8 Soils of Mongolia

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Abstract

Soil science is one of the integral parts of physical geography, and has evolved into an independent science due to its role and importance in nature and society. Soil science is the study of soil as a natural resource on the surface of the earth, including soil formation, classification, and mapping; physical, chemical, biological, and fertility properties of soils; and these properties are in relation to the use and management of soils. Mongolian soil scientific concepts such as nomenclature, classification units, and soil-geographical regions have been developed through Dokuchaev's theory, and the terminology has become a tradition through Russian soil science. According to the history of soil research, the work of Russian researchers is the main, and there are many works of Mongolian scientists. Among them, the works of academician D. Dorjgotov on soil geography are considered the largest, and there are many fundamental research materials based on the theory of physical geography and landscape. Therefore, the works of Sh. Tsegmid, D. Dorjgotov, O. Batkhishig, and N.D. Bespalov are mainly used in this chapter. Due to its different physical geographical conditions many soil types are distributed throughout Mongolia. Based on the latitudinal characteristics of these soils, the definition of each zone is given as an example of predominantly distributed soil. In the content of the chapter, the soil is considered in terms of the components of the landscape geosphere; the distribution patterns, types, classifications, and characteristics are briefly described, and the principles of soil-geographical zoning, soil use, and protection are compiled.

Keywords

Soil types · Soil classification · Soil-geographic region · Soil erosion and degradation

8.1 Overview of the Soil Research

The works of the Russian Geographical Society occupy an important place for the research of Central Asia and Mongolia, which began to be published in the second half of the nineteenth century. Since that time, a great deal of research material has been accumulated on the geography, history, ethnology, economy, climate, vegetation, geology and hydrology of Mongolia. There were no notes about the soil of Mongolia but in their literatures of the physical geography, such as N.

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M. Przewalski, GN Potanin, P.K. Kozlov, VA Obruchev, brief notes on stony, sandy, and gravelly soils are included (Bespalov 1951). The first scientific paper on the soil of Mongolia was published in 1912 by L.I. Prasolov, and it was a research report aimed at revealing the geographical patterns of soils in the southern part of Lake Baikal. This research was to map soil characteristics from Khiagt to Ulaanbaatar, and the study combined soil-forming bedrock, permafrost, and vegetation to identify local landscapes in that area.

After that, B.B. Polynov, I.M. Krasheninnikov, V.I. Lisovskii, N.N. Lebedev, and O.N Mikhailovskaya's 1925 studies of the soil in the Ar and Uvur Jargalant river basins are considered to be a massive contribution. In the course of this study, a detailed description of the physical geography and soil vegetation of the area was given and thick, fully developed black earth and brown soils were found to be distributed in the area. In 1926, B.B. Polynov, V.I. Lisovsky, and others conducted two surveys in the northern Gobi.

The first route is from Ulaanbaatar to Ikh Tukhum Lake, Sangiin Dalai, and Ongi River Khoshuu monastery. In terms of height, soils are divided into three main types: mountain-steppe chernozem and dark brown, carbonate steppe brown, steppe salt marshes, and salt marshes (Bespalov 1951).

The second route runs from Ulaanbaatar to the northern Gobi, including Choir, Sain-Us (Sainshand), and Baga-Uud (northeast of Dornogovi). The study determined that the upper part of the Gobi brown soil has two layers, humus and compacted, and that there is no gypsum in the steppe and desert steppe soils but it had high contents of manganese and silicon. So, it was noted that the Gobi region should be the object of detailed research in the future.

The work of a soil-agronomic research expedition led by Baranov in 1930 is important for the study of soil in Mongolia's agricultural lands. In this study, well-known Russian soil scientists G.V. Dobrovolsky, S.I Andreev, and others conducted research on food and fodder plants, crop development, and fertility of hay and pasture soils in Western Mongolia in Khovd, Buyant, Uyench, Bodonch, Bulgan river basins, Mongol Altai, Tsenkher, and Durgun lakes. This research remains an important fact in the study of arable soils. As a result, the distribution of saline and alluvial meadow soils in the Khovd, Buyant, and Khar Us Lake basins was mapped as a basis for subsequent research.

At the same time, Andreev surveyed 5,000 hectares of arable land in the Selenge Basin and identified the first terrace 40–50 cm above the water level of sandy-gravelly sediments in connection with the distribution of soil. The second terrace with saline and meadow soils, the third terrace with brown soils, and the fourth terrace with dark brown soils were mapped at a scale of 1:25,000. In addition, V.N. Ivanov identified the zoning patterns of fertile, alkaline dark brown and brown soils on 4,000 hectares of the Baru-unturuun hay-pasture zone. In 1931, the research team returned to Mongolia to conduct an independent soil study of the Great Lakes depression, and the first explanation of the zonal patterns of altitude and latitude contributed to the development of soil geography in Mongolia.

In 1940–1943, a research team led by Tsatsenkin conducted a soil survey in southern Mongolia, collected hay and pasture material in the eastern part of the Gobi, and they collected a lot of material about plants and designed a 1:1,000,000 soil map, which became a major work used in many fields. Although these surveys were conducted at different levels depending on the purpose and content of the work at the time, they have not lost their relevance as valuable evidence for soil surveys (Bespalov 1951).

In 1940–1942, a soil research team led by soil scientist N.D. Bespalov surveyed more than 20,000 km of land, covering more than 70% of Mongolia, collected more than 3,000 soil samples, and analyzed 13 groups of soils. This study was published in Moscow in 1951 in Russian under the title "Soils of the Mongolian People's Republic". This book is divided into seven regions of geomorphology based on physical geography regions, and for the first time, the characteristics of vertical soil zoning, soil properties, resources, and the area of soil types are determined. The importance of this book was emphasized by academician D. Dorjgotov noting that "until the 1970s, it was the only significant work on the soil of our country". In 1962, the Institute of Geography was staffed by national soil specialists. In 1970, a comprehensive joint Russian–Mongolian biological expedition began and independent soil research was carried out. In 1974, the Institute of Geography was expanded to include an independent soil laboratory, which intensified soil research. Since this period, the work of national researchers grew and new branches of research were created. Of these, D. Dorjgotov (soil formation and taxonomy), G. Undral (features of the geographical distribution of mountain taiga soils), U. Bekhtur (characteristics, distribution and origin of brown soil), D. Batbayar (chemical properties of steppe soil), B. Batjargal (soil characteristics of Khuvsgul mountainous area), J. Garidkhuu (Orkhon-Selenge basin distribution patterns and characteristics), Ch. Gonchigsumlaa (dry steppe soil geochemistry), R. Baatar (characteristics and use of floodplain soils), Z. Sanjmyatav (soil washing), O. Batkhishig (Tuul river basin soil geochemistry), O. Battulga (Gobi brown soil moisture and thermal regime), J. Mandakhbayr (characteristics of saline soils), D. Avaadorj (soil characteristics and evaluation), Ch. Lkhagvasuren (Mountain soils geochemistry), N. Nyamsambuu (soil erosion), there are many works in the field of crop yields, fertilizers, irrigation regimes, and soil agro-chemistry. Thus, soil science has become a major independent branch of physical geography in Mongolia. This chapter does not discuss the history of soil research in detail, but about the patterns, characteristics, and classifications of soil geographical distribution.

8.2 Soil Zones, Belts and Characteristics

The natural condition of Mongolia is very different and there are intercontinental location, geological history of territory, high position and specifics of mountain, plain, intermountain depression features. On the other hand, marked substantial contrasts of natural factors in different parts of the country define specific soil formation. V.V. Dokuchaev explains that the soil depends on physical and geographical conditions of the place of origin, and defines the soil as a "mirror" of the landscape. Soil is one of the parts of the ecosystem that is formed as a result of the interaction of other natural spheres. Soils develop over time under the influence of chemical, physical, and biological processes. They develop where rocks and sediments (lithosphere) are influenced by flora and fauna (biosphere), water (hydrosphere), and climate (atmosphere). Based on these characteristics, soils can be identified, named, explained, and widely used in the classification of natural zones and landscapes.

Mongolia's topography, climate, and latitude are the main factors in soil distribution. They also differ in the nature and land use, which is formed in different relief conditions. For example, mountain tundra soils have a long snow cover, low thermal activity due to low biological activity, incompletely decomposed organic residues, acidic and rocky properties, while brown soils have high weathering products, well-drained, carbonated and relatively good biological activity. The effects of climate such as heat transfer to great depths are relatively large. Steppe and mountain soils differ not only in geomorphological features but also in soil source

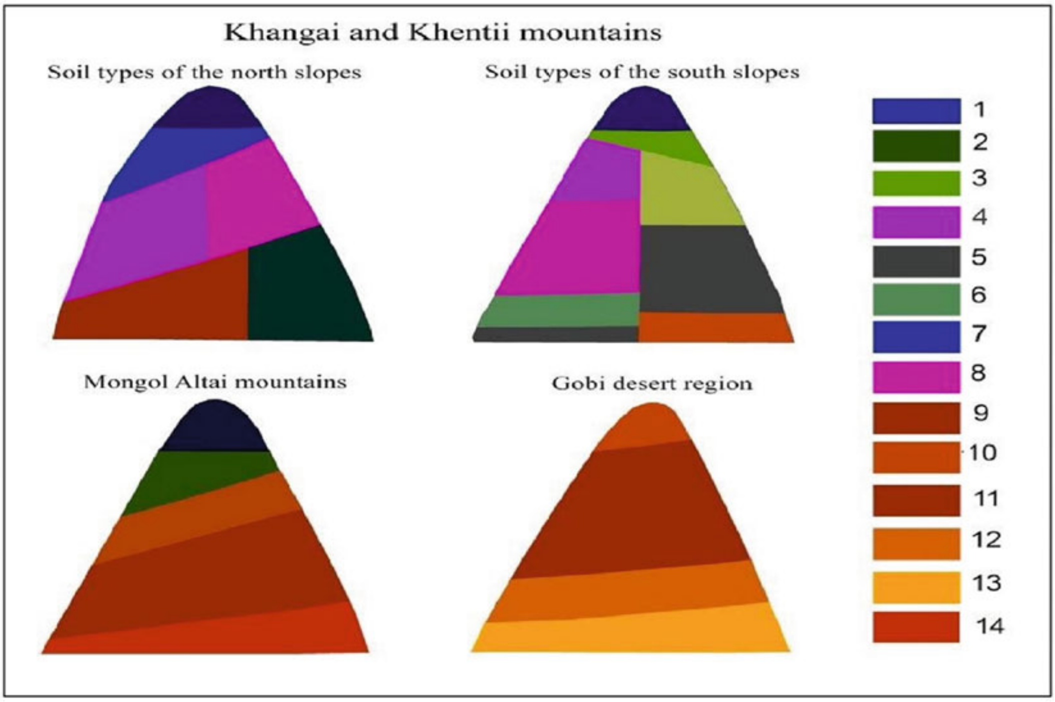


Fig. 8.1 Soil vertical zones (National Atlas of Mongolian People's Republic 1990). 1. Mountain tundra, 2. High mountain steppe raw humic, 3. Mountain meadow, 4. Mountain meadow steppe, 5. Mountain taiga cryomorphic surface ferrimorphic, 6. Mountain taiga cryomorphic, 7. Mountain derno-taiga depth permafrost, 8. Mountain meadow-forest freezing depth, 9. Mountain chernozem meal carbonated, 10. Mountain dark kastanozem, 11. Mountain kastanozem, 12. Mountain light kastanozem, 13. Mountain semi-desert brown soil, 14. Mountain desert gray brown soil

processes. Due to the fact that mountain soils are stable in conditions of surface fragmentation, slope, and extreme climatic conditions, slope erosion and temperature weathering are intensive, organic matter decomposes and mineralizes slowly, and the moisture-thermal regime depends on the mountain (Dorjgotov 2003) (Fig. 8.1).

