Chapter 12
Assessment of the Current Plant Diversity Status in Kazakhstan

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Abstract Biological diversity is a main source of satisfying the human needs and serves as the basis for adaptation to changing environmental conditions. The practical value of biodiversity lies in the fact that it is an inexhaustible source of biological resources. At present, the number of species on the Earth is a rapidly decreasing. Among the main environmental issues, reduction of biodiversity takes a special place. This chapter presents an analysis of the plant resource biodiversity in the Republic of Kazakhstan. Attempt has been made to explore such natural zones in the ecosystems such as the forest-steppe, desert, semidesert, foothill, and mountainous. All include a detailed description of communities and dominant plants, endemics, and relict taxa. Furthermore, has been carried out the assessment of current biodiversity status, as well as degradation degree of the steppe ecosystems subjected to a large-scale plowing in the 1960s too. The aim here has been to present a quantitative assessment of biodiversity parameters as indicators of ecological safety based on multivariate statistical analysis. According to the indices, the biodiversity is determined as high, acceptable, medium, low, and critical.

Keywords Kazakhstan · Plant diversity · Plant communities · Ecological safety

12.1 Introduction

Kazakhstan is located in the center of the Eurasian continent and is characterized by large species, genetic, ecosystem, and terrain diversity. The area is 2724.9000 km^2. This is about 2% of our global surface. It stretches from the east of the Caspian Sea and the Volga plains to the Altai mountains, from the foothills of the Tien Shan in the south and southeast to the West Siberian lowland in the north. Ecosystems and

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terrain complexes are very unique: from deserts to highlands to inland aquatic ecosystems. The country has a full range of subzonal vegetation variants comprised of steppes, deserts, and mountain belts. These in fact are the characteristic features of Central Asia. More than 75% of these are occupied by arid and subhumid territories, containing more than 40% of species composition of the entire biodiversity of the country (Republic of Kazakhstan 2010).

Plains compose 60% of total land area of the republic, 30% small hills, and 10% mountainous areas. The length of the territory from the west to east exceeds 3000 km, from south to north 1700 km. In the southeast, there is a mountainous range named as Khan Tengri, which is 7000 m high. Kazakhstan is the ninth largest territory in the world (National Atlas 2010).

Flora of Kazakhstan includes more than 13,000 species, including more than 5754 species of higher vascular plants, about 5000 fungi, 485 lichens, more than 2000 algae, and about 500 bryophytes. Among the plants, 14% of the species are endemic, including many tertiary and quaternary relics. The centers of floral endemism are the Mount Karatau and Western Tien Shan (National Report 2015). Unique natural pine forests on sands (Arakaragai, Aman-Karagai, Naurzum) and forests and steppes on the lowlands of Central Kazakhstan; desert communities of Betpak-Dala, Southern Balkhash area, and Ili basin representing original floral composition; forest, shrub, and steppe communities in the Southern Altai, the Kalbin Mountains, and Tarbagatai, the midlands of the Dzungarian Alatau and Tien Shan with coniferous fir forests and fragments of apple forests, as well as wetland-swamp ecosystems of the lower reaches of the Urals, Torgay hollows, Tengiz, and Alakol lakes; and floodplain forests (tugai) of the Syr Darya, Ili, and Charyn.

The country is located inside the continent, within temperate climatic zone. Basic botanical and geographical zones such as forest-steppe, steppe zone, semidesert, and desert zones stretch along its flat part, which in turn is divided into number of subzones. The analysis of current ecological status of bioresources reveals that as a result of urbanization and intensive agricultural development, ecosystems are experiencing a heavy pressure leading to a decrease in the biodiversity. The ecosystems like steppes and vegetation around the foothills are under very high anthropogenic activity. Our major objective here is to analyze the biodiversity status of the country's ecosystems, evaluate their current ecological status, and determine their ecological safety level, based on methods of multidimensional statistical analysis.

12.2 Plant Diversity

12.2.1 Forest-Steppe Zone

This zone occupies a small territory in the Northern Kazakhstan, around Petropavlovsk and Kokshetau cities, represented by forests (0,7 million ha) and is rich in herbal-transformed steppes. Two forest-steppe subzones are clearly outlined in this zone (4th National Report 2010):

