Chapter 2
Natural Conditions of Central Asia and Land-Cover Changes

2.1 Natural Geographical Division of Deserts in Central Asia and Kazakhstan

More than 40% (or more than three quarters) of the territory of Central Asia is desert lowland, which varies greatly in configuration as sandy, stony, salt, and clay deserts (Lewis 2003). The deserts of Central Asia expand from the shores of the Caspian Sea in the west up to the foothills of Alatau Mountain (Tianshan) and Pamir-Alay to the east and southeast. This wide territory is represented by a great variety of desert types.

Specific features of general lithological–edaphic conditions in the formation of Central Asian and Kazakhstan deserts are classified into six groups: sandy, sandy–gravel and gravel, crushed stone–gypsum, loess, clay, and solonchak (Fig. 2.1).

Sandy deserts are a widespread type of landscape in the territory of Central Asia. Deserts occupy much of Kazakhstan and almost all of Uzbekistan and Turkmenistan. They cover the Karakum, Kyzylkum, Pre-Aral Karakum, Moiynkum, Saryesikatyrau, and sandy deserts in the Ferghana Depression, etc. The total area of sandy deserts is approximately 618,000 km^2 (17%) of the territory of Central Asia and 246,000 km^2 (9%) of the territory of Kazakhstan (Table 2.1) (Babaev 1999).

The greatest of these deserts is the Karakum Desert, which stretches >350,000 km^2 and lies between the mountains and the Amudarya River. The desert borders with the northern Caspian lowland and the Usturt Plateau on the west, and on the east it lies on the foothills of the Pamir-Alay mountains. The primarily alluvial rocks are the origins of this desert, and aeolian erosion contributes as well (Lewis 2003).

The Kyzylkum Desert is a part of the Northern Desert. It is located southeast of the Aral Sea between the Amudarya and Syrdarya rivers. The cover area is approximately 300,000 km^2 and stretches across Kazakhstan, Uzbekistan,

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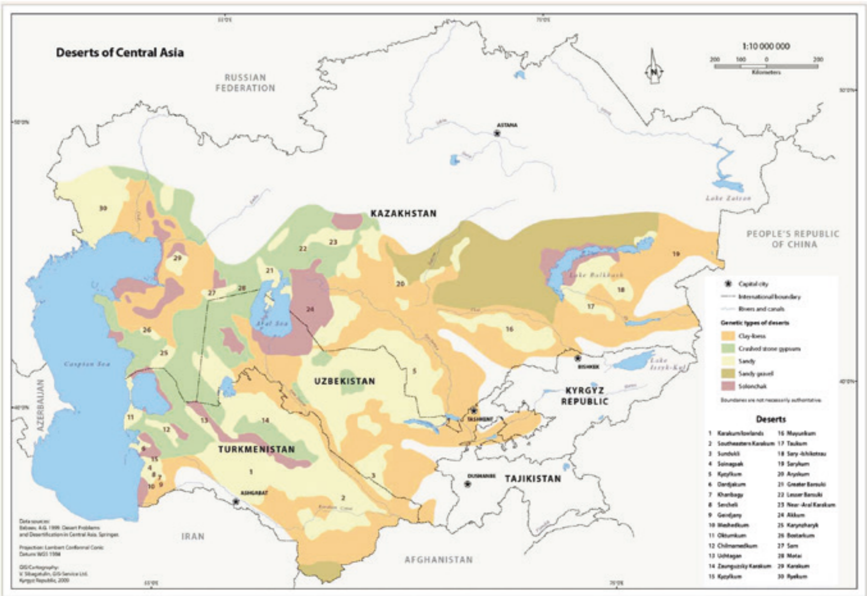

Fig. 2.1 Distribution of deserts in Central Asia and Kazakhstan [see Amid Deserts, Steppes and, Mountains (available at: http://www.carecprogram.org/ru/index.php?page=central-asia-atlas-natural-resources)]

Table 2.1 Area covered with deserts in Central Asia (Zakirov 1980)

Country	Total area	Area covered with desert		
		All types	Sandy desert	%
Kazakhstan	2,715,000	747,000 km^2	246,000	32.9
Turkmenistan	488,000	387,000	260,000	67.2
Uzbekistan	449,000	250,000	107,000	42.8
Tajikistan	143,000	25,000	5000	20
Kyrgyzstan	198,000	70,000		0
Total	3,993,000	1,479,000	618,000	41.8

and Turkmenistan. The desert presents a diversity of landforms and wealth of resources for Central Asia. Sandy, sandy-gravel, gravel desert, crushed stone gypsum, loess, and takyr soils are distributed in the desert. The desert consists of a massive plain with an altitude of $\leq$300 m that slopes down toward the northwest with a few small basins and mountains that rise to 900 m (Babaev 1999).

The arid Usturt plateau lies in northwestern Central Asia between the Caspian and Aral seas. It is a flat plain with occasional small hills containing salt lakes, salt marshes, and sand. Rain and running water are practically nonexistent on the plateau.

These sandy deserts have a different genesis, but they have developed largely over thick, loose, sandy sediments, mostly of a riverine and marine origin. In terms of sediment origin, they are subdivided into the following subtypes:

- Sands of ancient alluvial plains: Karakum lowlands, Chilmamedkumy, Sundukli, Kumcebshen, Kattakum, sands of the Central Ferghana, Pre-Aral Karakum, Moiynkum, and others.
- Sands of marine lowlands: Incorporate sands formed as a result of the deflation of ancient and recent marine deposits. They are locally developed mostly on the eastern coast of the Caspian Sea (Western Turkmenistan).
- Sands of piedmont plains: These spread mainly as separate, large, sand massifs on the piedmont plains of Kopetdag, Nuratau, Karatau, and others. In their geological structure the proluvial deposits (sands, loamy sands, loams) dominate.
- Sands of ancient structural plains composed of Paleogene, Neogene, and Cretaceous sandstones occurring mainly in Zaunguzsky Karakum, Uchtagan, and Kyzylkum.

Closer to the surface these plains are composed of mostly Neogene sandstones striking horizontally. More seldom outcrops of Paleogene and Upper Cretaceous sandstones and limestones are observed on large areas. Sands of this subtype are widespread.

