characterized by comparatively narrow beds (about 2–5 ms), little depth (down to 1 or 3 m), and swift torrents. The main sources providing the recharging of rivers are melting snow and glaciers (40–70 %), the share of groundwaters in annual river discharge makes up 10–15 % (Boldyrev 1978). There are 1003 lakes in the region with total area of 528 km^2. Average availability of irregularly located lakes is 0.5 % (Filonets et al. 1978). For the most part, they are found in the northern and north-eastern part of the region, the largest ones being located in river valleys and intermountain depressions, like Markakol (area is 455 km^2), Bukhtarminskoye (4.23 km^2), and Ulmes (2.51 km^2). The recharging occurs at the account of precipitation as well as streams and rivulets.

1.2.4 Soils

There are two vertical oroclimatic levels of zonal soils in the southern Altai that correspond to the southern and northern slopes (Sokolov 1977). The common upper elements of the levels are primitive mountain tundra soils that develop under the influence of high-mountain xerothermic factors. On the lower slopes of the northern and (partly) eastern exposure, primary mountain tundra peat soils are distributed, as well as mountain taiga acid soils, mountain forest dark gray, sometimes chernozem-like soils; sparse mountain forest steppe and steppe chernozems. On the southern and western slopes, there are primitive mountain tundra peat soils or mountain meadow soils. They are followed in the lower slope direction by mountain peat forest meadow dark soils, mountain meadow steppe, and mountain steppe dark xerophilic soils. Mountain dark chestnut soils lie on the slopes of all expositions. Dark chestnut chernozem-like forest and steppe chernozems are wide spread in the intermountain depressions.

1.2.5 Climate

The southern Altai represents a zonal climatic boundary between dry steppe subzone and semidesert zone that concurs with the great axis of the Eurasian continent. The climate features are determined by altitudinal zonality and influence of northwest Atlantic humid winds that bring precipitation. Annual precipitation varies from 400 mm in foothills up to 800 or 1000 mm in mountain forest belt. The southern Altai is the coldest place in the Kazakstan Altai. Annual radiation balance value in the Markakol Lake is 22.1 $kcal/cm^3$ (Bolshenarymskoye village—33.9; Katon-Karagai village—28.0). Average annual air temperature (1446 m a.s.l.) is −4.5 °C. The ice in the lake starts melting in May. The hottest month is July (average temperature is +15.6 °C, the maximum reaches to +36 °C, and the minimum is +4 °C). Snow cover appears in late October or early November. Average depth of snow cover is

40–70 cm on sites without forest, up to 3 or 4 m in the upper parts of depressions. Snow cover lasts for 160 or 170 days. Average depth of soil freezing in the settlement of Katon-Karagai is 67 cm (from 47 down to 100 cm).

The average long-term climatic data have been taken from the meteorological station of Katon-Karagai located in the mountainous valley, at an elevation of 1081 m a.s.l. (Reference Book 2004; Research and applied Reference Book 1992). Average annual temperature is +1.5 °C; average annual precipitation is 450 mm; number of frost-free period in days is 111; average January temperature is −13.6 °C; average July temperature is 16.5 °C (Tables 1.1 and 1.2); the absolute minimum temperature was −44.4 °C (1951); the absolute maximum +35.7 °C (1983);and the sum of positive air temperature indices during the period with an average daily temperature above 10 °C is 1768.

1.3 The Kyrghyz Alatau Range

The Kyrghyz Alatau range is located latitudinally in the midst of the northern and western Tien Shan Mountains, extending between the Chu and Talass Rivers. The range belongs to the north Tien Shan. Its length is 360 km, width 30–40 km (Shlyghin 1971). The range is asymmetrical geomorphologically. Southern slope is steep, less dissected, while the northern one is more gentle and elongate. In this connection, the river valleys of the northern macro- slope are long and deep, while those of the southern one—steep and abrupt. The upper layer of the Kyrghyz Alatau represents a dissected rocky and glacier highland that in lower layers is sequentially replaced by mid- and low-mountain relief with a belt of ridged and crimpy foothills. The snow line runs at an elevation of 3200–3500 m a.s.l.

1.3.1 Topography

Only western part of the northern slope enters the territory of Kazakhstan with absolute altitudes up to 3700 m a.s.l. The slope is composed of metamorphic rocks and granites covered with sandstones, lime rocks, and the Carboniferous aggregations. Within its limits, the following types of relief are distinguished: high-mountain ridge

Table 1.1 Average monthly temperature (°C) at the meteorological station of Katon-Karagai from 1932 to 2000

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
−13.6	−12.2	−6.7	2.8	9.8	14.6	16.5	14.8	9.7	2.2	−7.6	−12.2

Table 1.2 Average monthly precipitation (mm) at the meteorological station of Katon-Karagai from 1932 to 2000

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
14	13	15	30	60	62	65	56	42	40	31	22

relief (3000–3700 m) with the modern glaciers, mid-mountain relief (2200–3000 m), low-mountain relief intermittent with foothills and valleys (1000–2200 m; The Relief of Kazakhstan 1991). The high-mountain relief with the modern glaciations is typical of the dividing part of the range. In its extreme south-eastern part (within Kazakhstan), leveling surfaces are covered with the modern glaciers. There are traces preserved from the two old glaciations—mid-quaternary semi covered and upper valley quaternary glaciations in the form of moraine outliers, relicts of glacier trough valleys, circuses, and cirques. The mid-mountain ridge relief occupies a wide zone. Slopes of river valleys are steep and abrupt. The valleys have an aspect of gorges and canyons. Low-mountain relief parts from the mid-mountain one by clear-cut ledges, with an average dissection depth of 300 m, representing turf-covered gentle slopes. Upstream valleys are V-formed, well developed, with a narrow floodplain and fragments of the first and second river terraces above floodplain. Foothills represent trails of sediment cores involved in elevations and dissected into separate beds and ridges.

1.3.2 Hydrography

The region's large rivers are Chu, Talass, Kuragaty, and Assa. The Chu River is formed from confluence of two mountain streams: Karakhojur and Kochkur that recharge from melting snow and glaciers (Assing et al. 1967). Most notable mountain streams falling into the Chu River are the Greater Kemin, Merke, Aspara, and Karakistak. The Talass River is formed from confluence of two streams: Karakhola and Ush-Koshoma. The Talass River's upper course is of a mixed snow and ice recharging with a rapid flow.

1.3.3 Soils

The following soils are distinguished on the Kyrghyz Alatau northern macro-slope (Assing et al. 1967; Mamytov 1987): (1) gray soils (650–1000 m), (2) light chestnut soils (700–1100 m), (3) dark chestnut soils (1100–1300 m), (4) mountain dark chestnut soils (1400–1500 m), (5) mountain chernozems (1500–2200 m), (6) high-mountain meadow subalpine soils (2200–3000 m), (7) high-mountain forest soils (2500–3000 m), and (8) high-mountain meadow peat and semi-peat alpine soils (3000–3500 m). There is no mountain chernozem and high-mountain forest soils zone in the western part of the range (Durasov and Tazabekov 1981). Rocks and stones occupy large areas on the mountain slopes.

1.3.4 Climate

A typical feature of the Kyrghyz Alatau climate is harsh continentality and aridity in foothills. The amount of precipitation grows, moving from west to east. In the lower parts of the range, spring, winter, and autumn precipitations prevail, summers are hot and dry. In the higher parts of the range (at an elevation above 1600 m), precipitation patterns are equable, rain falls in summer as well. In the western extremity of the Kyrghyz Alatau Mountains, summers are dry with temperatures up to +30 °C or +35 °C. Winters are cold, with little snow and temperatures of January and February go down to −25 °C. The climatic conditions are not the same at various altitudes. As the elevation grows, temperature changes from hot zone to cold one with larger annual amount of precipitation reaching 500 mm and over (Serpikov et al. 1965). Annual precipitation in the foothills varies between 200 and 300 mm. The maximum precipitation falls in spring and early summer. The climatic conditions of numerous transverse valleys depend on expositions of slopes and available orographical features. Winters of the narrow meridional valleys are colder, last for more than 4 months, while those of lower parts of valleys—three and a half months. Summers are hot only in lower parts of the valleys, in other places moderately warm. Precipitation patterns are irregular, depending on altitude and slope exposition, its amount fluctuates from 290 or 300 to 400 or 500 mm (Puzyryova 1975).

Average annual climate data have been taken from the meteorological station of Merke town located in foothill plain, at an elevation of 690 m a.s.l. (Reference Book on Climate of Kazakhstan 2004a; Research and applied Reference Book 1992). Average annual air temperature is 9.9 °C; average annual precipitation 411 mm; number of frost-free days is 171; average temperature in January is −5.1 °C; that in July is +24.7°C (Tables 1.3 and 1.4); the absolute minimum temperature was—36 °C (1951); the absolute maximum was +44 °C (1997); and the sum of positive air temperature indices during the period with an average daily temperature above 10 °C is 3622.

1.4 The Western Tien Shan Mountains

The western Tien Shan part in Kazakhstan belongs to the western extremity of the Talass Alatau range which extends westward in the form of two long mountain ranges—one in north-western direction called Jabagly and the other in south-western direction under the name of the Ugam–Karzhantau Mountains (altitude 4200 m a.s.l.). There are also smaller mountains—Kazygurt, Alatau, and the Syr Darya Karatau range. All are composed by Paleozoic solid rocks (mostly with Carboniferous marine calcareous sediments). The mountain ridges are stretched, horseshoe formed. The front sides of the mountains look out on to west, length being

Table 1.3 Average monthly air temperature (°C) in the meteorological station of Merke from 1936 to 1958 and from 1966 to 2000

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
−5.1	−3.6	3.1	11.5	16.8	21.7	24.7	22.8	17.3	10.0	2.1	−3.1

Table 1.4 Average monthly precipitation amount (mm) in the meteorological station of Merke from 1936 to 1958 and from 1966 to 2000

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
24	30	52	66	56	36	17	12	14	39	38	27

120 km, width 30 km in the east, and 45 km in the west. The eastern extremity of the "horseshoe" at the extension of 25 km westwards represents entirely highlands (Karmysheva 1982).

1.4.1 Topography

High ridges of the mostly elevated parts are characterized by high-mountain alpine relief with prevailing steep and highly steep slopes, cliffs, and stony screes. The pre-glacier layer is located at 3400–3800 m a.s.l. There is a high-mountain alpine relief with steep slopes and rare sites of the old leveling in the dividing part of some ridges. As the altitudes lessen, the relief is replaced by high-mountain leveled one, distinguished for the prevailing slightly dissected planoconvex watersheds with gentle, slightly steep and steep slopes. The upper part of the high-mountain belt bears traces of the old and modern glaciations, and the lower parts reveal traces of the old glaciation only (relic troughs, cirques, moraines), as well as the modern glaciations in the form of summer-melting snowfields. As a rule, the high-mountain relief is replaced by mid-mountain one within the altitudes of 1400–2300 m, with prevailing steep and highly steep slopes. The mid-mountain belt is replaced by low-mountain one where slopes are less steep. However, near streams and rivers, steep and highly steep slopes and sometimes cliffs (in canyons) prevail. Low mountains and ridges are distinguished for more leveled relief with gentle slopes. On the contrary, their northern and north-eastern slopes are characterized by steep slope with highly dissected relief (Zhikhareva et al. 1969).

1.4.2 Hydrography

The Talass Alatau forms a mighty mountainous assembly on the frontier with Kyrghyzstan with considerable glaciation fields where from numerous streams take their origin and flow in various directions. The most important are Maydantal and Oygain which flow south-westward; Kurkureusu, Koksay, and Aksay run northward; and Jabagly and Aksu westwards. Although the streams are torrential, the water is distributed unequally. The uppermost regions of the mountains and their southern slopes are almost waterless. The northern slopes, on the contrary, are flooded abundantly, together with the large and small valleys in northern and north-western directions between 1300 and 3000 m (Galitskiy 1968). Some of the streams (Aksu, Koksay, Mashat, Daubaba, Irsu) after leaving the mountains, run on the bed of deep canyons. The Sayramsu, Chunkuldek, and Baldybrek streams are the most easily accessible water sources.

1.4.3 Soils

In the high mountains around the pre-glacier level, there is almost no soil. The high-mountain soil cover is mostly represented by mountain alpine meadow and steppe (or high-mountain meadow and steppe), primitive or accidentally by normal shallow soils. Of less distribution is mountain steppe alpine (or high-mountain steppe) soils that form on less humid slopes. Mountain meadow alpine hydromorphic soils are still less here. They develop in negative relief elements under conditions of additional surface moistening (snowfields) and ground moistening below low-grassy meadows ("sazy").

Brown mountain shingly gravel soils are typical of high-mountain meadow steppes. The mid-mountain soils pertain to brown soil type with gravel and large amount of broken stone (especially on the southern slopes). The gray-brown mountain soils of the steep and gentle slopes in southern and western expositions are covered by shrubby tallgrass savannoids. Low mountains are distinguished with chestnut or brown soils (in the belt of trees and shrubs) that have a larger humus horizon in comparison with silt soils (Ghirkina 1965).

1.4.4 Climate

The climate is typical of Central Asian Mountain, where summers are hot and dry, with air temperature up to +30 °C in mid-mountains and up to 39 or +40 °C in foothills and piedmont plains. Winters are snowy, though not long, are cold with frosts down to −30 to −35 °C. On the northern slopes of mid-mountain in juniper forest belt, the height of snow cover is around 1.4–1.6 m. The snow is easily blown off in places unprotected from the winds. Frost may be observed in the alpine belt even in early July, and then, beginning from the second half of August (Bulavkin et al. 1971). Average annual precipitation for mid-mountain zone is about 700 mm, for high mountain—about 1000 mm. According to the seasons, precipitation is distributed as follows: winter—28 %, spring—38 %, summer—9 %, autumn—25 %.

Average long-term climate data were taken from the meteorological station of Tasaryk (Blinkovo) village which is located in the mountain valley at an elevation of 1122 m a.s.l. (Reference Book 2004b; Research and applied Reference Book 1992). Average annual air temperature is +9.6 °C; average annual precipitation 707 mm; the number of frost-free days is 185; average temperature in January is −3.1 °C; in July is +22.3 °C (Table 1.5 and 1.6); the absolute minimum temperature was −2.8 °C (1951); and the absolute maximum temperature was 40 °C (1983).

Table 1.5 Average monthly temperature (°C) at the meteorological station of Tasaryk in 1936–2000

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
−3.1	−1.5	3.1	10.3	15.1	19.7	22.3	21.3	16.1	9.6	3.5	−0.8

Table 1.6 Average monthly precipitation (mm) at the meteorological station of Tasaryk in 1936–2000

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
64	69	102	114	83	29	17	9	15	59	72	74

1.5 Flora, Vegetation, and Altitudinal Zonality

1.5.1 The Southern Altai

The southern Altai flora comprises 2091 species belonging to 604 genera and 119 families (Isayev 1993; Baytulin and Kotukhov 2011), which makes up approximately 40 % of the whole flora of Kazakhstan. The richness of flora on the southern Altai is due to its location in the center of the continent and hearth of Asian flora formation, and the region's highly diverse ecological conditions. Major families are: Asteraceae—299 species (14.3 %), Poaceae—281 (13.4 %), Fabaceae—170 (8.1 %), Brassicaceae—121 (5.8 %), Rosaceae—106 (5.1 %), Ranunculaceae—96 (4.6 %), Cyperaceae—80 (3.8 %), Caryophyllaceae—72 (3.4 %), Lamiaceae—72 (3.4 %), Scrophulariaceae—71 (3.4 %). The first 20 families make up 61.9 % of the whole flora. The main genera are *Astragalus*—66, *Carex*—53, *Salix*—42, *Artemisia*—37, *Allium*—35, *Oxytropis, Potentilla* -32, *Elymus*—28, *Poa*—27, *Ranunculus, Saussurea, Stipa*—25, *Veronica*—21, *Festuca*—19, *Viola*—19, *Pedicularis*—18, *Alchemilla, Juncus*—17, *Calamagrostis*—16, *Draba, Euphorbia*—15 species.

