DESCRIPTION OF RUSSIAN SOILS

By Vladimir Stolbovoi

Soil refers to the uppermost layer of the earth, which displays a specific morphological structure, chemical composition, physical and biological characteristics originating from the transformation of rocks under the influence of live and dead organisms, climate, age, forms of relief, and the activities of human beings. Russian naturalist V.V. Dokuchaev, who first recognized specific features of soil morphogenesis and regularities of geographical distribution, founded a basis for modern soil science that identified soil as an original natural body. Soil has fertility that is a combination of substances and water-air and temperature regimes that support biomass production under natural or managed conditions. Therefore, soil is an essential component of terrain ecosystems. Soil performs an important regulatory function maintaining the exchange of energy and matter between the biosphere, atmosphere, hydrosphere and lithosphere, which is essential for the development of life.

Soil substance has solid, liquid, gaseous, and biotic phases. Their combination is soil specific and changes with depth and in space. Soil phases are also subjected to daily, seasonal, and long-term fluctuation. The solid phase (about 50% of volume) consists of minerals, organic, and organic-mineral substances. Primary (quartz, fieldspar, hornblende, mica, etc.) and secondary (hydromicas, smectite, kaolinite, etc.) minerals make up from 90% to 99% of the solid mass, excluding organogenous peat soils. The size of mineral particles and their proportional content determine soil texture, which varies from clay to sand. The organic phase consists of live and dead vegetation residues and soil fauna, including microbiota and humus. It is a product of deep transformation of initial organic matter associated with soil minerals. Soil has a fluffy consistency, which is determined by its structure. Pores between mineral granular and soil aggregates are filled by soil liquid and air. Soil liquid is a solution containing dissolved solids and gases, mainly originating from the turnover of plant-supporting (biophilic) elements. Soil air is the same kind of mixture as occurs in the atmosphere (N2, O2, CO2), but with a much higher concentration. The percentage of gases in the soil air is considerably different from that in the atmosphere and depends on biological activity, oxygen content, etc. Soil biota consists of microorganisms (bacteria, fungi, actinomyces, algae, etc.), abundant representatives of intertebrates (protozoa, worms, mollusks, insects and their larvae) and numerous digging vertebrates. Soil is a biostagnant natural object and living organisms have an important role in its formation.

Soil covers the earth's surface as a continuum, except on bare rock, water, and the bare ice of glaciers. It lacks internal boundaries. To meet scientific or applied goals, soil has been fragmented by agreed upon morphogenetic horizons and their sequences, called soil profiles. Specific hierarchical classes that use certain soil classification systems have combined the latter. The fundamental soil classifications are aimed at better understanding the nature of soils; organizing accumulated knowledge of soil characteristics and the diversity of their combinations; and applying soil groups that are centered on soil ranking to meet concrete tasks, like establishing soil suitability for crops, ranking soils according their engineering or sanitary capacities, critical loads, etc. Since V.V. Dokuchaev, all known fundamental soil classifications spring from a basic principle that considers soil characteristics in relation to their origin. This main principle allows us to distinguish characteristics originating from soil-forming processes from those whose origin is from geological rocks.

Soil forming is driven by natural factors. Therefore, changes of soil characteristics and/or their classification units in space follow certain geographical regularities, which are the subject of soil geography and are a focus of soil mapping and cartography. Soil zonality is well expressed in the vast plains of Russia covered by homogeneous deposits. Under such conditions, soil follows changes of vegetation formations and temperature/precipitation climate gradients.

Gleyzems and peat permafrost-affected soils are found in the tundra. Gley-podzolic, podzolic soils formed from fine-textured deposits, and podzols formed from coarse-textured deposits in combination with gleyzems and peats are widely spread in the boreal forest zone. Burozems and sod-podzolic soils are typical for the temperate forest zone having abundant on-ground grasses. Chernozems are found in the steppe zone. Chestnut and brown semi-desert soils are spread in the dry steppe and semidesert.

Bioclimatic conditions change with height, and this causes soil vertical zonality. Soil follows a heterogeneity of relief and geological rocks. These lithologo-geomorphological soil-forming agents create a diversity of soil mantle structures that result in a great diversity of soil features.

Human beings exploit soil in different ways, e.g., to produce food, fibers, or drugs or to filter water and recycle waste, etc. To enhance soil usefulness, people introduce a variety of utilization practices and management that considerably alter soils' natural features. In some cases this results in artificial man-made soils. Human activity is an important soil-forming agent; it leads to the conceptualization of a special class of anthropogenic soil.

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Soils of Russia

Russia is well known for its long tradition of studying soils. The country's soil knowledge is concentrated in the national soil classification. A new classification has been intensively debated over the last decades (Shishov and Sokolov, 1992; Shishov et al., 1998), and the process is not yet completed. However, it is clear that soil classification, as a conceptual framework, should meet the soil inventory and culminate in a countrywide soil map. The soil map of Russia at the scale of 1:2.5 million (Fridland, 1988) is currently the designated standard. Thus, the trend in soil classification development leads to an association of the soil map legend with soil classification in a consistent way. This seems to be an obligatory precondition for accepting the final classification in Russia. The nomenclature, suggested by Fridland (1982) who was the editor of the soil map mentioned, has been adapted below (Table 1). Table 1 contains a list of soil divisions (second highest level of the classification hierarchy) and their area.

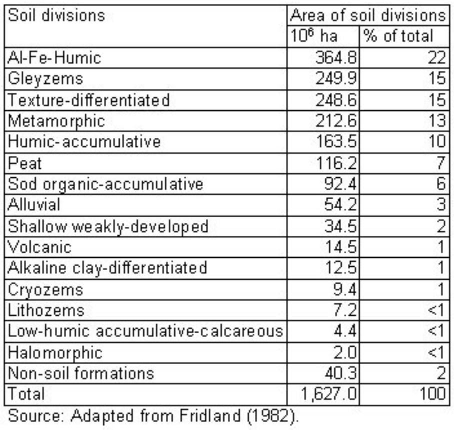
As can be seen from Table 1, cold and humid soil-forming assemblages cover some 80% of Russia. In combination with other soil-forming factors, this climate results in an enormous amount of Al-Fe-Humic soils occupying 365 million hectares (ha) or 23%; glyzems accounting for 250 million ha or 15% of the total area; texture-differentiated soils on 249 million ha or 15%, metamorphic soils occupying about 213 million ha or 13%, and peat (thickness of peat layer more than 50 cm) soil amounting to about 116 million ha or 7% of total area. These soils are widely found in European Russia and dominate in West and East Siberia and Far East Russia. The extent of warm soil formation in the semi-arid climate - e.g., humic-accumulative soils - is very limited in Russia (about 164 million ha or 10%). In particular, a small area in a hot arid climate is occupied by, e.g., alkaline clay differentiated soils amounting to some 12.5 million ha, or 1%; low-humic accumulative calcareous soils accounting for 4 million ha, or less than 1%; and halomorphic soils amounting to 2 million ha, or less than 1%. Soils of warm and hot climates are found in the southern parts of Europe and West and East Siberia.