Despite these differences, mountain and steppe soils have similar characteristics. Thin, gravelly soils on hilly plains are difficult to distinguish from mountainous soils, and thick-walled powdered soils formed on mountain plateaus or hollows and terraces are difficult to distinguish from steppe. This is due to the fact that latitude has a significant effect on the formation of steppe soils, while this feature is also observed in mountainous areas. In the mountainous part of Mongolia, the vertical belt is clearly visible and the latitude is sometimes lost. Although such differences do occur, geomorphological features are taken into account in distinguishing soil zones according to the latitudinal patterns of soil distribution in Mongolia. In the northern part of Mongolia, most of the mountains are located along the latitude, which is a key factor in differentiating the latitude of the soil. Therefore, there are two belts and three zones of soil from north to south: (1) mountain taiga belt with cryomorphic-taiga and derno taiga soils, (2) mountain forest steppe belt with chernozem, dark kastanozem, forest dark colored, and derno taiga soils, (3) dry steppe zone with

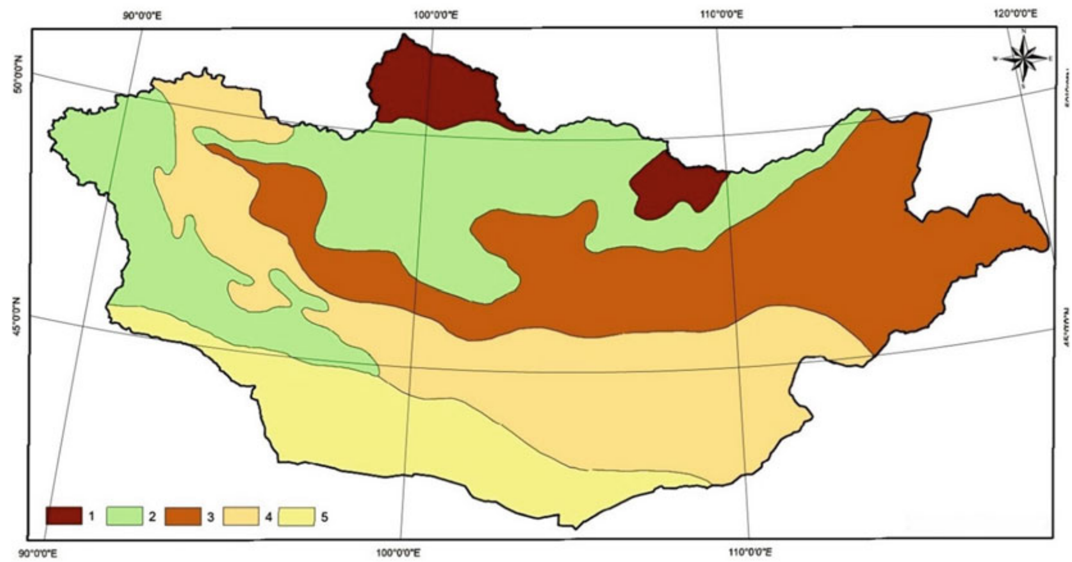


Fig. 8.2 Soil belt and zones (modified from Dorjgotov 2009). 1. mountain taiga belt with cryomorphic-taiga and derno taiga soils, 2. mountain forest steppe belt with chernozem, dark kastanozem, forest dark colored, and derno taiga soils, 3. dry steppe zone with kastanozem soils zone, 4. semidesert brown soils zone, 5. gray-brown desert soils zone

kastanozem soils zone, (4) brown semi-desert soils zone, (5) gray-brown desert soils zone. The wide distribution of taiga and forest steppe soils in Northern Mongolia cannot be possibly explained by just vertical zone; there is also influence of the horizontal zone of the territory (Fig. 8.2) (Dorjgotov 2003).

A brief introduction at the characteristics of these zones, belts, and some key soil characteristics is given below.

1. ***Mountain taiga belt with cryomorphic-taiga and derno taiga soils***. Belongs to the taiga of Khuvsgul and Khentii mountains. Because this belt is entirely in the permafrost region, the effect of permafrost on soil moisture and soil formation is significant. It is rare for the taiga turf to cover all sides of the mountain evenly, but the meadow steppe black earth soil is quite widespread on the mountain slopes. Permafrost soils in the mountain taiga are generally thin, with a total soil thickness of no more than 60–80 cm, and the reaction environment being acidic in all layers. The humus content usually fluctuates between 11 and 20% and decreases sharply. The high carbon/nitrogen ratio in the top soil indicates that the humus of the organic residue is weak. Researchers have noted that the upper layers are mostly small, granular, loamy-light loamy texture, and that the high content of sand and dust is a characteristic feature of permafrost taiga soils (Dorjgotov 1976). In the middle and upper part of the soil layer, gravel accumulates under the influence of permafrost and the formation of the layers is lost. Larch-birch-cedar mixed forests are dominated by taiga turf and turf-ash soils, and permafrost boggy are abundant in the foothills. In the turfy taiga soils of mountain turf, a thin layer of light gray or light spots are formed under

the humus layer. The southern part of the belt is dominated by mountain forest gray and mountain meadow steppe black earth soils.

2. **Mountain forest steppe, forest gray, and mountain steppe kastanozem belts** include the Khangai mountainous area, the Orkhon-Selenge basin, and the Khentii lowlands. The transfer of black earth and forest gray soils is found at the back of the mountain. The characteristics of this belt are forest gray, brownish-gray soils at the back of the mountain, mostly steppe kastanozems in mountainous areas, and a small percentage of forest gray soils in mountain black earth soils. Due to the high impact of the dry steppe, forest soils are spread only behind the mountains (Dorjgotov 1992). Mountain forest steppe, forest gray, and mountain steppe kastanozem belts include the Khangai mountainous area, the Orkhon-Selenge basin, and the Khentii lowlands. The transfer of black earth and forest gray soils is found at the back of the mountain. The characteristics of this belt are forest gray, brownish-gray soils at the back of the mountain, steppe kastanozem soils in mountainous areas, and, in most parts, a small percentage of forest gray soils in mountain black earth soils. Due to the high impact of the dry steppe, forest soils are spread only behind the mountains. Permafrost and temperature weathering have a significant impact on the origin of mountain forest soils. The content of texture varies greatly, depending on the intensity of weathering, gravel is up to 60%, and sand and dust are predominant above the foot of the mountain, while the amount of clay increases in the middle and lower part of the foot and is about 32–45%. The clay content of schist and sandstone, which is common in the soil, is very low. The concentration of exchangeable cation in sediments formed from acidic (5.1) alkaline (8.6), weathering granite and sandstone soils reaches 28 mg/eq, and in sediments formed from dolomite and limestone reaches 28.0–32.0 mg/eq (Krasnoshchekov 2013) (Table 8.1).

Most of Mongolia's mountainous terrain has a mountain steppe landscape. The most common soil in this zone is mountain kastanozem soil. It covers 29.6% of the total area and is distributed in the mountains of Khangai, Khentii, Orkhon, Selenge basins, Mongol Altai, Gobi-Altai, and Khyangan mountains (Dorjgotov 2003). In addition to the absolute height, the main criteria for distinguishing mountain kastanozem soils are the intensity of erosion on the mountain slopes. These soil layers are replenished by weathering products, so there is no accumulation of carbonate due to the large number of debris, thin underdeveloped strata, poor carbonate composition, and moisture regime that is washed away by mountain runoff, and the bedrock is close to or exposed to the surface. Depending on the slope of the mountains, the thickness of the humus layer varies between 10 and 40 cm and soils are thin, less stability, and low humus than slopes of the back side and covered stones. As the mountain slope increases, the fine earth layer becomes thinner, the gravel layer becomes more abundant, and the soil layer is no clear. The humus content in the upper layer of mountain kastanozem ranges from 1.5 to 4.5%. Effervescence of hydrochloric acid varies, in some cases from the surface, and sometimes even to a depth of 10–40 cm. Mountain kastanozem is not suitable for cultivation due to its agriculture and can be used for rangeland.

3. **Dry steppe zone with kastanozem soils zone**. This is widely distributed in the eastern part of Mongolia and extends westwards through the Khangai mountain range to the Great Lakes depression. Mongolian kastanozems are characterized by carbonate accumulation, which is associated with extreme climates and precipitation distribution. Steppe kastanozems are distributed in flat and hilly

Table 8.1 Characteristics of forest soil (adopted from Krasnoshchekov 2013)

Profile number	Depth, m	Sum of exchangeable cation, mg-eq/100 g	pH	The content of elements, %					Texture, %		
				SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	Sand	Silt	Clay
Soil of upper part of mountain slope											
865	80–90	5.6	7	62.74	6.3	16.59	2.03	1.24	77	17	24
866	65–75	12	8.6	47.5	10.23	19.92	7.22	4.4	74	21	17
867	75–85	17.6	6.7	60.95	6.23	16.02	2.88	1.98	41	47	32
869	50–60	9.5	5.9	60.07	7.22	15.7	2.3	1.4	57	32	39
Soil of middle, lower part of mountain slope											
862	40–50	20	6.8	59.14	6.52	17.83	1.37	1.15	46	22	77
868	30–40	8	5.8	63.31	6.54	16.82	2.88	1.98	68	25	26
782	80–90	20.3	6.5	56.36	6.04	14.62	2.33	1.61	50	38	43
873	60–70	10	6.6	68.37	6.08	16.43	1.09	0.93	55	34	36
895	20–30	17.3	5.5	65.09	3.98	18.1	6.2	4.44	27	59	51

steppes, dry steppes, and dry valleys of the Khangai and Khentii mountains, and are divided into three types according to humus content and layer thickness: dark kastanozem, typic kastanozem, and light kastanozem.

Dark kastanozems are distributed in the northern part of Mongolia in the valleys between Khangai and Khentii mountains, mountain slopes, foothills, valleys of large rivers, and in the steppes of Dornod and do not form a zone alone. The thickness of the humus layer is usually 30–40 cm, sometimes more than 50 cm, and the humus content is 3.5–4.5%. Carbonate accumulation occurs at 45–50 cm and is not gypsum. The predominant textures are loam, light loam, and sand. Dark kastanozems are important for agriculture due to their high nutrient content (Tables 8.2 and 8.3).