The number of plants on the high-mountain of the southern Altai lies around 374 species (17.9 %). Main families are Asteraceae—58 species (18.5 %), Poaceae—38 (10.2 %), Ranunculaceae—21 (5.6 %), Cyperaceae—19 (5.1 %), Brassicaceae—18 (4.8 %), Rosaceae—17 (4.5 %), Scrophulariaceae—16 (4.3 %), Fabaceae—15 (4.0 %), Caryophyllaceae—14 (3.7 %), Salicaceae—12 (3.2 %).

Endemic plants (68 species) demonstrate the unique features of the Altai flora: *Allium ledebourianum* Schult. et Schult., *Arenaria potaninii* Schischk., *Corallorrhiza trifida* Chatel., *Dactylis altaica* Bess., *Echinops saissanicus* (B. Keller) Bobr., *Elymus longespicatus* Kotuch., *Festuca kurtschumica* E. Alexeev., *Papaver tenellum* Tolm., *Pulsatilla patens* (L.) Mill., *Stemmacantha carthamoides* (Will.) M. Dittrich, *Rhodiola quadrifid*a (Pall.) Fisch.et Mey, *Trollius altaicus* C. A. Mey, *Tulipa altaica* Pall ex Spreng., etc. The abundance of endemic plants in the southern Altai is determined by intensive migration of species. An intensive hybridization of genus *Elymus* is observed at both species and generic levels in common habitats of mountain-steppe and mountain-siberian species, affected by severe environmental conditions (sharp continental climate, summer rainfall abundance, the presence of the modern glaciation, high insolation, and frequent negative temperatures in vegetative period). Intergeneric hybrids (x *Elymotrigia* Hyl) arise usually with *Elytrigia* (*E. gmelinii, E. repens, E. geniculata*, etc.; Kotukhov 1990).

From among the 73 rare plant species of the southern Altai, 27 are included in the Red List of Kazakhstan (The List of Rare and Threatened Plant species 2006): *Adonis vernalis L., Allium altaicum Pall., A. ledebourianum Schult. et Schult. fil., A. microdictyon Prokh., Arnica iljinii (Maguire) Iljin, Corydalis bracteata (Steph.) Pers., Cypripedium guttatum Sw., Dactylorhiza longifolia (L. Neum.) Aver., D. fuchsii (Druce) Soo, D. incarnata (L.) Soo, Epipogium aphyllum (F. W.Schmidt) Sw., Erythronium sibiricum (Fisch. et C. A. Mey.) Kryl., Gymnospermium altaicum (Pall.) Spach, Huperzia selago (L.) Bernh. et Schrank et C. Mart., Lilium pilosiusculum*

(Freyn) Miscz., Macropodium nivale (Pall.) R. Br., Paeonia anomala L., P. hybrida Pall., Paris quadrifolia L., Pulsatilla patens (L.) Mill., Rheum compactum L., Rhodiola rosea L., Sanicula europaea L., Sibiraea laevigata (L.) Maxim., Stipa pennata L., Tulipa patens Agardh ex Schult. et Schult. fil., T. uniflora (L.) Bess. ex Baker.

There are 98 wild relatives of crop species in the region, mostly belonging to the families of Fabaceae, Rosaceae, Alliaceae, Asteraceae (*Hordeum brevisubulatum, H. bogdanii, H. turkestanicum, Allium caeruleum, A. decipiens, A. flavidum, A. altaicum*, *Amygdalus ledebouriana, Fragaria vesca, F. viridis, Rosa majalis, R. acicularis, R. caesius, R. idaeus, R. saxatilis, Crataegus chlorocarpa, Glycyrrhiza uralensis, Medicago lupulina, M. falcata, Onobrychis arenaria, O. arvensis Vicia megalotropis, V. tetrasperma, Lactuca altaica, L. tatarica, L. undulata*, etc).

The following altitudinal belts are identified in the southern Altai ridges: desert steppe, dry steppe, meadow steppe, mountain shrub meadow steppe, mountain forest steppe, mountain taiga, subalpine, alpine tundra, and high-mountain nival belts (Dimeyeva et al. 2012).

1.5.2 Desert-Steppe belt (400–600 to 800 m a.s.l.)

Sagebrush–feathergrass–fescue and sagebrush–festcue desert steppes extend to foothills and foothill plains of southern slopes. The plant cover is dominated by bunch grasses: (*Stipa sareptana, Festuca valesiaca, Koeleria cristata*), sagebrushes (*Artemisia gracilescens, A. compacta, A. frigida*), dwarf shrubs and dwarf semishrubs (*Kochia prostrata, Ephedra distachya, Thymus marschallianus*), shrubs are also frequent (*Caragana pumila, C. camilli-schneideri, C. frutex, Spiraea hypericifolia*), including desert ones (*Krascheninnikovia ceratoides, Atraphaxis spinosa, Halimodendron halodendron*).

1.5.3 Dry Steppe Belt (400–700 or 800–1200 m a.s.l.)

Dry steppe belt (400–700 or 800–1200 m a.s.l.) is typical of piedmont gentle slope plains of southern exposure. The plant cover is composed of dry steppes of feathergrass–fescue communities with shrubs (*Festuca valesiaca, Stipa capillata, Stipa lessingiana, Spiraea hypericifolia, Caragana frutex*) and abundant forbs (*Jurinea multiflrora, Galium ruthenicum, Iris scariosa, Dianthus rigidus, Potentilla acaulis, Potentilla bifurca, Galatella tatarica, Artemisia frigida, Artemisia marschalliana*).

1.5.4 Meadow-Steppe belt (900–1500 m a.s.l.)

The plant cover is dominated by bunch grasses (*Stipa lessingiana, S. krylovii, Festuca valesiaca, Helictotrichon altaicum*) and meadow grasses (*Dactylis glomerata, Alopecurus pratensis, Poa sibirica, Calamagrostis langsdorffii*). Among forbs are

Achillea nobilis, Galium verum, Pulsatilla multifida, Ziziphora clinopodioides and broad-leaved species: *Heracleum dissectum, Veratrum lobelianum, Aconitum leucostomum, Angelica decurrens, Delphinium elatum*. At the upper highland sites, genuine forb-grass upland meadows are observed (*Poa pratensis, Carum carvi, Rhinanthus glacialis, Euphrasia hirtella, Taraxacum* spp., *Plantago* spp*., Lamium album, Geranium affine, Rumex confertus, Urtica dioica*). The sediment cores are dominated by steppe meadows with another set of prevailing grasses (*Phleum phleoides, Helictotrichon pubescens, Poa angustifolia*) and forbs (*Tragopogon orientalis, Bupleurum longifolium, Iris ruthenica, Ligularia glauca, Tanacetum achilleifolium*). In combination with these occur shrubby meadow steppes. The shrub layer consists of *Rosa pimpinellifolia, Lonicera tatarica, Spiraea media, S. chamaedrifolia, Cotoneaster melanocarpa*; herbs are dominated by *Phleum phleoides, Helictotrichon pubescens, H. altaicum, Poa angustifolia, Dactylis glomerata, Clematis integrifolia, Pulsatilla patens, Lupinaster pentaphyllus, Lathyrus humilis, L. transsylvanicus, L. gmelinii*. They are frequently mixed with secondary origin shrubby grooves of *Spiraea media, Rosa pimpinellifolia, R. acicularis, Cotoneaster melanocarpus, Rubus idaeus*.

1.5.5 Mountain Shrub Meadow-Steppe Belt (1200–1500 m or 1800 m a.s.l.)

Mountain shrub meadow-steppe belt (1200–1500 m or 1800 m a.s.l.) is located on southern, south-eastern, north-western, and north-eastern slopes, where humid tall-herb meadows are widespread (*Calamagrostis langsdorffii, Milium effusum, Dactylis glomerata, Veratrum lobelianum, Chamaenerium angustifolium*) in combination with shrubby thickets (*Spiraea chamaedrifolia, Lonicera altaica, Ribesatro purpureum, Rubus idaeus*), as well as moderate-humid shrub-like xeropetrphytic steppes with prevailing petrophytic species (*Cleistogenes squarrosa, Centaurea sibirica, Orostachys spinosa, Aster alpinus, Sedum hybridum, Thymus altaicus*) and thickets of steppe bushes.

1.5.6 Mountain Forest-Steppe Belt (1500–1900 m a.s.l.)

Mountain forest-steppe belt (1500–1900 m a.s.l.) is formed at the lower border of forest. For the most part, it consists of larches that grow on gentle and medium steep slopes of northern and north-eastern exposure, sometimes on north-western or western exposure. Timber stands of *Larix sibirica* are pure, with little presence of *Betula pendula* in young stands. Among the underwood we come across *Lonicera altaica, Spiraea chamaedrifolia, Ribes atropurpureum, Rubus idaeus, Rosa pimpinellifolia, Rosa acicularis, Cotoneaster melanocarpa*. Herb layer is well developed, with prevailing grasses of *Calamagrostis epigeios, C. langsdorffii, Dactylis glomerata, Alopecurus pratensis*; from forbs *Polemonium caeruleum,* *Galium verum, Lathyrus pisiformis, Vicia cracca, Alchemilla xanthochlora, Carex pediformis*, *Aconitum leucostomum, Chamaenerium angustifolium, Paeonia anomala, Galium boreale* are common.

On southern slopes, stony meadow shrub steppes are found. The shrubby layer is represented by *Spiraea media, Cotoneaster melanocarpus, C. uniflorus, Rosa pimpinellifolia, R. acicularis*. In the herb layer, *Phleum phleoides, Helictotrichon pubescens, Poa angustifolia, Festuca krylovii, Stipa pennata, Carex pediformis, Veronica spicata, Dracocephalum nutans* are observed. Stony habitats are dominated by *Corydalis nobilis, Rheum compactum, Aconogonon alpinum,* while sites with gravel chippings are covered by *Ziziphora clinopodioides, Scutellaria supina, Allium nutans*.

Birch-aspen (*Populus tremula, Betula pendula*) forests are widespread. Aspen stands with forbs are formed on burnt out and slashed sites. Underwood consists of *Spiraea media, Rosa pimpinellifolia.* Herbage is dominated by *Dactylis glomerata, Calamagrostis epigeios, Geranium albiflorum, Veratrum lobelianum.* Aspen stands with large herbs are located on south-eastern slopes of high steepness; they are frequent on rocky places, where vegetation begins to appear. Underwood consists of *Lonicera altaica, Spiraea media, Ribes altissimum*. In herbage, tall plants are present: *Heracleum dissectum*, *Aconitum septentrionale*, *Urtica dioica, Dactylis glomerata, Calamagrostis epigeios*. Moss cover is absent.

Floodplains are dominated by gallery poplar forests (*Populus laurifolia*) with forb-grass layer, sometimes mixed with larch, birch, and willows. In underwood, *Ribes nigrum, R. atropurpureum, Lonicera altaica* are found.

1.5.7 Mountain Taiga Belt (1550 or 1900–2100 m a.s.l.)

Mountain taiga belt (1550 or 1900–2100 m a.s.l.) is typical of northern and northwestern slopes. Three altitudinal sub-belts are distinguished there.

1.5.8 Lower Altitudinal Sub-Belt

Lower altitudinal sub-belt with birch-larch forests (*Larix sibirica, Betula pendula*) participated by *Abies sibirica*. The undergrowth is formed by *Lonicera altaica, Rosa acicularis, Ribes atropurpureum, Rubus idaeus, Sorbus sibirica*. The herbacous layer is dominated by *Calamagrostis epigeios, C. langsdorffii, Dactylis glomerata, Angelica decurrens, Paeonia anomala*; forbs are represented by *Rubus saxatilis, Crepis lyrata, Galium boreale, Saussurea controversa, Iris ruthenica, Geranium albiflorum*. Shrubby larch stands mixed with birches and fir trees are also found. Underwood is highly dense with *Spiraea media, Rosa acicularis, Lonicera altaica*. Herbs are composed of mesophylous grasses: *Calamagrostis epigeios, Aconitum leucostomum, Cerastium pauciflorum*. Moss cover is absent.

1.5.9 Middle Altitudinal Sub-belt

Middle altitudinal sub-belt is covered by larch and dark-coniferous forests. There are forbs, abies (*Abies sibirica*), moss larch forests. The underwood in forb larch communities is absent or rare (*Ribes atropurpureum, Spiraea media*). The herbs are multilayered and dense. Upper sites are dominated by *Dactylis glomerata*; in hollows mesophyllous species are found: *Aconitum septentrionale, Thalictrum simplex, T. minus, Heracleum sibiricum, Angelica decurrens*, *Paeonia anomala*. Mixed abies—larch forests with mosses are widespread in the lower part of northern slopes. The herb and moss cover is dominated by *Lycopodium annotinum, Pyrola rotundifolia, Linnaea borealis, Moneses uniflora.* Spruces (*Picea obovata*) occur on the slopes of eastern exposition. *Lonicera altaica, Spiraea media, Cotoneaster melanocarpa, Ribes atropurpureum* are widespread in shrubby layer. *Deschampsia cespitosa, Geranium pseudosibiricum, Chamaenerium angustifolium, Helictotrichon hookeri* are abundant in herb layer. Fir and birch (anthropogenic) forests are found in several places. Taiga with *Abies sibirica* occurs in the middle belt of the southern macro-slope of the Kurshum ridge, at an elevation of 1600–1700 m. *Abies sibirica* stands are pure, with occasional trees of *Betula pendula, Larix sibirica*. The underwood is sparse and consists of *Lonicera altaica, Sorbus sibirica*. Herbaceous cover is dominated by *Vaccinium myrtillus, Calamagrostis* spp, *Saussurea frolowii, Phlomoides alpina.* Moist dark coniferous forests consist of abies, singular trees of spruce (*Picea obovata*), Siberian cedar (*Pinus sibirica*), larch, birch. They are met in the middle part of northern slopes up to 1600 m. The underwood is composed of *Sorbus sibirica, Ribes altissimum, Lonicera altaica, Rubus idaeus.* Herbaceous cover of middle density is made up from *Carex* spp*, Saussurea frolowii, Pedicularis proboscidea*, in hollows we find *Calamagrostis* spp. Moss cover is well developed.

Pinus sibirica forests are located on the lower parts of slopes at an elevation of 1500–1700 m. In the shrub layer, *Lonicera altaica, Ribes atropurpureum* occur, and in the herbaceous layer *Calamagrostis langsdorffii, Carex macroura, Aconitum leucostomum, A. decipiens* are widespread. Cedar forests of *Vaccinium myrtillus* occupy the middle parts of slopes at an elevation of 1700–2000 m. Shrubby layer is sparse (*Lonicera altaica, Spirarea chamaedrifolia*). In herbaceous layer, *Linnaea borealis, Aconitum decipiens* are present, with widespread mosses (*Hylocomium proliferi, Pleurosium schreberi*).

1.5.10 Upper Altitudinal Sub-Belt

Upper altitudinal sub-belt corresponds to the upper border of forest (1800–2400 m a.s.l.) The vegetation is represented by larch woodlands with fragments of steppe alpine meadows (*Festuca valesiaca, F. kryloviana, Helictotrichon schellianum*). Underwood composition includes *Spiraea media, Juniperus sibirica, Cotoneaster uniflorus.* Steppe species prevail in the herbage: *Festuca valesiaca, Iris ruthenica, I. bloudowii*. Birch-and-blueberry-larch stands as well as birch–cedar woodlands are mixed with the mountainous and tundra vegetation.