Cold and humid climates are the major drivers of organic profile formation in Russian soils. About 1,206 million ha (74% of the country) are developed under thermal conditions that have annual negative soil temperatures. Such soil temperature is termed "permafrost" (FAO, 1998) and might be found in many soil divisions, as indicated by the World Reference Base for Soil Resources (WRB) (Table 1). In the Russian soil classification, permafrost is considered as being a parameter of a soil thermal regime. Cryozems in the Russian soil classification must have no soil diagnostic horizons and manifest a distortion of the soil profile due to cryoturbation. Such soils are not widespread in the country (about 1%). Cold soil temperature shifts the biological activity toward the warmer topsoil or even to the soil surface and is unfavorable for root development. This results in the conservation of abundant under-decomposed organic substances on the soil surface in the form of peat and peaty-muck materials. However, deep peat is not common for permafrost, especially in the tundra zone.

Humid soils are referred to as those manifesting under a permeable soil-water regime thereby causing intensive downward migration of dissolved organic substances. The latter is evident for the forest zone comprising about 63% in Russia. Poorly drained soils with an excess of water suffer from oxygen deficiency, which is indicated by redoximorphic features (e.g., olive and blue colors). This lack of oxygen slows the rate and degree of organic decomposition. Thus, excessive moisture results in an accumulation of the raw organic matter. The total area of soils with a peat horizon thickness of more than 30 cm exceeds 221 million ha in the country.

Soil zonality is caused by the alteration of the temperature-precipitation ratio from north to south. This results in gradual changes of major natural zones: polar desert, tundra, taiga (boreal) and temperate forests, steppe, semi-desert, and deserts. The soil spectra for the natural zones in Russia are illustrated in Figure 1. The polar desert occupies a rather circumscribed area in Russia and soil development is very limited due to the extremely severe environment. Cryozems and shallow weakly-developed soils characterize the zone. The tundra zone is occupied by a diversity of soils, in which gleyzems prevail. It is important to note that deep peat soils are very limited in this zone, but gleyzems with shallow peat horizons (within 30-50 cm) extend widely. This illustrates that the tundra zone is too cold for deep peat formation in Russia. Figure 1 shows that the pre-tundra and northern taiga zones are characterized by a great diversity of soils. The share of gleyzems decreases due to better drainage conditions compared with the tundra zone. However, at the same time, the proportion of deep peat soils considerably increases following improvements in thermal conditions. The middle taiga contains a great portion of Al-Fe-humic and metamorphic soils. It is important to note that this zone favors conditions for the formation of sod organic horizons in soils and supports the development of deep peat. The southern taiga is widely occupied by texture-differentiated and peat soils. The temperate forest zone is dominated by texture-differentiated and metamorphic soils. This zone presents a mosaic of forest and meadow-steppe vegetation and is also characterized by the expansion of humic-accumulative soils. The steppe zone is occupied by humic-accumulative soils, and the semi-arid dry-steppe condition also favors them. Lastly, low-humic accumulative calcareous soils and a range of salt-affected soils, such as alkaline clay differentiated and halomorphic, occupy deserts.

Table 1. Soil reserves.

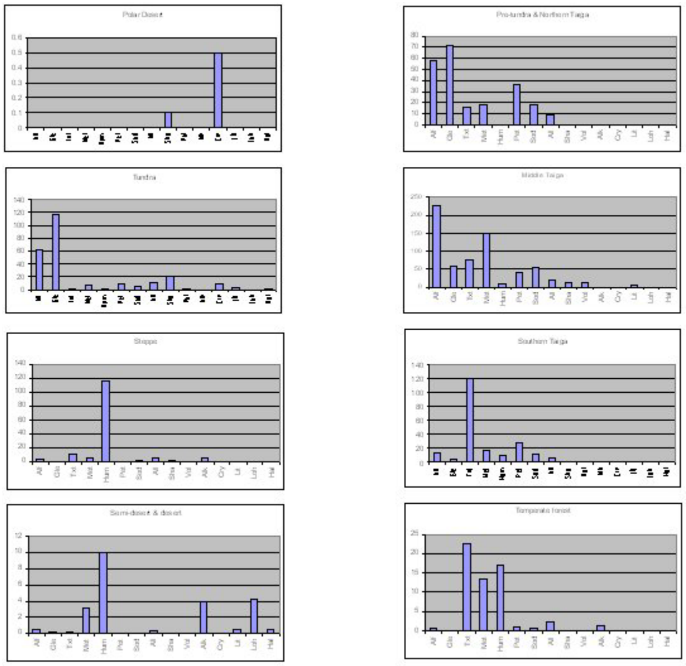


Soil divisions	Area of soil divisions	
	10^6 ha	% of total
Al-Fe-Humic	364.8	22
Gleyzems	249.9	15
Texture-differentiated	248.6	15
Metamorphic	212.6	13
Humic-accumulative	163.5	10
Peat	116.2	7
Sod organic-accumulative	92.4	6
Alluvial	54.2	3
Shallow weakly-developed	34.5	2
Volcanic	14.5	1
Alkaline clay-differentiated	12.5	1
Cryozems	9.4	1
Lithozems	7.2	<1
Low-humic accumulative-calcareous	4.4	<1
Halomorphic	2.0	<1
Non-soil formations	40.3	2
Total	1,627.0	100

Source: Adapted from Fridland (1982).

Figure 1. Soil spectra (million ha) of natural zones.

(Grasslands - left column & Open Woodlands - right column)



Descriptions of x axis

Alf Al-Fe-Humic; **Gle** Gleyzems; **Txt** Texture-differentiated; **Met** Metamorphic; **Hum** Humic-accumulative; **Pet** Peat; **Sod** Sod organic-accumulative; **All** Alluvial; **Sha** Shallow weakly-developed; **Vol** Volcanic; **Alk** Alkaline clay-differentiated; **Cry** Cryozems; **Lit** Lithozems; **Loh** Low-humic accumulative-calcareous; **Hal** Halomorphic.

Naturalness of soils

Naturalness is a measure of the intensity of anthropogenic pressure on soils in terms of impact on the functioning of their ecosystems from a pedogenetic point of view. Three major groups of soil naturalness have been proposed: managed, semi-natural, and natural soils.