Typic kastanozems spread throughout the east and the central part of Mongolia, up to the west southern part of Khangai. The humus layer of this soil is light kastanozem in brightly color, with an average thickness of 20–30 cm, the amount of humus is 2.0–3.5%, and it has a dry dusty texture. In some cases, the humus content of the AB layer of kastanozems are more than the top layer. This has been explained by the nature of the kastanozem residual which is moister than now. Kastanozem usually boils in hydrochloric acid from under humus layer, and in sandy and loamy sandy soils from a depth of 60–80 cm. The carbonate accumulation layer is about 35–40 cm, and 70–90 cm in sandy and loamy soils. The soil contains less soluble salts and no gypsum. These soils are loamy, light loamy and sandy loam texture, and mixed gravels and stones. Kastanozems are used for hay and rangeland due to their lack of nutrients, especially water and moisture (Fig. 8.3).

Light kastanozems are mainly distributed in the southern part of the steppe zone and occupy a large area in the Great Lakes depression. The thickness of the humus layer in the soil is 12–18 cm, and the amount of humus in the upper layer is about 1.0–1.5%. The morphological features of these soils are brownish, thin, dry, with a lot of gravel, unclear granular structure, low density, and frequent cracks. It is dominated by gravelly loam, light loam, sandstone, and sand texture. All layers of soil are rich in gravel, 8–12 cm in hydrochloric acid effervescence, and 80–100 cm in sandy and loamy soils. Light kastanozems are poor in nutrients, rich in gravel, and have a thin humus layer, so they are widely used in rangeland that are not suitable for agriculture (Fig. 8.4).

Table 8.2 Genetic horizon thickness and humus content in loamy kastanozem (soil cover and soil of Mongolia 1984)

Criteria	Loamy						
	Horizon A				Horizon AB		
	Number of samples	Average	Minimum	Maximum	Average	Minimum	Maximum
Dark kastanozem meal-carbonated							
Thickness, cm	26	24	9	40	13	10	40
Humus, %	16	3.2	2.3	6.1	1.3	0.5	2.9
Kastanozem meal-carbonated							
Thickness, cm	25	13	8	25	18	10	25
Humus, %	8	2.7	2.2	3.0	2.3	1.4	4.2
Light kastanozem meal-carbonated							
Thickness, cm	9	7	4	12	14	10	23
Humus, %	9	1.4	0.5	1.8	1.1	0.4	1.7

Table 8.3 Genetic horizon thickness and humus content in sandy loam, sandy kastanozem (Avaadorj 2018)

Criteria	Sandy loam and sandy						
	Horizon A				Horizon AB		
	Number of samples	Average	Minimum	Maximum	Average	Minimum	Maximum
Dark kastanozem meal-carbonated							
Thickness, cm	4	21	15	30	15	15	25
Humus, %	4	2.9	1.2	4.0	1.0	1.8	2.3
Kastanozem meal-carbonated							
Thickness, cm	15	14	3	25	19	5	35
Humus, %	15	1.6	0.6	2.5	1.4	0.2	2.2
Light kastanozem meal-carbonated							
Thickness, cm	25	10	6	12	9	7	12
Humus, %	5	1.0	0.3	1.7	0.9	0.1	1.9

4. **The desert steppe (Gobi) brown soil zone** includes the Great Lakes depression, the Lakes Valley, the Gobi-Altai Mountains, and the eastern part of the Gobi. Due to low rainfall, high winds, and dry heats in this area, soil formation takes place in dry conditions. The general characteristics of the soil are well-defined layers, loamy, low humus, effervescence in hydrochloric acid from the surface or topsoil, and not solonchak, lack of moisture, no gypsum, covered with gravel. The Gobi brown soil humus content reaches

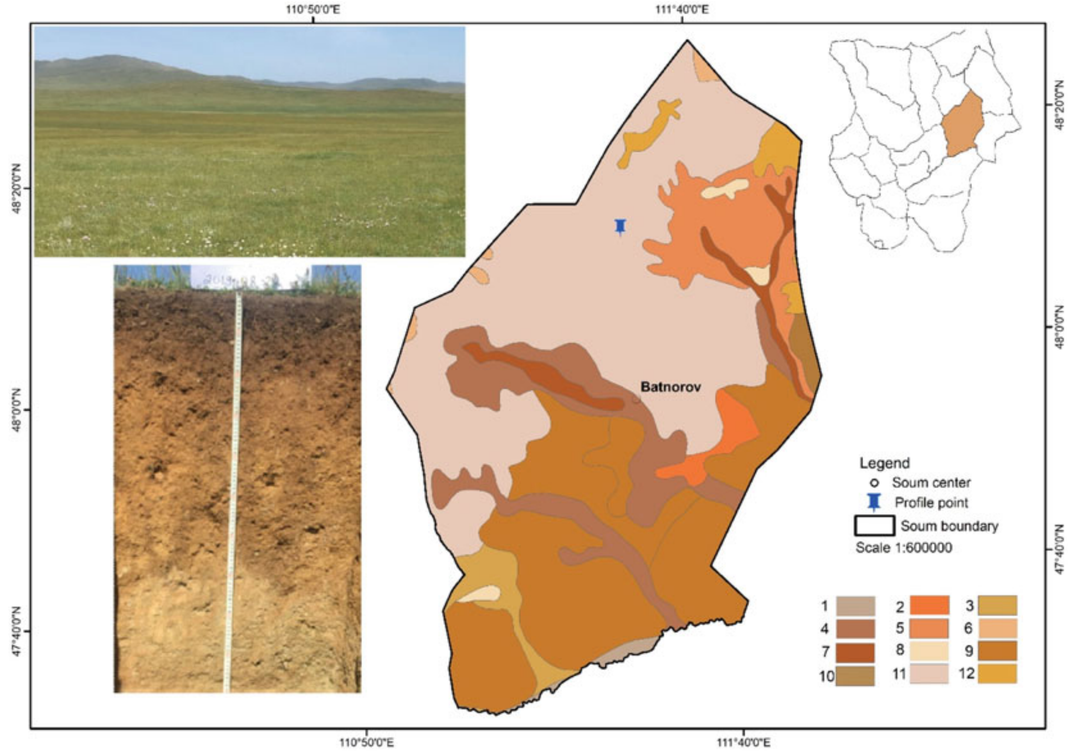


Fig. 8.3 Light kastanozem layers (Batnorov soum, Khentii): 1. Alluvial meadow, 2. Saline boggy, 3. Dark kastanozem weakly developed, 4. Dark kastanozem solonetzic non-carbonated, 5. Meadow dark kastanozem, 6. Chernozem non-carbonated, 7. Meadow cryoturabated, 8. Meadow solonchak, 9. Stony shallow dark kastanozem, 10. Mountain dark kastanozem non-carbonated, 11. Mountain chernozem noncarbonated, 12. Mountain forest derno dark colored

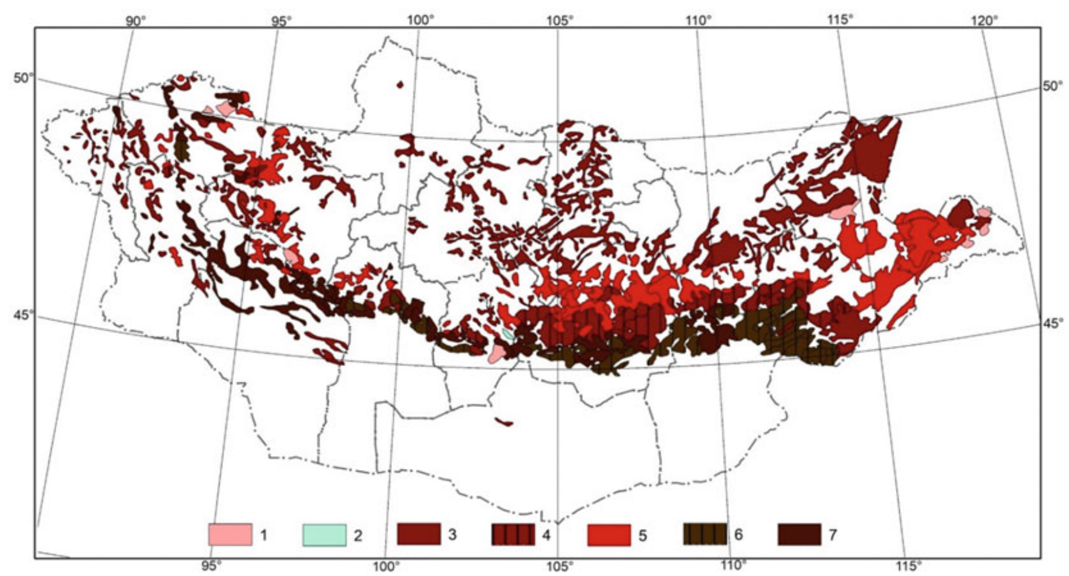


Fig. 8.4 Distribution of Kastanozem in Mongolia (Batkhishig et al. 2018). 1. Kastanozem 2. Crypto-gleyed, 3. Dark kastanozem, 4. Hill kastanozem meal carbonated, 5. Kastanozem residual meadowish, 6. Hill light kastanozem meal carbonated, 7. light kastanozem

up to 0.3–0.8% and the lower layer has a more humus content. This is due to the high temperatures of the soil surface, the mineralization of humus, and the spread of plant roots to about 10–30 cm. This is a feature of Gobi Desert soils. The depressions and hollows are saline and loamy, and sand accumulation is widespread.

5. **The northern edge of the Central Asian deserts** forms a desert belt in the Trans-Altai region. Semi-desert and desert soils cover 28.5% of the total area, of which 21.9% are in the steppes and 6.6% in the mountains and hills (Dorjgotov 1992). The three main types of desert and desert soils distributed in the highlands are desert steppe brown, desert brown gray, and borzon soils. Soil-forming bedrock in this area is mostly proluvial and diluvial sediments. The soils are clearly layered, with gravel, light loam, sandy loam, and alkaline soils. The humus content is 0.2–0.5% and is easily soluble in salts and gypsum, but is abundant in the lower layers of the soil formed on Cretaceous and Paleogene saline sediments.

Desert soils are predominantly gray-brown and reddish colors and have a granular, subungular structure, with almost no humus layer, and only toneless in the upper part of the illuvial layer of secondary gypsum accumulation (Avaadorj 2018). The depth of soil carbonate varies even in the different side of the profile, and sometimes occurs as a spot that does not effervesce in hydrochloric acid. There is a light-colored porous solid layer under the gravel cover of the soil surface. The main distinguishing feature is the formation of a light gray thin layer that is beneath this layer. The classification is also complicated by the fact that light brown soils are distributed along the boundaries of the desert brown-gray soils.

The mountain foothills of the region, intermountain depressions, gorges, and cracked hills are rich in dry gravel, and there are many sediments transported by temporary runoff during the rainy season. The surface of the soil is covered with gravel from the desert hamada, which is a common feature of desert soils (Fig. 8.5).

Depending on the characteristics of the landscape in these soil zones and belts, individual soil types are distributed. This includes *halomorphic, hydromorphic, and floodplain* soils.