Concerning sand mobility and thickness of a vegetation cover, the sandy deserts are subdivided into three groups:

- *Bare sands* are represented by single and group barkhans, complexes of barkhans, barkhan chains, and barkhan-ridge sands. They expand over an area of >3 million ha or approximately 7% of the area of sandy deserts. Such sands occur largely in Western Turkmenistan, Djillikume, along the Amudarya, in the eastern part of the Aral region, and in the Ferghana valley, etc. Barkhan sands also surround settlements, pits, or develop along point and linear objects. Sand formation is connected with a number of physiographical and anthropogenic factors. Affected by intensive winds, they can move, which can impede the operation of some economic units.
- *Semi-overgrown sands.* On the territory of Central Asia, semi-overgrown sands comprise many varieties: ridge, barkhan-mound, ridge-mound, cellular, ridge basin, and ridge-honeycomb sands. In general, they do not move. Barkhan-like mobile forms are found only on tops of ridges with very thin vegetation cover. Some mobile forms appear among overgrown sands as a result of an anthropogenic impact. After the end of that impact, the vegetation continues growing. Barkhan sands are overgrown with *Carex physodes*, *Stipagrostis karelinii*, and other pioneer grasses, then shrubs and grasses–ephemerals, and still later semishrubs. However, natural vegetative regeneration of barkhan sands is a very slow process that is connected with high sand mobility.
- *Overgrown sands.* This group incorporates stable, often unmovable, forms of sand relief-mounds, vegetated sand dunes, honeycomb, and slightly rolling

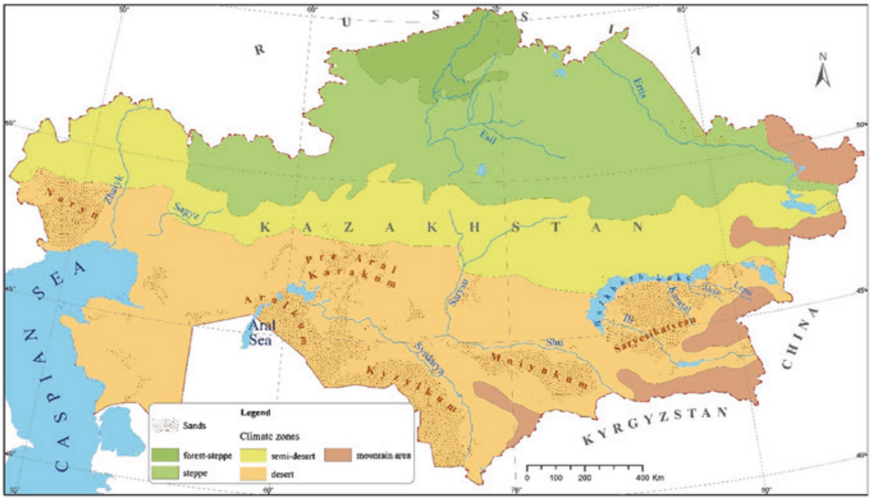

Fig. 2.2 Distribution of sandy deserts and climate zones within Kazakhstan

sands well fixed with vegetation. After destruction of a vegetation cover, they turn within a short time period into drifting, barkhan forms.

Sandy deserts are a widespread type of landscape in the territory of Kazakhstan. Kazakhstan lies between the Siberian Taiga in the north and the Central Asia deserts in the south, the Caspian Sea in the west, and the mountain range of the Tien-Shan and Altay in the east (UNDP 2002). Approximately 60% of Kazakhstan is flat lands. Deserts and semi-deserts occupy approximately 50% of the territory, most of them situated in the Turan plain. Arid territories spread from Caspian Sea to foothill plains of the Zhetysu (Dzhungar) Alatau, and Tien-Shan mountains. These vast territories have various geological structures and landscape features such as sandy deserts of Naryn, Kyzylkum, Pre-Aral Karakum, Moiynkum, and Southern Pre-Balkhash deserts (Saryesikatyrau, Taukum, etc.) (Fig. 2.2). The northern parts of Kazakhstan are steppes and forest-steppes (Danayev 2008). Desert areas are more often the principal source of dust- and sand-storm development (Squires 2001).

The southern Pre-Balkhash deserts (Saryesikatyrau) belong to the category of sandy deserts. The sandy deserts are located in southeast Kazakhstan, within the vast (size approximately 70,000 km^2) and shallow southern Balkhash Depression. The depression was formed in the Neogene period. The Paleogene rocky deposits are found mainly in the periphery (Abdullin 1994). The territory of Balkhash Lake basin is characterized by great diversity and complexity of geological structure. This depression is bordered by the Shu-Ili Mountains in the west, by Balkhash Lake in the north, and by the Arganty, Arharly, and Saikan mountains and north-eastern spurs of Zhetysu (Dzhungar) Alatau in the east (Dzhanalieva et al. 1998;

Skotselias 1995). The southern Pre-Balkhash deserts consist of the Taukum and Moiynkum deserts, which stretch along the left bank of the Ili River. The Saryesikatyrau, Bestas, Irizhar, and Zhamankum deserts are located between the Ili and Karatal rivers. Zhalkum sands are situated between Karatal and Aksu rivers.

The southern Pre-Balkhash sandy deserts are formed on quaternary sedimentary depositions. Among them maritime–alluvial, alluvial–delluvial, and sandy–clay deposits are widely distributed. Most of the territory is covered by aeolian sand deposits (Faizov 1983).

Arid climate, frequent strong winds, scarcity of vegetation, and dominance of friable (loose) sandy–clay rocks in the overburden contribute to the active development of aeolian processes. As a result of aeolian transportation and redeposition, the following huge sand massifs and deserts have formed: Kyzylkum, Naryn, northern Caspian Sea and Pre-Aral Karakums, Big and Small Barsuk, Saryesikatyrau, and Taukum (Fig. 2.2). The sand massifs and deserts have various relief forms such as alveolate, hilly, hilly–ridge, barchans–ridge, and barchans–alveolate, etc. Sandy and sand–loam deposition of various origins—as well as marine sediments, sediments of alluvial and alluvial–deltaic plains, sandy marine and river beach barriers, soil of light texture, and plump solonchaks—are subject to the aeolian process.

Aeolian processes are most intensive in piedmont areas composed mainly of poorly cemented sandstones, loess loams, and similar ground that is subject to easy scouring and weathering. After the demise of the ancient river system, the alluvial plains were gradually subject to deflation and aeolian dissection. Therefore, in Central Asia, most widespread are sandy deserts that were largely formed in areas of development of ancient or modern alluvial or lacustrine–marine, loose deposits (Babaev 1999).

Based on a variety of synoptic process, rainfall patterns, and annual and interannual temperature regimes, the Central Asian deserts are divided into two climatic provinces: northern and southern (Rachkovskaya 2003). The northern province includes the Northern Caspian Sea deserts (Naryn desert), Mangyshlak, Northern Usturt, Moiynkum, Southern Pre-Balkhash deserts, and Dzhungaria. The Southern province occupies the southern regions of the Aral–Caspian lowland–south part of Usturt Plateau, Karakum desert, and the Central and Southern Kyzylkum deserts.

These two major Northern and Southern deserts are characterized by temperature extremes, seasonal drought, snowy winters, and strong winds that move dunes, stir up blinding dust and sand storms, and erode agricultural land.

The climate of desert is characterized by dry and long summers with high temperatures. Deserts exhibit temperature extremes from winter to summer and from day to night. They receive little rain, and the rain received evaporates quickly. Deserts contain uncommon biodiversity where animals and plants have learned to make the most with less.

