GEOGRAPHY AND STRUCTURE OF THE WORLD SOIL COVER (PEDOSPHERE)

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Contents

Summary

Regularities of geographical spreading (occurrence) of the world soils are considered. The basis is a scheme of soil-geographic zoning. According to a notion on the soil cover as about complicatedly organized natural system, having a structural-subordinated type of structure, the multistep (multiphase) taxonomy has been adopted: 1) a soil-geographic belt; 2) a soil-bioclimatic area, and further on, for lowland (plain) territories: 3) a soil zone (subzone); 4) a soil province; 5) a soil county; 6) a soil region, and for mountain territories: a mountain soil province. Isolation of highest taxonomic units (including the province) is performed on the basis of features of a soil cover, mainly determined by influence of bioclimatic conditions of soil formation (pedogenesis). The lithologic-geomorphologic factors play leading role in isolation of countys and regions.

The soil cover of the world is characterized at the level of megastructures those are soil-geographic belts and bioclimatic areas. 5 belts are separated: polar, boreal, subboreal, subtropical, and tropical, divided into 25 groups of soil-bioclimatic areas. Detailed zoning at the level of macro- and mesostructures of the soil cover with isolation of soil zones (subzones), provinces and countys is considered by the example of the zone of soddy-podzolic soils of south taiga of Russia, located in the European-Siberian area of the boreal belt. It is shown how differences in the soil cover are manifested in the present-day economical use of the land resources. The necessity of taking account of the zonal-regional diversity of natural conditions as well as of the soil cover for

optimization of using and protection of soil resources is emphasized.

1. Introduction

The soil cover (the pedosphere) of the Earth's land is a complicatedly organized and hierarchically built open thermodynamic system that exchanges substance and energy with the external environment. One can isolate in the soil cover structure several levels of its organization, which are harmoniously embedded one to another. Those are microstructure, mesostructure, macrostructure, and megastructure. The microstructures (or elementary soil structures) are more often related in their occurrence with microrelief. The mesostructures are universally pronounced and they are usually related to a certain type of a relief or with special change of soil-forming parent materials. Spatial alternation of the mesostructures, determined (stipulated) by different factors, creates macro- and mega-structures of the soil cover, embracing large territories.

Diversity and regularities of spatial spreading of the soil cover is stipulated by joint influence of bioclimatic, lithologic-geomorphologic, and historical-geological factors on the land surface. Generalization and systematization of the soil cover structures is the purpose of soil zoning.

There are different approaches to the soil cover zoning on the land. Russian scientist M.A. Glazovskaya (1973) developed the soil-geochemical zoning of the world, where the largest unit is presented by soil-geochemical fields: a field of acid ulmate-fulvic gley siallitic soils, a field of neutral-alkaline humic siallitic and ferrosiallitic-carbonate soils, etc. V.A. Kovda (1973), taking account of soil-geochemical regularities and history of a territory, isolate on the land the following soil-geochemical formations as the soil cover megastructures: a formation of acid allitic, acid allitic-kaolinite, neutral and weakly-alkaline montmorillonite soils, etc. Dobrovol'sky G.V., Urusevskaya I.S., Shoba S.A. (1990), taking account of similar features of the soil cover of large and geotectonically isolated morphostructural regions of the land, connected with a commonness of geologic history and geomorphologic structure of a territory, isolate them as soil-geological countries: the Baltic accumulation-denudation-plain cycle, zonally weakly differentiated, with dominance of shallow, debris podzolic-Al-Fe-humus and peat soils; the East-European sculptural-accumulation-plain with distinct latitudinally-zonal spectrum of soils, i.e. from tundra soils to brown semi-desert ones; the West-Siberian lowland accumulation-plain with distinct latitudinally-zonal spectrum of soils, i.e. from tundra soils to chestnut and with abundance of boggys, etc.

General regularities of the soil cover structure and its regional differentiation are reflected in the most successive (logic) and clear form on maps of soil-geographic zoning.