1. *Southern weak-wet moderately warm tree cover* (1% of the territory of Kazakhstan) is represented by aspen-birch and aspen forests in small plantations, surrounded by steppe, in the undergrowth of which we come across species like *Salix alba*, *Salix berberifolia*, *Padus racemosa*, *Rosa acicularis*, *Rhamnus cathartica*, and *Viburnum opulus*, together with the graminaceous species like *Brachypodium pinnatum*, *Calamagrostis epigejos*, *Elymus repens*, and few other important taxa such as *Sanguisorba*, *Filipendula*, *Vicia cracca*, and *Peucedanum*.
2. *Moderately dry herbaceous cover* (1.04%) is represented by rich motley grass-cereal steppes. The motley grass includes mesophylls: *Filipendula ulmaria*, *Pulsatilla patens*, *and Galium boreale*. The cereal steppes are dominated by *Stipa rubens*, *Stipa pennata*, and *Fescue sulcata*; also in small numbers we find species like *Koeleria gracilis*, *Poa angustifolia*, *Phleum phleoides*, *Bromus inermis*, *Elymus repens*, and *Helictotrichon hookeri* ssp. *schellianum*. In the forest areas, birch trees (*Betula pendula*, *Betula pubescens*, *Betula kirghisorum*) flourish together with willows (*Salix triandra*, *Salix caprea*, *Salix rosmarinifolia*, *Salix fragilis*, *Salba*). The bushes include *Rosa acicularis*, *Rosa spinosissima*, *Spiraea crenata*, *Spiraea hypericifolia*, *Cerasus fruticosa*, and *Cotoneaster melanocarpa*.

The Artemisia-fescue-feather grass steppes with *Artemisia lercheana* are distributed in the saline depressions. The meadow cereal-mixed grassland is observed on the flat interfluves on wet habitats. Cereals include a dense cover of *Elymus repens*, *Calamagrostis epigejos*, *Bromus inermis*, and mesophyllous taxa like *Filipendula stepposa* and *Sanguisorba officinalis*. The saline habitats are covered by *Galatella punctata*, *Glycyrrhiza uralensis*, *Silaum silaus*, and *Artemisia tenuisecta*.

Steppes occur in complex formations on solonetzes, solonchaks, and saline meadows along the depressions on the flat interfluve and weakly drained valleys. In the northern part of the forest-steppe zone on flat interfluve, which is characterized by most humid habitats, aspen-birch forests are widespread, which are found in the depressions of the south.

The centers of *minor depressions* are characterized by wet and even marshy meadows. Solonchaks are inhabited by the mixed grass-cereal floodplain meadows, widely used with a predominance of *Hordeum brevisubulatum*. Swampy sedge meadows on meadow-bog soils are often haggard due to the abundance of the *Carex omskiana*, *Carex caespitosa*, *Carex acuta*, *Carex disticha*, and *Carex physodes* together with *Juncus ambiguus*, *Comarum palustre*, *Filipendula ulmaria*, *Lythrum virgatum*, and *Lythrum salicaria*.

The forest-steppe zone is characterized by solonetzes and solonchaks with predominance of halophytic vegetation. On dry solonetzes, *Camphorosma monspeliaca* and *Artemisia pauciflora* with *Limonium gmelinii*, *Kochia prostrata*, and a number of annual *Salsola* taxa prevail. *Atriplex verrucifera* and *Puccinellia dolicholepis* grow on more humid crustal solonetzes and solonchaks; *Plantago maritima* prevails in the transition zone on gray meadow solonchaks. On wet solonchaks thickets of the *Salicornia europaea* grow densely (Fig. 12.1).

Fig. 12.1 A view of *Salicornia europaea.* Source: http://www.petrovne.ru/flora_fauna/mediterranean_wildlife/

12.2.2 Steppe Zone

The steppe zone covers an area of 121 million ha (45,5% of the territory of the Republic) between 48° and 52° north latitude, where the entire spectrum of zonal steppe types is observed. The climate of the steppes is characterized by cold winters and hot summers. Annual amount of precipitation is 350–400 mm, and in the southern regions, their amount drops to 250 mm. Vegetation period in the steppes lasts up to 190 days (from late March to late September). In the eastern part of the zone, due to increasing continental feature and longer winters, the vegetation period is shorter and lasts about 175–160 days.

Since steppe plants during the vegetation period are influenced by high temperatures, combined with insufficient precipitation, main vegetation cover is composed of xeromorphic and turf grasses. From north to south, their share in the plant cover increases. In addition, as the ratio of living forms changes, the number of ephemerals and ephemeroids increases. Ephemeral plants with a very short vegetation period grow in early spring and autumn, when there is a lot of moisture in the soil. These plants grow early in the spring and don't exceed a few centimeters in height and include small spring groove, spring veronica, etc. They are distinguished by a very short period of growth—fast and are ephemeral. In a short time period, they sprout, bloom, give seeds, and die down.

The perennial plants with short vegetation period are hibernating in the form of bulbs, nodules, or rhizomes. These are called ephemeroids and include *Tulipa* (Fig. 12.2), *Iris*, *Gagea*, *Hyacinthus*, some species of *Carex*, etc. (Rachkovskaya et al. 1999). The steppes in Kazakhstan, being a unique part of the Eurasian steppe region,

Fig. 12.2 A general look of *Tulipa greigii* Regel. Source: http://www.phytology.ru/cveti-v-sadu/nemnogo-interesnoie-informacii-o-stepnix-tyulpanax.html

represent a transitional zone from the boreal type of vegetation to arid (4th National Report 2010). In the vegetation cover of the steppe zone of the country, xerophilous turf grasses are dominant: *Stipa rubens*, *Stipa lessingiana*, *Stipa capillata*, *Stipa sareptana*, as well as *Festuca valesiaca*. The western part of the steppe zone is characterized by the *Stipa stenophylla* and partly *Stipa ucrainica* and the east by the *Stipa kirghisorum*. The distinctive feature of the eastern part of the steppe zone in comparison with the western part is the presence of shrub steppes (especially with the taiga and caragana), as well as the presence of such oriental species as *Iris scariosa*, *Chamaerodos erecta*, *Potentilla acaulis*, *Orostachys spinosa*, *Astragalus fruticosus*, *Ferula songorica*, etc. in many types of steppes.