Managed soils are those whose soil-forming processes are guided by human beings in order to meet their specific goals, e.g. production, construction, waste management, etc. Anthropogenic impact is a permanent additional soil-forming factor. Human intervention results in establishment of artificial soil characteristics or horizons, which are missing under natural conditions. The appearance of new soil profiles is very common. It might be a ploughed horizon, drained aerated horizon, artificially created stratification, man-made layers, etc.

Semi-natural soils are those that manifest as natural objects, but pose features introduced by a temporary anthropogenic intervention. They might be soils subjected to intensive grazing, affected by fires, or underflooded and therefore, covered by secondary vegetation communities, and so on. It is clear that the natural ecosystem has been distorted in both managed and semi-natural soils. Soil characteristics reflect the features of anthropogenic influence (e.g. chalk in a topsoil, development of redoximorphism, etc.), but soils follow the horizon sequences of natural soils.

Natural soils are those that function under natural conditions and do not give evidence of anthropogenic influence, either internally (soil characteristics) or externally (soil-forming factors).

The database on soil naturalness has been elaborated by means of GIS map-overlap. Three coverages have been applied to distinguish a geometric part of the database: soil, land categories, and vegetation. Managed soils have been distinguished by the combination of soils with cropland items. Semi-natural soils have been identified from the association of soils with pastures and secondary vegetation items. The database contains soil degradation characteristics as a soil response to improper anthropogenic impacts, either in terms of land use or intensity of use.

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SOIL REFERENCE PROFILES

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Field sampled and analytically investigated soil profiles represent a key element of the semantic soil database. The data are introduced in two tables: Table 1, measured soil data and Table 2, soil data with default values where measured data are lacking. The latter approach is common, since analysis provided for soil profiles is incomplete and it is difficult to find publications where all data are discussed. However, for many practical research and modeling tasks we need complete data for all soils. In such cases, the second table is recommended. It contains a complete set of data, some of which originates from different sources or expert estimates.

The reference soil profiles come from numerous literature sources. The extent and practical importance were major reasons for the profile selection. Therefore agricultural soils have received priority in the database elaboration. While the collection aims to cover all soils of Russia, there were problems with analytical data for some poorly investigated soils in the north, Siberia, and the Far East. The geographical distribution of measured soil referenced profiles is shown in Figure 1. The total number of measured referenced soil profiles is 234.

Figure 1. Distribution of soil reference profiles.

Soil analytical data

Methods of soil laboratory analysis vary from country to country on the basis of different pedological traditions and practical preferences. Although there are several reasons for these differences, local soil peculiarities are usually the most important. Actually, this notion corresponds to the well-known heterogeneity of soils, which are an admixture of solid, liquid, and gaseous phases. Soil properties expressed by textural, mineralogical, chemical, etc. composition vary in space and change over time. The soil heterogeneity results in the variability of soil characteristics detected by laboratory analysis.

Another source of variability in soil attributes originates from the continuous nature of soils. An example of this is given by Rode (1978), who wrote that grades of soil water retention have a relative value, which depends on the conditions of their determination. In fact, the volume percent of water in the soil horizons is defined at certain standard pressures, i.e., 1, 10, 100, 1,500 kilopascal (kPa) (Madsen and Jones, 1993). Changing the extraction conditions will lead to different values of the field water storage capacity. Another important note is that national soil databases have been derived from their own experience and standards that are aimed at meeting the needs of regional practices, and would therefore not be suitable for other environments. This consideration applies to almost all soil attributes. It is particularly valid for the analysis of nutrient availability, as this is correlated with actual productivity and yields that are closely associated with crop specifics, agronomic measures, etc.

This section presents the analytical methods used to determine soil attributes used in the database ((Table 1 and Table 2). The description of the analyses is taken from Arinushkina (1970), supplemented by explanatory comments.

Organic matter (OM)

The level of organic matter (OM) in Russian soils is determined by one of two methods, depending upon whether the soil is a mineral soil (organic content <15% of soil mass) or an organic soil (organic content >15%). The analysis of OM in mineral soils is carried out by the Turin method. It is based on wet combustion, which is an indirect method of carbon determination. The method gives results compatible with the widespread method of Walkley-Black (Kogut and Frid, 1993). Carbon recovery efficiency is about 70-84%, depending on the soil type. Chemical determination is based on oxidation of OM by an excessive amount of $K_2Cr_2O_7$. The basic reaction follows the equation:

$$3CO + 2K_2Cr_2O_7 + 8H_2SO_4 = 2Cr_2 (SO_4)_3 + 2K_2SO_4 + 8H_2O + 3CO_2 .$$

The oxidation is carried out in a strongly acid solution and is accompanied by reduction of hexavalent chromium into trivalent chromium, i.e.,

$3CO + 4CrVI = 4CrIII + 3CIV$.

Detection is based on titration with Fe^{2+} of excess $K_2C_2O_7$.

$K_2Cr_2O_7 + 7H_2SO_4 + 6FeSO_4 = Cr_2 (SO_4)_3 + 3Fe_2 (SO_4)_3 + K_2SO_4 + 7H_2O$,

where

$2CrVI + 6Fe^{2+} = 2CrIII + 6Fe^{3+}$.

The analysis of OM in organic soils is carried out by dry combustion. The method is based on the combustion of the soil sample in oxygen at 950°C. The oxidation reaction proceeds through the following equation:

$C + O2 = CO_2$.

The reaction product (carbon dioxide) is determined by either weighing or volumetric methods. Volumetric methods are based on the absorption of CO_2 by KOH by the equation:

$CO_2 + 2KOH = K_2CO_3 + H_2O$.

Calcium carbonate equivalent ($CaCO_3$)

Equivalent $CaCO_3$ is calculated as a hypothetical content of $CaCO_3$, based on the assumption that there are no other mineral carbonates. This assumption is valid for traditional methods of carbonate determination, which are based on destruction of calcareous minerals and emission of carbon dioxide gas (CO_2). The options for calculations are the following:

1. If data available on CO_2 content (in percent):
   $CaCO_3$ (eq.), % = 100/44 CO_2 carbonates = 2.2727*CO_2 carbonates

2. If data available on content of $CaCO_3$ and $MgCO_3$ (in percent):

$CaCO_3$ (eq.), % = $CaCO_3 + 1.19MgCO_3$.

Gypsum content ($CaSO_4$*$2H_2O$)

The two values usually found in the scientific literature of Russia are:

$CaSO_4$*$2H_2O$ content (in percent);

SO_4 gypsum (in percent) or, rarely, in mg-eqv/100g;

$CaSO_4*2H_2O$ (in percent) = 1.792*SO_4 gypsum (in percent) = 0.086*SO_4 gypsum (mg-eqv/100g)

Active $CaCO_3$

This analysis is not common for Russia. Recalculation for active $CaCO_3$ is generally not valid due to the nature of the analytical procedure. The method is based on the following equation:

Active $CaCO_3$ (%) = (A-B) N 50 (0.125) ,

where:

A = ml $KMnO_4$ in the blank (oxalate only);

B = ml $KMnO_4$ in sample;

N = normality; and

50 = equivalent weight of $CaCO_3$.