The Northern province is characterized by a cold and dry continental Central Asian type of climate, whereas the southern one is distinguished by a hot and dry Mediterranean climate. The Northern Desert during cold season is under the activity of the winter Siberian anticyclone, and severe, long winter with frosts and lasting snow cover is typical for the area. In the Southern Desert, precipitation is ≤70 mm with a maximum at spring with the remainder in the late autumn and winter seasons. This creates two seasons: a mid-May through mid-October, which is the dry season, whereas the rest of the year is the humid season. Winters are generally mild with unstable snow cover. January temperatures between −1 and 5 °C, and most plant growth stops for a short period only. Climate conditions are more severe in the equally large Northern Desert where January temperatures are −10 to −15 °C and increase to 24–26 °C in July. Precipitation may fall any time of year on average ≤150 mm annually. The precipitation amount varies between 80 and 200 mm within the provinces. Less than 100 mm of precipitation has been registered in the Karakum and Kyzylkum deserts, Betpakdala, and the western Balkhash shore (Indoitu et al. 2012).

Among the Eurasian deserts, the Central Asian deserts—particularly the sandy Northern Desert in central Kazakhstan and the Southern Desert, which distributes in Turkmenistan, Uzbekistan, and southern Kazakhstan—present the greatest species of desert diversity. Black and white saxauls are the most common tree shrub vegetation in the deserts. The deserts are also home to Asian wild asses and Bactrian camels, which belong to rare and endangered animals with small numbers (Babaev 1999).

2.2 Climate Conditions and Weather Process in Central Asian Deserts

Central Asia is a land-locked region of the Eurasian continent with multiple climatic regimes that range from heavy precipitation in the mountains to arid deserts. Climate conditions in Central Asian deserts are multiple and complex. Annual precipitation patterns explain the arid environments in the region generally. Annual precipitation in the deserts of Central Asia is <100 mm/y, which indicates a dearth of precipitation across the great deserts of Turkmenistan, Uzbekistan, and Kazakhstan. Precipitation gradually increases to the north, south, and east around the deserts on the steppes and plateaus. The majority of precipitation received by the eastern and southeastern mountains of the Central Asia amounts to ≥1000 mm on average. The mighty rivers that flow from these mountains provide power (electricity) to Kyrgyzstan and Tajikistan and irrigation to southern Kazakhstan, Uzbekistan, and Turkmenistan (Fig. 2.3).

Temperatures across most of the steppes and deserts in the region vary from north to south. The temperature is as low as −20 °C in January. Winters are severe in northern Kazakhstan, and crops and pasturelands are covered by snow for much of the winter (Fig. 2.4). Climate conditions in the south become milder, but average mid-winter temperatures do not exceed zero except in southern Turkmenistan and Uzbekistan.

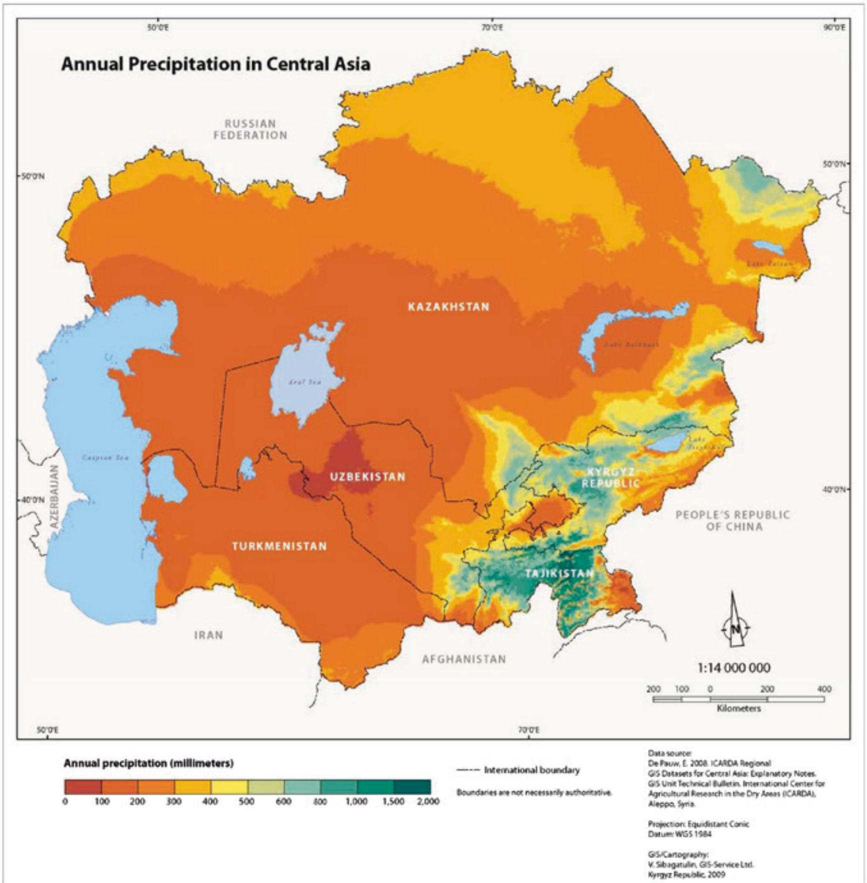

Fig. 2.3 Annual precipitation in Central Asia [see Amid Deserts, Steppes and, Mountains (available at: http://www.carecprogram.org/ru/index.php?page=central-asia-atlas-natural-resources)]

Throughout the steppes and deserts, the temperature is above zero in the summer season. In northern Kazakhstan, temperatures are on average ≤25 °C in midsummer and >30 °C in southern Turkmenistan (Fig. 2.5). However, temperatures decrease quickly with altitude in the mountains in the east and southeast. Winters are bitter, and the temperature is lower than −25 °C on average in the highest plateaus, which remain snow-covered year round. Even temperature in the lower slopes of the mountainous areas average ≤10 °C or less in middle summer.

The following climatic regions/zones exist in the territory of Central Asia and Central Kazakhstan: (1) temperate zone/belt: continental steppe region, continental North Turan region, and Tianshan mountain region; (2) subtropical zone: continental South Turan region and Pamir-Alai mountain region (Alisov 1969).