The steppe zone is divided into three subzones (Ivashchenko 2009):

1. *Moderate dry rich mixed grass-cereal steppes* distributed on normal and southern black soils (24 million ha or 9%). The basis of the herbage includes dense-turf cereals with a large number of motley herbs on fertile soils. The mixed grasses include *Phlomis tuberosa*, *Salvia stepposa*, and *Medicago lupulina*. These are the most important agricultural regions of the country, which have been subjected to the largest economic development.
2. *Moderate dry steppes* occupying dark chestnut and chestnut soils (53 million ha or 20%) and represented by the feather grass, tyrsa, and fescue as well as ephemerals and ephemeroids—*Poa bulbosa*, desert sedge (*Carex physodes*), *Spiraea hypericifolia*, and *Halimodendron halodendron* which grow in *minor depressions*, in the river floodplains—aspen, and poplar forests with hips, honeysuckle (*Lonicera tatarica*). Most part of it is plowed up.

3. *Desert steppes* on light chestnut soils (44 million ha or 16.5%). This subzone is a transition zone between steppe and desert. It is characterized by the predominance of wormwood-cereal-thin vegetation. Solonets and solonchaks predominate here. The vegetation is similar to the forest-steppe zone. Deserted steppes are distinguished by great complexity of vegetation cover.

The specific feature of these steppes is that the largest number of endemic species are mostly concentrated in the northeast of Kazakhstan. These include the *Amygdalus ledebouriana*, *Calophaca tianschanica*, herbs—*Stipa iljinii*, *Agropyron tarbagataensis*, *Silene karkaralensis*, *Isatis frutescens*, *Clausia kasakhorum*, *Astragalus trautfetteri*, *Cachris macrocarpa*, *Hyssopus ambiguus*, and *Hyssopus macranthus*—*Craniospermum subfloccosum*, etc. The number of endemics decreases in southern direction and especially in western parts. Some endemic species like *Craniospermum echioides*, *Astragalus subarcuatus*, *Astragalus mugodsharicus*, and *Jurinea mugodsharica* are recorded from Ulytau, Mugodzhary, and Western Kazakhstan.

The turf grasses include mesophilic grasses. Meadow-steppe plants such as the *Salvia*, *Phlomis*, *Gypsophila*, *Syzygium*, *Libanotis*, and *Laserpitium* are common in depressions and on the northern slopes of the gullies. Half-shrubs such as the *Artemisia*, *Pyrethrum*, and *Linosyris* play a significant role in the grass stands.

12.2.3 Semidesert Zone

Semideserts are a transition zone between steppes and deserts—stretching from the banks of Zhaiyk to the Altai Mountains, 2900 km in width from 30 to 300 km. They occupy 10.8% of the territory of the country. The southern boundary of the zone passes 48° northern latitude.

The climate of semideserts is much drier than in the northern zones. Precipitation is low; average annual amount varies between 180 and 300 mm. The Most precipitation falls at the end of the spring—the beginning of summer and least in winter and midsummer. The summer in the whole territory is characterized by hot season. The average temperature in July is +22, +24 °C, and sometimes it rises to +40 °C. Winter is severe; clear frosty days prevail. The average temperature of January is −15 to −17 °C; the lowest temperature −50 °C is observed in the east.

In the desert-steppe zone, both steppe and desert plants are common. The vegetation cover mainly consists of the *Festuca valesiaca*, *Artemisia*, *Matricaria*, and *Stipa capillata*. Often *Artemisia* occupies large areas, creating a dull monotonous picture. In some places, among *Artemisia* grow *Kochia*, *Ceratocarpus*, *Krascheninnikovia ceratoides*, and *Atriplex*. Thickets of *Achnatherum splendens* are represented in places where groundwaters approach close to the surface of the earth, on solonchak soils.

According to Gvozdetskiy and Nikolaev (1971), two subzones are distinguished in the semidesert zone:

1. *Desert* (*semishrub-turf-cereal*s *steppes*—northern semidesert with a dominance of turf-cereal steppe, which are combined with desert communities.
2. Steppe deserts—the southern semidesert. Desert communities dominate in the southern semidesert: cereal-*Artemisia* deserts are combined with turf-cereal steppe communities, *Artemisia*, and *Salsola* deserts. So, in both cases the complex nature of vegetation cover is typical with a combination of steppe and desert communities where the first ones dominate in the northern semidesert and the second in the southern. In comparison with vegetation of the steppe and dry steppe zones, the vegetation cover of the semidesert is characterized by depleted species composition, thinness, and a lower height of grass stand (10–15 cm). Moreover, vegetation in desert communities is especially thin. Drought-resistant annual plants predominate: *Stipa sareptana*, *Festuca sulcata*, and *Artemisia*. *Salsola* is common on saline soils. Ephemerals and ephemeroids such as the *Poa bulbosa* and *Tulipa* are widely represented. The seasonal vegetation development is sharply expressed. In spring and early summer, when there is enough moisture in the soil, the plants grow rapidly, but in the second half of the summer, most of them dry up and burn out. In autumn, when temperatures go down and rainfalls begin, the plants come to life again for a short time.