2. Principles and Taxonomic System of Soil-Geographic Zoning

The soil-geographic zoning is division (separation) of a territory into regions, which are one-type according to structure of soil cover, combination of soil-forming factors, and possibilities of agriculture use of soils. As the basis of, soil-geographic zoning the bioclimatic principle is used since it corresponds to the present-day functioning of the soil cover and meets mostly requirements of agriculture production.

According to the notion on the soil cover as the complicatedly organized natural system, having the structural-co-ordinating (subdominant) type of structure, the multi-step taxonomic is adopted in the soil-geographic zoning. It consists of the following units: 1) soil-geographic belt; 2) soil-bioclimatic area; further on for the plain territories: 3) soil zone (subzone); 4) soil province; 5) soil county; 6) soil region; and for mountain territories: mountain soil province.

Isolation of the highest taxonomic units (including a province) is performed on the basis of features of a soil cover, mainly conditioned by influence of bioclimatic conditions of soil formation. In isolation of countys the lithologic-geomorphologic factors play the leading role. The last ones determine the soil topography, forming the certain types of mesostructures of the soil cover.

The soil-geographic belt represents by itself a totality of soil zones and mountain soil provinces, united (combined) by similarity of radiation and thermal conditions.

The soil-bioclimatic area is understood as a totality of soil zones and mountain soil provinces, united within a belt by not only a similarity of the radiation and thermal conditions, but also by similarity of conditions of humidification and a continentality of climate.

The soil zone (subzone) is an area of a zonal soil type (subtype) and accompanying to it intra-zonal soils.

The soil province is a part of a soil zone (subzone), differing by specific features of soils and conditions of soil formation those are connected with either differences in humidification and continentality [within latitudinal segments of zones], or with differences in temperatures [within meridional segments of soil zones].

Soil county is a part of a soil province, being characterized by a certain type of soil combinations, conditioned by features of a relief and soil-forming parent material. Several types of the soil cover mesostructures alternate within a county, which are connected with large morphostructures of the relief, and a consequence of that is unity of history of development of the soil cover in the county.

Soil region is a part of a soil county, being characterized by one type of a soil cover mesostructure, which is determined by morphosculpture and/or specific features of lithology of the soil-forming parent materials.

Mountain soil province is a mountain country or its part within limits of a soil-bioclimatic area, which is characterized by one-type structure of vertical zoning, determined by features of mountain macroclimate and its general orography.

Further on, we will consider the soil cover megastructure in a scheme, proposed by N.N. Rozov and M.N. Stroganova (1979, 1998) with consideration for global bioclimatic regularities, generalized in frameworks of soil-geographic belts and soil-bioclimatic areas (Figure 1). In more details they will be considered below by the example of the zone of soddy-podzolic soils of south taiga of Russia, which is a part of the European-Siberian area of the boreal belt.