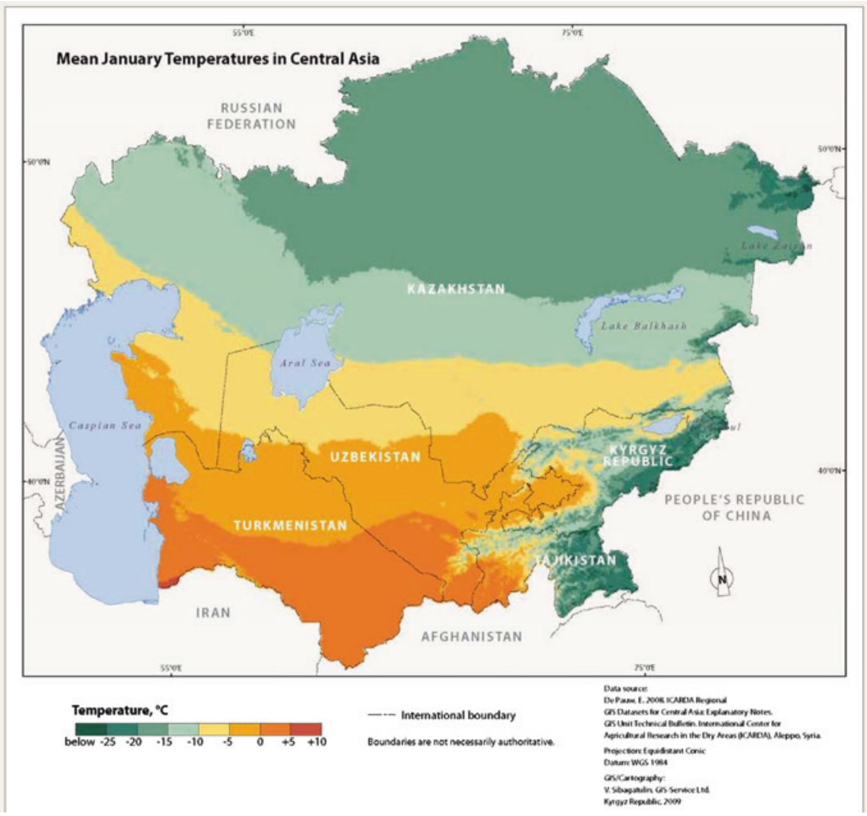

Fig. 2.4 Mean January temperatures in Central Asia (see Amid Deserts, Steppes, and Mountains: http://www.carecprogram.org/ru/index.php?page=central-asia-atlas-natural-resources)

(1) *Temperate zone/belt.* The climate of the continental steppe region comprises a significant exposure to radiation factors characterized by rapidly increasing aridity to the south. The southern border of the region coincides with the northern boundary of the desert zone. January temperature ranges from −18 to −15 °C and in July from 22 to 25 °C. The annual precipitation is 200–300 mm. The snow cover is low.

The continental North Turan region occupies the central and northern part of the Turan lowland and Balkhash Lake. Radiation factors have a decisive influence on the formation of the climate, especially in the summer. In winter, the prevailing northeasterly winds bring continental Siberian air. In the summer, the northern and northwesterly winds bring continental air from Western Siberia and the southeastern regions of the European part of the USSR. These air mass within the region undergo the second phase of transformation and become closer to tropical air masses. The temperature difference between the air and the transformed tropical

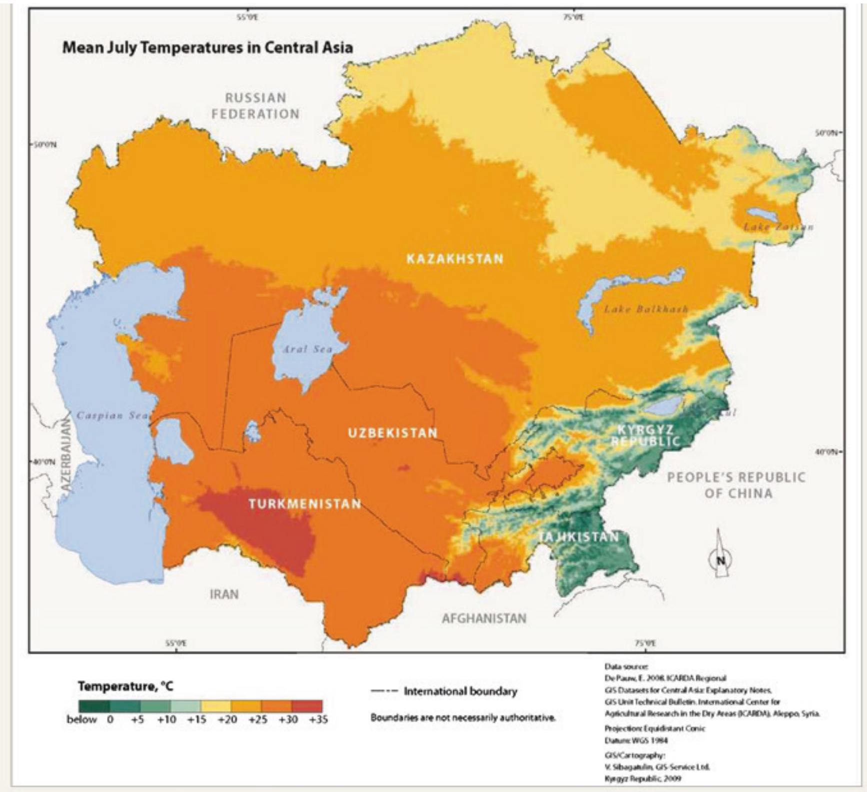

Fig. 2.5 Mean January and July temperatures in Central Asia [see Amid Deserts, Steppes, and Mountains (available at: http://www.carecprogram.org/ru/index.php?page=central-asia-atlas-natural-resources)]

air of southern origin are smoothed out, and the cyclonic activity is weakened. January temperatures range from −15 °C in the north to −3 °C to the south and in July from 25 to 30 °C. The annual precipitation is ≤10–200 mm.

The Tienshan Mountain region occupies the main part of the mountain range. The climate is formed by the action of circulation processes, which develop over Kazakhstan and Western Siberia, and under the influence of altitudinal zonation. The mountainous terrain increases the cyclonic activity and rainfall. The temperature decreases with height in January to 0.5 °C and in July to 0.7 °C/100 m. On the western slopes, the rainfall averages approximately 800 mm average for the year (in some places it is >1600 mm).

(2) *Subtropical zone.* The continental South Turan region occupies the southern part of the Turan lowland corresponding to the southern subtropical desert zone. Major climatic factors are radiation and cyclonic activity of the Iranian branch of the temperate-latitudes front. January temperature ranges from

−3 °C in the north to 2 °C in the south (between the western extremity of the Kopetdag and Caspian is 4 °C) and in July range from 30 to 32 °C. The annual precipitation is 150–200 mm. The zone is characterized by spring rainfall and sudden changes in weather conditions in the winter.

In the Pamir-Alai mountain region the major climatic factors are radiation, cyclonic activity of the Iranian branch of the temperate-latitudes front, and altitudinal zonation. The average January temperature in the foothills ranges from −5 °C in the north up to 2 °C in the south; on the high plateau (approximately 4000 m) it averages −20 °C. In the foothills, the average July temperature is 25–30 °C, and on the high plateau (approximately 4000 m) is averages 8 °C. In the high-altitude area with forests, precipitation >1000 mm/year, sometimes >1600 mm, falls on the Fedchenko Glacier; in the Western Pamirs precipitation is 2236 mm/year; and on the plateau of the Eastern Pamirs precipitation averages approximately 100 mm/year.

The atmospheric circulation is primarily affected by the continental position and the division of Central Asia and Kazakhstan into a terrain of deserts and mountains (Borisov 1965).

The mountain system located in the surrounding areas of Central Asia have a great influence on the climate of the region. It involves not only the barriers protecting Central Asia from the south (from the South Asian monsoon penetration), it also involves the mountains located to the west and southwest (Greater and Lesser Caucasus and the Armenian Highland, Zagros, etc.). They form a barrier in excess of 3000-km length and have a distorting effect on the high-altitude frontal zones, which significantly affects the development of cyclonic activity in Central Asia. Due to this mountain barrier, atmospheric waves cause the development of strong foehn that eliminate precipitation. The effect of these processes is observed almost over all of the territory of Turkmenistan. The mountain barrier greatly reduces the amount of rainfall brought by the West, in particular the Southwestern (Mediterranean) cyclones to Central Asia.