Complex feature is the most characteristic of the semidesert vegetation cover with a combination of steppe (turf-cereal) and desert (*Artemisia*-*Salsola*) communities. The *Festuca sulcata*, *Stipa*, *Agropyron desertorum*, and *Agropyron sibiricum* grasses dominate in the steppe communities and in the desert—the *Agropyron sibiricum*. The *Artemisia lercheana*, *Artemisia lessingiana*, and *Artemisia sublessingiana* are common on light chestnut soils and *Artemisia pauciflora* on solonetzes. The *Pyrethrum achilleifolium* and *Kochia prostrata* play a significant role in the vegetation cover of the southern subzone. Except for *Artemisia pauciflora*, *Anabasis salsa*, and *Atriplex cana*, *Camphorosma monspeliaca* grow widely on crockery solonetzes. *Nanophyton erinaceum* is found on salinized gravelly soils. Solonchaks are home to various succulent *Sálsola*. The meadows are dominated by *Lasiagrostis splendens*, *Aeluropus littoralis*, and *Puccinellia distans*. These prevail in river valleys and lake depressions and mostly on saline soils. On low-capacity crashed stone light chestnut soils in Kazakh small hills, the sparse vegetation cover consists mainly of *Stipa capillata* and *Artemisia sublessingiana*, and in the most stony areas grow *Artemisia frigida*, *Stipa orientalis*, shrub thickets of *Spiraea*, *Cytisus biflorus*, and rose hips (*Rosa*).

12.2.4 Desert Zone

Deserts (area of 124.6 million ha) cover the regions of the Caspian lowland, the peninsula of Mangyshlak, the Ustyurt Plateau, the southern part of the Turgai and Kazakh small hilly areas (eastern Betpak-Dala and Balkhash area), Turan Lowland (Aral area), Kyzylkum, Moyinkum sands, Alakol depression, and Ili basin and in the south reach the foothills of Northern Tien Shan, Dzhungar Alatau, and Tarbagatai mountains.

The climate is characterized by very strong radiation, exceptional aridity of the entire vegetation period, very high temperatures, and extremely low precipitation (100–200 mm/year). In the northern regions of Central Asian and Caspian deserts, winter is quite severe: the average January temperature is −15 °C, and absolute minimum temperature in winter reaches −40 °C with very low snow cover. Spring is frosty. The summer is very hot; average July temperatures range from +24 to +27 °C. Precipitation falls mainly in autumn, winter, and early spring. In order to survive under such conditions, desert plants develop some adjustments such as reduction of evaporating surface by reducing the leaf surfaces (up to their reduction) and developing a thick cuticle layer. As a rule, all desert plants have powerful underground organs, which are much bigger than the mass and volume of the aboveground parts. Along with roots that go deep into the soil, many plants have a large surface area and very thin roots, with the help of which the plants catch moisture from condensed dew (Ogar 2003).

The vegetative component of the desert ecosystems (main communities) is represented by semishrubs and shrubs. It is characterized by small species diversity, small projective cover, and absolute dominance of drought-resistant xerophytes and hyperxerophytes. Three subzones of the desert ecosystems are represented on the plains, northern, middle, and southern, as well as special climate type of foothill deserts (The State cadastre of plants 2006).

1. *Northern* (*steppe deserts*) on brown desert soils (area of 40.0 million ha). They form a huge arc, based on the northern coast of the Caspian Sea in the west and on the foothills of the Tien Shan and Dzhungar Alatau in the east, including the north of Ustyurt Plateau, the Northern Aral area (up to the Syr Darya River), Betpak-Dala desert, southern Balkhash area, and Moyinkum. They include not only the *Artemisia*-semishrubby, *Artemisia-Salsola* deserts, but also sand deserts in the Kyzylkum, dominated by the *Haloxylon* and shrub deserts. They are characterized by semishrub communities, mostly sagebrush and rarely perennial *Salsola* (Toderich et al. 2010). The specific feature of plant communities is the presence of steppe grasses *Stipa sareptana*, *Stipa kirgisorum*, *Stipa richteriana*, and *Agropyron fragile* on the sands.
2. *Middle deserts* (area 51.2 million ha) on gray-brown desert, freezing soils. In the middle deserts, perennial *Salsola* dominate—*Anabasis salsa* (Fig. 12.3), *Salsola arbusculiformus*, *Salsola orientalis*, *Nanophyton erinaceum*, and *Artemisia* species such as *Artemisia terrae-albae* and *Artemisia turanica*. *Saxaul* white (*Haloxylon persicicum*) and black (*Haloxylon aphyllum*) are widely spread on the sand and psammophilous shrubs and semishrubs (*Calligonum*, *Ephedra*, *Ammodendron*).
3. *Southern deserts* (area of 30.3 million ha) occupy the southern part of the arid-denudational Ustyurt Plateau composed of limestone and marls and Kyzylkum sandy area, as well as part of the territory of Southern Kazakhstan within the Atyrau, Kyzylorda, and Shymkent regions. Due to uneven terrain and different salinity levels of the substrate, vegetation cover of these desert communities is heterogeneous and differs in complexity, i.e., combination of different plant micro groups in small areas and in sandy deserts—sand relief and their firmness.