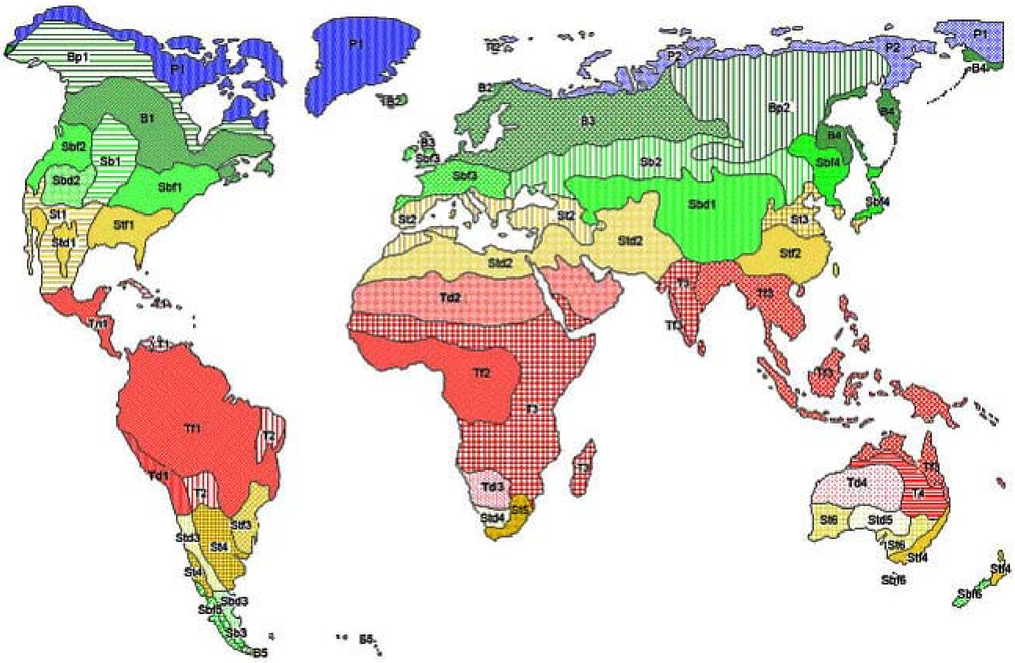

Figure 1. Soil-geographic belt and soil-bioclimatic areas of the World
Polar belt and areas: P1- North-American; P2- Euro-Asian; Boreal humid taiga-forest and extrahumid meadow-forest areas: Btf1- North-American; Btf2- Iceland-Norway; Btf3- European-Siberian; Btf4- Bering-Okhotsk; Btf5- Tierra del Fuego;Boreal permafrost-taiga areas: Bpf1- North-American; Bpf2- East-Siberian;Sub-boreal humid-forest areas: Sbf1- North-American (Near-Atlantic East); Sbf2- North-American west (Pacific states of the USA); Sbf3- West-Euripean; Sbf4- East-Asian; Sbf5- South-American; Sbf6- New Zealand-Tasmania; Sub-boreal semihumid and semiarid steppe areas: Sb1- North-American; Sb2- Euro-Asian; Sb3- South-American; Sub-boreal arid semi-desert and extremely desert areas: Sbd1- Central-Asian; Sbd2- North-American; Sbd3- South-American; Subtropical humid-forest areas: Stf1- North-American; Stf2- East-Asian; Stf3- South-American; Stf4- Australian; Subtropical semihumid xerophyte-forest and semiarid dry scrub-steppe areas: St1- North-American; St2- Mediterranean; St3- East-Asian; St4- South-American; St5- South-African; St6- Australian; Subtropical arid semi-desert and extremely desert areas: Std1- North-American; Std2- Afro-Asian; Std3- South-American; Std4- South-African; Std5-Australian; Tropical extremely humid and alternatively humid forest areas: Tf1- American; Tf2- African; Tf3- Australian-Asian; Tropical semihumid xerophyte-forest and semiarid dry savanna areas: T1- Central-American; T2- South-American; T3- Afro-Asian; T4- Australian; Tropical arid semi-desert and extremely desert areas: Td1- South-American; Td2- Afro-Asian; Td3- South-African; Td4- Australian.

3. Soil-Geographic Belts and Soil-Bioclimatic Areas of The World

3.1. Soil Cover of the Polar Belt

The polar belt occupies 13% of the land area, and more than 2/3 of its territory is covered with glaciers of the Antarctica, Greenland, and other isles. Within this belt, two soil-bioclimatic areas are isolated: ***the Euro-Asian and the North-American ones***. In the South Hemisphere, i.e. in the Antarctica, there are only quite small regions, free from ice.

The Arctic and Subarctic zones are distinguished in the soil cover of the polar belt. In the arctic zone, being characterized by very severe and dry climate, the arctic soils are formed along frost clefts under vegetation clusters (*Leptic Cryosols Aridic, Skeletic; Leptosols Lithic, Gelic, Rendzic*). They are characterized by shortened profile, absence of signs of gleization, subacid or neutral reaction, almost complete saturation with bases of absorbing complex. In the extreme north of the arctic zone, i.e. under the most arid conditions, the arctic desert soils (*Salic Cryosols*), having salt crusts on their surfaces, are formed.