The destruction of carbonate minerals by ammonium oxalate leads to precipitation of calcium oxalate products in the solution. This process is heavily dependent on composition of carbonate minerals in the soil solid phase, i.e., calcite ($CaCO_3$), dolomite ($MgCO_3$), nahcolite ($NaHCO_3$), trona (Na3H$(CO_3)_2$*$2H_2O$) etc., and degree of dispersion of the mineral. A finer degree of mineral granularity will result in higher active $CaCO_3$. However, the dispersion of carbonate minerals is different for various parent materials, and the calculation procedure for active $CaCO_3$ therefore must be based on regional regression analyses that include mineralogical determination, special soil sampling, etc.

SAR and ESP

Sodium Adsorption Ratio (SAR) is determined for surface water or saturated paste extracts. The latter is rarely performed in Russia, where analysis is conducted on solutions with a water/soil ratio of 1:5. Formerly, SAR could be calculated from the following equation:

SAR = CNa/[(CCa + CMg)/2] –1/2 ,

where CNa, CCa, and CMg are concentrations of Na, Ca, and Mg in solution (in mg-eqv/l).

However, the result should be used with considerable caution due to the much lower concentrations of ions in solution (15–20 times) in comparison with those in water-saturated pastes. Some adjustment of the solution is also necessary if the soil contains carbonates or gypsum, due to cation exchange reactions.

Exchange Sodium Capacity (ESP) can be determined by a variety of methods. Corrections may need to be applied to soils containing easily soluble salts of carbonates and gypsum. This correction is usually done by deduction of the amount of Na removed by water extraction (from a 1:5 ratio water-soil solution) from the total amount of exchangeable Na. Although many publications show that this correction is the major source of errors, it remains the most widely used procedure at present.

pH (H_2O)

Usually, solutions with a 1:5 water-soil ratio are used in Russia to determine pH(H_2O). These solutions result in values 0.1–0.5 times higher (pH units) than those obtained from 1:2.5 water-soil solutions. For acid soils, the difference between pH(H_2O) and pH(1M KCL) varies from 0.5 to 1.1 pH units.

Electrical conductivity (EC)

Determination of EC using a saturated paste extract is rarely done in Russia. Recalculation from data obtained from extracts with a soil-water ratio of 1:5 is rather coarse. In practice, however, the following empirical equation could be suggested for a rough estimate:

EC (dCm/m 250C) = 750*Stoxic/W

where:

Stoxic = sum of toxic salts in water:soil extract 1:5 (in percent); and

W = water content corresponding to the upper limit of soil plasticity (Table 2).

Table 2. Range of water content corresponding to the upper limit of soil plasticity, depending on soil texture and mineralogical composition.

Texture and Mineralogical Composition	Water Content (%)
Sand	8-20
Loamy Sand	15-30
Sandy Loam	20-40
Loam	35-60
Clay Loam	40-65
Kaolinite and hydrousmica clay	50-70
Smectite clay	65-100

Exchangeable bases

The methods used to determine exchangeable bases are different for acid soils and calcareous/saline soils. An extraction with 1M NH_4Cl at pH 7.0 is used for the acid soils. The Pfeffer method (0.1M NH_4Cl + 70% ethanol) or its modifications are used for calcareous/saline soils.

Cation exchange capacity (CEC) and base saturation (BS)

The CEC is determined at pH = 6.5 in Russia. It seems that the results obtained at pH = 8.1 will be compatible with Russian data for soils/horizons having humus content < 0.2%. For soils/horizons richer in organic matter, the CEC obtained for Russia will be less. Laboratory experiments correlating both methods are lacking.

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Carbon Density and Pools

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The C content is given for native soils and illustrates the pre-development status of Russian soil. It is derived from (XXX) in the database. The SCD^o varies greatly by soil divisions (Table 1). For topsoil [0–0.3 meters (m)], the highest SCD^o is found for peat soils (20.9 kg/m^2), which contain practically pure organic matter. The lowest SCD^o (1.7 kg/m^2) is shown by low-humic accumulative calcareous soils. These two values identify the major extremes of SCD^o of Russian soils. For other soils within this range, the highest organic accumulation in gleyzems was with a topsoil peaty [less than 50 centimeters (cm) thick] horizon (17.6 kg/m^2). Metamorphic, humic-accumulative, and sod organic-accumulative soils illustrate a medium degree of organic accumulation (10–12 kg/m^2). Other soil divisions fall into the intermediate group ranging from 3 to 7 kg/m^2. This is a rather heterogeneous soil assemblage that combines soils having clearly recognized constraints for the biological processes.

Table 3. Area-weighted average organic and inorganic C density (kg/m^2) of native soils in Russia (layers in m).

Soil Division / Layer Thickness (m)	**Organic SCD^o**				**Inorganic SCD^m**			
	0–0.3	**0–0.5**	**0–1.0**	**0–2.0**	**0–0.3**	**0–0.5**	**0–1.0**	**0–2.0**
Peat	20.9	37.2	81.3	134.1	0	0	0	0
Gleyzems	17.6	22.0	23.1	24.1	0	0	0	0
Metamorphic	12.2	13.6	15.2	15.7	0	0	0.2	0.2
Humic-accumulative	11.7	16.2	20.2	22.4	0.1	0.3	1.7	3.4
Sod organic-accumulative	10.3	11.9	13.9	15.1	0.1	0.2	0.6	0.5
Volcanic	7.0	10.1	18.2	22.3	0	0	0	0
Texture-differentiated	7.0	9.3	10.8	11.9	0	0	0	0.1
Lithozems	6.8	n.d.	n.d.	n.d.	0	n.d.	n.d.	n.d.
Al-Fe-Humic	6.7	8.3	9.7	10.0	0	0	0	0
Alluvial	6.2	9.2	14.1	18.0	0.1	0	0.1	0
Halomorphic	5.0	7.0	9.0	10.4	1.3	0.5	4.4	9.0
Alkaline clay-differentiated	4.8	5.5	7.3	8.2	0.3	0.8	2.6	1.3
Cryozems	4.6	6.6	n.d.	n.d.	0.1	0.5	0.4	0.2
Shallow weakly developed	3.1	4.0	n.d.	n.d.	0	0	n.d.	n.d.