Fig. 12.3 A general view of *Anabasis salsa.* Source: http://silkadv.com/ru/node/800

Fig. 12.4 A general view of *Haloxylon aphyllum*. Source: http://www.plantarium.ru/page/image/id/221341.html

In addition, semishrubs and shrubs dominate in these deserts, but their species composition varies accordingly. The communities of *Salsola gemascons* and *Artemisia kemrudica* prevail. The phytocoenotic role of ephemerals and ephemeroids is significantly increased on the sands, especially of the *Carex physodes* (Figs. 12.4 and 12.5) and juzgun plants (Novikova 1990).

Fig. 12.5 A general view of the *Haloxylon* white (*Haloxylon persicum*). Source: http://nahman.livejournal.com/213044.html

This *Haloxylon* (Chenopodiaceae) is named as black because of its crown which is painted in a rather dark green color. This color is preserved in spring and summer. In autumn the crown becomes orange-brown. It grows on soils containing many salts. This is what distinguishes it from most of the accompanying plants, which die from excess salts in the soil. As a result, its notched young branches taste salty-acidic. For the normal growth, black *Haloxylon* requires heavily wet soil; it grows on lowlands, the places where rivers used to flow and groundwater approaches close to the soil surface or where the wind forms deep basins. Black *Haloxylon* forest is often located in close proximity to oases and protects them from moving sands.

4. *Piedmont desert* (area 14.8 million ha). Mountain systems play a barrier role and, thus, contribute to the distribution of desert communities which is due to latitudinal changes in hydrothermal conditions. After approaching the mountains, the amount of precipitation on the foothills increases due to the intensive thermal convections and active atmospheric fronts. The leading factor in the formation of ecosystems in foothill areas (plains, small hills, and sand areas) is a significant increase in the precipitation due to the effect of piedmont moistening, which forms a "humid-foothill" zone.

In the foothill areas, precipitation is two to three times higher than on the plains which are beyond the influence of the mountains. Mountain massifs serve as significant barrier traps for the northwestern air masses. Piedmont deserts occur at the foot of all mountain systems of Kazakhstan from the Tarbagatai to Karatau and the Western Tien Shan. The main soil types in the ecosystems of foothill deserts are light gray soils (northern and southern). The vegetation of the foothill deserts is characterized by the presence of semishrubs and shrub communities in their composition, as well as well-marked tier of ephemeroids formed by *Poa bulbosa* and *Carex pachystilis*.

In many respects it resembles black *Haloxylon*, but the color of the crown is lighter and slightly whitish. This impression is due to the fact that branches of the previous year are almost white and the shoots of the current year are light green. The trunk is rough, curved, and covered with grayish bark. White *Haloxylon* differs from black by the presence of quite discernible leaves, although poorly developed. They resemble small scales, which transfer upward in a rather long taper. These scales are located on the shoots in pairs, opposite and closely adjacent to the surface of the stem. Difference between black and white *Haloxylon* is that the black shoots taste salty or sour-salty and white ones have bitter taste. *Haloxylon* white grows mainly in the sandy desert and defines the indigenous terrain of the Central Asian sand deserts, emphasizing its originality.

12.3 Mountain Ecosystems

12.3.1 Classification of Vertical Zoning by Semyonov-Tyan-Shansky

The vertical zoning means change in vegetative cover in the mountains and is determined by the position of mountains on the earth's surface, general climatic conditions of certain terrain, and altitude above the sea level. The vertical zoning in the Tien Shan mountains is especially expressed and, accordingly, well explored, which flora is extremely rich and diverse, including almost half of the species diversity of Kazakhstan. It is two to three times higher than the flora of any of the European regions. The number of endemic species is up to 10% of the flora. The endemism is progressive type with neo-endemic characters (Volkova 2003). In addition, Popov has found relict representatives of tertiary mesophilic forests in Tien Shan. His aforementioned "ginkgo flora" includes thickets of wild apple (*Malus sieversii*), apricot (*Armeniaca vulgaris*), and maple (*Acer semenovii*) in the lower belts of Dzungar and Ile (Trans-Ili) Alatau, as well as herbaceous species such as the remarkable *Corydalis semenovii*, *Adonis chrysocyathus*, and others.