In the subarctic zone with less cold and wetter climate, the tundra gley soils (*Umbric Cryosols*) are widely distributed under moss-lichen and moss-shrub vegetation on loamy-clayey parent materials. Weak evaporating capacity and permafrost, occurring shallowly, facilitate (promote) waterlogging (overwetting) and gleization of the profile. The tundra gley soils (*Umbric Cryosols*, Gleysols *Gelic*) are characterized by mobile fulvate humus and differ from the arctic soils by larger acidness and smaller saturation with bases. On stony and gravelly (calculous) sandy-loamy parent materials, rich by their mineral composition, the tundra podburs (*Entic, Rustic Podzols*; *Cambisols Gelic*) are formed under conditions of good drainage, which are soils with brown morphologically non-podzolized and non-gley profile. These are acid, non-saturated soils, enriched with organic substance, in composition of which the fulvic acids, connected with iron and aluminum, predominate. In the soil cover of the subarctic zone, the peaty soils are widespread (*Histic Cryosols; Histosols Gelic*).

General feature of soil cover of the polar belt is its complexity connected with manifestation of permafrost processes. The fractured-nanopolygonal complexes prevail in the arctic zone and continental parts of the subarctic zone. The swelling-nodular complexes are the most widely presented in more wet oceanic and moderately continental facieses of the subarctic.

Territories of majority of tundras are occupied by the perennial permafrost; and only in the west of Russia, on coast of North Norway, and in regions, which are close to warm current the Gulf Stream and the Barents Sea, the tundra soils, having no permafrost in their depths, occur.

The soil cover of ***the Euro-Asian polar area*** is presented mainly by subarctic zone of the tundra soils of Russia, extending from the Kola Peninsula to the Bering Straits. The south boundary of this zone, and, respectively, of the polar belt, runs approximately along latitudes 67-72° N. In basins of the Sea of Okhotsk and Bering Sea it goes down to 60° N.

The North-American polar area extends farer to the North than the Euro-Asian one, and in regions of the Labrador peninsula, on one side, and the Aleutian Islands, from the other side, it goes down to the South till 55° N. The same, but still more dry and cold landscapes are typical for also Antarctic regions, free from ice covers.

Over the vast expanses of the polar belt, hunting and reindeer breeding are distributed. Agriculture in tundra is focal (organized by closed areas), and it is mainly of covered ground, developed near cities and industrial centers. The tundra soils are easily eroded after deterioration of vegetation. That is why protection of Nature in tundra regions is the important problem, arising in connection with economics development of the Extreme North.

3.2. Soil Cover of the Boreal Belt

The boreal belt occupies 18% of area of the Earth's soil cover, and it is well developed in only the Northern Hemisphere. It embraces vast territories in the North America, Europe, and Asia with moderately cold climate, those are covered by mainly taiga forests. Sums of the air temperatures higher 10°C amount to 400-2200°, duration of vegetative season is from 40 to 150 days. In winter, soils can be frozen through for a term up to 5-8 months and longer. Mountain territories occupy about 34% of the total area of this belt. The soil cover is mainly formed on loose siallite deposits of the Quaternary age.

Several groups of the soil-bioclimatic areas are isolated within limits of the boreal belt: 1) humid taiga-forest continental ones (the ***North-American and the European-Siberian***) with predominance of acid podzolic (*Albeluvisols*) and partly burozem (*Cambisols*); 2) extrahumid meadow-forest oceanic soils with peat-soddy ones (*Umbrisols*) (the ***Iceland-Norway, Bering-Okhotsk, and Tierra del Fuego***); 3) permafrost-taiga with cryogenic soils (*Cryosols*) (***North-American and East-Siberian).***

The humid taiga-forest continental areas with predominance of taiga or broad-leaved-taiga forests contains two areas: ***the North-American***, including the greater part of Canada (from boundaries of the subboreal belt in south to boundaries of the permafrost-taiga area in north) and ***European-Siberian,*** embracing the north part of West Europe (Finland, Sweden, Norway, Poland), the Baltic Sea countries, north-west and center of the Russian Federation (up to boundary with the East-Siberian permafrost-taiga area).