1.5.11 Subalpine Belt (1800–2200 m a.s.l.)

Subalpine belt (1800–2200 m a.s.l.) comprises communities of the upper forest border. These are meadow and subalpine forest communities with two sub-belts.

1.5.12 Sub-Belt of Subalpine Meadows

The conditions are characterized by sufficient moistening due to late melting of snow cover, vapor condensation, and large rainfall in summer. Tall-herb subalpine meadows are expressed on the northern slopes. In the lower part of subalpine belt, they alternate with tall-herb-larch stands; in the upper micro-slopes of northern exposure—with subalpine larch communities. They have similar type of vegetation as in forest tall-herb meadows. However, they are characterized with an original species composition and genesis representing a primary formation, related to the upper forest border, while forest meadows result from fires and forest degradation as in the Mediterranean (Ozturk et al. 2010a, b). Grass composition is poor: *Calamagrostis* spp, *Poa sibirica, Alopecurus alpinus.* Moss cover is either absent or poorly developed. The herbage includes 64 % of forest species which are present in layer I: *Stemmacantha carthamoides*, *Saussurea frolowii*, *Trollius altaicus, Geranium albiflorum, Bupleurum longifolium, Delphinium elatum, Aconitum septentrionale*, *Hedysarum austrosibiricum, Veratrum lobelianum*; and 50 % of arcto-alpine species which are present in layer II: *Dracocephalum grandiflorum, Phlomoides alpina, Aquilegia glandulosa, Omalotheca norvegica.*

Low-herb subalpine meadows are formed as a result of exceeding grazing and consist of *Ptarmica ledebourii, Tanacetum achilleifolium*, *Delphinium elatum, Aconitum leucostomum*. The degradation is accompanied by the disappearance of palatable species and plants trampled by cattle, with enhanced role of rosette forms as in the high altitudes of east Mediterranean (Ozturk et al. 2008). Dominants are *Alchemilla sibirica, Geranium albiflorum, Sanguisorba alpina, Saussurea frolowii.*

1.5.13 Sub-Belt with Dominating Dwarf Shrubs

Betula rotundifolia thickets develop under the cover of subalpine forest communities. At the border with alpine tundra belt, the species form combinations with tundra communities (fragmented complex of alpine meadows, moss and lichen tundras). Prostrate juniper thickets (*Juniperus sibirica, J. pseudosabina*) occupy the southern slopes.

In the place of glacier moraine lakes, high-mountain swamps develop. Water sites are dominated by *Carex* species, *Eriophorum polystachion* flourishes on dry habitats, hills and hummocks are covered with moss. Community composition includes dwarf shrubs (*Salix* spp, *Betula rotundifolia*). Among alpine herbage, *Allium ledebourianum, A. schoenoprasum, Pedicularis compacta, Swertia obtusa* are present.

In the upper course of streams, subalpine willow communities occur (*Salix glauca, S. krylovii, S. vestita*). Herbage is composed by *Aconitum altaicum, Swertia obtusa, Angelica decurrens,* but *Rhodiola rosea, Allium altaicum* cover the rocks.

1.5.14 Alpine Tundra Belt (2000–2500 m a.s.l.)

There is not a clear floristic and phytocoenotical difference between alpine tundra and alpine meadows. Sparseness of plant cover as well as moss and lichen development is taken as a criterion for distinguishing grassy tundras from alpine meadows. There are frequent species that occasionally penetrate the alpine tundra zone from the lower mountainous belts: *Caltha palustris, Angelica decurrens*. The elevated relief elements of the lower part of the belt are represented by low-herb alpine meadows dominated by the following species: *Viola altaica, Bistorta major, Lloydia serotina, Gentiana grandiflora, Schulzia crinita, Aquilegia glandulosa*. Grasses are few: *Festuca kryloviana, Anthoxantum odoratum, Festuca altaica.* Prostrate dwarf willows are present: *Salix turczaninowii.* Moss cover is usually developed. Sedge-grass tundras are mostly distributed on is 25–30 %. *Festuca kryloviana* is dominant, and *Trisetum spicatum, Anthoxanthum odoratum, Carex melanocarpa, Lusula sibirica, Poa alpina* are the codominants. Forbs include *Tripleurospermum ambiguum, Potentilla evestita, Dracocephalum grandiflorum*. Meadow tundras with *Kobresia myosuroides* are found rarely on the northern slopes. Small abundance of *Festuca kryloviana,* and *Rhodiola quadrifida* is noted.

Alpine low-herb meadows with *Ranunculus altaicus, R. rubrocalyx, Potentilla evestita, Pedicularis amoena* tend to grow in depressions with lately melting snowfield spots (late July to early August). In gravel habitats, lichen tundras (*Cladonia, Cetraria*) are observed. On slopes, near groundwater outcomes, high-mountain moss swamps are spread (*Minium, Bryum, Sphagnum* spp.). Herb layer is dominated by *Carex* spp, *Eriophorum angustifolium, Allium schoenoprasum.*

Tundras with low ecoform of *Betula rotundifolia* and alpine willow species (*Salix glauca, S. turczaninowii, S. vestita*) are found rarely. Gravel and rocky tundras occupy highly gravel soils on the southern slopes of ridges. The herbaceous cover is not closed. Among grasses dominants are *Festuca kryloviana, Poa altaica, Trisetum spicatum.* Forbs include *Bistorta major, Callianthemum angustifolium, Rhodiola quadrifida, Potentilla gelida, Eritrichium villosum, Papaver nudicaule*, *Huperzia selago*, *Patrinia sibirica, Leiospora exscapa.*

Tundras with *Dryas oxyodontha* are occasional and tend to gentle gravel permafrost slopes.

1.5.15 High-Mountain Nival Belt (above 2800 m a.s.l.)

Higher plants are absent. Only some lichen species occur on the rocky outcrops.

The spatial distribution of plant cover in the southern Altai follows the altitudinal zonation pattern, and an asymmetry is clearly expressed by the plant cover on slopes of northern and southern exposure with prevailing forest and forest-steppe communities. The slopes of intermediate exposure are distinguished with rich diversity; mosaic distribution of plants is typical of herbaceous communities.

According to the ecological-physiognomic classification, six vegetation types are found in the southern Altai: arboreal, shrubby, steppe, meadow, swamp, and tundra vegetation (Table 1.7).

1.5.16 The Kyrghyz Alatau Range

The flora of Kyrghyz Alatau, within the area of Kazakhstan, is represented by over 850 species of vascular plants belonging to 345 genera from 74 families (Aralbay et al. 2007). The dominant families are Asteraceae—128 (15%), Fabaceae—76 (9%), Poaceae—59 (7%), Caryophyllaceae—47 (5.6%), Ranunculaceae—47 (5.6%), Brassicaceae—41 (5%), Rosaceae—40 (4.7%), Lamiaceae—36 (4%), Scrophulariaceae—35 (4%), Apiaceae—30 (3.6%). The dominant genera are *Astragalus*—33, *Erygeron*—19, *Veronica*—16, *Allium*—16, *Ranunculus*—15, *Artemisia*—12 species.

High-mountain plants growing in the subalpine and alpine zones make up 30% of the flora including 254 species from 129 genera and belonging to 38 families. The dominant families are Asteraceae—39 species (15.4%), Ranunculaceae—27 (10.6%), Poaceae—16 (6.3%), Scrophulariaceae—14 (5.5%), Apiaceae—13 (5%), Caryophyllaceae—11 (4.3%), Fabaceae—10 (4%), Lamiaceae—10 (4%), Rosaceae—10 (4%), Brassicaceae—9 (3.5%), Caprifoliaceae—9 (3.5%), The dominant genera are *Ranunculus*—8, *Saxifraga*—7, *Rhodiola*—5, *Draba*—5, *Polygonum*—5. Among them, 25 species grow in the alpine belt, on the old moraine soils, on sandy and stony slopes, on talus and stone soil bottoms up to the elevation of 4000 m, close to glaciers and snow fields. These are *Erigeron heterochaeta* (Benth. ex Clarke) Botsch., *E. pallidus* M. Pop., *E. olgae* Regel et Schmalh., *Dracacephalum origanoides* Steph., *D. grandiflorum* L., *D. stamineum* Kar. et Kir., *Festuca coelestis* (St-Yves) V.I. Krecz. et Bobrov.

There are 15 (1.8%) endemics distributed here: *Atragene sibirica* L., *Limonium dichroanthum* (Rupr.) Ik.-Gal., *Primula minkwitziae* W.W. Sm., *Rosularia turkestanica* (Regel et C. Winkl.) A. Berger, *Cotoneaster oliganthus* Pojark., *Oxytropis macrocarpa* Kar. et Kir., *Aulacospermum tianschanicum* (Korov.) C. Norm., *Scutellaria subcaespitosa* Pavl., *Pseuderemostachys sewerzowii* (Herd.) M. Pop., *Echinops talassicus Golosk.*, *E. fastigiatus* R. Kam.et Tscherneva, *Cousinia kazachorum* Juz. et Tschern., *C. triflora* Schrenk, *Allium trachyscordum* Vved., *A. talassicum Regel.*

In addition, there are 30 rare plant species listed in the Red List of Kazakhstan (2006). Trees and shrubs are represented by seven species—*Malus sieversii* (Ledeb.) M. Roem., *Juniperus seravschanica* Kom., *Celtis caucasica* Willd., *Sorbus persica* Hedl., *Ribes janczewskii* Pojark., *Louiseania ulmifolia* (Franch.) Pachom., *Abelia corymbosa* Regel et Schmalh, *Armeniaca vulgaris* Lam. The rest of the species

Table 1.7 Ecological-physiognomic types of vegetation in the southern Altai Mountains

Vegetation type	Vegetation subtype	Main community types
Arboreal	Light coniferous forest	Communities dominated by: *Larix sibirica*, with *Vaccinium myrtillus*, *Hylocomium proliferi*, *Pleurosium schreberi*, *Spiraea chamaedrifolia*, *Lonicera altaica*, *Ribes atropurpureum*, *Aconitum leucostomum*, *Paeonia anomala*, *Dactylis glomerata*, *Chamaenerium angustifolium*. *Trollius altaicus*, *Bupleurum longifolium*, *Geranium pseudosibiricum*, *Seseli condensatum*, *Luzula sibirica*, *Hieracium korshinskyi*, *Thalictrum simplex*
	Dark coniferous forest	Communities dominated by: *Picea abovata*, *Abies sibirica*, *Pinus sibirica*, with *Lonicera altaica*, *Vaccinium myrtillus, Spiraea media*, *S. chamaedrifolia*, *Cotoneaster melanocarpa*, *Ribes atropurpureum*, *Carex macroura*, *Deschampsia cespitosa*, *Calamagrostis langsdorffii*, *Helictotrichon hookeri*, *Geranium pseudosibiricum*, *Chamaenerium angustifolium*, *Luzula sibirica*, *Linnaea borealis*, *Hylocomium proliferi*, *Pleurosium schreberi*, *Aconitum leucostomum*, *A. decipiens*
	Deciduous forest	Communities dominated by: *Populus laurifolia*, *P. canescens*, *P. tremula*, *Betula pendula*, with *Salix pyrolifolia*, *S. viminalis*, *S. rorida*, *Rosa laxa*, *Crataegus chlorocarpa*, *Viburnum opulus*, *Lonicera tatarica*, *Spiraea media*, *Dactylis glomerata*, *Bromopsis inermis*, *Calamagrostis epigeios*, *Agrostis gigantea*, *Helictotrichon pubescens*, *Filipendula ulmaria*, *Inula helenium*, *Sanguisorba officinalis*, *Mentha arvensis*, *Angelica decurrens*, *Lupinaster pentaphyllus*, *Lathyrus pratensis*, *Allium flavidum*
	Floodplain forest	Communities dominated by: *Betula pendula*, *Salix pentandra, S. rosmarinifolia*, *S. jenisseensis*, *Padus avium* with *Picea obovata*, *Myricaria bracteata*, *M. squarrosa*, *Pentaphylloides fruticosa, Ribes nigrum*, *Carex aterrima*, *Deschampsia cespitosa*, *Lupinaster pentaphyllus*, *Chamaenerium angustifolium*, *Aconitum leucostomum, Caltha palustris, Linnaea borealis, Pyrola rotundifolia*, *Equisetum palustre*, *Filipendula ulmaria*, *Geum rivale*
Shrubby	Xeromesophytic dwarf semishrub	Communities dominated by: *Spiraea hypericifolia*, *S. chamaedrifolia*, *Amygdalus ledebouriana, Rosa pimpinellifolia*, *Lonicera tatarica*, *L. altaica*, *Ribes atropurpureum*, *Rubus idaeus*, *Daphne altaica*
	Petrophytic dwarf shrub	Communities dominated by: *Juniperus sibirica*, *Cotoneaster pojarkovae*, *Spiraea trilobata*, *Caragana frutex*, *Lonicera microphylla*
Steppe	Desert steppe	Communities dominated by: *Stipa sareptana*, *Festuca valesiaca*, *Koeleria cristata*, *Artemisia sublessingiana*, *A. gracilescens, A. compacta*
	Dry steppe	Communities dominated by: *Stipa capillata, S. lessingiana, S. zalesskii*, *Festuca valesiaca*, with *Koeleria cristata*, *Phleum phleoides*, *Cleistogenes squarrosa*, *Agropyron tarbagataicum*, *Jurinea multiflora, Galium ruthenicum*, *Iris scariosa*, *Dianthus rigidus, Galatella tatarica*, *Artemisia frigida*, *A. marschalliana*

Table 1.7 (continued)

Vegetation type	Vegetation subtype	Main community types
	Meadow steppe	Communities dominated by: *Stipa lessingiana*, *S. kryloviana*, *Festuca valesiaca*, *Helictotrichon altaicum*, with *Achillea nobilis*, *Galium verum*, *Pulsatilla multifida*, *Ziziphora clinopodioides*, *Fragaria viridis*, *Lathyrus gmelinii* and shrubs (*Rosa pimpinellifolia*, *Spiraea hypericifolia*)
	Xeropetrophytic shrubby steppe	Communities dominated by: *Stipa lessingiana*, *S. sareptana*, *S. capillata*, *Festuca valesiaca*, *Koeleria cristata, Helictotrichon altaicum*, *Carex pediformis*, with shrubs (*Spiraea trilobata*, *S. hypericifolia*, *Juniperus pseudosa-bina*) and herbs (*Centaurea sibirica*, *Patrinia intermedia, Orostachys spinosa*, *Phlomoides alpina*, *Allium rubens*, *Centaurea sibirica*, *Thalictrum foetidum*)
Meadow	Mountain rich forb-grass meadows	Communities dominated by: *Calamagrostis langsdorffii*, *Dactylis glomerata*, *Alopecurus pratensis*, *Brachypodium pinnatum*, *Helictotrichon pubescens*, *Agrostis gigantea*, *Cirsium helenioides*, *Delphinium elatum*, *Aconitum leucos-tomum*, *Veratrum lobelianum*, *Heracleum dissectum*. *Geranium albiflorum*, *Viola disjuncta*, *Vicia cracca*, *Lathyrus pratensis*, *Phlomoides tuberosa*, *Stemmacantha carthamoides*
	Floodplain-valley swamp meadows	Communities dominated by: *Deschampsia cespitosa*, *Alopecurus pratensis*, *Dactylis glomerata*, *Calamagrostis langsdorffii*, *Phragmites australis*, *Carex cespitosa*, *C. vesicaria*, *Parnassia palustris*, *Geranium albiflorum*, *Hylotelephium triphyllum*, *Stellaria palustris*, *Angelica decurrens*, *Filipendula ulmaria*, *Ligularia altaica*, *Scirpus sylvaticus*, *Sanguisorba officinalis*, *Thalictrum simplex*, *Ranunculus repens*
	Floodplain- valley true meadows	Communities dominated by: *Bromopsis inermis*, *Leymus ramosus*, *Elytrigia repens*, *Dactylis glomerata*, *Alopecu-rus pratensis*, *Calamagrostis epigeios*, *Helictorichon pubescens*, *Aconitum decipiens*, *A.anthoroideum*, *Bupleurum multinerve*, *Gentianopsis barbata*, *Geranium collinum*
	Floodplain- valley steppe meadows	Communities dominated by: *Stipa kirghisorum*, *S. sareptana*, *Festuca valesiaca*, *F. pseudoovina, Koeleria cristata*, *Poa transbaicalica*, *Bromopsis inermis*, *Galium verum*, *Achillea nobilis*, *Artemisia armeniaca*, *Dianthus superbus*, *Tanacethum achilleifolium, Alcea nudiflora*, *Centaurea ruthenica*, *Hypericum perforatum*, *Medicago falcata*, *Phlo-mis tuberosa*, *Paeonia hybrida*
	High-mountain subalpine meadows	Communities dominated by: *Helictotrichon pubescens*, *Elymus* sp., *Anthoxanthum odoratum*, *Phleum phleoides*, *Bistorta elliptica*, *Crepis chrysantha*, *Alchemilla ledebourii*, *Antennaria dioica*, *Phlomoides alpina*
	High-mountain alpine meadows	Communities dominated by: *Dactylis glomerata*, *Phleum alpinum*, *Deschampsia koeleroides*, *Carex stenocarpa*, *C. aterrima*, *Antennaria dioica*, *Omalotheca norvegica*, *Allium ledebourianum*