Altitudinal climatic zonation appears in the mountain regions of Central Asia. The lower zone of the mountain is exposed to the same air masses and circulation processes as the neighboring deserts. The frontal process is aggravation of the slopes. The western air transport in the middle layers of the troposphere strengthen in the upper zones. The windward slopes produce a significant amount of rainfall (in some places >1600 mm), and in the "shadow of the barrier" it falls sharply. In the Eastern Pamirs, annual rainfall is as low as in the most arid regions of the Turan lowland.

Atmospheric circulation, solar radiation, and landscape shape are the three main factors that determine a climate. Solar radiation to the surface depends on cloudiness, fog, haze, and dust and sand storms, etc. The process of global atmospheric circulation is mainly a planetary factor and determined the input of solar radiation. In Central Asia, the atmospheric circulation are diverse with several types such as cyclonic, anti-cyclonic, frontal, and local (breeze, highland–valley, etc.). Each type of the atmospheric circulation has its own features. For instance, the cyclonic circulation occurs in the zones with low pressure and is characterized by constant turbulent air movement. The airflow trajectory inclines toward the minimal pressure, namely, to the storm center. According to the law of conservation of mass, and due to a convergence of airflows, the air is displaced upward. The mass of air expands while moving upward moves into upper strata with lower pressure. It cools down adiabatically (1 °C/100 m of altitude) and becomes saturated with moisture. Thus, vast cloud systems are formed in the cyclones and rain falls constantly. Anti-cyclonic circulation occurs in areas with high pressure. Any area with high pressure is characterized by the clockwise turbulent movement of air. With that, the airflow trajectory inclines from the center of maximum pressure toward the periphery. This leads to a divergence of airflow that give rise to a vertical movement of the air from the top downward. This factor moves air masses into the strata with higher pressure downward and warms up adiabatically (1 °C/100 m of altitude). Warming of the air leads to an abrupt decrease of the relative humidity and leads to a dissipation of cloud systems, which favors fair weather without rainfall.

The synoptic processes can be divided according to the type of weather. For instance, the synoptic processes in Central Asia are classified into four main categories: cyclonic circulation, cold-wave intrusions, the group of synoptic processes conditioning fair weather, and the group of synoptic processes causing unstable weather.

Cyclonic circulation is one of the main categories of synoptic processes in Central Asia. The South-Caspian, the Upper-Amudarya, and the Murgab are three basic types of cyclones (Fig. 2.6).

Cold-wave intrusions are subdivided into three types—western, northwestern, and northern—according to areas of their origin and direction of movement. The most abrupt deterioration of weather occurs when intrusions move in the rear of cyclones. Northwestern cold intrusions form sandstorms and haze in the dry season (Fig. 2.6).

Three types of processes—such as confining cyclones, wave activities, and the southwestern and southern peripheries of anti-cyclones—belong to group of synoptic processes causing unstable weather. The wave activities are typical for highland areas, and they take place in cold frontal partitions. Such a process can continue with significant rainfall from several days to 1 week. The process is accompanied by widespread rainfall in the winter and springtime when an influx of arctic air masses occurs along the southeastern periphery of the anti-cyclones with intrusions of western and northwestern humid air.

The following processes—thermal depressions, southwestern peripheries of the Siberian anti-cyclone, and small-gradient fields of decreased or increased air pressure—belong to the group of synoptic processes conditioning fair weather. The thermal depression is characterized by very hot, hazy weather and is typical only in the summer season. The thermal depression played a major role in creating a long drought in Central Asian countries in 2000.

The climatic features of Central Asia and Central Kazakhstan are determined by: (1) their inland position and remoteness from the oceans, which are the main

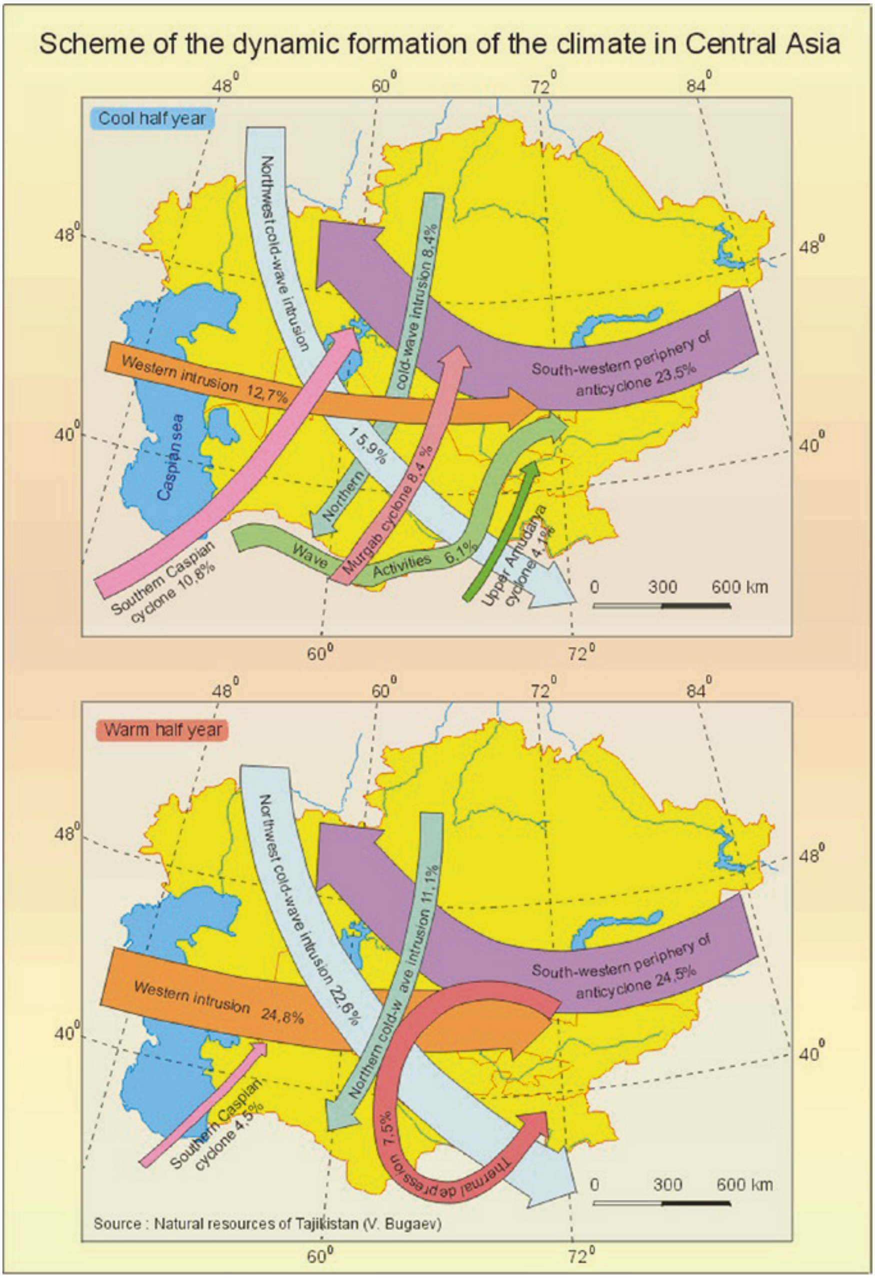

Fig. 2.6 Formation of climate in Central Asia (see http://enrin.grida.no/htmls/tadjik/vitalgraphics/eng/html/c9add.htm)

sources of atmospheric moisture; (2) location at a relatively low latitudes caused by the relatively high value of the radiation balance; (3) their surface, which largely depend on the characteristics of atmospheric processes.