These areas underwent pleistocene glaciation. Glacial and water-glacial types of relief prevail on these territories as well as conjugated with them moraines, fluvioglacial, lake-glacial (lacustrine-glacial) deposits of different granulometric composition and periglacial covering loess-like loams. Latitudinal-zonal and facies regularities, especially distinct in the East-Siberian area, are pronounced in structure of the soil cover. Gley-podzolic (*Epigleyic Albeluvisols*), podzolic (*Albeluvisols*), soddy-podzolic (*Umbric Albeluvisols*) soils are distributed in the soil cover of this area, while on those is Al-Fe-humus podzols (*Podzols*), in lowlands – burozems (*Dystric, Haplic Cambisols).* The podzolic soils are characterized by presence of bleached eluvial horizon (albic) under the forest litter, by clear eluvial-illuvial differentiation of their profile, by acid reaction, low capacity of absorbing complex and non-saturation with bases, and low humus content of light-texture composition. In the gley-podzolic soils (*Epigleyic Albeluvisols*), unlike the podzolic ones (*Albeluvisols*), signs of surface gley manifest, and in the soddy-podzolic soils (*Umbric Albeluvisols Endoeutric*) the humus-accumulative horizon with more significant content of humus is formed. In the Al-Fe-humus podzols, like in podburs (*Entic Podzols*), processes of illuviation of organo-mineral complexes are developed, but, since the podzols are formed on poorer parent materials, a whitish podzolic horizon appears in them under the forest litter. In the structure of the soil cover of continental taiga-forest areas, a noticeable role is played by the peaty-podzol (*Gleyic Albeluvisols; Gleyic, Histic Podzols*) and peaty soils (*Histosols*), and on the carbonate rocks – by the soddy-carbonate soils (*Rendzic Leptosols*). The processes of gleying and peating are especially widespread on the West-Siberian Plain.

On the carbonate loess-like loams, under broadleaved or coniferous-broadleaved forests on the west of the European-Siberian area the burozems (*Cambisols Distric*, *Eutric* and *Haplic, Stagnic Luvisols*) are developed, while on the east, i.e. in more continental area (the East-European Plain) near its south boundary, they are replaced by grey forest soils (*Albic*, *Gleyic Luvisols*).

The extrahumid meadow-forest oceanic areas with predominance of birch forests and grass-meadow landscapes include**:** ***the Iceland-Norway area*** (includes islands and the mainland coasts of the Norwegian Sea), ***the Bering-Okhotsk area*** (includes coast of the Sea of Okhotsk, Sakhalin, Kamchatka, the Kuril Islands, and the Aleutian Islands) as well as ***the Tierra del Fuego area*** in the Southern Hemisphere (includes south part of the Tierra del Fuego and the Falkland (Malvinas) Islands).

The soddy-peaty subarctic soils (*Leptosols Folic; Sapric Histosols; Umbrisols*) under forbs and graminaceous meadows are typical for these areas. The main process in them is the humus-accumulative. Specific feature of the soil cover of these territories is a wide distribution of volcanic ash soils (*Andosols*). There are much of those at the Kamchatka Peninsula, at the Kuril and Aleutian Islands, at Alaska, and in Iceland. The volcanic ash soils (*Andosols*) are layered and contain buried soil profiles because of periodically repeated ash accumulation.

In the group of **boreal permafrost-taiga areas *the East-Siberian* and *North-American* areas** are isolated. Their main distinctive feature is a presence of permafrost within the soil profile or near its low boundary, which merges in winter with upper seasonally frozen layer.