Soil Division / Layer Thickness (m)	**Organic SCD^o**				**Inorganic SCD^m**			
	0–0.3	**0–0.5**	**0–1.0**	**0–2.0**	**0–0.3**	**0–0.5**	**0–1.0**	**0–2.0**
Low-humic accumulative-calcareous	1.7	2.2	2.6	2.9	1.2	2.4	6.2	5.9

Note: n.d. = not distinguished for shallow soils.

Most of the soil divisions show an intensive C accumulation in the topsoil (Table 1). This pattern follows the above-mentioned morphological feature of cold soils in Russia. It can be calculated from the data presented in Table 1, that the upper 0–0.3 m layer contains more than 50% of C accumulated in the 0–2.0 m layer for most of the soil divisions. The concentration of C in the topsoil of some soils is even higher, e.g., the corresponding values for gleyzems are 17.6 kg/m^2 (0–0.3 m) and 24.1 kg/m^2 (0–2.0 m), which roughly accounts for about 70%. The exception is found in soils formed under a specific lithogenic regime, such as volcanic and alluvial soils, where pedogenesis co-exists with sedimentogenesis. These soils have profiles with numerous buried organic horizons.

The SCD^m profile (right-hand side of Table 1) is different from that of SCD^o. Most Russian soils do not contain inorganic C. This is obvious for soils formed under humid climates that originated from carbonate-free deposits. The inorganic C is mainly found in the 0–0.3 m layer of halomorphic (1.3 kg/m^2), low humic-accumulative-calcareous (1.2 kg/m^2), and alkaline clay-differentiated (0.3 kg/m^2) soils, which is common for soils in an arid climate. Soils in a semi-arid climate have less inorganic C in the topsoil 0–0.3 m layer (about 0.1 k/m^2). The profile of inorganic C also shows an increase of the C content with depth. This distribution identifies a process of carbonate leaching. All of the above-mentioned examples demonstrate that inorganic C in Russian soils is mainly non-pedogenic in origin and comes from calcareous rocks or from evaporation of hard groundwater.

The soil organic matter is mainly concentrated in six soil divisions, namely: Al-Fe-Humic, Gleyzems, Texture-differentiated, Metamorphic, Humic-accumulative, and Peat (*Table 2*). It is important to note that Gleyzems occupy 15% of the area and contribute 26% of the SCP in the 0–0.3 m layer. This is due to the fact that excess of water and redoximorphizm are favorable for organic C conservation. The proportion of C accumulated by deep peat (peat layer more than 50 cm thick) reaches 32% for the 0–1.0 m layer and exceeds 42% for the 0–2.0 m layer. The total accumulation of organic C in deep peat soil is 156 petagrams (Pg) in the 0–2.0 m layer.

About 20% of the C in Russian soil is captured by deep (1.0–2.0 m) soil. Half of this amount (about 50%) is associated with deep peat soils and Chernozems (*Table 2*). The other half originates from an intensive downward migration of dissolved organic substances, which is common for soils in a boreal humid climate, such as Al-Fe-humic, Gleyzems, Texture-differentiated, and Metamorphic soils. At the pre-developed stage, the 2.0 m layer of soils in Russia accumulated 448 Pg of organic and inorganic C (*Table 2*). From this amount, the 0–0.3 m layer, 231 Pg by the 0–0.5 m layer, and 337 Pg by the 0–1.0 m layer, captured some 170 Pg. As can be seen, the topsoil in Russia holds about 70% of organic C accumulated in the 0–1.0 m layer. The latter is about 20% more than the global average. This detail coincides with the expansion of a cold and humid climate, which deteriorates the decay of organic residues, and favors the accumulation of under-decomposed raw organic matter, such as litter and peat.

The proportion of organic C reached 99% in the topsoil and gradually declined with soil depth to about 83% for the 0–2.0 m layer. Thus, Russian soils are rich in C that is tightly linked with living forms and the biologically driven C cycle. As with any biological matter, this organic is vulnerable to environmental changes, which causes concerns regarding the possible impacts of climate change extremely important to Russia.

Soil Respiration

Vladimir Stolbovoi

Soil respiration (SR) refers to CO2 release from soils, which is resulted from microbiological processes of decomposition of organic substances. Database on SR comes from publications, e.g., Makarov (1993), Kudeyarov *et al*. (1996),

General terms can be described by some equations (Stolbovoi, 2001):

$TSR = AR + HSR$,

where TSR is total soil respiration;

AR is autotrophic soil respiration (mainly roots); and

HSR is respiration by heterotrophic microorganisms associated with the decomposition of all organic substances in soils.

HSR includes the decomposition of organic residues and the mineralization of humus substances, which is:

$HSR = TSR – AR - SRd - SRm$,

where TSR and AR are as defined above;

SRd is the decomposition of organic residuals (vegetation and microbe biomass); and

SRm is the mineralization of soil humus.

The estimate of HSR involves numerous emission factors and variables. Mainly, they are respiration records from different soils subjected to functional dependence on climate and weather conditions, type of vegetation, organic input, land use, etc. The combination of the emission factors is spatially explicit and difficult to account by traditional tabular-derived approaches. The application of GIS tools is a practical solution and requires establishing a relevant georeferenced database.

Following GIS-based model for HSR estimation has been developed:

$$HSR = \sum_{q-1}^{n} k_{(<5oC)}\, DSR_q * AR_q * N_{q(0to+5oC)} * P_q + \sum_{q-1}^{n} k_{(>+5oC)} * DSR_q * AR_q * N_{q(>5oC)} * P_q ,$$

where HSR is the total heterotrophic soil respiration;

*k*is a coefficient for the dependence of emission intensity by temperature in the intervals from 0 to 5^{o}C and above 5^{o}C for soil *q*;

DSR_q is the daily emission in temperature intervals from 0 to 5^{o}C (<5^{o}C) and >5^{o}C for soil *q*;

ARq is the autotrophic respiration from soil *q*;

N_q is the number of dayswith a temperature from <+5^{o}C and >5^{o}C for soils *q*; and

P_q is the area of soil *q*.

A cold climate limits the duration of biological activity in soils (Table 1). This study suggests that HSR appears when temperatures exceed 0^{o}C. In the interval from 0 to 5^{o}C, the daily emission rate changes from 0 to 75% of the mean emission at temperatures above 5^{o}C. The number of emission days for different temperature intervals is derived from the thermal regimes specified by each of the soils in Russia. The number of days with a positive temperature for the most frequent soils in the country is about 150 days. A small extent of soils has an emission period of 90 or 210 days.