The location of the region in the interior part of Eurasia, at a great distance from the oceans, causes a pronounced continental condition and is associated with intense radiation in the southern part, which yields the continental climate of the low plains of the main parts of the territory that has an arid character; desert landscapes develop under these circumstances.

The value of total radiation (direct plus diffuse) is approximately 100 kcal/cm^2 in the north of the region and >160 kcal/cm^2 in the south. Radiation balance is approximately 22 kcal/cm^2 in the north and in the south is >40 kcal/cm^2/year.

The air of temperate latitudes is dominated in the region, and during the summer it is vigorously transformed into a tropical (i.e., rain) climate in the most part. In the south, the seasonal change of the prevailing air of temperate latitudes in the winter rain, which dominates in the summer, is due to the characteristic of the subtropical zone of seasonal movements of the temperate-latitudes fronts.

The temperature conditions are an indicator of continental climate in Central Asia. Central Asian deserts are hotter than the tropics in the summer season. The average July temperature is 26–32 °C, whereas in the tropics it is equal to 24–28 °C. The absolute maximum temperature reaches 50 °C (Southeast Karakum desert, Termez on the Amudarya River), and the surface of the sand in the desert heats up to 79 °C (Repetek in the Karakum Desert). However, the plains of Central Asia do not have a cold winter, and the average annual air temperature amplitude reaches very high values (−32 to 40 °C). The region is characterized by large temperature variations from year to year: sharp daily fluctuations in temperature, sharpness of the transition from season to season (especially from winter to summer), a small amount of precipitation (<200 mm/year; in vast territory it can be <100 mm and sometimes even <75 mm), little cloudiness, many hours in sunshine, and dry air (average relative humidity of 20–25% in the summer; however it significantly decreases below).

Central Asia and Kazakhstan lie at the periphery of two important pressure systems, which explains the continental climate. In the winter season, the Asiatic High, which originates over northwestern Mongolia, is dominated by the pressure systems of Central Asia (Lewis 2003). The pattern of pressure divergence that forms over northern Kazakhstan results in a high pressure ridge where winds diverge north toward Siberia and the Arctic and south toward Central Asia (Lydolph 1977). In winter season, this brings a northeasterly flow air into Central Asia and a decrease in barometric pressure from north to south with isobars trending east–west. The prevailing northeastern winds are very cold because they transfer the air from a more northerly part of the continent to a more southerly part (Lewis 2003).

An eastern extension of the Azores High is the other major pressure system. In summer season, the Azores High brings moisture to southern Europe but loses almost all moisture while crossing the Caucasus Mountains and reaching Central Asia. This tropical air mass brings a northwesterly airflow to Central Asia. Air from the north reaches the region as well. Ninety percent of the air mass in Central Asia consists of continental temperate and continental tropical air (Borisov 1965).

The climate of deserts in Central Asia, Kazakhstan, and elsewhere in the world are characterized by high air temperatures and a long dry period during the summer. The Aralkum Desert is located within the Asiatic Desert belt. The northern part of the desert belongs to the Kazakh–Dzungarian Desert and the southern part to Turanian deserts (Breckle and Wuchere 2012). The climatic conditions and weather process of the Aralkum (Aral Sea region) are mainly governed by relatively low elevation of the Aral Sea Basin within the center of the Asian continent (Budyko 1956, 1974; Grigoriev and Budyko 1959). In general, the Aralkum region is characterized by hot and dry summers and cold winters with strong continentality. The continentality is a reason for the very intensive radiation. The temperature amplitude varies from 40 to 85 K during the year. The relevant monthly means may reach almost 40 K, and the absolute temperature extremes can reach >85 K. Rare cloudiness and low precipitation is typical for the region. The number of days without clouds amounts to approximately 260. Low precipitation, rare cloudiness, and high radiation result in hot and very dry summer months.

High mountains do not influence the atmospheric circulation of the region. Most of the year, the surrounding region of Aralkum is under the influence of northwesterly and northerly air intrusions and a southwestern margin of a huge Asiatic (Siberian) anti-cyclone system (Bugaev 1957). The region geographically is located opposite to the Turanian or Turgai gate, i.e., in the main axis, which plays an important role in invasion of cold air masses from the north along the Ural mountains. The basin, which lies at low altitude within Middle Asia, favors the development of stable cold air masses and relatively considerably low temperatures in winter. The normal synoptic processes in the Region—such as the stable southwestern peripheral part of the Siberian anti-cyclone in autumn, winter, and early spring—cause clear and dry weather and drastic temperature minima (Myachkova 1983). This is a consequence of the advection of low-humidity air masses from continental Siberia and the Arctic.

During the winter season, moist Atlantic air masses from the west normally do not reach the Aralkum region; they reach this region only in spring and rarely in summer. Consequently, strong winds and storms can occur due to the drastic differences in temperature between air masses. Those air masses from the west and south are driven by cyclones followed high humidity and rains. During the summer, a clear to cloudless sky and very high temperature are typical weather conditions in the region. Air masses play a major role in temperature and precipitation variations. For instance, the northerly and northwesterly air masses can occur from time to time and lead to slight a decrease in temperature and often to some precipitation.

The climate of the Southern Pre-Balkhash Desert is arid and continental. The desert is characterized by high level of solar radiation and experiences large daily and annual variations of air temperature. In the northern part of the desert, the average air temperature in January is −16 °C and in the southern part of the plain territory it is −5 °C. The average air temperature in July is approximately

20–25 °C. The distribution of precipitation over the region is very variable. In the north, northwest (coast of Balkhash Lake) precipitation is approximately 150 mm and 200–300 mm in the southeast in the foothill (submountainous) areas. Precipitation on the plain during the warm seasons almost completely disappears through the process of evaporation. The greatest amount of precipitation falls during the spring months (April through May) and the least amount falls in February and August through September (Akhmedsafin et al. 1980). Strong winds are very common in the region, especially in the Zhungar Gates region, with a wind speed of 70 m/s.