Halomorphic soils are also found in dry steppe, Gobi, desert and forest steppe zones. It is most common in intermountain depressions, around salt lakes, in river floodplains and lowlands, and accounts for about 1.7% of the total area. All saline soils in Mongolia are divided into two main groups: solonetz and solonchack. A saline soil is one, or all of the soil layers are easily soluble in salts (NaHCO, NaCl, Na, SO, CaCl, MgSO, Ca (HCO_3)). Depressions in the arid steppe, Gobi, and desert areas are prone to salinization, and easily soluble salts are transported by precipitation from the highlands and are associated with groundwater mineralization. Due to its high sodium content, soil is highly alkaline, dense, columnar, and impermeable, so it has a low moisture content that is beneficial to plants, and in the lower stages, it often contains salt that is harmful to plants.

Wind has a significant effect on the formation and accumulation of salt in arid areas. Saline soils are usually found in the central part of the depression, so they are carried by the wind and affect the surrounding soil. The process of salt accumulation in meadow soils is regulated by normal leaching, such as overflow of snow and spring floods (Pankova 1992) (Fig. 8.6).

Hydromorphic soils are distributed in small areas through mountain valleys, ravines, wet meadows, wetlands, and in more humid conditions. Extra moisture is due to the proximity perched groundwater to the surface, fluctuations of groundwater levels, more infiltration of precipitation into the soil, and permafrost thawing. In these cases, some chemical compounds can accumulate in the soil. Organic matter, iron, and manganese compounds accumulate in the humid mountainous areas of Khuvsgul, Khentii, and Khangai, while carbonates, soluble salts, and gypsum easily accumulate in the Gobi and steppe regions. The geochemical processes of moist soils take place in an anaerobic environment, so gleying is common. Hydromorphic soils may be

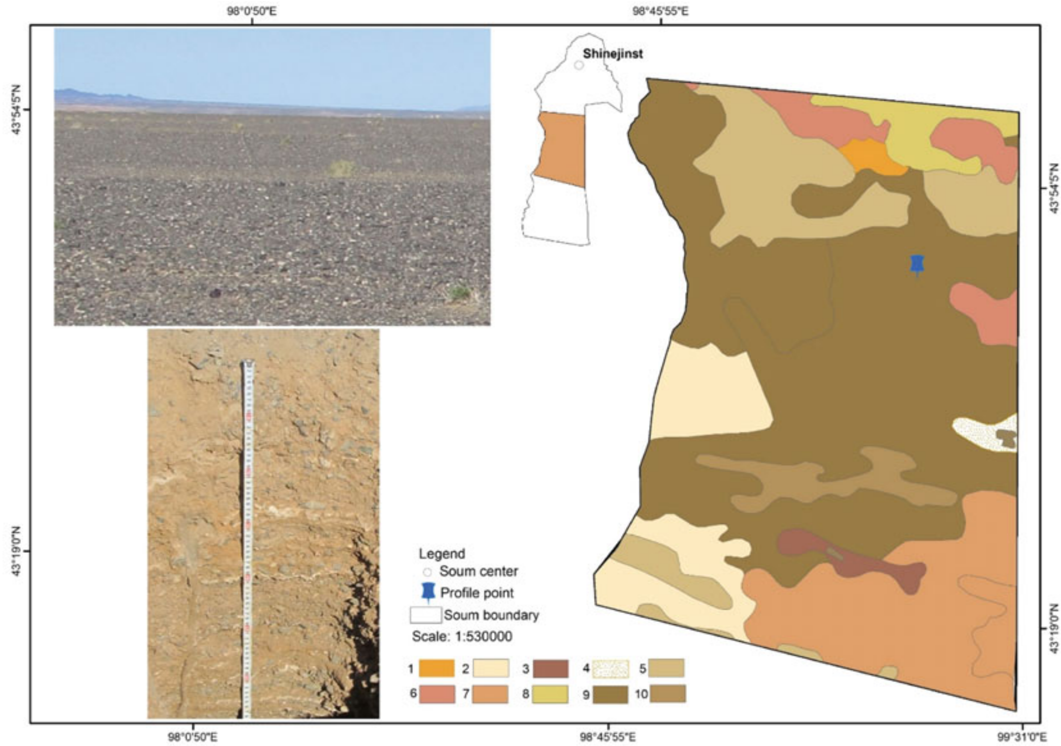


Fig. 8.5 Desert soils and profile (Shinejinst soum, Bayankhongor): 1. Weakly fixed sands, 2. Extra arid desert borzon, 3. Extra arid desert solonetzic borzon, 4. Solonchak weakly fixed sands, 5. Hills shallow gray brown, 6. Desert gray brown covered sand, 7. Desert gypsum gray brown, 8. Desert solonetzic gray brown, 9. Desert sairic gray brown, 10. Mountain steppe desert shallow gray brown

classified into following three types referring to their conditions for additional moisture formed in soil, accumulation of organic substances, and shapes and forms of gley: (1) meadow humic gleyed; (2) meadow boggy raw humic gleyed; and (3) boggy peaty gleyed (Tsegmid 1969). In soils saturated with moisture, the reduction reaction is activated and the bluish, light gray color is weakened, the oxidation/reduction capacity is weakened, and ochre-brown and yellowish colors appear. Hydromorphic soils are spread mosaic in various natural zones and are formed in meadow and wetland landscapes.

Floodplain soils vary in origin depending on the geological structure, and origin of the river valley, the size of the river, and the flood and feeding regimes. Depending on the development of the riverbed, the floodplain soil consists of a thin layer of sand and clay. Depending on the distance from the main riverbed of the flood river there will be soil differences. Derno soils is formed in the high areas along the river banks, meadow soils in the central part, and boggy soils in the edge of the floodplain. Alluvial soils are formed by the inundation of rivers, that is, they are composed of rock particles, which rivers carry from the upper to the lower course and leave on their banks during the flood. This material is called alluvium. It is very fertile, as rivers lay down not only minerals, but also biological remains of plants and animals. Groundwater is a major factor in the formation of alluvial soils. As the central floodplain usually has 1–1.5 m of water, it is constantly moistened at the bottom of

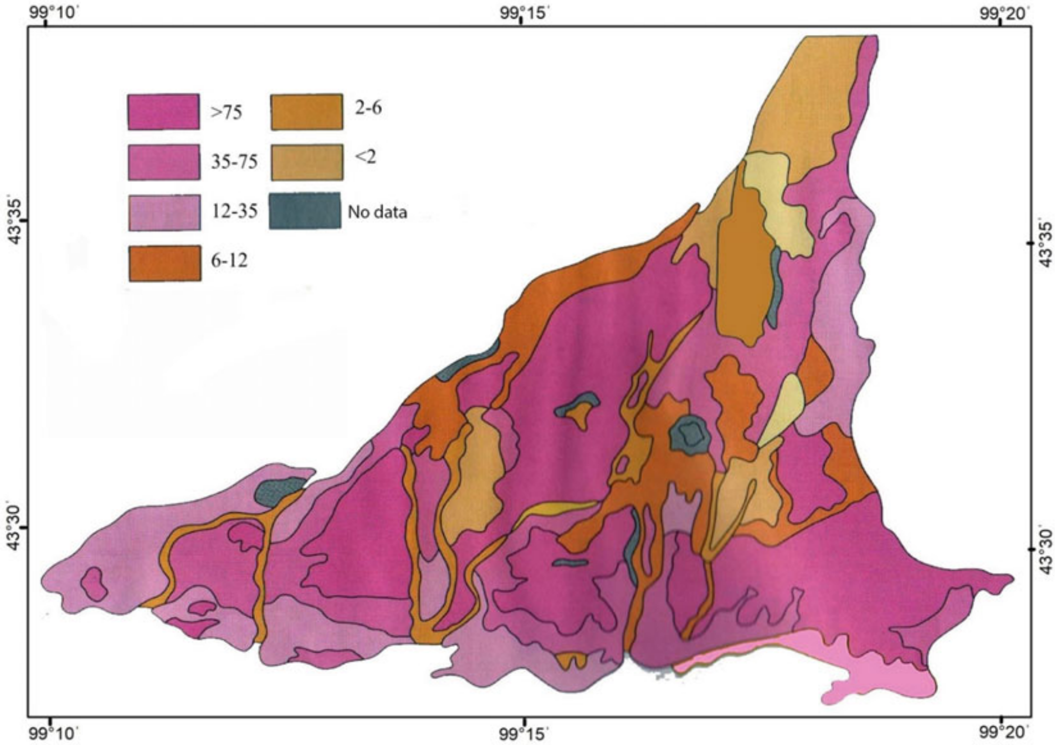


Fig. 8.6 Soil salinization in the oasis Ekhiin-Gol, at a depth of 100 cm (Na content in water extract, mgE/100 g) (Vostokova 2019)

the soil, creating conditions for the formation of moist soil. Occasionally, marshland is more humid, with groundwater up to 1.0 m or stagnant water at the surface, so swamping is predominant. At the same time, permafrost soils are common. However, it has little effect on the peripheral soils along the river banks, where groundwater levels are relatively low. In river floodplains, various minerals are transported from the plateau, deep and surface runoff, so the accumulation process in the floodplain soils is clearly visible.

Floodplain kastanozems are distributed in the lowlands between the mountains. It is morphologically different from other kastanozems due to the influence of groundwater. The humus layer is gray brown, 45–80 cm thick; in some soils it is more than 1.0 m, and the humus content is 3.0–4.5%. It gradually decreases to the depth, and there are several layers of compacted humus in the lower layers. Granular structure, dusty, light loam, loam, effervescence depths in hydrochloric acid are varying. Due to the moisture regime, this soil is residual-saline and solonetz. Meadow kastanozems are considered to be a fertile soil for agriculture (Fig. 8.7).

8.3 Soil Classifications of Mongolia

Depending on the geographical location of Mongolia, its topography, and climatic conditions, many types of soils have been formed, and researchers have followed different criteria to classify them. The first soil classification in Mongolia was made in the early 1950 by N.D. Bespalov, who classified 13 groups of soils (Soils of the Mongolian People's Republic 1951). Since then, scientists and researchers have classified Mongolian soils into different levels, such as groups, types, subtypes, and so on, and are compared in Table 8.4 with some other classifications (Table 8.4).