Undoubtedly, the plantations of the *Fraxinus potamophila* should also be referred to the same forest relics in the valley of the Charyn River, described by Bykov (1979). In the ash forests (the lower reaches of Charyn River), Bykov (1979) has found a kind of mesophilous orchid (*Neottia kamtschatica*). In general scheme of this system zoning, six vertical zones have been outlined (Chupakhin 1987).

Semyonov-Tyan-Shansky has presented a general scheme of this system zoning, where he distinguished six vertical zones:

1. *Steppe*, stretching from the Ili River valley to the foot of the Trans-Ili Alatau, between 153 and 612 m above the sea level. This zone, now rather called desert, is divided into two tiers. The lower tier stretches from 153 to 306 m above the sea level and is characterized by the presence of *Halóxylon*, solonchak plants, *Calligonum*, *Tamarix*, *Alhagi*, and *Halimodendron.* The upper tier of this zone is

located between 306 and 612 m and is characterized by a vegetation cover of *Artemisia* with some admixture of European species.

2. *Zone of shrub-motley grass steppe* occupies the plumes and foothills of the Trans-Ili Alatau, starting from a height of 612 m and ending near the lower boundary of the coniferous forest on the northern slope at an altitude of 1377 m and on the southern slope in the valley of the Issyk-Kul lake, at an altitude of 1530 m. This zone is rich and diverse, in both herbaceous and tree-shrubby vegetation. This zone is characterized by a wild apple tree (*Malus sieversii*) and apricot (*Armeniaca vulgaris*), which Popov considers a native of China. Also *Crataegus songorica*, *Crataegus altaica*, *Atraphaxis muschketovii*, *Rhamnus cathartica*, *Padus racemosa*, *Acer semenovii*, and a lot of thorn bushes, which usually remain after cutting down as the main components, *Berberis heteropoda*, *Rosa platyacantha*, *Rosa spinosissima*, and others characterize this belt as a zone of hardwood species.
3. *Zone of coniferous forests* or subalpine zone is located along the mountain slopes at altitudes from 1377 m to 2325 on northern exposures and 2448 m on southern slopes. Its upper boundary is the upper limit of forest vegetation. The dominant species is the Tien Shan spruce (*Picea schrenkiana*). There are hardwood species in the subordinate state: *Populus tremula*, *Betula*, and *Sorbus*, in addition to a number of shrubs, including seven species of *Lonicera*. Significant areas of subalpine meadows are found. Ecologically, the Tien Shan spruce differs significantly from other species of this genus. Firstly, it is much more photophilic than all other spruces, and, secondly, it needs less moisture. They usually grow dissociated, rarely forming light rare forests with lots of glades and clearings, often interspersed with rocks, gravelly areas, or stony placers. Seed reproduction of spruce occurs not under the canopy but in strongly lighted places: on fringes, glades, etc.
4. *Zone of the lower Alpine or Alpine bushes begins above the coniferous forest, i.e., above 2448 m and ends at an altitude of 2754 m*. The characteristic shrubs are *Juniperus turkestanica*, *Juniperus sibirica*, *Caragana jubata*, *Spiraea*, *Salix*, *Potentilla fruticosa*, *Potentilla salessovi*, currants, honeysuckle, etc. In addition to shrubs, this zone is also rich in excellent meadows—summer pastures "zhailau."
5. *Zone of the upper Alpine or Alpine grasses* extends over the Alpine shrubbery and up to the lower boundary of the eternal snows located at the altitudes of 3213–3366 m. Various herbaceous alpine forms are mainly spread in this zone, including not more than 25% of European alpine-polar plant types. About 75% of the rest is typical for the Alps, Altai, and Sayan Mountains as well as Polar Siberia, a small part of Himalayan, and a whole number of actually Tien Shan species. However, in the main and the most extensive area is typical grouping of low-grass cereal-mixed grass Alpine meadow. This is low, only 25–30 cm squat grass which fully covers the soil and densely and is unusually flowery, because all dicotyledons of its composition bear bright and large flowers which are disproportionate with the height. Above them stand the single stems of several peculiar alpine cereals and sedges: *Poa pratensis* and *Poa alpina*, *Festuca kirilovii*,

Fig. 12.6 A general view of *Viola altaica.* Source: http://m.cvetki.org/cvetki_viola.php

Trisetum spicatum, and *Anthoxanthum odoratum*. *Carex melanantha* prevails within the sedges. From the representatives of cereals *Polygonum nitens*, *Polygonum viviparum*, *Viola altaica* (Fig. 12.6), *Anemone protracta* and especially bright orange *Erigeron aurantiacus* grow widely. New species also join here: *Aster flaccidus*, *Pedicularis violascens*, *Pedicularis songorica*, *Gentiana algida*, and *Gentiana kaufmanniana*.