2.3 Land Resources (Soil Cover) and Changes in Vegetation Cover and Climate

Soils in deserts are very thin, and humus content in them is meager (Faizov et al. 2006). The main characteristics the soils in deserts are low contents of humus, significant presence of carbonates and gypsum and also phenomena of solonetz and solonchaks. A special structure of the soils in deserts is marked: there is no soil-forming horizon in the upper part of the soil profile, which is typical of the steppe pedogenesis. Desert crust changing by sub-crust is presented. The main soil types in the desert are sandy desert, brown, grey-brown, serozems, takyr-like, takyrs, solonchaks, and solonetz (Fig. 2.7). Zonal types of soils are brown desert and grey-brown desert. Sandy and piedmont serozems are formed in automorphic conditions, takyr like soils and takyrs at additional watering conditions on alluvial plains as well as different types of solonchaks. The soil cover of the desert zone has great diversity. Soil cover and its composition in the desert zone are different.

Brown desert soils haven't a grass sod; upper humus horizon is low consolidated. It belongs to desert soil type (Uspanov and Faizov, 1971). Humus is about 1.5 % and it is evenly distributed within the soil profile. Fulvic acids

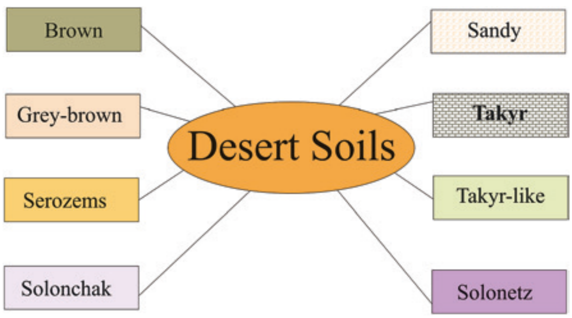

Fig. 2.7 Desert Soils

dominate in humus composition. It can be observed the accumulation of silty particles in soil horizon B. Effervescence begins from 15 cm or from the surface. Carbonates accumulated on the depth 25–35 cm, gypsum and light soluble salts on 60 cm (Rachkovskaya, 2003).

Grey-brown desert soils are distributed on the Usturt Plateau, in the Betpakdala (Central Kazakh Hillocky area), the Mangyshlak and Krasnovodsk Peninsula. They are formed on rocks of various petrographic composition. There are some soil horizons in the soil profile of grey-brown soil: desert porous crust, undercrusting scaly horizon, condensed soil horizon B, and horizon with gypsum accumulation. Soil profile can be overfill with gypsum. All grey-brown soils are carbonate from the surface and usually carbonates in maximum amounts are found in the upper-most soil horizons (Rachkovskaya, 2003).

Serozem is an original soil type on piedmont territories. They occupy inclined piedmont plains and hilly piedmonts that are a lower step in vertical zonation of mountains. Soil profile of serozem has the following soil horizons: humus light grey horizon soded in upper part; transitional with low content of humus and some carbonates; condensed carbonate-illuvial soil horizon with white soft carbonate spots. In upper soil horizon quantity of humus varies from 1 up to 3.5 %. Such significant varieties determine the dividing on soil subtypes such as light, typical and dark serozem (Rachkovskaya, 2003).

Solonchaks belong to saline soils and they occupy the large territories in desert zone. They are formed under influence of saline rocks or owing to high-mineralised ground waters. Solonchaks are divided into automorphic and hydromorphic. The automorphic type is formed on the outcrops of ancient saline rocks, mainly clays. Water regime is not ablutional. The superficial soil horizon contains not less than 1 % of light soluble salts. The hydromorphic solonchaks is developed in conditions of close ground waters. They have a specific character of surface. which is covered by salt efflorescence and may be puffy, crust-puffy or even wet in dry season. The content of salts in upper soil horizon is 2 % up to 6–8 %; and it may be 20–30 % in the most superficial soil horizon. There are typical, meadow and sor solonchaks (Rachkovskaya, 2003).

Sandy desert soils differ depending on a degree of consolidation, which is caused by presence of oozy particles. Humus horizon is weak-developed and often has small thickness, consequently humus content is very low. Low accumulation of silty and clayey particles is fixed in the middle part of soil profile. Sandy desert soils have a light texture and therefore they are severely prone to the deflation process (Rachkovskaya, 2003).

Takyr is a specific soil formation having a polygonal-fissuring surface with stagnant atmospheric water on it. The same genetic soil horizons as in takyr-like soil but with another physical properties. Crust horizon is rather solid and it becomes compact and viscous under influence of watering. Horizon under crust is enough firm also. The lower unstructured soil horizon is not distinguished essentially from soil forming rock. All takyrs are carbonate from surface only and carbonate in new formations are absent. The majority of takyrs have solonchak's properties. Gypsum accumulations are absent and it is typical for takyrs. Mostly takyrs have a heavy mechanical composition or soil texture (Rachkovskaya, 2003).

Takyr-like desert soils are rather young. They are distributed on dried alluvial and proluvial-alluvial plains without ground watering. Differentiation of the soil profile of takyr-like soils is fixed in its uppermost part only. Crust is not solid; both scaly horizon and the condensed unstructured soil horizon, turning into weakly changing mother rock, and they are marked insufficiently. Soils are carbonate on soil surface only. Illuvial carbonate horizon is absent. A total content of gypsum is insignificant (Rachkovskaya, 2003).

Solonetz have the heightened content of sodium (Na) in humus horizon that results in the presence of such specific properties as alkaline reaction and formation of soda, which are regarded as solonetz. They belong to saline soils and mainly distributed in northern and central parts of Kazakhstan. Usually the solonetzes occur in conjunction with zonal and intrazonal soils, rarely whole massif. Solonetz is characterized by small water penetration and low physiological availability of water. According to the character of water regime, solonetz is divided into three types such as automorphic, semihydromorphic and hydromorphic. The lower soil horizons of the solonetz soil profile contain the toxic salts for plants (Rachkovskaya, 2003).

The natural conditions in the region promote the formation of a huge area of saline soils, solonchaks, and sand massifs. The total area of the desert zone is 119.2 mln.ha (43.7%) of the whole territory of Kazakhstan (Faizov 1983). The soil cover is 113.7 mln.ha, including 55.7 mln.ha with brown soil in the northern desert, and 58.0 mln.ha with gray-brown soils in the central desert zone. Automorphic soils are dominant in the soil composition, i.e., approximately 45–53%. The ratio of hydromorphic and semi-hydromorphic soils is approximately 15% from the whole soil cover of the desert zone. Saline soils (solonchaks, solonetz) cover >20 mln.ha (18%) in the zone (Fig. 2.8). Most of them are distributed in Atyrau, Mangystau, Kyzylorda regions, and the Zhambyl and Almaty regions. Takyr-like soils and takyrs cover 9.0 mln.ha (8%) from soil cover of the zone (Fig. 2.8). They are mostly distributed in ancient alluvial undrained plains such as Balkhash–Alakol, Shu Moiynkum, and Syrdaria. These types of soils are inclined toward the salinization process during irrigation (Faizov 1983).