Table 1.7 (continued)

Vegetation type	Vegetation subtype	Main community types
Swamp	Tussock hollow sedge swamps	Communities dominated by: *Carex cespitosa*, *C. acuta*, *Calamagrostis langsdorffii*, *Juncus filiformis, Deschampsia cespitosa*, *Sanguisorba officinalis*
	Forb-sedge swamps	Communities dominated by: *Carex cespitosa*, *C. acuta*, with *Dactylis glomerata*, *Calamagrostis langsdorffii*, *Deschampsia cespitosa*, *Filipendula ulmaria*, *Veronica spicata*, *Mentha aquatica*
	Reed swamps	Communities dominated by: *Scirpus sylvaticus* with *Carex, Juncus filiformis, Agrostis gigantea*, *Poa palustris*, *Vicia cracca, Stellaria palustris*, *Veronica longifolia, Lathyrus pratensis, Trollius altaicus*, *Filipendula ulmaria*
	High-mountain sedge–cotton-grass swamps	Communities dominatied by: *Eriophorum angustifolium*, *Carex caryophyllea*, with *Salix* sp., *Betula rotundifolia*, *Allium ledebourianum, A. schoenoprasum, Pedicularis compacta*, *Swertia obtusa*
	Moss swamps	Communities dominated by: *Mnium*, *Bryum*, *Sphagnum* with *Carex* sp., *Eriophorum angustifolium*, *Allium schoenoprasum*
Tundra	Sedge–grass tundra	Communities dominated by: *Festuca kryloviana*, *Carex melanocarpa*, with *Trisetum spicatum*, *Anthoxantum odoratum, Luzula sibirica*, *Poa alpina*, *Potentilla evestita, Tripleurospermum ambiguum*, *Dracocephalum grandiflorum*, *Salix turczaninowii*
	Meadow-kobresia tundra	Communities dominated by: *Kobresia myosoroides*, with *Festuca kryloviana*, *Rhodiola quadrifida*, *Salix glauca*, *S. turczaninowii*, *S. vestita*
	Dryad tundras	Communities dominated by: *Dryas oxyodonta* with *Festuca ovina*, *Rumex alpestris*, *Ranunculus altaicus*, *Lagotis integrifolia*, *Rhodiola quadrifida*, *Potentilla gelida, Eritrichium villosum, Papaver nudicaule*, *Huperzia selago*, *Patrinia sibirica, Leiospora exscapa*
	Lichen tundra	Communities dominated by: Cladonia, Cetraria, with *Festuca kryloviana*, *Trisetum spicatum*, *Gentiana algida*, *Schulzia crinita*, *Swertia obtusa*, *Salix glauca*, *S. turczaninowii*, *S. vestita*
	Dwarf shrub tundra	Communities dominated by: *Betula rotundifolia* with *Salix glauca*, *S. reticulata*, *S. lanata*, *Lonicera hispida*, *L. altaica*, *Ribes fragrans*
	Gravel and stony tundra	Single plants and micro-groups of *Cortusa altaica, Saxifraga sibirica*, *Macropodium nivale, Oxyria digyna, Rhodiola algida*, *Paraquilegia anemonoides*, *Bergenia crassifolia*, *Festuca kryloviana*, *Trisetum spicatum*, *Anthoxanthum odoratum*

are perennial herbs which mostly grow in low-and medium mountain steppes. Two species reach the subalpine belt: *Juno orchioides* (Carr.) Vved., *Pseuderemostachys sewerzowii*. *Aconitum talassicum* Popov, *Allochrusa gypsophiloides* (Regel) Schischk*., Armeniaca vulgaris, Kosopoljanskia turkestanica* Korovin., *Abelia corymbosa, Iridodictyum kolpakowskianum* (Regel) Rodionenko*, Rheum wittrockii* Lundstr. belong to the Central Asian endemic plants. Narrow endemics growing on several mountain ridges (the Talass, Kyrghyz, Syr Darya Karatau Mountains) are represented by *Astragalus trichanthus* Golosk., *Scutellaria subcaespitosa*, *Pseudoeremostachys sewerzowii*, *Chondrilla kusnezovii* Iljin, *Stemmacantha aulieatensis (Iljin) Dittrich. Echinops fastigiatus* R. Kam.et Tscherneva*, Cousinia rigida* Kult., *C. vavilovii* Kult., *Tulipa zenaidae* Vved. Are found only in the Kyrghyz Alatau. On the frontier range: there are *Celtis caucasica, Sorbus persica, Louiseania ulmifolia, Pistacia vera* L. The main reasons to list the species in the Red Book include the reduced number of plants and intensive economic activities (plowing, grazing, collection of beautiful and medicinal plants, felling). Local endemics and species on the range frontier are the most vulnerable plants under threat.

Over 75 species of crop wild relatives are found here, including forage plant species such as *Elytrigia repens, Bromopsis inermis, Lathyrus pratensis, Vicia cracca, Phragmites australis, Dactylis glomerata, Trifolium repens, T. pretense*. The medicinal plants are: *Mentha longifolia, Hypericum perforatum, Ziziphora clinopodioides, Ephedra equisetina, Origanum vulgare, Achillea asiatica, A. millefolium, Glycyrrhiza glabra, G. uralensis*; food crops: *Allium caeruleum, A. caesium, Artemisia dracunculus;* fruit and nut crops found here are: *Malus sieversii, Pirus regelii, Armeniaca vulgaris, Cerasus tianschanica, Rubus caesus, Hyppophae rhamnoides, Rosa platyacantha, Crataegus songorica, Pistacia vera;* cereal crops are: *Taeniatherum crinitum, Aegilops cylindrica, Bromus macrostachys, B. japonicus, Hordeum leporinum*.

A special "Kyrghyz type of altitudinal zonality" has been identified (Rachkovskaya et al. 2003), which reveals transitional features of the north and west Tien Shan vegetation, showing the fragmented nature of the forest belt, abundance of ephemerals and ephemeroids in the steppe belt on foothill plains and mountain trails (Rachkovskaya et al. 2003; Aralbay et al. 2007). Juniper open woodland belt is common for the west Tien Shan region.

1.5.17 The Foothill Desert Belt (400–500 m a.s.l.)

The foothill desert belt (400–500 m a.s.l.) is distinguished by ephemeroid sagebrush vegetation with grasses: feather grass–sagebrush with ephemeroids (*Artemisia semiarida, Stipa sareptana, S. richteriana, Poa bulbosa*), and *Artemisia semiarida—Kochia prostrata—Ceratocarpus utriculosus* communities. The community composition is often participated by sedges (*Carex pachystylis, C. stenophylloides*). Sagebrush dwarf semishrubs predominate. The community composition is participated by bunch grasses, which predetermine the steppe features of foothill deserts. A similar role is also played by ephemeroid low grass savannoids (*Taeniatherum* *crinitum*, *Poa bulbosa*, *Hordeum brevisubulatum, H. leporinum, Aegilops cylindrica*). Frequently they become subdominants in plant communities under average human impact. Foothill plants are subjected to severe human-induced changes, basically connected with agricultural production (arable lands, rangelands). Along irrigation ditches, small reed (*Leymus multicaulis, L. angustus*), reed (*Phragmites australis*), and licorice (*Glycyrrhiza uralensis*) thickets are widespread.

1.5.18 The Steppe Belt

The steppe belt is divided into three sub-belts.

1.5.18.1 The Desert Steppe Sub-belt (500–800 m a.s.l.)

The desert steppe sub-belt (500–800 m a.s.l.) is represented by the communities of ephemeroides with dwarf subshrubs and bunch grasses: ephemeroid–sagebrush–feather grass (*Stipa sareptana, S. lessingiana, S. caucasica, Festuca valesiaca, Artemisia* spp., *Kochia prostrata, Poa bulbosa*) with shrubs (*Spiraea hypericifolia, Cerasus tianschanica,* species of *Atraphaxis, Rosa*), sometimes in combination with petrophytic shrub communities (*Artemisia rutifolia, A. juncea, Ephedra intermedia, Convolvulus tragacanthoides*) is the common sight here. In the springtime, ephemeral synusium (*Bromus japonicus, Anisantha tectorum*) is abundant with ephemeroids (*Poa bulbosa,* species of *Gagea, Tulipa*). Gallery floodplain forests are formed by willow (*Salix alba*) and hawthorn (*Crataegus songoricus*). The shrub layer is represented by *Rubus caesus*, *Rosa beggeriana*, *Halimodendron halodendron,* the grass layer—by *Phragmites australis, Pseudosophora alopecuroides*. On high river terraces and in other automorphic habitats, *Artemisia sublessingiana* is often predominating.

1.5.18.2 The Savannoid Steppe Belt (800–1200 m a.s.l.)

The savannoid steppe belt (800–1200 m a.s.l.) is represented by ephemeroid–forb–bunch grass and ephemeroid–bunch grass vegetation together with ephemeroid–forb–feather grass–fescue (*Festuca valesiaca, Stipa capillata, Elytrigia trichophora, E. repens, Botriochloa ischaemum, Hypericum scabrum, Eremurus tianschanicus*) communities and shrubs (*Spiraea hypericifolia, Atraphaxis pyrifolia*) as well as thorn cushion plants (*Allochrusa paniculata*). Steppes are mixed with shrub thickets, rocks and screes. The phytocoenotic diversity within the sub-belt is connected with gallery forests extending along the mountainous flows. The wood layer is composed basically from *Acer semenovii,* hawthorn species (*Crataegus korolkovii, C. sanguinea, C. turkestanica, C. songorica*), willow (*Salix alba*). Shrubs are represented by dog rose (*Rosa beggeriana, R. platyacantha*), blackberry (*Rubus caesus*), sea buckthorn (*Hyppophae rhamnoides*); in grass layer *Elytrigia* *repens, E. trichophora*, *Mentha longifolia*, *Cynodon dactylon* are widespread. On dry stony slopes, cherry trees (*Cerasus erythrocarpa*, *C. tianschanica*) are met with low abundance. Apple thickets (*Malus sieversii*) and pear trees (*Pyrus regelii*) are quite rare. Savannoids are abundant in grass layer (*Bromus macrostachys, Aegilops cylindrica, Botriochloa ischaemum, Taeniatherum crinitum, Hordeum leporinum*); often they form microcoenoses.

The richest phytocoenotic diversity is formed in the inter-mountainous gorges and river valleys. Each valley has its typical and unique view. The Shunkyr River valley forms several side branches. Floodplain forests are formed by white willow (*Salix alba*), in shrub layer, apart from hawthorn and blackberry, *Lonicera tatarica, Cotoneaster multiflora* are found. The species composition of meadows is abundant with valuable fodder crops (*Elytrigia repens, Calamagrostis pseudophragmites*), liquorice (*Glycyrrhiza uralensis*), and estragon wormwood (*Artemisia dracunculus*). *Equisetum ramosissimum, Plantago lanceolata, Inula britannica, Galium aparine, Medicago falcata*, etc., are also distributed here. On high river terraces, sagebrush communities are spread (*Artemisia sublessingiana*) with participation of weeds (*Centaurea squarrosa, C. cyanus, Acroptilon australe, Peganum harmala*). On slopes, shrub thickets of dog rose, spirea, and honeysuckle are along with Tien Shan cherry; in grass layer, couch grass and ephemeral savannoids are found. A bright aspect is made by *Eremurus tianschanicus*, *Delphinium biternatum*, *Salvia deserta*.

In the Soghety River valley, *Acer semenovii, Crataegus songorica* predominate in the floodplain forests. Dog rose species are found in shrub layer, grass layer is formed by meadow grasses: *Elytrigia repens*, *Festuca pratensis*, *Bromopsis inermis*. On the western steep slopes, forbs grass–dwarf shrub communities are spread. Shrub layer is formed by *Cerasus tianschanica, Rosa platyacantha, Atraphaxis pyrifolia, A. virgata, Spiraea hypericifolia*. Herbs are represented by *Elytrigia repens, Poa bulbosa, Origanum vulgare*. The plant cover is used for grazing; in some places it has degraded with *Hulthemia persica* and *Centaurea squarrosa* showing degradation indices.

The Almaly (apple) gorge forest layer is mainly composed by *Acer semenovii, Malus sieversii*. Shrub layer is formed by *Rosa beggeriana, Rubus caesus*. Floodplain meadow vegetation consists of grasses and forbs with predomination and high abundance of legumes (*Lathyrus pratensis, Vicia cracca*). Eastern slopes are occupied by fescue steppe with herbs (*Elytrigia repens, Glycyrrhiza glabra, Galium verum, Hypericum scabrum*). The plants are used for grazing, the impact is often severe, which is shown by the abundance of weeds and unpalatable species: *Centaurea squarrosa, Artemisia serotina, Dodartia orientalis, Hulthemia persica*.

The gallery forests in the Koghershin gorge are formed by the following plants: *Crataegus songorica, C. korolkowii, Salix alba, Acer semenovii*. Shrub layer is represented by *Rubus caesus, Spiraea hypericifolia, Rosa beggeriana, Cotoneaster melanocarpa, Atraphaxis pyrifolia*. The species composition of flood meadows is as follows: *Elytrigia repens, E. trichophora, Medicago falcata, Hypericum perforatum, Achillea asiatica, Sanguisorba officinalis, Mentha longifolia, Allium caeruleum*. Groups of species *Impatiens parviflora* occur in some places (up to 10 %), indicating the habitat disturbance.

The Kaiyndy (birch) gorge forests are formed by *Betula tianschanica, Malus sieversii, Salix alba. Acer negundo, Ulmus pumila,* and are frequent in the forest layer, coming from cultivated plantations. Shrub layer has hawthorn, blackberry, apricot undergrowth. Floodplain meadows have high grasses (up to 200 cm), predominated by *Elytrigia repens*, *Achillea millefolium, Festuca pratensis, Allium caeruleum, Bromopsis inermis*. Other components of the communities are: *Scaligeria setacea, Daucus carota, Phleum paniculatum, Nepeta pannonica, Delphinium biternatum, Veronica spuria, Alcea nudiflora.*

In the western Kyrghyz Alatau range, the sub-belt comprises northern-most pistachio habitat. Woodlands with pistachio (*Pistacia vera*), Semyonov maple trees, Regel pear are found on dry stony steep slopes of the south-western exposure.