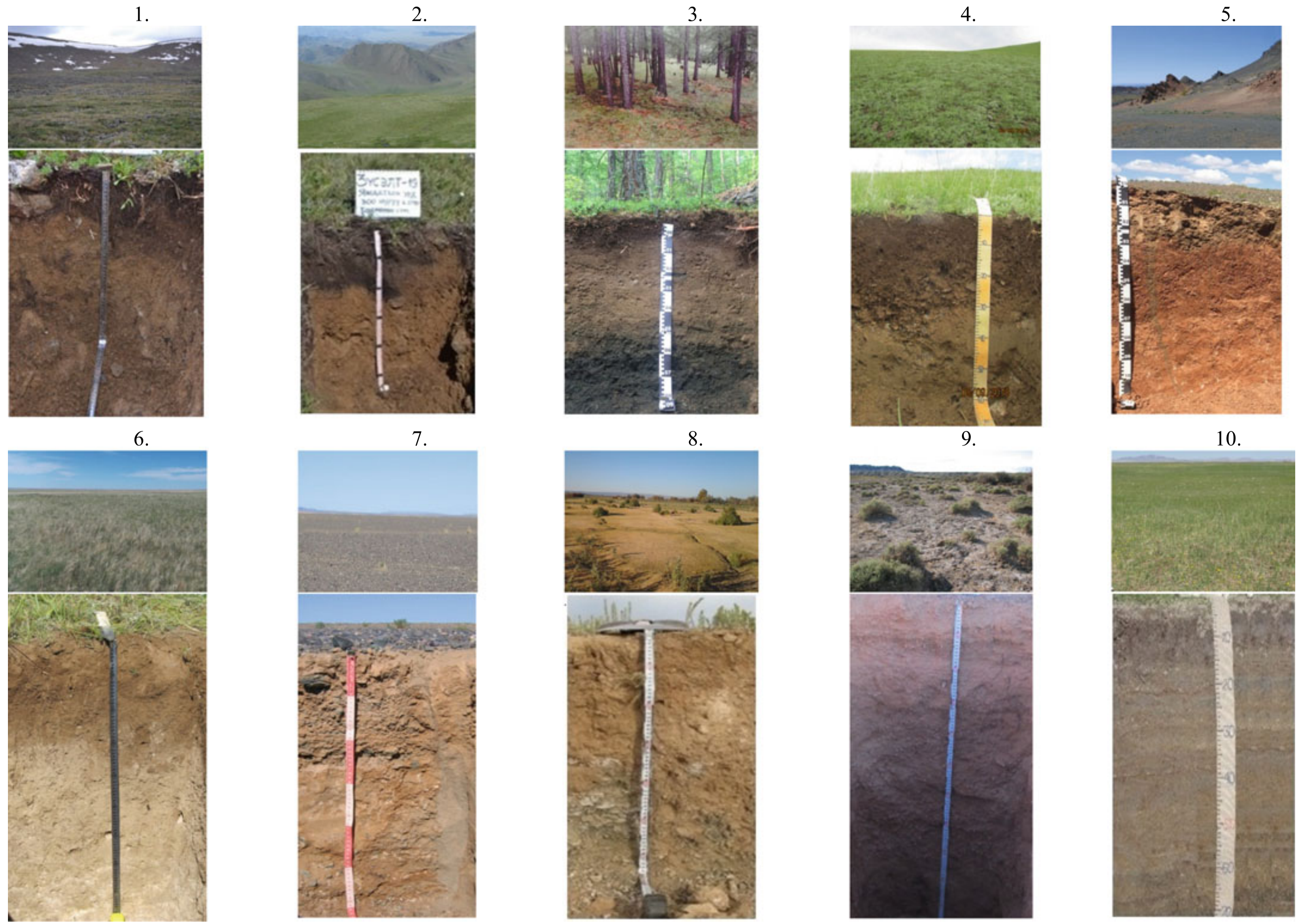


Fig. 8.7 Soil types (photos by Khadbaatar, S). 1. Mountain tundra soil, 2. Mountain meadow steppe soil, 3. Mountain forest soil, 4. Mountain meadow steppe soil, 5. Mountain desert steppe, 6. Steppe soil, 7. Semidesert and desert soil, 8. Hydromorphic soil, 9. Halomorphic soil, 10. Floodplain soil

Table 8.4 Checklist of the soil classification

Year	Soil classification			
	Group	Type	Subtype	Genus
Bespalov (1951)	13	17	–	5
Dorjgotov et al. (1974, 1981, 1986)	13	38	–	–
Nogina et al. (1980, 1984)	10	37	–	100
Dorjgotov (2003)	10	34	66	100
Krasnoschekov (classification of forest soil) 2013	6	18	50	–
Batkhishig (2016)	12	34	–	150

Since 1970, the Mongolian Academy of Sciences has been conducting soil research in Mongolia in several stages, focusing on the development of a unified soil classification. As a result of these studies, Russian and Mongolian researchers have developed an updated version of soil classification and identified 38 types and more than 100 subtypes of soil (Nogina and Dorjgotov 1982). A 1:1,000,000 scale map of the soil of Mongolia (edited by Mikhailov, Dorjgotov) is published in 1981. This map shows the distribution of more than 220 soils in 13 groups. Until the 1990, large, medium, and small-scale thematic maps of aimag, soum, hay, rangeland, and agricultural soils were published in large numbers, and soil classifications varied depending on the purpose and scope of the study. Subsequent versions of the soil classification were developed by national researchers, who elaborated on large- and small-scale thematic drawings, detailing soil types, subtypes, and types (Dorjgotov and Batbayar 1986). Following the theory of Dokuchaev, the relief plays a decisive role in the formation of mountain soils. Soils were divided into two main groups: mountain and steppe. Due to their natural state, mountain soils are divided into independent taxonomic groups, but due to insufficient study of high mountain soils, there is not enough material for their detailed classification (Dorjgotov and Batbayar 1986) (Fig. 8.8).

The International Soil Classification considers only the characteristics, composition, and bedrock characteristics of soil layers, regardless of landscape differences. For example, thin, gravelly soils formed on bedrock are classified as Leptosol, while rocky, permafrost, crumbly, limestone as mollic, and coarse humus soils are classified as umbric (Jahn et al. 2006). In the case of Mongolia, it is located in the center of the continent and is very different from similar soils of the same latitude due to its mountainous, geological structure, and climatic characteristics. Mongolia has an arid and cold climate due to its geographical location of inland and mid-latitude highlands. Due to this, it makes different from other soils in the temperate zone of the world. Most of Mongolia's mountains are latitudinal, and natural zones transfer in relatively short distances in mountainous areas. As a result, in the northern part of the country, in addition to the latitudinal features, there is a mixed landscape that retains the characteristics of a vertical belt. In such landscapes, mountain latitudes, taiga, and mountain black soils are affected by both latitude and altitude differences. Therefore, the soils of Mongolia in the group of mountain soils are classified, in addition to the vertical belt soils, which included latitudinal features. This classification of soils is based on the principles of geomorphological features and soil origin. The classification of soils in this category retains the terms used in the previous version, and uses some traditional local names, such as takyr and borzon. Therefore, this is a classic classification of soil science that is based on characteristics of the landscape.

There are 18 types of mountain soils that are grouped into five groups: tundra, meadow and meadow steppe, forest, steppe, desert steppe, and

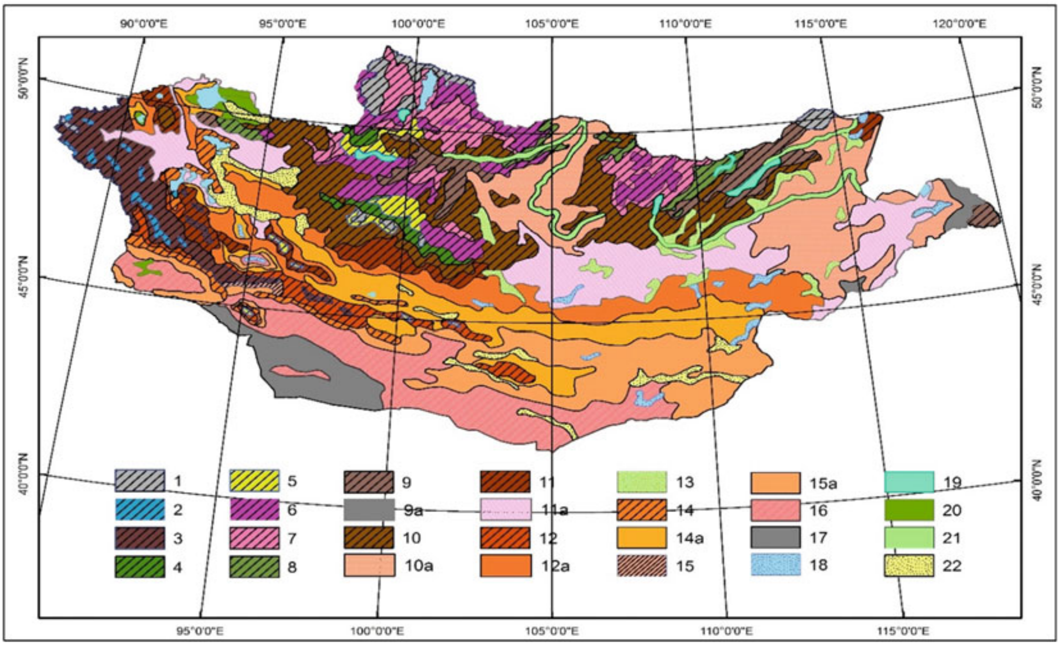


Fig. 8.8 Geographic distribution of soil (modified from Nogina 1982). 1.Tundra, 2.Tundra and high mountain steppe, 3. High mountain steppe, 4. Mountain dry steppe now humic, 5. Mountain meadow, 6. Mountain meadow steppe podzolic, 7. Mountain cryomorphic-taiga and podzolic, 8. Mountain derno-taiga, 9–9a.Chernozem meal carbonated and noncarbonated, 10–10a.Dark kastanozems meal carbonated, noncarbonated, 11–11a. Carbonated meal carbonated, 12–12a. Light kastanozems meal carbonated, 13. Meadow-kastanozems, 14–14a. Semidesert brown, 15–15a. Dessert stepped brown, 16. Desert gray-brown, 17. Extra arid desert gray-brown, 18. Soloneztic and solonchak, 19. Meadow-boggy, boggy-cryomorphic, 20. Meadow-boggy, halomorphic, 21. Alluvial, 22. Sand

desert; Steppe soils divide 16 types into five groups: steppe, some desert and desert, wet origin, saline and river floodplain, which is 10 groups in total divided into 32 types (Table 8.5).

The last version of soil classification in 2016 by Batkhishig is characterized by organic content, stony, thickness, and thickness in terms of the international classification principle (Batkhishig 2016). It introduced new classification of soils that were developed and clarified by authors based on field investigations and other published materials (Fig. 8.9).

Soils of Mongolia are characterized by severe frost in the upper part of winter with deep freezing up to 3–4.5 m, a long period with seasonal permafrost (6–9 months a year). The coincidence of warm months with rainiest seasons of the year promotes biological activity. During this period, the amount of carbon dioxide in soils increased comparatively, which influenced the shift of air carbonates to soluble forms; therefore, a more migratory form, and at the same time, the regime of moisture penetration prevailed in soil profiles. All these situations provided geochemical migration of carbonates in steppe soils of Mongolia; therefore, the top part of soils was usually leached with carbonates. In some cases it occurred without a carbonate variant. Such very clear migration of carbonates was not usually observed in steppe soils of other regions.