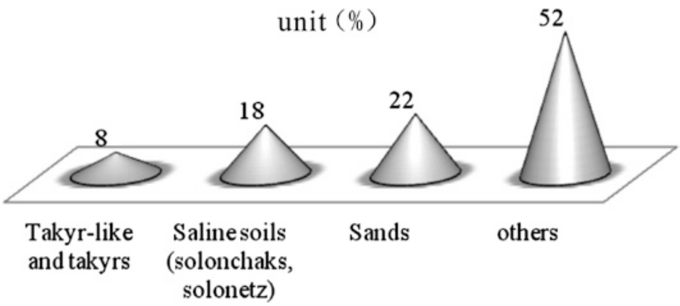

Fig. 2.8 Portion of soil types in the desert zone of Kazakhstan

The huge territory of desert zone is covered by sand massifs with both ancient and modern accumulation of sands. The total area of them is >25 mln.ha including 8.3 mnl.ha in the brown soil subzone; in the gray-brown soil subzone the area is 17.4 mln.ha (20%) of the entire territory of the zone (Fig. 2.8). The large sand massifs are distributed in the Balkhash–Alakol, Shu–Moiynkum, Kyzylkum–Shardara, Northern Caspian, and Aral Seas regions.

Sandy desert soils dominate in the southern Pre-Balkhash deserts. They stretch latitudinally from the western bank of the Balkhash Lake to Alakol Lake in the east (Faizov 1983). The foothill plains of Arganty Mountain are covered by gray-brown soils, whereas the foothill plains of the Shu-Ili Mountains have predominantly light sierozems with fine structure. Floodplain meadow soils are typical for major near-river plains and deltas such as the Ili River. Modern floodplain terraces of rivers in the southern Pre-Balkhash deserts have alluvial–meadow soils and shallow groundwater. The takyr-like soils are distributed in most areas of the Bakanas and Akdala ancient dry delta plains, along the left bank of Karatal river, and in the northeast outskirts of Zhusandala. The takyr-like soils have mostly fine structure (Asanbayev and Faizov 2007). Takyrs are very common in the southern Pre-Balkhash deserts, but they cover a small area and are often buried under sands (Faizov et al. 2006). Solonchaks are common along the coastal stripe of the Balkhash Lake. The largest solonchaks are found along the western and eastern coast of the Balkhash Lake, as well as in the delta of the Ili River, where all types of solonchaks are observed. The desert solonchaks are the main source for salt atmospheric aerosols (Orlova and Seifullina 2006). The surface layer of solonchaks is covered by soluble salts (Borovsky 1978, 1982). The sparse vegetation of the region is characterized by Ephedra, sagebrushes, and various shrubs (Kudekov 2002; Ivashenko 2005).

Sandy desert soils are widely distributed in the Aral Sea region. Sands and soils of light texture dominates most parts of the Aral Sea region. There is a predominance of soil with light texture favoring the development of wind-erosion processes in the region and the formation of aeolian land forms. The average size of sand particles in the region varies from 90–100 to 170–270 μm: 90–160 μm on the desiccated seafloor and 170–270 μm in adjacent desert areas (former coastal dunes, former islands, and sandy deserts). These particles are most easily involved in wind transportation (Semenov 2011). In terms of chemical composition, the soil is sulfate–chloride and chloride–sulfate (Orlovsky and Orlovsky 2001) and is formed on sandy or sandy–loam maritime soils (Semenov 2011).

Since the 1960s, the Aral Sea surface area has started to decrease, and this has caused a significant decrease in precipitation. Saline dust blows from the dried bottom of the sea, and the exposed lake bed has been implicated in rapid climate and vegetation changes. The sea desiccation has caused significant climate and vegetation changes not only in the coastal area but also he entire system of atmospheric circulation in the basin. Air temperatures in the summer and winter months at weather stations near the sea shore have increased by 1.5–2.5 °C, and diurnal temperatures increased by 0.5–3.3 °C (Glazovsky 1995; Chub 2000; Lioubimtseva et al. 2005). The mean annual relative humidity near the coast has decreased by

23%, and the occurrence of days with drought has increased by 300% (Glazovsky 1995). In addition, there has been a change in annual cycle of temperature and precipitation. A seven-fold rise in the albedo of the area previously occupied by the Aral Sea caused a three-fold increase in reflected solar radiation and increased the overall continentality of the climate (Chichasov 1990; Glazovsky 1995). Regional modelling scenarios suggest that the increased air temperature in Central Asia should cause a further increase of evaporation by 8–15%, whereas further aridization of the climate in the Aral Sea area may result in an evaporation increase to 20% in this region (Chub 2000). Additionally, the exposed former lake-bed areas, especially on the eastern side of the Aral Sea, represent by enormous source of highly saline wind-blown material and salt that contain ≤1.5% of the total mass of hard particles transported by the wind. Dust, sand, and salts from the dried bottom of the Aral Sea are deposited at a long distance from the source and, the aeolian deposition of salts has adversely affected the vegetation cover of vast adjacent areas and environment as well. According to an estimation by Semenov (1990), the amount of aeolian deposition from the former Aral Sea bed exceeds 7.3 to 10^6 ton/year, which includes 5 to 710^4 tons of salt/year. Currently, the dried bed (i.e., the bottom of the Aral Sea) has become one of the most powerful and active sources of dust, sand, and salt aerosols and storms in the world. Salt storms or dust containing salty aerosols are blown from the dried playa into the atmosphere, and they play a major role in climate conditions and climate changes at the global and regional scales. This is another important factor that must to be considered in the modelling of climate simulations at different levels. Dust reflects the sunlight back into space and cools the Earth. As a result, this decreases rainfall by suppressing atmospheric convection. Consequently, there are changes in climate and vegetation cover as well. After increasing the rainfall in arid regions, the dust flux decreases, which is explained by increased stabilizing vegetation cover and soil moisture. The dust flux decrease causes a further increase of rainfall. However, according to the generally forecast, the global climate becomes moist due to increasing greenhouse gas levels; this effect is patchy, and some desert areas may become drier according to certain climate-simulation models. In this case, the increased dust flux may increase aridity and also suppress rainfall outside of the desert areas themselves.

In addition to climate changes, there are changes in the vegetation cover in Central Asian countries. The grazing impact on vegetation cover in Central Asia has been constantly increasing during the past decade, especially in the Aral Sea region (Neronov 1997; Kharin et al. 1998; FAO 2004). Over-grazing is the main reason for environmental changes in many parts of the Karakum and Kyzylkum deserts. As a result of significant anthropogenic activity, over-grazing with different types of livestock degrades rangelands and causes a desertification process (Manzano and Narvar 2000). Approximately 75 mln.ha of land on the Earth are severely degraded by overgrazing, i.e., the original biotic functions of the soil are largely destroyed (Sinha 1998). In addition, soil and vegetation degradation in arid and semi-arid environments is particularly related to surrounding areas with water (natural or artificial) such as wells or boreholes (Lange 1969).

The natural ungulate fauna in the area are almost extinct. The grazing impact on vegetation cover has significantly increased: Annual grasses or mosses have gradually replaced the sparser natural perennial vegetation, and the surface has become more compacted. During the last decades, unprecedented growth of kara-harsangs from microphytic communities occurs only in the undergrazed areas perhaps this is associated with increasing of CO_2 fertilization (Lioubimtseva et al. 2005).

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