A negative soil temperature is unfavorable for root development in soils. Evidently, deep-freezing during severe winter and slow and shallow thawing in summer, shift biological activity towards warmer topsoil or even the soil surface. Due to the deterioration of the rhizosphere, the organic residuals arrive from the soil surface where they pass through metamorphism within food chains of the soil fauna, microbes, chemical and biochemical disintegration, etc. All of the above mentioned is unfavorable for intensive AR. In general, data on root respiration is very limited (Grishina, 1986; Blagodatski *et al*., 1993). Table 1 illustrates that the fraction of AR in the TSR ranges from 15 to 25%

The minimum TSR for the majority of soils is about 0.2–0.4 g/m2/day (Table 1). The upper threshold (2.4 g/m2/day) is reported for soil with the highest porosity and rich in microbiota (Humic-accumulative). There is a lack of correlation between the number of emission days and TSR in Russia (Table 1). The difference between minimum and maximum TSR for one soil is about 30%, which illustrates a variability of SR for specific soils caused by fluctuation in annual weather conditions. The range of the emission intensity for different soils is considerably higher and reaches 400% (Table 1). This range is defined by a variety of soil factors, such as aeration, redoximorphizm, pH, etc., which differ within a soilscape.

Table 4. Aggregated characteristics of soil respiration in Russia in 1990.

Soil division	**Area**		**Number[b] of days above 0°C**	Total emission,[b] g/m^2/day		**Root emission,[b] % of total**	**Emission**			
	10^6 ha[a]	**% of total**		**Min**	**Max**		**Total, Tg**		**Heterotrophic**	
							Min	**Max**	**Tg**	**% of total**
Alcaline clay-differentiated	12.5	0.7	210	0.34	0.47	15	9	12.4	10.6	0
Al-Fe-Humic	364.8	23	150	1.19	1.86	25	650.5	1020.3	766.2	24
Alluvial	54.2	3	150	0.89	1.29	20	72	105	84.4	3
Cryozems	9.4	1	90	0.44	0.60	16	3.7	5.1	4.3	0
Gleyzems	250.0	16	150	0.37	0.52	15	140.3	194.2	165.3	5
Halomorphic	2.0	0	180	0.39	0.53	16	1.4	1.9	1.6	0
Humic-accumulative	163.5	10	210	1.55	2.44	25	533.7	837.1	628.6	20
Lithozems	7.2	0	150	0.23	0.31	15	2.5	3.4	2.9	0
Low-humic accumulative-calcareous	4.4	0	180	1.38	1.91	15	10.9	15.1	12.8	0
Metamorphic	207.7	13	150	1.13	1.56	15	350.6	485.3	413	13
Peat	116.2	7	150	1.43	1.97	15	248.4	343.8	292.6	9
Shallow weakly developed	34.5	2	150	0.40	0.55	15	20.6	28.5	24.3	1
Sod organic-accumulative	92.4	6	150	0.98	1.35	15	135.5	187.6	159.6	5
Texture-differentiated	248.7	16	210	1.00	1.47	20	521.3	766.7	614.1	19
Volcanic	14.5	1	150	0.67	0.92	15	14.5	20	17	1

Soil division	**Area**		**Number[b] of days above 0°C**	Total emission,[b] g/m²/day		**Root emission,[b] % of total**	**Emission**			
	10^6ha[a]	**% of total**		**Min**	**Max**		**Total, Tg**		**Heterotrophic**	
							Min	**Max**	**Tg**	**% of total**
TOTAL	***1582***	***100***				***21***	***2714.9***	***4026.4***	***3194.1***	***100***

[a] GIS-derived values; [b] Area-weighted average values of emission with temperature >0°C.

The application of minimum-maximum emission rates results in a considerable difference of the TSR, which are 2715 and 4026Tg respectively (Table 1). As demonstrated above, the TSR for a soil is driven by weather conditions, e.g., for a cold year one should take the lower CO_2 emission rate, and for a warmer year the rate is the highest. Following this assumption, we took the upper TSR value because 1990 was found to be the warmest year among climate records. The total HSR from soil in Russia is estimated to be about 3194 Pg (Table 1) after root respiration correction has been made.

Al-Fe-Humic soils have the largest contribution (24%) to HSR, which coincides with their share of Russian soils. About 20% of HSR come from Humic-accumulative soils. The proportion of these soils in the amount of soils is considerably less (10%). These soils have the highest emission rates. Gleyzems contribute about 5% and occupy some 16% of the soil area, which shows redoximorphizm and poor internal drainage to be unfavorable factors for HSR in the country.

The HSR follows geographical zonality that is defined by climate temperature-precipitation ratio (Table 2). Table 2 illustrates that the lowest intensity of HSR is found for arctic deserts. Southward, the emission rate gradually increases reaching the highest value in the steppe zone. The HSR becomes lower in hot semideserts and deserts. This pattern coincides with NPP. It is worth noticing that HSR on average comprises about 70% of NPP. This shows other fluxes (humification, leaching, runoff, vegetation disturbances, etc.) are important agents in the terrestrial C cycle of Russia.

Soils of the cold zones emit less CO_2 than their share in the country area. Soils of warm zones release more CO_2 compared with the proportion of their area. This principal difference coincides with the formation of humus accumulative horizons, which are found in the warmer southern soils of the southern taiga, temperate forest, and steppe natural zones in Russia.

Table 5. Heterotrophic soil respiration by natural zones in Russia.

Bioclimate zone	**Area**[a]		**NPP, kg/m^2/y**	**HSR**			**NPP/HSR %**
	10^6 ha	**% of total**		**Tg**	**% of total**	**kg/m^2/y**	
Arctic deserts	0.7	<<1	0.01	<1	<<1	0.03	
Tundra	266.4	16	0.12	304	10	0.11	92
Forest tundra and northern taiga	232.5	14	0.18	297	9	0.13	72
Middle taiga	682.5	42	0.26	1145	36	0.17	65
Southern taiga	211.2	13	0.33	565	18	0.27	82
Temperate forest	60.2	4	0.43	182	6	0.30	70
Steppe	148.1	9	0.53	582	18	0.39	74
Semideserts and deserts	25.3	2	0.41	65	2	0.26	63
Total	*1 627.0*	*100*	*0.27*	*3194*	*100*	*0.19*	*70*

[a] Including rock outcrops.

Cropland manifests the highest rate of HSR and contributes twice as much as their area in the country (Table 3). In contrast, pastures show the lowest emission rate, which is 2.5 times less than the share of the country area. We found the higher intensity of CO_2 release from wetlands and less intensity of the HSR from forest and natural grasses and shrubs. Present-day climate warming in Russia drives both phenomena. It is reported that the decrease of HSR in grasslands is caused by the highest rate of C accumulation in soils of the steppe and forest-steppe zones. The latter has been favored by the gradual increase of climate humidity, which is observed during last century.

Table 5. Heterotrophic soil respiration by land use patterns in Russia.