In this classification, he focuses on two main criteria: soil source process and soil properties, and uses numerical values. For example, each soil type is classified according to detailed criteria, such as humus layer thickness of at least 40 cm, permafrost within 1 m, and rocks more than 40% within 1.0 m (Table 8.6). In order to make the soil classification criteria simple and clear, the organic content, color, humus layer thickness, and rocky properties have been quantified, and some traditional

Table 8.5 Soil classification of Mongolia (Dorjgotov 2003)

Group	Type	Sub-type	Genus
Mountain soils			
1. Mountain tundra	Mountain tundra ochre	Typic; Row humic Podzolic; Gleyed	Ordinary; Residual carbonated; Stony
	Mountain tundra peaty-gleyed soil		
	Mountain tundra cryoturabated		
2. Mountain meadow, mountain meadow-steppe soil	Mountain meadow peaty raw-humic Mountain meadow dark-colored raw-humic	Typic; Ochric; Chernozem-like; Gleyed	Ordinary; Residual carbonate; Non-complete developed
	Mountain meadow peaty raw-humic		
	Mountain meadow steppe mull-humic	Typic; Meal carbonated Crypto-gleyed	Ordinary; Residual carbonatic
3. Mountain forest soil	Mountain taiga cryomorphic ochro soil (podbur)	Typic; Surfacely ferrimorphic; Podzolic; Gleyed	Gleyed; Residual carbonatic
	Mountain taiga cryomorphic peat-muck humic soil	Typic; Gleyed	Ordinary; Residual carbonatic
	Mountain taiga podzolic soil		
	Mountain derno-taiga (ferrimorphic) soil	Typic; Raw humic; Podzolized; Crypto-gleyed	Ordinary; Residual carbonatic
	Mountain forest, dark colored derno soil	Typic; Meal carbonated; Crypto-gleyed; Gleyed; Raw humic; Buried layers	
	Forest slightly podzolic sandy soil		
4. Mountain steppe soil	High mountain steppe raw humic	Typic; Ochric; Pillow like	
	Mountain chernozem	Non-carbonated; Meal carbonated; Crypto-gleyed	Low humic; moderate humic, High carbonated; Deep carbonated; Warped; Non-complete developed;
	Mountain kastanozem	Non-carbonated dark kastanozem; Meal carbonated dark kastanozem; Meal carbonated kastanozem; Meal carbonated light kastanozem; Crypto-gleyed	Ordinary; High carbonated; Deep carbonated; Warped; Non-complete developed; Aeolian sandy covered
5. Mountain desert-steppe and desert soils	Mountain semi-desert brown soil		
	Mountain desert gray brown soil		
Plain and valley soils			

(continued)

Table 8.5 (continued)

Group	Type	Sub-type	Genus
6. Steppe soil	Chernozem	High humic; low humic; Crypto-gleyed; Anthropogenic	Ordinary; High carbonated; Deep carbonated; Low carbonated (or leached); Warped; Residual solonetzic; Buried gravel layer in humus; Non-complete developed; Sandy
	Kastanozem	Dark kastanozem; Kastanozem; light kastanozem; Crypto-gleyed; Anthropogenic	Ordinary; Warped; Residual meadowish; Paleocryogenic; Non-carbonated (low carbonated); High carbonated; Deep carbonated; Buried gravel layer in humus; Solonetzic; Solonchak; Non-complete developed; Seolian sandy covered; Sandy
7. Semi-desert and desert soils	Semi-desert brown soil	Brown; light brown; Crypto-gleyed; Anthropogenic	Ordinary; Solonetzic; Solonchak; Gypsic; Aeolian sandy covered; Sandy; Sairic
	Desert gray-brown soil	Typic; Crypto-gleyed	Ordinary; Solonetzic; Solonchak; Gypsic; Aeolian sandy covered; Sandy; Sairic
	Extra-arid desert 'Borzon' soil	Ordinary; Gypsic; Sairic	
	Takyr soil	Takyr; Takyr like	Ordinary; Solonetzic; Crypto-gleyed (residual meadowish)
8. Hydromorphic soil	Meadow dark humic gleyed soil	Crypto-gleyed; Gleyed	Ordinary; Solonchak; Stepped
	Meadow-boggy raw humic gleyed soil	Raw humic gleyed; Gleyed	Ordinary; Residual carbonatic; Solonchak
	Boggy peaty gleyed soil		
9. Halomorphic soil	Solonchak automorphic	–	Chloric-sulphatic; Sulphatic-chloridic
	Solonchak hydromorphic	Gleyed; Crypto-gleyed	Sodic; Chloridic-sodic; Chloridic-sulphatic; Sulphatic-chloridic; Sodic-chloridic; Sodic-sulphatic; Sulphatic; Residual humic (sulphatic-chloridic)
	Solonetz automorphic	–	Ordinary; Solonchak
	Solonetz hydromorphic	–	Ordinary; Solonchak
10. Floodplain soil	Alluvial boggy gleyed soil	Alluvial boggy gleyed soil; Alluvial meadow boggy derno gleyed; Alluvial boggy clayed, gleyed	Ordinary; Carbonatic; Solonchak; Cryoturbated
	Alluvial meadow gleyed soil	Alluvial meadow derno gleyed; Alluvial meadow dark-colored crypto-gleyed	Ordinary; Layered; Solonetzic; Solonchak; Stepped
	Alluvial derno soil	–	Ordinary; Layered; Stepped

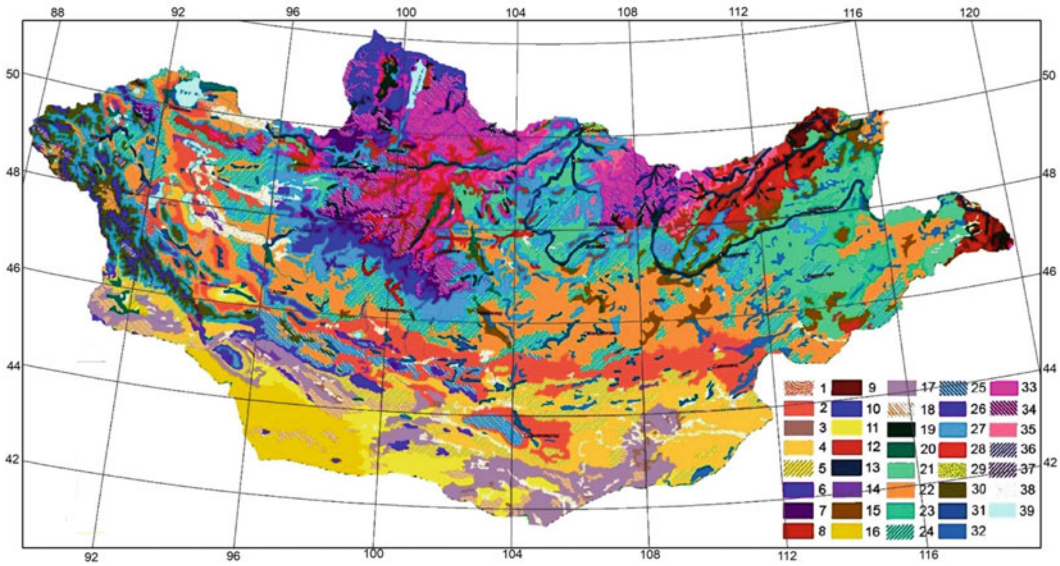


Fig. 8.9 New classification of soil types in Mongolia based on the FAO (by Batkhishig 2016). 1. Arenosols, 2. Calcisols Aridic, 3. Calcisols Takyric, 4. Calcisols Yermic, 5. Leptic calcisols, 6. Cambisols, 7. Mollic cambisols, 8. Chernozems, 9. Haplic chernozems, 10. Cryosols, 11. Gypsisols, 12. Leptic Chernozems, 13. Fluvisols, 14. Aridic Gleysols, 15. Mollic Gleysols, 16. Gypsisols Yermic, 17. Calcic Gypsisols, 18. Leptic Gypsisols, 19. Gelic Histosols, 20. Salic Histosols, 21. Kastanozems, 22. Aridic Kastanozems, 24. Leptic Kastanozems, 25. Leptosols, 26. Calcic Leptosols, 27. Mollic Leptosols, 28. Phaeozems, 29. Arenic podzols, 30. Regosols, 31. Solonchaks, 33. Umbrisols, 34. Gelic umbrisols, 35. Mollic umbrisols, 36. Glacier, 37. Rock cliff, 38. Sand, 39. Lake

Table 8.6 Soil classification criteria

Characteristics	Criteria
Peaty horizon (H)	Organic content more than 20% or carbon content more than 12%
Layer of organic accumulation (O)	Organic content 10–20%, or carbon content 6–12%, plant residue
Humus horizon (A)	Organic content 1–10%, carbon content 0.6–6%
Carbonate soil (k)	First 5 cm effervesce with 10% HCl, or in 0.5 m carbonate layer more than 15 cm, $CaCO_3$ content more than 2%
Gypsum soil (y)	Throughout 0.5 m soil the gypsum content is more than 5%, horizon thickness more than 15 cm
Stoneless soil	Stone size bigger than 2 mm makes up less than 5%
Sairic	Stone size with 2–20 mm makes up 5–40%
Stony	Stone size with 2–20 mm makes up more than 40%, or bigger than 20 mm is more than 20%

Mountain peat: Organic peat layer, organic content less than 20%, 1.0 m permafrost, rock less than 40%, rocky, Mountain dark: Organic layer 30–50 cm, no carbonate accumulation, less than 40% per 1 m of rock

nomenclature has been retained. This classification will be useful in updating the Guidelines for Soil (2006) to suit the soil characteristics of Mongolia. For example, high mountain coarse humus soils are regosol humic, mountain taiga soils are umbrisols, dark brown soils are kastanozem, brown soils are calcic kastanozem, light chestnut soils are aridic kastanozem, and international classifications (gypsic, mollic, calcic) are used (IUSS Working Group WRB 2015). Based on these criteria, a total of 12 groups, 34 types and 150 genus of soils were identified and mapped in Mongolia. In the field, quantitative data are important for soil identification, diagnosis, and distillation using laboratory test results (Table 8.6). International criteria show that the organic content of the humus layer of brown soils is more than 1.0% (Mollic) and less than 1.0% for the Gobi soils (Table 8.7).