The upper limit of vegetation is a scattered and disconnected plant cover of large-scale moraines, terminating around the glaciers at altitudes above 3000 m, which serve as a transition to the final plant free glacial zone: eternal snows, ice, and stone. At the lower edge of the moraines, one can find some Himalayan species, for example, *Viola kunawarensis* or *Lonicera glauca*. On the moraine itself, usually many species of *Poa lipskyi* and *Poa dschungarica* grow together with *Festuca tianschanica*, *Carex griffithii*, *Taraxacum lilacinum*, and *Saussurea glaciales*.

6. *Zone of eternal snow is* represented by peaks and high ridges, lying above 3366 m. In this zone only some areas open up from snow for a short time, and rare representatives of plants from the upper-alpine zone can be seen here.

12.4 Current Biodiversity and Ecological Status

Conservation and careful use of biodiversity is a key element of sustainable development. The species composition of any ecosystem is formed as a result of long evolution. In the ecosystem, all species are in close relationship with each other and with their habitat, performing certain functions, and therefore the whole system is well balanced. Loss of one species can lead to an imbalance as a result of loss of certain functions performed by this species. This does not pass without consequences not only for the ecosystem but for the entire biosphere (Ozturk et al. 2010). In a report published in early 2010, the UN Commission on Biodiversity draws attention to catastrophic changes in the wildlife on global basis. Currently, more than 40% of all living species on the Earth are threatened with extinction. If these rates of extinction continue or accelerate, the number of endangered species in the next decades will be counted in millions (http://web.unep.org/annualreport/2016/index.php).

The variety of natural conditions of Kazakhstan determines the wealth and diversity of its biological resources. The country's biological resources are vital for its economic and social development. Biological diversity is an asset of great value to the present and future generations. In Kazakhstan as in the rest of the world, the decrease of biodiversity is taking place. Major reasons are a loss of habitat, excessive exploitation of resources, environmental pollution, and displacement of natural species by introduced exotic species (Ozturk et al. 2010). Apparently, in all cases, these reasons have anthropogenic character. Among the globally threatened (CR, EN, VU, NT) categories in the flora of Kazakhstan, there are 15 species, including five critically endangered (*Berberis karkaralensis*, *Calligonum triste*, *Lonicera karataviensis*, *Populus berkarensis*, *Sibiraea tianschanika*), eight endangered, and two vulnerable. The list of rare and endangered plant species at the national level contains 387 plant species (5th National Report 2015).

As a result of large-scale plowing of land which took place more than 50 years ago, the total changes in majority of ecosystems have occurred, especially in the steppe and forest-steppe zones. This is fully observed in the rich mixed feather grass, 8.5 million ha, and mixed feather grass steppe, 13.6 million ha. The transformation of territories on the plains reaches 90%, in small hills areas up to 30%. The dry steppes in the plains have changed by 50–60% and in small hills areas by 10–15%. The depletion of biodiversity in the desert subareas is different. In northern deserts, predominantly sagebrush, the local overgrazing around wintering grounds, settlements, a linear trend is observed along the livestock trail routes. In the middle and southern deserts (perennial *Salsola*), except for overgrazing, the violations are associated with technogenic impacts and not well-planned road network, regulation of river flow, and illegal cutting of *Halóxylon*. Vegetation of sandy deserts has been strongly disturbed. Severe disturbance of the vegetation cover has occurred due to urbanization and intensive agricultural development around the foothill zones. The areas in the original Kazakhstan ephemeroid-wormwood deserts have practically been destroyed. Especially sharp changes in meadow vegetation have taken place in the floodplains of the Ili, Syr Darya, Shu, and Talas rivers. Moreover, highly productive floodplain communities have almost completely got degraded. In connection with limited river flow, meadow vegetation has degraded everywhere, and meadows have disappeared as a type of vegetation. Their diversity has reduced; yield capacity has also reduced 10–15 times (from 15–40 to 1.5–2 ha).

In northwest Kazakhstan floodplain forests (oak forests, ash trees, maple trees, elms, willows, etc.), there has been degradation due to violation of hydrological regimes. Mountain forests are also under the pressure of livestock overgrazing, which has resulted in the degradation of live surface cover and destruction of natural renewal. Logging has resulted in a decrease in the density of plantations and a change of coniferous species to deciduous and shrubby ones (East Kazakhstan region). Lower boundary of the spruce belt has gone up to about 200 m in the Ili Alatau during the last 100–150 years and in the Dzungar (Zhetysu) Alatau fir belt up to 100 m (5th National Report 2015).

12.5 Evaluation of Biodiversity and Ecological Safety Levels

Ecological safety under current conditions is considered as an integral and important part of the security of the "individual, society, and the state." The main subject of ensuring environmental safety is the state, which performs its functions in this area through the bodies of national legislative, executive, and judicial authorities. The main objects of environmental safety are:

- Individuals have a right to live a healthy life in a favorable environment.
- Society and its material and spiritual values, depending on ecological status of the country.
- Natural resources and natural environment are the basis for sustainable development of society and welfare of future generations.

Environmental safety is a sustainable environmental status, which provides an opportunity for improving the life quality of the society and the state as well. Ecological safety means environmental impacts, which can result in the changes in the environment and, as a consequence, changes in the conditions for the existence of human and society.