1.5.18.3 The Meadow Steppe Sub-Belt (1200–1600 m a.s.l.)

The meadow steppe sub-belt (1200–1600 m a.s.l.) is represented by rich forb-grass–fescue communities like: *Festuca valesiaca*, *Phleum phleoides, Dactylis glomerata*; meadow-steppe forbs: *Salvia deserta, Nepeta pannonica, Galium verum,* with *Stipa capillata, S. kirghisorum, Helictotrichon schellianum, Phlomoides pratensis, Geranium collinum,* in combination with shrub thickets *Spiraea hypericifolia, Rosa spinosissima, Atraphaxis pyrifolia*, sometimes with juniper woodlands like *Juniperus semiglobosa, J. pseudosabina*. *Eremurus regelii, E. tianshanicus, E. cristatus*, constitute the herbal layer. Cereals (*Taeniatherum crinitum, Aegilops cylindrica, Botriochloa ischaemum*) occur in stony habitats. The vegetation of the Karabulak inter-mountainous valley is unique and diverse in species. At an elevation of 1485 m a.s.l., rich forb-grass meadow steppes are distributed. The herbage is basically composed of *Elytrigia trichophora, E. repens, Festuca valesiaca, including Salvia deserta, Scaligeria setacea, Nepeta pannonica, Achillea millefolium, A. asiatica, Potentilla asiatica, Potentilla impolita, Pseudohandelia multifida, Senecio jacobea, Senecio erucifolius, Dipsacus dipsacoides, Origanum vulgare, Hypericum perforatum*. Species such as *Medicago falcata, Lathyrus tuberosus* are less abundant. At an elevation of 1558 m a.s.l., grass-rich forb (*Eremostachys fetisowii, Trifolium hybridum, Lathyrus pratensis, Allium caesium, A. caeruleum, Betonica foliosa, Nepeta pannonica, Rumex confertus, Potentilla asiatica*) communities are typical. Grass cover is formed by *Dactylis glomerata, Elytrigia repens, Bromopsis inermis, Festuca valesiaca*. The plants of the valleys are used for haymaking.

Willow and Semyonow maple trees form floodplain forests. *Rosa beggeriana, Lonicera microphylla, Euonimus semenovii, Rubus caesus, Berberis sphaerocarpa* are presented in the shrub layer. High grasses of *Melica altissima, M. transsilvanica, Phalaroides arundinacea* occur in herbal layer. Forb meadows are formed by *Amoria repens, Trifolium hybridum, Plantago major, P. longifolia, Festuca arundinacea,* close to the water there is *Veronica anagalis-aquatica, Mentha longifolia*. Meadow vegetation on high river terraces is forb grass with predominating *Elytrigia repens* and abundant milfoil (*Achillea millefolium*). Species such as *Potentilla impolita, P. asiatica, Galium verum, Ligularia thomsonii, Ligularia heterophylla,* *Dipsacus dipsacoides, Allium caeruleum, Conium maculatum, Lathyrus pratensis* are found among forbs. On stony cliffs, single plants of *Armeniaca vulgaris, Crataegus songorica, Juniperus semiglobosa, Ephedra intermedia* occur. Savannoid groups tend to grow on dry slopes.

In the Merke and Kaiyndy gorges, the recreation impact is severe. The abundance of *Impatiens parviflora, Urtica dioica* has increased in the grass layer. Frequently, coverage of species *Impatiens parviflora* reaches 50–60 %.

1.5.18.4 The Juniper Woodland Belt (1600–2200 m a.s.l.)

The juniper woodland belt (1600–2200 m a.s.l.) is represented by juniper–shrubby woodlands (*Juniperus pseudosabina, J. semiglobosa, Rosa platyacantha, Spiraea lasiocarpa, Atragene sibirica*) in combination with steppes (*Festuca valesiaca, Helictotrichon schellianum, Stipa kirghisorum, Phleum phleoides, Phlomoides pratensis*) and meadows. In the Kogeshin gorge, juniper woodlands are usually combined with grass-forb meadows, forb-grass meadow steppes, and shrub thickets. Juniper woodlands (*Juniperus semiglobosa*) tend to grow on steep slopes. In the lower part of slopes, there are dense shrub thickets dominated by *Rosa spinosissima*, *R. beggeriana, Cotoneaster uniflora, Lonicera microphylla*. Grass layer has meadow species: *Campanula glomerata, Veronica spuria, Lathyrus pratensis, Origanum vulgare, Achillea asiatica, Thalictrum collinum*. On gentle slopes and valleys, tall-grass-herb meadow steppes are distributed. The plant cover is disturbed due to grazing. There are sites with severe degradation—in cattle stands. At primary stages, the manured sites of rangelands overgrow with *Malva pusilla, Rumex confertus*.

Dense shrub thickets are formed along river flows with *Rosa platyacantha, R. beggeriana, Spiraea hypericifolia, Spiraea lasiocarpa, Sorbus tianshanica, Lonicera microphylla, Salix triandra*. Grass layer is dense, formed by *Melica transsilvanica, M.altissima, Bromopsis inermis, Festuca pratensis, Phleum phleoides, Patrinia intermedia, Delphinium oreophyllum, Allium caesium, Medicago falcata, Potentilla impolita,* etc. On stony slopes, *Ephedra equisetina, Atraphaxis pyrifolia* grow.

In the eastern part of the Kyrghyz Alatau range (Kyrghystan), at an elevation of 2000 m, spruce stands of *Picea schrenkiana* are found on the bottoms and abrupt slopes of gorges. There is shrub layer of *Juniperus pseudosabina, Berberis sphaerocarpa, Lonicera hispida* and herbaceous cover of *Dactylis glomerata, Poa nemoralis, Ligularia heterophylla* in these stands (Rachkovskaya et al. 2003).

1.5.19 The Belt of Subalpine Meadows and Prostrate Juniper Thickets (2200–2800 m a.s.l.)

The belt of subalpine meadows and prostrate juniper thickets (2200 to 2800 m a.s.l.) have typically grass-rich-forb, forb-grass meadows (*Phlomoides oreophila,* *Bistorta elliptica*, *Poa pratensis, Poa angustifolia, Phleum phleoides, Dactylis glomerata*) with prostrate taxa (*Juniperus pseudosabina*) and tree juniper (*Juniperus semiglobosa*), as well as steppe communities on dry slopes (*Festuca valesiaca, Helictotrichon schellianum, Ziziphora clinopodioides, Potentilla nivea, P. bifurca*). Forb-grass meadows run along river beds and ravines. Herbal cover is formed by *Phleum phleoides, Poa angustifolia, Alopecurus pratensis*. *Phlomoides oreophila, Trifolium pratense, Amoria repens, Rhodiola kirilovii, Miosotis asiatica, Iris ruthenica, Alchemilla retropilosa, Alchemilla sibirica, Aconogonon alpinum, Lamium album, Achillea millefolium, Artemisia santolinifolia*. Plants are used for grazing, degradation is severe. In this belt, thorn cushion-like plants are met (*Acantholimon fetisowii, A. purpureum, A. alberti*).

1.5.20 The Alpine Belt of Cryophytic Meadows and Communities of Kobresia (2800–3500 m a.s.l.)

The alpine belt of cryophytic meadows and communities of Kobresia (2800–3500 m a.s.l.) is represented by xerophytic low-herb meadows with domination of *Alchemilla reptopilosa, Bistorta vivipara, Potentilla gelida, Festuca kryloviana, Poa alpina,* as well as *Kobresia humilis, K. capilliformis* communities. Kobresia communities are typical of the alpine belt only (3000–4000 m a.s.l.); they grow on plateau-like ridges, old moraine sediments, where soil erosion is almost absent (Rubtsov 1966). The tops of ridges are occupied by open aggregations of cryopetrophytes like: *Thylacospermum caespitosum, Rhodiola coccinea, Saxifraga flagellaris* (Rachkovskaya et al. 2003). On stony slopes: rocks, moraines, taluses, *Lonicera semenovii* and *Ephedra regeliana* grow; the cliff crevices, humid fine-grained slopes are covered by *Potentilla gelida, Waldheimia tomentosa, Saussurea gnaphalodes.*

According to ecological-physiognomic classification, in the Kyrghyz Alatau range there are six vegetation types: arboreal, shrubby, dwarf semishrub, meadow, steppe, savannoid (Table 1.8.).

Vegetation types are not always attached to altitudal zones. Arboreal plants can be found in all the belts, including subalpine meadows. Shrubby thickets reach the subalpine belt. Dwarf semishrub plants are typical of the steppe desert belt. Steppe vegetation covers a wide range of altitudes, from low up to high mountains. Meadow vegetation, occupying different areas, can be found from foothills up to high mountains. Savannoid vegetation is mostly spread in low mountain and sometimes occurs in foothills and mid-mountains.

Savannoid vegetation is an indigenous type, characteristic of south Kazakhstan and Central Asian foothills and low-mountain landscapes (Rubtsov 1955; Korovin 1961/1962; Karmysheva 1982; Rachkovskaya et al. 2003). Its origin is connected with loess sediments and with the formation of a special (ephemeral) vegetation development rhythm, when plants start in winter and spring seasons (Korovin 1961/1962), thus avoiding summer drought. The most typical species are: *Elytrigia trichophora, Botriochloa ischaemum, Eremurus tianschanicus, Alcea nudiflora,* there are subdominants and components of savannoid and meadow steppes.

Table 1.8 Ecological-physiognomic types of vegetation in the Kyrghyz Alatau range

Vegetation type	Vegetation subtype	Main community types
Arboreal	Evergreen juniper	Shrub–juniper (*Juniperus semiglobosa*, *J. pseudosabina*, *Rosa platyacantha*, *Spiraea lasiocarpa*, *Atragene sibirica*) woodlands
	Floodplain forest	Hawthorn–maple (*Acer semenovii*, *Crataegus korolkovii*, *C. sanguinea*, *C. turkestanica*, *C. songorica*) forests
		Birch (*Betula tianschanica*) forests with apple trees (*Malus sieversii*), willows (*Salix alba*) and apricot trees (*Armeniaca vulgaris*)
Shrubby	Petrophytic shrub thickets on stony soils and on rocks outcomes	Communities and groups of *Spiraea hypericifolia*, *Cerasus tianschanica*, *Cotoneaster multiflora*, *Atraphaxis pyrifolia*, *A. virgata*, *Rosa spinosissima*
		Shrub-sagebrush (*Artemisia rutifolia*, *A. juncea*, *Ephedra intermedia*, *Convolvulus tragacanthoides*) comunities
	Thickets of mesophilic and mesoxerophilic shrubs in river valleys	Communities dominated by *Rosa beggeriana, R. platyacantha*, *Rubus caesius*, *Hyppophae rhamnoides,Cotoneaster melanocarpa*, *Lonicera microphylla*, with *Euonimus semenovii*, *Berberis sphaerocarpa*
Dwarf semishrub	Bunch grass–sagebrush steppe deserts with ephemeroids in foothills	*Artemisia semiarida–Stipa sareptana*, *S. richteriana* with *Poa bulbosa* communities
		Artemisia semiarida–Kochia prostrata–Ceratocarpus utriculosus communities
Steppe	High-mountain steppes	Forb–fescue (*Festuca valesiaca*, *Helictotrichon schellianum*, *Ziziphora clinopodioides*, *Potentilla nivea*, *P. bifurca*) communities
	Mid-mountain meadow steppes	Rich forb-grass–fescue (*Festuca valesiaca*, *Stipa capillata*, *S. kirghisorum*, *Helictotrichon schellianum*, *Phleum phleoides*, *Dactylis glomerta*, *Elytrigia trichophora*, *E. repens*, *Bromopsis inermis*, *Salvia deserta*, *Napeta pannonica*, *Geranium collinum*) communities
		Rich forb-grass and grass-rich forb communities in intermountain valleys Grasses: *Festuca valesiaca*, *Elytrigia trichophora*, *E. repens*, *Bromopsis inermis*, *Dactylis glomerata* Forbs: *Scaligeria setacea*, *Achillea millefolium*, *A. asiatica*, *Potentilla asiatica*, *Dipsacus dipsacoides*, *Allium caeruleum*, *A. caesium*, *Hypericum perforatum*, *Betonica foliosa, Medicago falcata*

Table 1.8 (continued)

Vegetation type	Vegetation subtype	Main community types
	Low-mountain savannoid steppes	Hemiephemeroid–forb–feather-grass–fescue (*Festuca valesiaca*, *Stipa capillata*, *Phleum phleoides*, *Elytrigia trichophora*, *Botriochloa ischaemum*, *Hypericum scabrum*, *Eremurus tianschanicus*, *Alcea nudiflora*) communities
		Forb–fescue (*Festuca valesiaca*, *Stipa capillata*, *Allochrusa paniculata*, *Elytrigia repens*, *Carex turkestanica*, *Poa bulbosa*, *Centaurea squarrosa*, *Taeniatherum crinitum*) communities
		Fescue–wheat-grass (*Elytrigia trichophora*, *Festuca valesiaca*) communities
	Foothill desert steppes	Ephemeroid–sagebrush–feather-grass (*Stipa sareptana*, *S. lessingiana*, *S. caucasica*, *Festuca valesiaca*, *Artemisia sublessingiana*, *A. valida*, *Kochia prostrata*, *Poa bulbosa*) communities
Savannoid	Low-mountain savannoids	Ephemeroid (*Botriochloa ischaemum*, *Poa bulbosa*) communities
		Hemiephemeroid (*Eremurus tianschanicus*, *Alcea nudiflora*, *Delphinium biternatum*, *Convolvulus pseudo-cantabrica*, *Lagochilus platycalyx*) communities
		Ephemeral (*Aegylops cylindrica*, *Thaeniatherum crinitum*, *Bromus macrostachys*, *B. japonicus*, *Hordeum bulbosum*, *H. leporinum*) communities
Meadow	High-mountain low-herb alpine meadows	Kobresia–grass-forb (*Alchemilla retropilosa*, *Polygonum songaricum*, *Leontopodium campestre*, *Festuca alatavica*, *Poa calliopsis*, *Kobresia humilis*, *K. capilliformis*)
	High-mountain mid herb subalpian meadows	Forb-grass (*Poa angustifolia*, *Alopecurus pratensis*, *Phleum phleoides*, *Helictotrichon schellianum*, *Miosotis asiatica*, *Phlomoides oreophila*, *Trifolium repens*, *Cerastium davuricum*, *Bistorta major*, *Aconogonon alpinum*, *Geranium collinum*)
	Floodplain meadows	Forb-grass Grasses: *Elytrigia repens*, *E. trichophora*, *Calamagrostis pseudophragmites*, *Festuca pratensis*, *Bromopsis inermis*, *Phleum paniculatum*, *Melica altissima*, *M. transsilvanica*, *Phalaroides arundinacea* Forbs: *Glycyrrhiza uralensis*, *G. glabra*, *Plantago lanceolata*, *Inula britannica*, *Galium aparine*, *Medicago falcata*, *Mentha longifolia*, *Cynodon dactylon*, *Achillea millefolium*, *Allium caeruleum*, *Daucus carota*, *Nepeta pannonica*, *Veronica spuria*, *Lathyrus pratensis*, etc.

The vegetation of the Kyrghyz Alatau range has undergone human-induced changes. In general, the degradation degree is medium. Sometimes, severely impacted sites are located. Steep slopes are disturbed slightly. Grazing, haymaking, and recreation are the basic impact factors.