Table 8.7 New classification of soil types in Mongolia (adopted from Batkhishig 2016)

Group	Type	Genus
High mountain, tundra	Mountain peaty	*Mountain; Mountain stony; Mountain cryomorphic*
	Mountain dark colored	*Mountain; Mountain stony; Mountain peaty; Mountain cryomorphic*
	Raw humic	*Raw humic; Stony raw humic*
Forest, taiga	Mountain taiga cryomorphic	*Taiga cryomorphic; Taiga cryomorphic ferrimorphic*
	Mountain derno-taiga	*Taiga derno; Stony; Carbonated*
	Podzolic	*Podzolic; Sandy weakly podzolic*
	Forest dark colored derno	*Forest dark colored; Carbonated; Gleyed*
Mountain steppe	Stony humus	*Stony humic; Shallow stony humic*
	Stony dark kastanozem	*Stony dark kastanozem; Shallow stony dark kastanozem*
	Stony kastanozem	*Stony kastanozem; Shallow stony kastanozem*
	Stony light kastanozemara>	*Stony light kastanozem; Shallow stony light kastanozem*
Gobi mountain, hills	Stony brown	*Stony brown; Shallow stony brown*
	Stony gray brown	*Stony gray brown; Shallow stony gray brown*
Steppe	Chernozem	*Chernozem; Sairic; Stony; noncarbonated*
	Dark kastanozem	*Dark kastanozem; Sairic; Noncarbonated; Carbonated; Stoneless; Thickness sandy; Covered sand; Sandy; Crypto gleyed; Solonchak; Solonetzic; Bazaltic*
Dry steppe	Kastanozem	*Kastanozem; Sairic; Carbonated; Stoneless; Thickness sandy; Covered sand; Sandy; Crypto gleyed; Solonchak; Solonetzic; Solonetzic gleyed; Noncarbonated*
	Light kastanozem	*Light kastanozem; Sairic; Shallow sairic;Covered stony; Carbonated; Thickness sandy; Covered sand; Sandy; Gleyed; Solonchak; Solonetzic gleyed*
Gobi-desert steppe	Brown	*Brown; Sairic; Shallow sairic; Solonchak; Carbonated; Thickness sandy; Covered sand; Sandy; Gleyed; Reddish*; *Solonchak; Solonetzic; Solonchak gleyed*
	Light brown	*Light brown; Sairic; Shallow sairic; Covered stony; Carbonated; Thickness sandy; Covered sand; Sandy; Solonetzic; Solonchak; Gypsic*
	Gobi reddish	*Gobi reddish; Sairic covered stony; Covered sand; Solonchak*

(continued)

Table 8.7 (continued)

Group	Type	Genus
Desert	Gray-brown	*Gray brown; Sairic; Shallow sairic; Covered stony; Carbonated; Covered sand; Sandy; Reddish; Solonetzic; Solonchak; Gypsic*
	Borzon soil	*Borzon; Covered stony; Sairic; Covered sand; Solonchak; Gypsic*
Meadow-boggy	Peaty	*Peaty; Gleyed; cryomorphic; Carbonated*
	Dark colored	*Dark colored; Peaty; Peaty dark colored cryomorphic; Solonchak; cryomorphic*
Floodplain, sairic	Alluvial	*Alluvial; Derno; Loamy; Saline; Gleyed; cryomorphic*
	Alluvial peaty	*Alluvial Peat; Alluvial Peaty*
	Alluvial coarse	*Alluvial coarse; Alluvial sand*
	Sairic Soil	*Sairic; Coarse, Sandy; Stony*
Halomorphic soil	Solonetzic	*Solonetzic; Solonchak*
	Solonchak	*Solonchak; Humic solonchak*
	Takyr like	*Takyr like*
Anthropogenic	Agrozem (Антросол)	*Loamy; Clayey; Brown*
	Urban soil (Technosol)	*Technosol, degraded*

8.4 Soil-Geographic Zoning of Mongolia

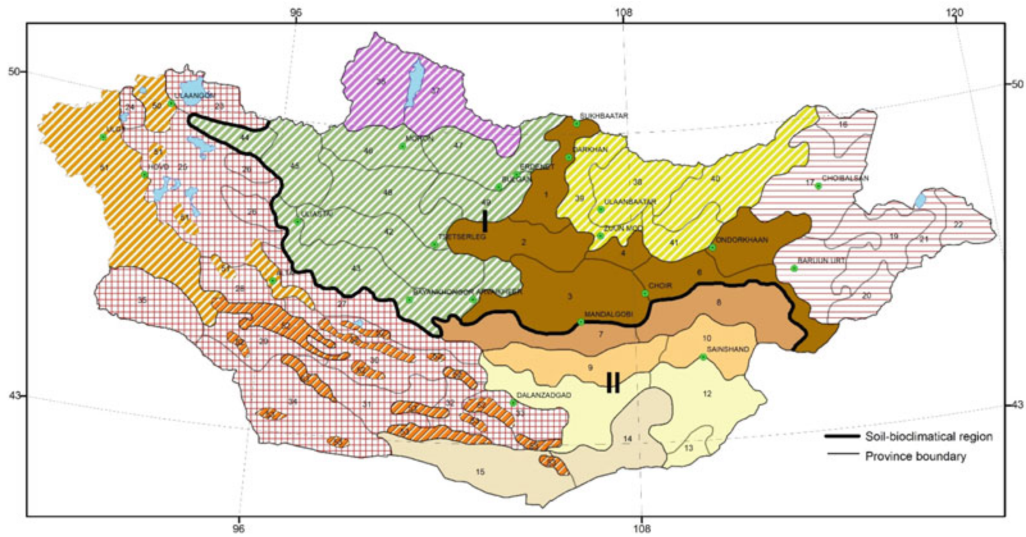
The division of territories into regions and provinces with different natural conditions is based on the scientific planning, location and efficiency of urban, economic and industrial development. These divisions are divided into relief, climates, surface- and groundwater, soils, and vegetation. From the physical geographic component, criteria such as soil zoning, its characteristics, landscape appearance, bioclimatic regime, and geomorphological features are considered. Geographical zoning of soils is important, not only for land management, ecology, and conservation but also for the construction and transportation sectors.

Bioclimatic, lithological, and historical and genetic factors in the spatial differentiation of the soil cover of Mongolia are of first-rate importance for orographic factors. Large mountain structures, intermountain depression, foothills, and other orographically well-distributed areas always differ clearly peculiar soil cover and the natural-landscape conditions, and they occupy a position as independent structural units at appropriate levels of the hierarchical zoning system. In such areas, the soil cover structure is determined by the influence of a complex combination of different geographical patterns: latitudinal, depression-vertical, humid-piedmont, and arid zones. Materials obtained from the map of soil in Mongolia are used at a scale of 1:1,000,000 (1981) and are compared with soil-geographical zoning schemes with those developed for Russia and the World soil zones. (Dorjgotov1992)

It is divided into 2 major provinces, 7 provinces, 5 latitude sub-regions, and 53 districts, taking into account the soil distribution characteristics and bio-climatic factors of Mongolia (Dorjgotov 2009). A brief description of the soil regions is given.

Khangai soil region. Extreme climatic conditions in the northern part of the country significantly soften the soil cover. The steppe kastanozem are mainly distributed here, and depending on the internal differences of the provinces, they can be dark kastanozem, kastanozem, light kastanozem, mountain kastanozem, meadow kastanozem, and forest kastanozem. There are also turf-ash and mountain forest gray, mountain black earth, meadow-swamp and saline soils. Soil-forming bedrock consists mainly of granite, schist, and bedrock, as well as thin alluvial sediments, diluvium, and thick proluvial sediments formed as a result of their weathering. Loess-type loam of wind and proluvial origin occurs in the mountainous areas of the Khangai region. In this region, most of the annual rainfall falls in a short period of time in late summer, so the soil is washed away intensively. According to the geomorphological characteristics, the Khangai soil region is divided into four provinces of Khuvsgul, Khentii, Khangai and Dornod, and one sub-region of latitude, and each province is divided into a sub-province. The general features of soil formation in this region are: (1) significant accumulation of humus as a result of sod process; (2) continuous distribution of long-seasonally frozen and deep frozen soils; (3) powdery forms of carbonate excreta; (4) non-salinity of automorphous soils and absence of easily soluble salts, gypsum and salinity in them; (5) peculiarity of geochemical migration of carbonates, connected with peculiarities of water-heat river and frequent occurrence of carbonate-free steppe soils; (6) short biologically active periods; (7) relatively low thickness of humus horizon in the whole soil profile; (8) wide spread of relic features in modern soils (paleohydromorphism, paleocryomorphism, residual salinity, residual carbonated, etc.); (9) light granulometric composition and crushed stone, causing high water permeability. In this area, there are territories with all three types of structural zonality. All mountains belong to the sub-humid type of vertical soil zonality. The East Mongolian plain is characterized by a wide spread of dark-kastanozem soils and the existence among them of extensive depressions with more arid kastanozem soils as a result of the manifestation of depression vertical zonality. At the outlying areas of the Eastern plain of Mongolia, the humid-mountainous zonality is clearly defined. A significant part of dark kastanozem soils has signs of contact meadowiness. In the south of the Khangai region there is a vast area with a latitudinal type of structural zoning, covering subzones of kastanozem and dark kastanozem.

Gobi soil region. In the northern part of the Gobi, light brown and brown soils are spread to the south by light desert brown and gypsum soils, and the area of solonetz and solonchak soils increases. Due to the influence of wind on the soil formation process, the surface of the Gobi is characterized by a thin or coarse layer of gravel. It has three provinces, Mongol Altai, Gobi-Altai and Baruun Khuurai, and four latitudinal sub-provinces (Gunin and Vostokova 2005). Soils of the Gobi region are characterized by (1) development of arid soil formation processes without modern salt accumulation; (2) formation of rounded and obtuse-rounded gravel on the soil surface; (3) low humus content; (4) lack of readily soluble salts and gypsum in the profile; (5) residual salinity, carbonated, salinity; (6) retardation of the ecological activity of soils due to acute lack of moisture; (7) strong development of deflation processes to the erosion of sairic; (8) profile shortening. Within the limits, the region is distinguished by territories with all three types of structural zoning. Mountainous areas are divided into two types of vertical zonality: sub-arid and arid. The territory with a mixed type of zoning is represented by two provinces: the Great Lakes depression and the Baruun-Khuurai Basin. The province of the Great Lakes depression occupies a vast depression located between the mountain systems: the Mongol Altai and Khangai, and is divided into several independent lake depressions. Accumulative and denudation inclined plains prevail within the limits of the basin, and there are island mountains and hills and low-mountain ranges along its periphery. A huge area is occupied by semi-fixed and wavy sands. This province sharply differs from other territories of the region by its climatic conditions. It is characterized by a more extra continental dry cold climate (Fig. 8.10).