The issues of ensuring environmental safety and issues of sustainable development are becoming especially relevant today and are treated as the most important for each state. Currently, in the context of globalization, environmental safety for any country is considered an obligatory, necessary, and the most important part of the general state policy. Ecological safety of each state separately determines the overall international political stability and global security.

The national report on biodiversity of the Republic of Kazakhstan (5th National Report 2015) notes the depletion of biodiversity and ecosystem degradation in the 66% of the country's area. Reduction of biodiversity components is caused, first of all, by anthropogenic influences. Main threats include desertification, economic activities, environment pollution, natural disasters, forest fires, and illegal logging on the territory of the state forest resources, the impact of introduced species (biological pollution) (5th National Report 2015). It is especially necessary to note that Kazakhstan, as an agricultural country, has practically mono crop agriculture which has adverse effects on biological diversity.

Threats to environmental safety include conditions and factors that represent a threat to environmental resources, natural balance, human-friendly natural environmental conditions, and economic value of natural resources. A threat to ecological well-being can be a result of the excessive extraction of natural resources and, as a result, a decrease in biodiversity. Biodiversity is the basis of life on the Earth, is one of the most important life resources, and is considered to be the main factor determining the stability of biogeochemical cycles of the substance and energy in the biosphere (Ozturk et al. 2010). Based on the importance of this issue, we calculated the level of biodiversity ecological safety.

12.6 Methods Used

Indicators of biodiversity have been estimated by many researchers, but none has primarily focused on quantitative values but qualitative parameters of the ecosystem. Such indicators cannot be estimated in view of environmental safety management; therefore we propose a system of quantitative assessment on biodiversity parameters, which determines the indicator of biodiversity ecological safety. The principle of quantitative evaluation is oriented on the fact that populations of species depend on the average life expectancy of each representative and more precisely on the life cycle of population. However, the dependence for life forms is nonlinear but rather quadratic; therefore there is a slight increase in the population life cycle, and population increases significantly. In nature such phenomena are considered anomalous. To express the Ginni index, the larger the anomaly, this index changes more rapidly (Russell 2013). Therefore, to determine the biodiversity safety coefficient (B_{SC}), we used the following formula:

$$B_{SC} = \frac{\left|1 - \sum_{i=2}^{n} \left(Y_i - Y_{i-1}\right)\right|}{\left|1 - \sum_{i=2}^{n} \left(Z_i - Z_{i-1}\right)\right|} \times \frac{\sum_{i=1}^{n} Z_i}{\sum_{i=1}^{n} Y_i}$$

where n is the number of animal species inhabiting Kazakhstan, Y_i, Z_i is population number of i (fauna species) and population life cycle. The sets (Y_1, Y_2, …, Y_k, Y_{k+1}, …, Y_n) and (Z_1, Z_2, …, Z_k, Z_{k+1}, …, Z_n) go in strictly descending order. In high biodiversity of the study area, the safety index tends to be 1. Disturbance of ecological balance occurs in dominance of the populations of the species at approximately the same stage in the population life cycle; in this case the safety index tends to be 0.

In general, such innovative approach on biodiversity requires additional large-scale researches and refinements, but following the logic of our research, we tried to assess the safety levels on a five-point scale given in Table 12.1.

Table 12.1 Biodiversity safety levels

Index	Safety level	
I	More than 0,7	High
II	0,7–0,6	Accessible
III	0,6–0,5	Average
IV	0,5–0,4	Low
V	Less than 0,4	Critical

12.7 Conclusions and Recommendations

As a result of the large data base analysis, this study includes an assessment of the bioresources of Kazakhstan on the basis of botanical-geographical zones like forest-steppe, steppes, deserts, semideserts, and mountain zones. They characterize the country's rich biodiversity. Reduction of biodiversity as a result of strong anthropogenic pressure on the environment is more than urgent for Kazakhstan, as well as around the globe. The estimation of current ecological condition here shows the degree of ecosystem degradation caused by climate change, habitat loss, excessive exploitation of resources, environment pollution, and displacement of natural species by introduced exotic species. Moreover, we propose the formula to calculate the indicator of biodiversity ecological safety level, which is defined according to five indices as high, acceptable, average, low, and critical.

The following recommendations are proposed for effective biodiversity management:

- Inventory assessment of plant communities and determination of new boundaries of natural zones in the context of the climate change and development of desertification processes
- Further expansion of specially protected natural areas linked by ecological corridors
- Inclusion of the republic's specially protected natural areas in the UNESCO World Natural and Cultural Heritage List and Biosphere Territories under the program "Human and Biosphere"
- Conservation of natural populations of rare, endangered, relict, and endemic species through their artificial ex situ reproduction and restoration in disturbed areas

The analysis of the rich fauna status in ecosystems of Kazakhstan, agrobiodiversity, diversity of aquatic ecosystems, as well as specially protected natural areas (SPNA), which occupy 8.6% of the total territory, has not been included in this study, as these are a subject of separate research study.

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