1.5.21 The Western Tien Shan Mountains

The Western Tien Shan flora of vascular plants within the territory of Kazakhstan includes 1491 species (Karmysheva 1982) from 483 genera and 91 families, which makes up 28 % of the whole vascular plant flora in Kazakhstan. Dominant families are Asteraceae—230 species (16.2 %), Fabaceae—147 (10.4 %), Poaceae—127 (9.0 %), Lamiaceae—76 (5.4 %), Apeaceae—75 (5.3 %), Rosaceae—70 (4.9 %), Cariophyllaceae—64 (4.5 %), Brassicaceae—62 (4.4 %), Ranunculaceae—54 (3.7 %), Scrophulariaceae—49 (3.4 %). Dominant genera are *Astragalus*—67, *Oxytropis*—27, *Cousinia*—25, *Allium*—24, *Carex*—22, *Veronica*—21, *Erigeron*—18, *Gagea*—17, *Potentilla*—17, *Poa*—15.

This part occupies a marginal location and borders on desert plains, which results in the impact of dry eastern and north-eastern winds. Low precipitation is observed in summer months and early autumn, which determines the xerophytic vegetation type, prevaillance of herbs in the floristic composition, in particular, xerophytic and mesoxerophilic species, as well as communites that they form: destitute timber plants.

On the basis of life-forms, the western Tien Shan flora can be distinguished as follows: trees—27 species, arborous shrubs—9 species, shrubs—67, dwarf shrubs—12, semishrubs—24, dwarf semishrubs—12, lianas—3; perennial herbs—1011 species, biennials—56, annuals—231.

For the Aksu-Jabagly Nature reserve located in the Talass Alatau, Ivashchenko (2001) has developed a list of vascular plants. She has revised the data of Karmysheva (1982, 1983) and completed the list with the results of her own studies. Her list numbers 1312 species, including 37 species recorded in the Red List of Kazakhstan (2006): *Dryopteris mindshelkensis* N. Pavl., *Adiantum capillus-veneris* L., *Juniperus seravschanica* Kom., *Stipa karataviensis* Roshev., *Arum korolkowii* Rgl., *Eminium lehmannii* (Bge) O. Ktze, *Colchicum luteum* Baker., *Tulipa greigii* Rgl., *Tulipa kaufmanniana* Rgl., *Allium pskemense* B. Fedtsch., *Ungernia sewerzowii* (Regel) B. Fedtsch., *Juno coerulea* (B. Fedtsch.) Poljakov, *J. orchioides* (Carr.) Vved., *Iridodictyum kolpakowskianum* (Regel.) Rodionenko, *Epipactis palustris* (L.) Crantz., *Betula talassica* P. Pol., *Celtis caucasica* Willd., *Rhaphidophyton regelii* (Bunge) Iljin, *Allochrusa gypsophiloides* (Regel.) Schischk, *Aconitum talassicum* M. Pop., *Pseudosedum karatavicum* Boriss., *Ribes janczewskii* Pojark, *Malus sieversii* (Ldb.) M. Roem., *M. niedzwetzkyana* Dieck., *Sorbus persica* Hedl., *Medicago tianschanica Vass., Oxytropis talassica* Gontsch., *Euonymus koopmannii* Lauche., *Kosopoljanskia turkestanica* Korovin., *Karatavia kultiassovii* (Korov.) Pimenov & Lavrova, *Primula minkwitziae* W.W. Sm., *Pseuderemostachys sewerzowii* (Herd.) M. Pop., *Morina kokanica* Rgl., *Lactuca mira Pavl., Cousinia* *grandifolia* Kult., *Centaurea turkestanica* Franch., *Ugamia angrenica* (Krasch.) Tzvel., *Hippolytia megacephala* (Rupr.) Poljak.

The flora here is of highly endemic nature which may be related to the microendemism reported for some other mountainous areas (Uysal et al. 2011). There are about 557 Central Asian endemic species here (38 % of the total species number). Among these are the endemics pertaining to Kyrghyz Alatau—7 (1.9 %), Pamir-Alay–West Tien Shan—17 (2.5 %), and the Junggar Alatau—8 species; those pertaining to north Tien Shan are 69 species (12.3 %).

In the western Talass region, the following families are distinguished on the basis of number of endemic species: Asteraceae (six species), Apiaceae (four species), Fabaceae, Lamiaceae, Scrophulariaceae (three species in each). Each of the remaining families is represented by one species (Karmysheva 1982). From among the above endemics, there is only one tree species (*Betula talassica*), the rest are perennial grasses, lacking any dominants of the plant communities. Of subdominant importance are species of *Leymus flexilis* (Nevski) Tzvelev, *Schrenkia kultiassovii* Korovin., *Nepeta mariae* Regel., *Cousinia fetissowii* Winkl., *C. tianschanica* Kult., *Lactuca mira* Pavl. Zonal distribution of endemics is also irregular. Their richest diversity is found in mid-mountain (11 species) and subalpine belt (10 species); in low-mountain there are 6 species, in alpine belt—4, and 1 species in the nival belt: Some species occur in two adjacent belts.

Relict plants also occur: *Lepidolopha karatavica, L. komarowii*, *Thesium minkwitzianum,* which are considered by Pavlov and Lipshits (1934) to be living monuments of the ancient desert Mediterranean flora. *Pseuderemostachys sewerzowii* is classified as a representative of the Syr Darya Karatau and Western Tien Shan Tertiary flora. Pavlov (1970) identifies *Calophaca soongorica var. tianschanica* as a relict endemic. With this type of endemic, he also associates *Stephanocarium olgae* (B. Fedtsch.) M. Pop. and *Sergia sewerzowii* (Regel.) Fed. The last species occurs in the crevices of canyon rocks along the Mashat and Aksu rivers, while less often in the Sayramsu, Saryaygyr and Naut river canyons. Kamelin (1973) associates *Trichanthemis* and *Schrenkia* genera as Neogenic relict endemics.

There are 15 plant species threatened as a result of human activities: *Juniperus turkestanica* Kom, *Pistacia* vera L., *Malus sieversii, Betula talassica* Poljak., *Ephedra equisetina* Bunge, *Allium pskemense, A. longicuspis* Regel., *Korolkowia sewerzowii* Regel., *Rheum maximowiczii* Losinsk., *Allochrusa gipsophiloides, Oxytropis talassica* Gontsch., *O. auliatensis* Vved., *Hippophae rhamnoides* L. (Karmysheva 1982)

In protected areas (nature reserves and national parks), vegetation development and phytocoenoses formation are free from human-induced impact as reported for similar other areas (Ozturk 1998; Celik et al. 2003; Ozturk et al. 2012). A favorable effect of protected conditions is marked in the mountain vegetation. However, after many years of strict reserve regime, some of the low sites of grass meadows become filled with litter and weeds. Periodical haymaking is necessary to improve the meadow vegetation.

The western Tien Shan is rich in plant diversity with about 1500 plants, it also contains original ancestral forms of many economically important plants like: the species of *Rosa, Crataegus, Cerasus, Allium, Medicago tianschanica, Malus* *sieversii, Pyrus regelii, Hippophae rhamnoides, Amygdalus spinosissima, A. petunnikowii, Pistacia vera, Prunus sogdiana, Padellus mahaleb,* wild relatives of cereals (*Aegilops cylindrica, Hordeum bulbosum*), and ornamentals (*Tulipa, Juno, Eremurus*). A total of 103 species of wild relatives of economically important species have been identified in the region.

According to the existing classification of zonality types based on associating plant communities distribution with environmental factors (soil, relief, climate), the region relates to the Middle Asian group of altitudinal zonality types. Depending on humidity degree, two lines are distinguished in the Middle Asian group: wet line, typical of windward ridges of the western Tien Shan, and more droughty line in the Syr Darya Karatau (Rachkovskaya et al. 2003). The vegetation of the west Tien Shan ridges is characterized by a complete wet line zonality column of the Middle Asian group of altitudinal zonality types.

1.5.22 Belt of Low-Herb Savannoids (600–800 m a.s.l.)

Foothills are occupied with low-herb ephemeral–sedge–bluegrass communities (*Poa bulbosa, Carex pachystylis, Alyssum turkestanicum, A. dasicarpum, Anisantha tectorum, Taeniatherum crinitum*). Low-herb ephemeral and ephemeroid vegetation develops profusely in spring, grows only on low-mountain slopes, as the agricultural lands (arable lands, orchards, vineyards) reach close to hills.

1.5.23 Belt of High-Herb Savannoids and Xerophytic Deciduous Woodlands (800–1500 m a.s.l.)

In phytocoenotical aspect, this belt is heterogeneous and diverse. Its lower part is occupied by communities of tall herbs and cereals that exist for a long time in place of flattened woodlands. They are participated by *Elytrigia trichophora, Hordeum bulbosum, Eremurus regelii, Alcea nudiflora, Echinops spaerocephalum*; in upper slopes such communities are also composed of various shrub species, together with the endemic species for the western Tien Shan (*Calophaca tianschanica, Amygdalus petunnikowii*), and species with a wider Central Asian distribution (*Rosa kokanica, R. beggeriana, R. corymbifera, R. fedtschencoana*, *Crataegus pontica, C. turkestanica, Cotoneaster soongoricus*).

Along the mountain streams, tree and shrub vegetation includes the following species: *Juniperus semiglobosa, J. seravschanica, Malus sieversii, Betula tianschanica, Salix triandra, S. alba, Cotoneaster melanocarpus, Berberis integgerrima, Lonicera nummulariifolia, Hippophae rhamnoides*. In the Karzhantau western ridge gorges, *Prunus sogdiana, Crataegus turkestanica, Acer semenovii, Morus alba, Armeniaca vulgaris* also occur in the layer of trees; *Amygdalus spinosissima, Rubus caesius, Rosa corymbifera, R. kokanica, Spiraea hypericifolia* are found among the shrubs.

On the small sites, pistachio open woodlands as remanants of widely distributed stands can be found. More considerable areas are occupied by deciduous open woodlands of *Crataegus pontica, C. turkestanica, Malus sieversii,* sometimes with *Acer semenovii* and the cover of tall herbs and grasses. The stony and cobble slopes are overgrown with bunchgrass and forb–bunchgrass steppe communities dominated by *Festuca valesiaca, Elytrigia trichophora*, and participated by feather grass (*Stipa sareptana, S. hohenackeriana*). Walnut forests (*Juglans regia*) are sometimes found on the humid sites of slopes.

1.5.24 Belt of Juniper Woodlands (1500–2000 m a.s.l.)

Juniperus seravschanica and *J. semiglobosa* are widespread with *Acer turkestanicum*. Sometimes these species form quite dense stands (Pavlov 1970). In such juniper forests, mesophilic shrubs present are: *Lonicera microphylla, Cotonoaster soongoricus, Restella albertii*; herbaceous layer with hemiephemeroid tall herbs include *Prangos pabularia, Aconogonon coriarium, Ferula tenuisecta, F. prangifolia*. The herbaceous layer consists of mesophilic grasses and forbes (*Bromopsis inermis, Poa nemoralis, Achillea millefolium, Hypericum perforatum, Origanum tyttanthum, Dracocephalum nodilosum, Vicia cracca*), sometimes they are mixed with xerophilic grasses: *Festuca valesiaca, Elytrigia trichophora, Stipa sareptana, S. hohenackeriana.*

In the same belt, there are original walnut forests in humid "western corners" of the ridges. These forests do not form the belt in western Tien Shan and grow only in small groups on the slopes of northern exposure. Here, so-called complex walnut forests, in which (besides *Juglans regia*) *Malus sieversii,* and *Acer turkestanicum* participate, occur more often than others (Rachkovskaya et al. 2003). A rich layer of mesophyllous shrubs developes (*Exochorda tianschanica, Crataegus tianschanica, Lonicera nummulariifolia*) in these forests, herbaceous layer consists of forest mesophyllous species (*Brachypodium silvaticum, Poa nemoralis, Aegopodium tadshikorum*). On the driest internal slopes of the uppermost part of mid-mountain, juniper woodlands of *Juniperus turkestanica* and *J. semiglobosa* with steppe cover of *Festuca valesiaca, Poa angustifolia, Phleum phleoides* grow. Herbaceous layer is formed by *Abelia corymbifera, Lonicera altmannii*. As a whole, xerophytic types of juniper woodlands are not typical of the western Tien Shan Mountains.

1.5.25 Belt of Subalpine Meadows (2000–2800 m a.s.l.)

Tall umbellate communities— "umbellares" are the most usual ones for the lower part of the western Tien Shan high mountains (subalpine belt). The main dominants are *Prangos pabularia* and *Ferula tenuisecta.* Umbellares represent one of the prevailing vegetation types in the region. In addition to basic dominants, which are hemiephemeroids, some mesophyllous and xeromesophyllous species, as *Polygonum* *coriarium, Bromopsis inermis, Dactylis glomerata, Inula macrophylla,* sometimes *Festuca valesiaca* participate in the communities of umbellares.

In the same belt on northern slopes, where the Mediterranean rhythm of precipitation becomes weak, more mesophytic medium-herb meadows with genera like *Geranium, Polygonum, Phlomis* occur and take up larger areas than umbellares (Rachkovskaya et al. 2003). Prick herb coenoses with endemic *Cousinia bonvalotii* are confined mostly to slopes and saddles on a more or less developed fine-grained layer of soil. *Prangos pabularia, Ligularia alpigena, Onobrychis echidna* codominate the prick herb coenoses. Prostrate juniper communities of *Juniperus turkestanica* occupy the stony slopes of southern exposition.

1.5.26 Alpine Belt of Cryophytic Low-Herb Meadows (2800–3400 m a.s.l.)

The belt comprises communities of microthermal and xeromesophyllous herbaceous plants, cryophytic meadows with forbes (*Waldhemia tridactylites, Cerastium litospermifolium, Cystiocorydalis fedtschenkoana, Allium polyphillum*, etc.) and communities of *Carex stenocarpa, Kobresia cappiliformis, Puccinella subspicata, Festuca kryloviana, Helictotrichon hookeri, Hordeum turkestanicum, Poa alpina, Trisetum spicatum.* The species of *Ranunculus, Lagotis, Primula, Draba, Allium semenovii, A. kaufmannii* are predominant. On rock outcrops, screes, stony slopes of middle and highland belt cryopetrophytes occur: *Allium polyphillum, A. pskemense, Paraquilegia grandiflora, Delphinium oreophillum, Saxifraga albertii, Campanula capusii,* etc., in low and middle mountain belt, there are *Pentaphylloides parviflora, Artemisia rutifolia, Silene braghuica, Parrya albida, Eremurus lactifloris, Spiraea pilosa,* and others.

The wide presence of rocks and screes at all altitudes alters the traits of plant distribution. The role of slope exposure for some species is of greater importance than the altitude a.s.l. For instance, species typical of low mountain go up the sun-warmed sites and reach the subalpine altitudes (*Silene guntensis, Allium karataviense, Thalictrum isopyroides, Phlomoides brachystegia*), while high-mountain species go down the shady slopes to middle mountains and lower parts(*Draba arsenievii, Viola biflora, Aquilegia tianschanica, Saxifraga sibirica,* and others).

According to ecological-physiognomic classification, the vegetation of the western Tien Shan Mountains can be divided into six types: arboreal, shrubby, steppe, savannoid, meadow, and prick herbaceous plants (Table 1.9).

Arboreal vegetation type consists of juniper growth that lays the basis of mountainous forests in the western Tien Shan. Deciduous forests and woodlands are widespread in stream and rivulet valleys are also classified as arboreal vegetation type.