The East-Siberian area embraces vast areas of Central and East Siberia. Typical for this region are the extreme continental (extra-continental) cold climate with great range of the atmospheric humidification, predominance of a mountain relief and diversity of composition of the soil-forming parent materials, which are mainly products of the bedrock weathering. Vegetation is presented by light-coniferous larch taiga. Within limits of the area, the mountain-zonal the soil cover macrostructures dominate. Two subzones are distinguished on the plain territory: the north- and middle-taiga ones. The soil cover, which are formed on loamy-clay parent materials, is presented by mostly the gley-permafrost-taiga (*Cryosols Gelic*) (in the North taiga) and by the permafrost-taiga (*Umbric Cryosols*) (in the middle taiga) soils in combination with the permafrost-boggy (*Histic Cryosols*) ones. The permafrost-taiga soils (*Cryosols Gelic*) have weakly differentiated profile with signs of cryoturbations and above-permafrost gleization, acid reaction, low base saturation, the fulvatic impregnated humus. In the gley-permafrost-taiga soils the gleization penetrates the whole profile. In middle taiga, the acid burozems (*Cambisols Dystric*) do also occur on products of weathering of basic rocks. The podburs and Al-Fe--humus podzols are confined to light parent materials, while the humous- and soddy-carbonate soils (*Rendzic Leptosols*) are – to the carbonate rocks. In the most dry and cold conditions (the Central Yakutskaya Depression) the pale-yellow permafrost soils (*Cambisols Gelic*, *Umbrisols Gelic*) occur, and among them the meadow-chernozem (*Gleyic Chernozems*) and salinized soils occur in depressions of the relief. Accumulation of salts is promoted by the relief with depressions, dry climate, and the permafrost aquiclude (impermeable layer). The pale-yellow permafrost soils (*Cambisols Gelic*, *Umbrisols Gelic*) have a monotonic profile, neutral or weakly alkaline reaction, and they are saturated with bases and contain 3-5% of humus.

The North-American permafrost-taiga area is smaller in its area and its soil cover is less diverse. Territory of this area is located in a subzone of north taiga of Canada and the USA. The dominating are podburs (Podzols Gelic), the gley-permafrost-taiga (*Cryosols Gelic*, *Leptosols Gelic*) and permafrost peat soils (*Histic Cryosols*, *Gleysols Gelic*).

Agricultural development of lands in the boreal belt does hardly reach 5%. The main reason for that is the severity of climatic conditions, first of all is lack of heat for growing of majority of agricultural crops. That is why the basic directions of economic use of biological resources of the boreal belt are forestry, hunting, and the reindeer breeding. At the same time, soil-climatic conditions of south regions of the taiga-forest areas are favorable for growing of many grain and technical crops, and they are intensively developed. Main problems of agriculture here are fertilization with organic and mineral fertilizers as well as improvement of boggy soils.

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Biographical Sketches

Marina N. Stroganova, Dr.Sc., professor was born in 1935 in Moscow (Soviet Union). In 1959, she had been graduated from the Lomonosov Moscow State University as a pedologist in the area of agrochemistry. Since that time she is young scientist and then professor of the Lomonosov Moscow State University. A citizen of Russia, she is now one of leading Russian scientists in the field of geography and ecology of soils. Her PhD (1969) and Dr.Sc. (1999) theses were devoted to study of geography and mapping of soils. She was active participant of a number of national and international symposiums and conferences. She is the author of more 200 published scientific works (including 10 monographs) and the textbooks on pedology. She is the State Prize Laureate USSR for the cycle of works "Soils of the world: cartography, genesis, resources, and development" (1987).

Inga S. Urusevskaya, Dr.Sc., professor was born in July 1933 in Moscow (Soviet Union). In 1956, she had been graduated from the Lomonosov Moscow State University as a pedologist in the area of agrochemistry. Since that time she is young scientist and then professor of the Lomonosov Moscow State University. A citizen of Russia, she is now one of leading Russian scientists in the field of geography of soils. Her PhD (1964) thesis was devoted to studying of grey forest soils, and Dr.Sc. (1992) thesis - to the problem of soil-geographic zoning. She was active participant of a number of national and international symposiums and conferences, presented reports at International Congresses of pedologists. She is the author of about 150 published scientific works on pedology. She is the State Prize Laureate.