Soil-bioclimatic region	Soil-geographical regions		
	Latitudinal	Depressional	Altitudinal
I Khangai	**Chernozem, kastanozems sub region** *Provinces:* 1. Orkhon-Shaamar 2. Tuul-Dashinchilen 3. Burd-Bayantsagaan 4. Maant 5. Undurkhaan-Tumentsogt 6. Borundur - Uulbayan	**Eastern region** *Provinces:* 16. Ereentsav 17. Bayantumen 18. Baruun-urt 19. Menen-Matad 20. Dariganga 21. Tamsagbulag 22. Khyagan	**Khuvsgul region** *Provinces* 36. West Khuvsgul 37. East Khuvsgul Khentii region Provinces: 38. Central Khentii 39. Khentii out 40. Eastern Khentii 41. Kherlenbayan-Ulaan Khangai region Provinces: 42. Central part Khangai 43. Southern Khangai 44. Khankhukhii 45. Telmen 46. Delgermurun 47. Selenge 48. Northern Khangai 49. Khanui-Orkhon
II Gobi	**Light kastanozems sub region** *Provinces:* 7. Dundgovi 8. Bayandelger Semidesert brown soil sub region Provinces: 9. Khuld-Undurshil 10. Altanshiree **Semidesert light brown soil sub region** *Provinces:* 11. Manlain 12. Dornogvi 13. Sulinkheer **Desert gray brown soil subregion** *Provinces:* 14. Galba gobi 15.Zag shuuj-Borzon gobi	**Southern region** *Provinces:* 23. Uvs lake 24. Achit lake 25. Khyargas-Khar lake 26. West Khangai 27. Valley of lakes 28. Sharga gobi 29. Zakhui gobi 30.Biger-Bayangol 31. Ingen khuuvur-Lig 32. Bayandalai 33. Dalanzadgad 34. Trans Altai 35. Baruun khuurai	**Mongol Altai region** *Provinces*: 50. Kharkhiraa-Turgen 51. Mongol Altai **Gobi Altai region** Provinces: 52. Gobi Altai 53. Trans Altai Gobi

Fig. 8.10 Soil-geographic zoning of Mongolia (based on Dorjgotov 2009)

8.5 Soil Degradation

There are two main factors, natural and social, and both influence each other. Natural factors include wind, water, climate, precipitation, and from a social point of view, urbanization, population concentration, transportation, livestock numbers, grazing capacity, and agriculture. The most important diagnostic degradation of soils, the transformation of the soil profile, includes: from morphological characteristic to the thickness of the humus horizon, from chemical to the content of humus, and from physical to the structural composition. In these indicators the peculiarities of soil formation processes and genetic characteristics of soils are shown with completeness, and under the influence of anthropogenic factors in them shows the most significant changes (Undarmaa et al. 2018). Due to Mongolia's generally dry climate and high wind speeds in the spring, soil erosion is quite common. Soil erosion is relatively high in the Orkhon-Selenge and Onon-Kherlen basins, which are Mongolia's main agricultural areas. Due to the fact that the driest and windiest periods of the year coincide, soil erosion intensifies in the spring.

Water degradation moves the top layer of fertile soil and gradually causes an adverse impact on circulation of fertile substance of soil, vegetation shrouds development, and providing ecosystems balance. The process of soil is degraded by water and is determined by climate conditions, land surface inclines, and physical properties of soils. As of the territorial space, the soil degradation grade has relatively high value, stable soil is distributed in hilly steppe, typical steppe, southern part of dry steppe, deserts where takyr and takyr-like are dominantly spread. Any soils susceptible to degradation processes include dry steppe kastanozem, floodplain soil, hill hydromorphic soil, alluvial soil, and sand assimilation. Landscape features should be taken into account in the scientifically based development of the proper location of agriculture and its efficiency, which is the basis for regulating various environmental and social processes such as determining agricultural areas, selecting tillage technologies, soil protection, and improvement will occur. In the Orkhon-Selenge basin, the agricultural region of Mongolia, soil erosion is relatively high due to the high density of arable land and because of the inadequacy of soil improvement technologies. For example, compared to the dry steppe zone, the compost content of pasture and arable brown soil decreased by 50–60% in the plowed area, the amount of fine grains decreased by 40–50%, while the forest steppe zone reduced the humus content by 30–50%, and the sand and dust by 20–40% (Bazha et al. 2018).

8.5.1 Water Degradation

On estimating the soil, degradation grade is high by the edges and boundaries of mountainous areas. Steppe zones and basins of major rivers are in the moderate grade. Great Lakes depression, central part of the Valley of Lakes, and lowlands of eastern Gobi are included in territories which are not incurred in soil degradation or improved in comparison with the previous years. Areas with dramatic changes on soil degradation are not noticed after comparison, and a slight reduction of territories with high degradation grade is noticed. In extremely arid regions, soil salinization is increasing due to the evaporation of groundwater, where its water table is near the surface. One of the most remarkable examples of soil salinization is the Ekhiin-Gol oasis. The slight changes are also noticed in the southern part of Sukhbaatar aimag, at the neighboring area of Uvurkhangai and Dundgovi aimags and along the Khovd river (Khudulmur et al. 2013) (Fig. 8.11).

8.5.2 Wind Erosion

Wind erosion is a common sight in dry and arid areas where vegetation doesn't hold soils in place. Soil erosion can be a slow process that continues relatively invisibly or can occur at an alarming rate, causing serious loss of topsoil. There are number of reasons for the plant shrouds to get sparse, the most influential of which are droughts, pastureland pressure, and mining operations. Soil degradation by wind effects is determined by such factors as the climate, plantation and physical properties of soil. The wind causes deterioration which drives the coarse granule soil to move which is a very common natural phenomenon that takes place in dry and droughty regions (Garidkhuu 1975; Nyamsambuu 2004; Khadbaatar 2010). Due to the impact of climate change, desertification and soil degradation are the most serious problems in Mongolia. Thus, soil quality issues are studied in

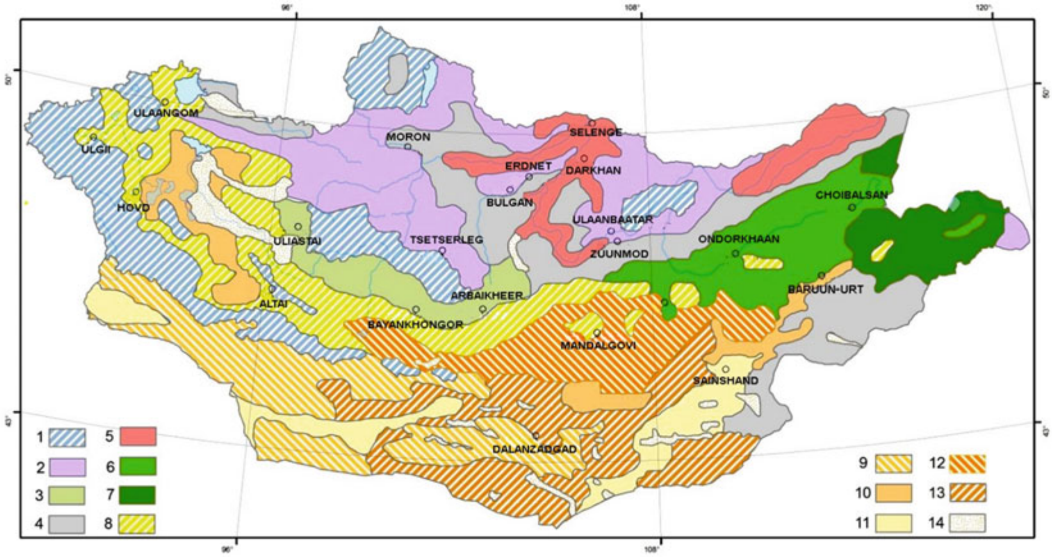


Fig. 8.11 Water erosion vulnerability map (based on National Atlas of Mongolia 2009). 1. Glacier and permafrost-related hazards; 2. Lower rank due to relatively slope run-off; 3. High rank due to relatively slope run-off; 4. Lower rank due to relatively flood; 5. High rank due to relatively flood; 6. Low risk rank due to relatively water; 7. No risk rank due to relatively water; 8. High erosion by break-stone; 9. Low erosion by break-stone; 10. Lakes; 11. High surface run-off; 12. Low surface run-off; 13. Low effect surface run-off erosion; 14. High effect surface run-off erosion

combination with desertification, especially through soil erosion. The last research used the ArcGIS wind erosion equation model to assess wind erosion throughout Mongolia (Mandakh et al. 2016). Due to the fact that the driest and windiest periods of the year coincide, soil erosion intensifies in the spring. In the Gobi Desert region, sand cover is often formed on the surface of the soil where sand movement occurs in some places due to strong winds. Sandy soils cover more than 3 million hectares in the western and southern parts of the country. Depending on the thickness of the sand carried by the wind, the properties of the soil will change and affect the vegetation cover (Batkhishig et al. 2018).

In general, the process of wind erosion is more pronounced in semi-desert and desert areas in Mongolia (Gunin 2019). High-grade wind erosions are noticed in Gobi regions, Great Lakes depression of and along the lakes valley from the soil mapping. Specially there are some high grades that are recorded at the Baruun Khuurai depression, Trans-Altai Gobi, Ulaan lake and near Mandal-Ovoo. Plants shrouds are short and scarce in these places and there are fewer slopes and obstacles on the surface. In other words, every indication estimated by us has high grade in these places. Steppe and desert steppe zones of our country, especially, eastern prairie, Zamiin Uud and Sainshand of eastern Gobi are included in moderate grade. The changes of wind erosion processes are clearly noticed in valleys and gorges of Sharga, Nomin, Ingen khuuvur, Galba and Borzon Gobi in southern sides of Gobi-Altai, Bayankhongor and Umnugovi aimags and there is an estimation released by comparing 2000 and 2010, that 165.7 t/ha of soil is moved annually from these regions (Fig. 8.12). However, soil erosion by wind is 57.7 t/ha a year in the western part of the Great lake depression or in Khar Us lake and along the Buyant river basins and reduced in other places.

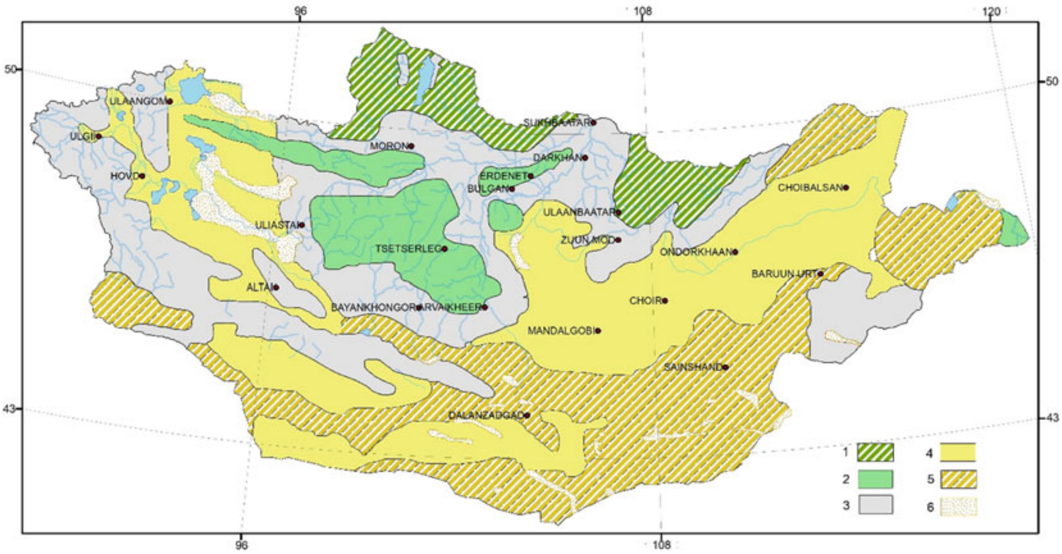


Fig. 8.12 Soil wind erosion vulnerability map (based on National Atlas of Mongolia 2009). 1. No risk, 2. Low, 3. Moderate, 4. High, 5. Very high, 6. Sands

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