In general, the vegetation of the western Tien Shan ridges is medium disturbed, but sometimes severely degraded sites are found. Due to grazing, haymaking, and recreation impact, there is almost no natural vegetation in foothills. The degradation is also connected with cultivation and livestock production. Outside the protected

Table 1.9 Ecological-physiognomic types of vegetation in the western Tien Shan Mountains

Vegetation type	Vegetation subtype	The main community types
Arboreal	Evergreen juniper	Juniper (*Juniperus semiglobosa, J. seravschanica*) herbaceous woodlands:
		With meadow species (*Phleum phleoides, Poa angustifolia, Dactylis glomerata, Trifolium pretense*)
		With steppe species (*Stipa kirghisorum, Festuca valesiaca*)
		With savannoids (*Elytrigia trichophora, Hordeum bulbosum*)
		Maple–juniper woodlands with shrubs (*Acer turkestanicum, Lonicera microphylla, Cotoneaster soongoricus, Restella alberti*)
		Shrub–juniper woodlands with tall-herb savannoids (*Rosa* spp., *Pistacia vera, Cononoaster melanocarpa, Cerasus tianschanica, Elytrigia trichophora, Eremurus regelii, Alcea nudiflora*)
	Deciduous forests and woodlands	Forests with dominanting *Malus sieversii, Crataegus turkestanica, C. pontica;* with *Acer semenovii, Celtis caucasica*
		Floodplain forests of *Betula talassica, B. tianschanica, B. turkestanica, Salix niedzwieckii, S. picnostachya, S. alba*
		Hawthorn grooves (*Crataegus turkestanica*)
Shrubby	Thickets of deciduous shrubs	Thickets with prevailing *Rosa kokanica, R. fedtschenkoana, R. marocandica;* species of *Lonicera, Cotono-aster, Berberis;* with *Amygdalus spinosissima, Prunus sogdiana*
	Mesoxerophylous shrubs	Thickets with prevailing *Spiraea hypericifolia, Cerasus erythrocarpa, C. tianschanica, Atraphaxis pyrifolia*
	Evergreen prostrate juniper	Shrub–juniper (*Juniperus turkestanica, Lonicera humilis, Lonicera karelinii, Rosa albertii*) communities
Steppe	True steppes	Forb–bunchgrass (*Stipa kirghisorum, S. capillata, Festuca valesiaca, Helictotrichon desertorum, Ferula tenui-secta, Alcea nudiflora, Eremurus regelii, Elytrigia trichophora*) communities
	Steppes with savannoid elements	Forb–hemiephemeroid–fescue (*Festuca valesiaca, Poa bulbosa, Hordeum bulbosum, Ferula tenuisecta, Alcea nudiflora*) communities
		Forb–feather–grass communities:
		Stipa kirghisorum, Cousinia minkwitziae, Eremurus regelii
		Stipa capillata, Elytrigia trichophora, Hordeum bulbosum

Table 1.9 (continued)

Vegetation type	Vegetation subtype	The main community types
Meadow	High-mountain low-herb meadows	Communities with *Carex stenocarpa, Kobresia cappiliformis, Puccinellia subspicata, Poa alpina, Festuca kryloviana, Helictotrichon hookeri, Hordeum turkestanicum, Trisetum spicatum*
		Cryophytic meadows with *Waldheimia tridactylites, Cerastium lithospermifolium, Cysticorydalis fedtschenkoana, Allium carolinianum, Oxytropis albovillosa, O. chionobia, etc.*
	Mid-herb subalpine meadows	Forb-grass (*Festuca kryloviana, Alopecurus pratensis, Dactylis glomerata, Poa pratensis, Elytrigia repens, Phleum phleoides, Bromopsis inermis, Calamagrosris epigeios, Carex melanantha, Geranium collinum, G. saxatile, Allium hymenorhizum, Medicago tianschanica, Polygonum coriarium*, etc.
	Floodland meadows	Polydominant forb-grass and grass-forb meadows Grasses: *Alopecurus pratensis, Dactylis glomerata, Poa pratensis, P. angustifolia, Elytrigia repens, Phleum phleoides, Bromopsis inermis, Calamagrostis epigeios, Elymus caninus;* Forbs: *Carex melanantha, Geranium collinum, Allium hymenorhizum, Medicago tianschanica, Polygonum coriarium*
Savannoid	Low-herb savannoids of low mountain	Ephemer–sedge–bluegrass communities (*Poa bulbosa, Carex pachystilis, Phlomis salicifolia, Cousinia minkwitziae, C. micricarpa, Bromus lanceolatus, B. oxyodon*, etc.)
	Tall grass savannoids	Forb-grass, grass, shrub–forb-grass communities with prevailing ephemeroids (*Elytrigia trichophora, Hordeum bulbosum, Botriochloa ishaemum, Poa bulbosa, Carex pachystylis*) and communities of mesophylous and xeromesophylous geophytes (species of *Prangos, Ferula* genera)
Prick herb, thorn cushion (Phryganoid)	Prick herbs, thorn cushion (Phryganoid)	Communites of sclerophylous dwarf shrubs (*Onobrichis echidna, Acantholimon* spp.), dwarf semishrubs (*Artemisia* species) and perennial prick herbs (*Cousinia* species) with sinusions of meadow and cryophylous steppe plants

territories (Nature reserve Aksu-Jabagly, Sayram-Ugam National Park) the overall abundance of weeds and unpalatable species is observed, such as *Artemisia dracunculus, Rumex tianschanicus, Eremurus fuscus, Ligularia heterophylla*, etc.

1.6 Expected Impact of Climate Change on Plant Cover

Air temperature in Kazakhstan has been increasing steadily, on an average by 1.5°C, during the past five decades. The changes in the amount of precipitation are of an ambiguous nature. Climate change features in plains differ from those in mountains (Republic of Kazakhstan 2006).

Projections of climate change in Central Asia (temperature and rainfall) for the late twenty-first century (2071–2100) are suggested in the review by Ibatullin et al. (2009). The review was prepared accounting for two possible scenarios: A2 B2 greenhouse gases' concentration and based on four global climatic models (CSIRO2, CGCM2, HAD3, PCM). All the models and scenarios show that average annual and seasonal temperatures are expected to increase in Central Asian countries by the end of the twenty-first century. Reduction in rainfall during summers is expected, while winter precipitations will increase. According to the A2 scenario, in late twenty-first century, annual average temperature increase in Kazakhstan in different models will be from 3.3 to 6.7 °C in comparison with the basic period of 1960–1990. Annual average precipitation will increase by 27 %. According to the B2, which is more "mild," annual average temperature changes are expected to be less than 1 or 1.5 °C as compared with the A2 scenario. Changes in precipitation are within the same limits as in the A2 scenario.

Glaciers are one of the most sensitive indicators of climate change (Aizen et al. 1997; Republic of Kazakhstan 2006). Annual average temperature increase by 1°C during the recent century has resulted in a 30 % reduction in the south-eastern Kazakhstan glaciers (Republic of Kazakhstan 2006). Average rate of glaciers reduction from 1955 to 1990 is around 0.70 % per year. The process of glacier degradation will last for at least 80 or 100 years, then it will be followed by a new climatic cycle, which will be more favorable for development of glaciations (National Strategy 2001).

The latest investigations over the whole Tien Shan mountains based on remote sensing data have revealed that the numbers of glaciers are 7590, with a total area of 13,271.45 km^2 (Aizen et al. 2008). The main factor controlling the glacier regime in Tien Shan is the impact of air temperature that affects the type of precipitation, the duration, and the intensity of snow and ice melting throughout the altitudinal belts. The Tien Shan glaciers lost 8.5 % of their total area since 1970. The largest absolute as well as relative glacier area loss occurred in the northern Tien Shan (−361 km^2, 14.3 %), where the annual and seasonal sums of precipitation decreased at elevations above 3000 m (18.6 mm), and the summer air temperatures increased by 0.44 °C. The least absolute glacier recession has occurred in the western Tien Shan (−45 km^2), where summer air temperatures increased only by 0.23 °C and annual precipitation decreased by 13.4 mm. Glacier area change data are available for the western Tien Shan (−51 km^2, 29.8 %) from 1961 to 2000 (Konovalov, 2012). Tien Shan glaciers exist in arid continental climate only because of the spring–summer or summer maximum precipitation, which increase albedo in period of glacier melt. Therefore, even small decrease of precipitation along with increase of air temperature causes acceleration in Tien Shan glacier recession (Aizen 2011a). Glacier degradation rate depends on the size of glaciers, threshold area being 13–14 km^2. The regime of each glacier is particular. The territorial disparity of degradation rates is determined by the background air temperature, orographic conditions, relief, slope expositions, glacier morphology. Southern slope glaciers are less resistant (Republic of Kazakhstan 2006).

The latest studies in Altai-Sayan Mountains based on remote sensing data have recorded 2340 glaciers with a total area of 1562 km^2 (Surazakov et al. 2007). Between 1950 and 2000, Altai-Sayan glaciers have lost 14 % area. The accelerated glacier recession in Altai-Sayan Mountains is mainly due to the result of increased summer air temperatures by 1.03 °C in the past 50 years, which intensify the melting of glacier's (Aizen 2011b).

In order to estimate the recent changes of the southern Altai, north Tien Shan, and western Tien Shan range glacier areas within the territory of Kazakhstan, satellite images were chosen with spatial amplification (30 м)—Landsat ETM + Landsat OLI in the ablation period. The following combinations of spectral channels were used for the interpretation (http://gis-lab.info/qa/landsat-bandcomb.html): Landsat ETM +—5,3 wavelength Band 7 (1.55–1.75 nm), Band 3 RED (0.630–0.690 nm); Landsat OLI—7,4 wavelength Band 7 (2.1–2.3 nm), Band 4 (0.63–0.68 nm). Combinations of channels RGB—4,3,2 for Landsat ETM + and RGB—5,4,3 for Landsat OLI were used for data visualization. For a trustworthy identification and mapping of ice and snow we applied a normalized-difference snow index (NDSI). The borders of the open glacier part (pure ice and snow) are identified trustworthily from space satellite imagery. The borders of moraine formations were not accounted for, as their identification is not sufficiently trustworthy.

In 2000, the area of glaciers and snowfields in the southern Altai (Sarymsakty, Kurshum, Tarbagatai, south Altai ridges) made up 418.7 km^2, in 2013 it was only 228.8 km^2 (Fig. 1.2). Assessing the 13 years' dynamics, we can establish a recession of glaciers and snowfields by 190 km^2 (46 %).

Glacier and snowfield in the Kyrghyz Alatau (north Tien Shan) has recessed by 50 % during the recent 14 years (from 14 km^2 down to 7.1 km^2) (Fig. 1.3)

The area of glaciers and snowfields in the western Tien Shan (Ugam, Mayndantal, Talass Alatau ridges) in recent 11 years has increased by 17 % (it was 123.2 km^2 and is now 142.4 km^2 (Fig. 1.4).

The comparison of satellite images and calculation of areas has revealed the dynamics of glacier and snow cover changes during the recent decade. This process coincides with the general trends in the regions under study. The increased glacier areas in Kazakhstani west Tien Shan proves the statement concerning the ambiguous nature of the process and underlines the necessity of annual satellite and ground monitoring. Also, this may be connected with the fact that pure snow and ice are indentified en masse, therefore errors may occur in areas.

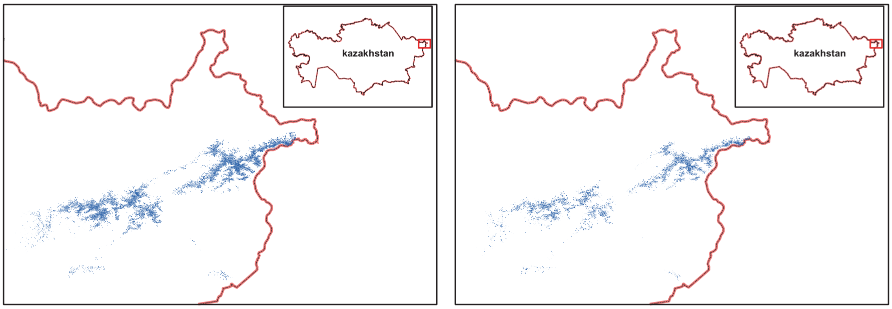

Fig. 1.2 Glacier and snowfield dynamics in the southern Altai

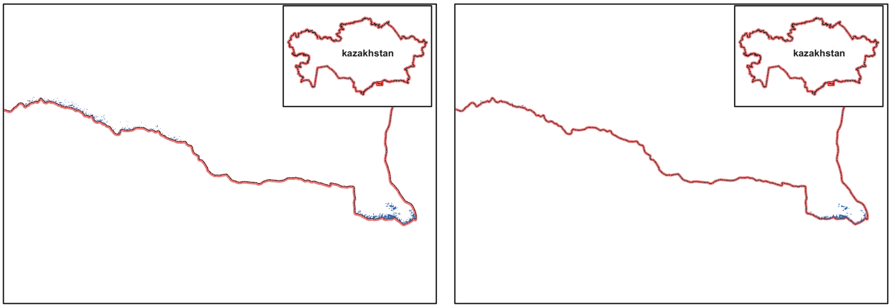

Fig. 1.3 Glacier and snowfield dynamics in the Kyrghyz Alatau

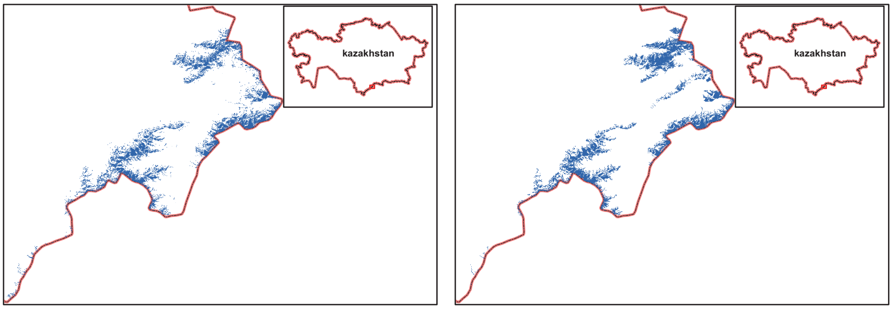

Fig. 1.4 Glacier and snowfield dynamics in the western Tien Shan

The studies of climate change impact upon the plant cover of Kazakhstan mountainous systems are in entry point. Recent publications by Proskuryakov (2010, 2012, 2013) pay much attention to chronobiological study of plants. Its principle consists in the establishment of monitoring facilities in the key sites for short-term (8–12 years) and long-term period (lifetime of plant cover dominants). Such a chronobiological study may include various indices: plant phenology, productivity, structure of plant populations, physiological, and biochemical processes. The original climatic background of each altitudinal belt varies in slope relief and correlation of warmth and moisture and solar radiation connected with the relief, which create a wide spectrum of plant habitats (Proskuryakov 2012). Chronobiological research in mountains is based on gradient study, drawing up empirical scales of quantitative features of distribution of the dominants depending on environmental condition. According to Proskuryakov, climate change still affects plants in a latent form, i.e., at the physiological, phenological, consortive levels. Thus, phenological study of Sievers apple tree (*Malus sieversii*) flowering at the lower border of wild fruit forests (800 m s.a.s.l.) since 1994 has illustrated the availability of two clearly expressed 6-year fluctuation cycles of apple flowering commencement date shift (Proskuryakov 2010). The first cycle—from 1998 to 2004. From 1998 to 2001, the flowering date shifted to the earlier stage by 16 days, then, from 2001 to 2004, the date had a shift to the later stage by 11 days. The latest flowering date at the absolute altitude of 800 ms corresponded to the flowering date for the absolute altitude of 1400 ms (Jangaliev 1977). The second cycle followed from 2004 to 2010, reveals that the flowering date first shifted to the earlier stage by 12 days; from 2007 to 2010 it again shifted to the later stage by 9 days. By the end of the 20 years' observations, the overall apple flowering shift to the earlier stage at the altitude of 800 m, overlapped the value of the whole amplitude of altitudinal belt variety of flowering commencement date within 1100–1800 m as of 1977. Thus, the observed apple flowering date shifts have resulted from the climate-induced deep internal changes in the life of plants. Many researchers observe the shifts of phenological dates (Zhou et al. 2001; Orlandi et al. 2005; Menzel et al. 2006; Chang et al. 2012; etc).