Land use	**Area[a]**		**NPP, kg/m^2/y**	**HSR**		
	10^6 ha	**% of total**		**Tg**	**% of total**	**kg/m^2/y**
Agricultural land, including:						
Cropland	130.3	8	0.5	501	16	0.38
Pasture	81.3	5	0.38	75	2	0.09
Forest	763.5	47	0.22	1386	43	0.18
Wetland	222.0	14	0.22	605	19	0.27
Grasses and shrubs	432.5	27	0.28	627	20	0.12
Total	*1629.6*	*100*	*0.27*	*3194*	*100*	*0.19*

[a] Including rock outcrops.

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SOIL CORRELATION

Vladimir Stolbovoi

An agreed-upon method for correlating soils is lacking (Stolbovoi and Sheremet, 1995). Various scientists treat it differently. The correlation of soils in the CD-ROM is achieved in two steps. In the first step, the soil groups of the Soil Map of Russia (SMR) were correlated with the soil units of the legend of the FAO Soil Map of the World (SMW) (FAO-UNESCO, 1988) and the Soil Taxonomy (ST) (USDA, 1999). Furthermore, all soil polygons of the original SMR were described by attributes according to the FAO Revised Legend and the Soil Taxonomy.

In the second step, neighboring soil mapping units were combined to fit the 1:5 million scale, when containing genetically, morphologically, and analytically related soils. This procedure eliminated soils whose extent was less than 4% of the area of newly created soil polygons. When appropriate, other relevant information was shown as soil phases.

Two main difficulties had to be addressed in creating soil texture attributes. The first dealt with differences in information on the soil texture shown on the SMR and that required by the FAO/ST standards. Practically new data on soil texture was collected for numerous soil polygons. The sheets of the State Soil Map (scale 1:1 million) of the USSR were used for this purpose. The second difficulty relates to the differences in the definition of textural fractions in Russia and the FAO/ST. The discrepancies between the two systems can be found in Table 1. However, the differences are not too big and the general textural classes could roughly be correlated for practical tasks at this scale. For a more precise analysis at a more detailed scale this correlation needs to be done more accurately on the basis of laboratory measurements.

Texture classes

The difficulty in developing data on soil texture arises from differences between Russia and FAO/ST in defining textural fractions. This disparity raises the problem of methodological compatibility. The principal differences in fraction definition between Russia and FAO/ST are shown in Table 1. It is apparent that FAO/ST system uses fewer textural fractions than the Russian system. As can be seen from the table, there are major differences between the definition of both coarse and fine textural fractions. Clearly, different applications require different classifications. Nevertheless, special attention should be paid to fine clay-sized fractions, which consist of clay minerals, metal hydrous oxides, soil humus, or a combination of inorganic and organic materials, and colloidal particles. These are the most physically and chemically active constituents that define primary soil characteristics such as absorption and exchange capacity, etc. Unfortunately, there is no precise way to distinguish a direct correlation between fractions. The table therefore introduces the following approximation:

- Coarse textured, corresponding to FAO/ST sands, loamy sands, and sandy loams with less than 15% clay and more than 70% sand;

- Medium textured, corresponding to FAO/ST sandy loams, sandy clay loams, silt loams, silt, silty clay loams, and clay loams with less than 35% clay and less than 70% sand; the sand fraction may be as high as 85% if a minimum of 15% clay is present;

- Fine textured, corresponding to FAO/ST clays, silty clays, sandy clays, clay loams, and silty clay loams with more than 35% clay.

Table 6. Correlation of particle size distribution between FAO/ST and Russian systems.

Name of texture fraction	Particle size (mm)^a, FAO system (1988)	**Particle size (mm), Russian system (1967)**
Gravel, fine gravel	>2	>1
Sand Coarse sand Medium sand Fine sand	–0.06	–0.5 –0.25 –0.05
Silt Coarse silt Medium silt Fine silt	–0.002	–0.01 –0.005 –0.001
Clay	<0.002	<0.001
	General Classes	
Coarse	–0.06	0.05
Medium	–0.002	–0.001
Fine	<0.002	<0.001

FAO soil coverage

Vladimir Stolbovoi and Boris Sheremat

The first internationally compatible digital soil database for the USSR was created in 1997 by the joint efforts of FAO, the United Nations Environmental Programme (UNEP), the European Soil Bureau, IIASA, and the Dokuchaev Soil Institute, together with contributions from numerous national organizations (Soil and Physiographic…, 1999). The database was compiled at the scale of 1:5 million and incorporated all contemporary knowledge on soils of the region into the international SOil and TERrain (SOTER) system (van Lynden and Wen, 1993). Considerable efforts were made to translate national soil classifications, analytical methods, and soil characteristics. Details on both the scientific results and technical problems associated with this study can be found in a number of publications (Stolbovoi and Savin, 1996; Stolbovoi and Sheremet, 1995; Stolbovoi, 2000). However, a major output of the efforts is that soil data on more than one-sixth of global terrain (namely, the area of the former Soviet Union) has been made available in a uniform classification and GIS formats. However, standardization is not the only achievement of the research. The database under consideration includes new soil data on a considerable part of the Russian North, Siberia, and the Far East, all of which have low population densities and are not easily accessible. These regions are still poorly investigated; however, the demand for soil information for this territory is great and has risen significantly over the last decade. Much of this interest is due to the potentially serious impacts of global climate change on terrains at high latitudes. It is suggested that the magnitude of such impacts might have global consequences. Prediction of such consequences would be rather speculative if background data are insufficient or of low quality. Controversial and conflicting conclusions and theories would be sure to arise.

Soil Taxonomy

Vladimir Stolbovoi

Soil Taxonomy (ST) is a basic system of soil classification in the USA for making and interpreting soil surveys. The primary objective of ST is to establish hierarchies of classes that facilitate an understanding of the relationship among soils and between soils and the soil-forming factors. A second objective is to provide a common language for soil science.

ST is not static but is subjected to changes as knowledge on soils expands. Since the original edition of ST was published in 1975, eight international committees have made proposals that have been approved and incorporated. This development resulted in the second edition of ST, published in 1999 (USDA, 1999).

Genesis is fundamental to ST. On the basis of this presumption, the system establishes 12 soil orders that manifest major pedogenetic features by the presence of diagnostic horizons. These orders are not the only possible orders in the taxonomy. The hierarchy is flexible, and other ad hoc orders may be defined to emphasize properties not considered in the 12 orders. Sixty-four suborders currently are recognized. The definitions for suborders vary with the order and are aimed at distinguishing the major reasons for absence of horizon differentiation. The smallest taxonomic units are great groups, subgroups, families, and series. The series is the lowest category in the ST system, and more than 19,000 of them have been recognized in the United States. The differentiae used for series generally are the same as those used for classes in other categories, but the range permitted for one or more properties is narrower than the range permitted in a family or in some other higher category.