Plant species will respond to climate change in one of three possible ways: migrate to keep pace with climate change (but limited by habitat fragmentation, dispersal ability, and substrate requirements), adapt in situ through selection of tolerant traits, or become extinct (Aitken et al. 2008).

The studies in the southern Alps (Erschbamer et al. 2009) illustrate that even short-term (5 years) observations along the altitudinal gradient may reveal plant cover changes. It was noted that the species richness at the upper border of subalpine and alpine (sub-nival and nival) vegetation increased significantly, in the ecotone area of forest insignificant increase was marked. The changes can most likely be attributed to climate-warming effects and to competitive interactions. Species of the lower belts (mid-mountain forests) may penetrate into high-mountain belts. Such species may compete with the original plants and replace them at the account of shady and dense herbaceous cover. Endemic species of narrow habitats are especially vulnerable. Displacements of alpine species may be predicted for the near future. At the higher summits, expansions of the established alpine species and further invasions of species from lower altitudes are forecasted.

Accounting for the global climate change, the neighboring Republic of Kyrghyzstan has projected a shift in the environmental belts upward the mountain slopes (Titova 2002; Ionov 2003). The altitudinal belts of the mountainous systems bordering Kazakhstan will gradually move up. It is expected that the upper line of desert belt is going to rise by 200–400 m, steppe belt—by 200–250 m, forest and meadows—by 150 m, and subalpine belt—by 100 m (without changes in the Issyk-Kul depression). Desert landscapes will stay the same. In steppe belt that will replace meadow steppes and tall-herb meadows, savannoids will prevail: *Botriochloa ischaemum, Elytrigia trichophora, Inula grandis* as xerophyllous perennials of the late summer vegetation. Increased air temperature, sums of positive temperatures, vegetation period duration, and the amount of annual precipitation in steppe ecosystems will result in increased spring sinusium of ephemerals and ephemeroids, better productivity of desert and steppe communities. Significant changes might occur in the upper environmental belts. An intensive melting of glaciers will result in widened subalpine, alpine, and pre-glacier belts. High-mountain ecosystems of Kyrghyzstan will be dominated by xeromesophilic and xerophilic species. Many plant species, especially dominants, have natural adaptation features for surviving under new environmental conditions: a wide habitat and accommodation to the conditions of minimal rainfall amount and temperature contrasts. Increased air temperature, long summers, and the shift in vertical belts will not catastrophically affect the species diversity in the flora and vegetation. Many dominant plants have a wide environmental range and natural adaptation capacities. For instance, *Festuca valesiaca* grows in almost all the vertical belts of the mountains, prevails in plain steppe communities. This typically mesoxerophilous plant is highly resistant to extreme drought and trampling. *Dactylis glomerata* is a typical plant of meadows, including high-mountain and subalpine meadows. *Kobresia capilliformis, K. humilis* are dominants in alpine meadows, with wide habitat from Tibet to Tien Shan. All the vegetation types possess significant capacities: viable germs of plants, seeds, roots, bulbs, tubers that facilitate the accommodation to severe conditions. Mesophilous species receive a better development in humid years, the phytocoenotical role of xeromorphic plant species augments in droughty years. Rare, endemic, and threatened plants will be particularly vulnerable to the adverse effects of climate change, as well as plants and communities of a small environmental range (Uysal et al. 2011).

In Kazakhstan Mountains, altitudinal belt shifts are also expected. The fir belt will rise by 120–150 ms (The Second National Paper 2009). With global warming by 2–3°C, the steppe climate of the upper foothill level of Ile Alatau ridge (North Tien Shan) will be transformed into desert climate. Loess cover will disappear, foothills that currently are overgrown with herbs and shrubs will turn to badlands, involving the formation of catastrophic mudflows (Ibatullin et al. 2009).

Scenarios of future vegetation cover transformation will depend on the age of dominants in altitudinal belts. Fir age limit (*Picea schrenkiana*) reaches 500 years, tree juniper species live from 500 up to 800 years, climax communities will occupy their niches much longer than deciduous trees (*Malus sieversii, Armeniaca vulgaris, Crataegus* spp.), lifetime of which covers 100–150 years (Proskuryakov 2012).

A prediction of plant changes under new climatic conditions in the mountainous systems described in this chapter is based on the study of satellite images (Fig. 1.5). Plant cover dynamics has been identified from the same images which were used for the estimation of glacier and snowfields area changes. However, in plant cover studies we used the combination of spectral channels of Landsat ETM +—3,4 wavelength Band 3 RED (0.630–0.690 nm), Band 4 (0.75–0.90 nm); Landsat OLI—4,5 wavelength Band 4 (0.63–0.68 nm), Band 5 (0.845–0.885 nm). Different types of vegetation with their typical straight percentage cover and biomass possess certain spectral features in the visible and infrared ranges. Therefore, we used a soil-adjusted vegetation index (SAVI), which is well proven (Malakhov and Islamgulova 2014) even for the areas with sparse plant cover (< 30 %), typical of high mountain. To ensure a greater sensibility of the index in conditions of highland vegetation, we used in our estimations a correction factor 0.25.

BandMath mathematic operation tools were used for the calculation of index values of spectral brightness relations, and density slice function of ENVI 4.8 software was used to establish quantitative borders of separate classes; ArcGIS 10.1—for correcting administrative frontiers and for calculating areas. To assess the changes of plant spatial distribution, a digital model of relief was used as well.

According to the calculations, the reduction of glacier areas has taken place and a new substrate is formed for plant colonies, as well as expansion of the “sparse plant cover” class areas (Fig. 1.5). Each mountain ridge has its own scenario of ecosystem changes. The most severe plant transformation has taken place in Kyrghyz Alatau. During the recent 14 years, the plant cover has changed in the following way: the “sparse plant cover” class areas have expanded by 54 km^2 (Fig. 1.5), in water flows and canyons of various altitudinal belts a shear decrease in the straight percentage cover is noted. This testifies the aridization processes, which signifies that xeromorphic species will receive favorable conditions. Overgrowth is insignificant in the open surfaces exposed after the ice and snow reduction; ascension of plants to the next altitudinal level is not observed. It is still early to discuss the shifts of altitudinal belts. However, rangeland and hayfield productivity reduction is quite real.

A more favorable state of vegetation is typical in the western Tien Shan. Glacier area expansion has been observed. During the recent 11 years, the “sparse plant cover” class areas have expanded by 29 km^2 (Fig. 1.5). This has happened due to overgrown open surfaces not connected with glaciers and snowfields, as well as due to general aridization of plant cover and decrease in the straight percentage cover in the mid-mountain belt. In some places, plant aggregations rise averagely by 100 m.

In south Altai glacier area too, reduction is observed. The total area occupied by the “sparse plant cover” class areas has expanded by 97 km^2 in 13 years (Fig. (1.5). This happened due to the overgrowth of the exposed surfaces free from ice and snow. Thus, the altitudinal limit of the habitats of plants has ascended averagely by 200 m and in some places by 300 m. In other territories too, a reduction in the general plant abundance is noted in all the belts.

All the above data illustrate that the vegetation of mountain systems has undergone reconstruction. SAVI decreased index values are possibly connected with

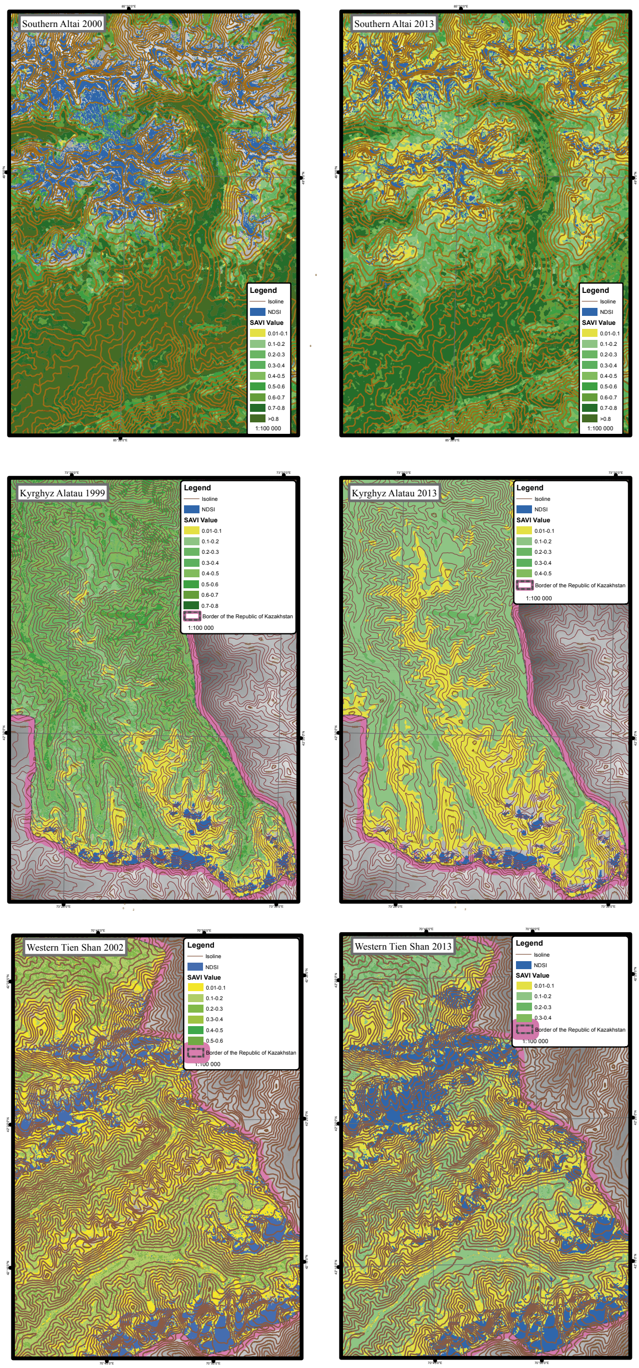

Fig. 1.5 Spectral features dynamics in the mountainous systems of Kazakhstan

ecosystem aridization resulting in less abundance of some species, reduced straight percentage vegetation cover and biomass. On the other hand, the reduced cover is possibly connected with changes in species composition, disappearance of one species and invasion by others. All these changes can be established only with the help of ground and space satellite monitoring.

Colonization of high-mountain plant groups has already commenced in the areas left exposed from glaciers. The species composition of such groups will aggregate in accordance with the environmental features and adaptive strategy of each species in each particular mountain range. In the high-mountain belt of Kyrghyz Alatau and western Tien Shan, rare and endemic plant species with a narrow environmental range occur which need a particular care.

Among these are: *Pseudoeremostachys sewertzowii, Juno orchioides, Allium talassicum, Primula minkwitziae, Scutellaria flabellulata, S. talassica, Polygonum coriarum, Oxytropis talassica, Scrophularia nuranii,* etc. The changes in the ecological condition may result in decreased number of plants in populations and disappearance threats. Wide environmental range species that are able to grow on mountainous meadow and meadow-steppe slopes, along river valleys, on gravelly and stony slopes, at the foot of glaciers and snowfields (*Festuca kryloviana, Helictotrichon shellianum, H. hookeri, Potentilla gelida, Artemisia aschurbajevii, A. rupestris, Omalotheca supina,* etc.) will migrate gradually, without species diversity losses. Species hybridization processes are observed in the southern Altai Mountain conditions (Kotukhov 1990).

Against the background of the general xerophytization of plant cover, rare, endemic, and threatened plants will be particularly vulnerable to the adverse effects of climate change, as well as plants and communities of a small environmental range. Species from the Red List do not always have narrow ecological niches; many of them reduce in number due to anthropogenic impacts. Therefore, protection activities would contribute to avoid their disappearance; still no protection can completely secure this.

Conclusions

Mountainous systems of Kazakhstan occupy less than 9 % of the country's area, but they embody over 60 % of Kazakhstan's plant species diversity. Being the centers of floristic genesis, mountainous ecosystems are characterized by a maximum accumulation of rare, endemic, and economically valuable species. There are centers on Kazakhstan's mountains which represent a unique genetic fund of agrobiological diversity as there are many wild relatives of different crops and fruit trees with their centre of origin lying here such as: apple trees, pears, blackcurrant, pistachio, almond trees, walnut trees, barley, alfalfa, liquorice, etc.

The information cited above has revealed a high plant diversity in the mountainous systems of Kazakhstan. A total of 2091 species of vascular plants grow in the southern Altai, 850 species in the Kyrghyz Alatau and 1491 species in the western

Tien Shan. The floras are rich in endemics; all of the ridges have narrow endemics not found in other regions. The traits of spatial plant distribution are unique as well as the features of altitudinal zonality. Each mountainous system has its own type of zonation. Common features of plant cover in combination with some dominant species are revealed in the mountainous belts. There are steppe representatives, such as *Festuca valesiaca, Stipa capillata, Helictotrichon schellianum, H. hookeri,* meadow—*Dactylis glomerata, Phleum phleoides, Hypericum perforatum,* shrubs—*Spiraea hypericifolia, Lonicera tatarica, L. microphylla*. Common signs peculiar to dominant arboreous species are found in the northern and western Tien Shan Mountains (*Juniperus semiglobosa, Betula tianschanica, Acer semenovii*). However, the species composition of plant communities is unique for each mountainous system.

Generally, there is an average degree of disturbance. In some places, severely degraded sites are found. The main factors of impact include grazing, haymaking, recreation, felling, and agriculture in foothills. During some decades human-induced impact has grown, which has already resulted in a considerable degradation of mountainous systems. In south Kazakhstan Mountains, juniper woodlands have perished because of soil pollution. Forest areas of east Kazakhstan have decreased as a result of unsustainable felling. Self-restoration of coniferous trees has almost stopped in the northern Tien Shan; advancing degradation of rangelands is increasing. Issues connected with recreation impact control are still underdeveloped. The experience of the alpine countries shows that the most efficient type of economic development of mountains is the combination of recreative and environmental policies (National Strategy 2001). There are nature-protected areas in the mountains of Kazakhstan: the Markakol Nature reserve and the Katon-Karagai National Park in the Southern Alatai, the Aksu-Jabagly Nature reserve, and the Sayram-Ugam National Park in the Western Tien Shan. There are no protected areas in the Kyrghyz Alatau ridge.

The plant cover of Kazakhstan's mountainous systems is double pressed under the conditions of the current global climate change. On one hand, there are man-made factors, on the other side changes provoked by the climatic background. Those changes show themselves already at the organismal level; phenological dates are shifting. The ecosystem level also undergoes transformation which can be seen on satellite images showing glacier melting, sparse plant groups growing in the places of former glaciers, and decrease of plant cover density in other altitudinal belts resulting from aridization.

A scientifically based action plan should be developed in order to safegaurd the vegetation of mountains and high-mountain plant communities in case of global warming. Such a plan should include (National Strategy 2001; Ionov 2003; Proskuryakov 2012):

- Drawing up a complete inventory of biological diversity and an assessment of its dynamical state.
- Conducting a cadastre of vegetation in the mountain regions.
- Establishing a system of protected areas aimed at biological diversity conservation.
- Conducting annual space and ground monitoring of the ecosystems.

- Realizing a chronobiological study of the basic species in the key sites.
- Developing actions for the restoration of the degraded ecosystems.
- In situ and ex situ conservation of rare and endemic species, wild relatives of crops and fruits trees.
- Sustainable use of the natural capacity of the biological and landscape diversity.
- Finally, introducing rotational grazing and haymaking, observing seasonality and multiplicity of the use of grasslands.

The observation of the dynamics of the basic ecosystem components in the structure of geoecological monitoring should be aimed at the identification of the main issues connected with the problems of mountainous areas, including biological diversity, climate change, and desertification. The priority segments of the structure would be monitoring of glaciers, water resource dynamics, and plant cover state. These environmental elements are the brightest indicators of the current geoecosystem transformations, including those provoked by the climate change.

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