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PEDO- AND TAXATRANSFER FUNCTIONS

Vladimir Stolbovoi

The concept of pedo- and taxatransfer functions is not used in Russia. However, it is popular in international studies at European and global levels. Soil correlation is used to create parameters derived from pedo- and taxatransferring rules, which are given below.

Pedotransfer function is a mathematical relationship between soil parameters, which shows a sufficient level of statistical confidence. This relationship is used to derive unknown parameters from measured ones. Application of the pedotransfer function is particularly important for defining default values or establishing characteristics that are missed in the soil profile description.

A taxatransfer function is the elaboration of parameters based on modal characteristics associated with the name of the soil classification taxon. Basically, a certain range for a number of parameters is used to identify the taxonomic unit in any soil classification. This range stems from expert knowledge, empirical rules, and statistical analysis of a large number of soil profiles.

The pedo- and taxatransfer functions concept is developed for the Food and Agriculture Organization (FAO) soil units and has never been adopted in Russia (World Soil Resources, 1993). The database under consideration allows distinguishing characteristics to be linked with Russian soil names by means of GIS.

These parameters are derived:

- Effective depth;
- Soil drainage class;
- Water storage capacity; and
- Plant available water storage capacity.

Reference

World Soil Resources. An explanatory note on the FAO World Soil Resources Map at 1:25,000,000 Scale.1993. World Soil Resources Reports, 66 Rev. 1, FAO, Rome, 66 pp.

Effective depth

Effective soil depth refers to the thickness of the layer for roots development. This characteristic is a very important indicator of soil suitability for crops and vegetation growth. Soil effective depth is also a main factor determining water storage capacity.

To estimate effective soil depth for soils of Russia the algorithms are as follows:

1. Soils are considered <10 centimeters (cm) deep if they occur on the map as rock, lithosols, glaciers;
2. Soils are considered between 10 and 50 cm deep if they are classified as rendzinas, rankers, or have lithic phase. In addition, half of the area of soil polygons with petroferric phase is considered to have an effective depth between 10 and 50 cm;

3. Soils are considered between 50–100 cm deep for the other half of the polygon area characterized by a petroferric phase (see 2, above). In addition, other soils occurring on steep slopes (>30%) or having permafrost are considered for half of their area to have a soil depth between 50 and 100 cm;
4. All other soils are considered to have a soil depth between 100–150 cm except histosols, which – when not occurring on slopes of more than 30%, nor having permafrost –are assumed to be between 150 and 300 cm deep.

Soil drainage class

The soil drainage class reflects the combined effects of climate, landscape, and soil. The concept of soil drainage relates to the frequency and duration of periods when the soil is free of saturation or partial saturation. Rainfall, seepage, soil permeability, surface infiltration rate, internal vertical and lateral movement of water, and external surface run-off and run-on, may all affect the drainage class.

Soil drainage is defined by seven classes:

1. Excessively drained: Water is removed from the soil very rapidly. The soils are commonly very coarse-textured or rocky, shallow, or on steep slopes.

2. Somewhat excessively drained: Water is rapidly removed from soil. The soils are commonly sandy and very pervious.

3. Well drained: Water is removed from the soil readily but not rapidly. The soils commonly retain optimal amounts of moisture, but wetness does not inhibit root growth for significant periods.

4. Moderately well drained: Water is removed from soil somewhat slowly during some periods of the year. The soils are wet for short periods within the rooting depths. They commonly have an almost impervious layer or periodically receive heavy rainfall.

5. Somehwat poorly (imperfectly) drained: Water is removed slowly so that the soil is wet at a shallow depth for considerable periods. Soils commonly have an impervious layer, a high water table, additions of water by seepage or very frequent rainfall.

6. Poorly drained: Water is removed so slowly that the soils are commonly wet at a shallow depth for considerable periods. The soils commonly have a shallow water table, which is usually the result of almost impervious layers, seepage or very frequent rainfall.

7. Very poorly drained: Water is removed so slowly that the soils are wet at shallow depths for long periods. The soils have a very shallow water table and are commonly in level or depressed sites or have very high rainfall falling almost every day.

The algorithms used are as follows:

1. Histodsols are considered to be very poorly drained.

2. All gleysols and the fluvisols with clayer topsoil textures are considered to be partly very poorly and partly poorly drained.

3. All planosols and the gleyic soil units of other FAO soils groups are considered to be partly poorly drained and partly imperfectly drained.

4. All vertisols are considered for two-thirds of their area to be imperfectly drained, the remainder is considered poorly drained.

5. Gleyic cambisols are considered partly imperfectly drained and partly moderately well drained.

6. All arenosols, non-gleyic podzols and regosols with a coarse topsoil texture and occurring on gentle slopes (<8%) are considered to be partly excessively, and partly somewhat excessively drained. If the same soils occur on steeper slopes (>8%) then they are considered to be excessively drained.

7. Lithosols, rankers and rendzinas with sandy topsoil and when occurring on gentle slopes are considered moderately well drained. When the same soils have a loamy or clay-like topsoil and occur on gentle slopes they are considered imperfectly drained. When these soils occur on steeper slopes they are considered to be partly well drained and partly somewhat excessively drained.

8. Luvisols and podzoluvisols and luvic soil units in other FAO soil groups, when having a sandy topsoil texture and occurring on flat (<8% slopes) terrain, are considered to be partly well drained and partly moderately well drained. When these soils have a finer topsoil texture and occur on slopes of less than 8%, they are considered dominantly well drained, partly moderately well drained, and partly somewhat excessively drained.

9. All other soils with sandy topsoil textures occurring on flat terrain are considered to be dominantly well drained, partly excessively, and partly somewhat excessively drained. When such soils are finer and occur on flat or gently sloping terrain, they are considered partly well and partly moderately well drained. When these soils have a sandy topsoil

texture and occur on steeper slopes (>8%) they are considered to be partly moderately well and partly well drained. Whern these soils are loamy or clay-like and occur on steeper slopes (>8%) they are considered to be dominantly well drained, partly somewhat excessively drained, and partly moderately well drained.

10. Soil discussed under 8. and 9. above the having a petroferric phase are less deep than the typical soil units. Therefore, half of their area is considered to have similar drainage as those considered under algorithm 7 (Guidelines for Soil…, 1990).

Reference

Guidelines for Soil Profile Description. 1990. 3rd Ed. (Revised). FAO, Rome, 70 pp.

Fertility capability

The fertility of a soil is related to its capacity to store, retain, and release plant nutrients in such kinds and proportions as are required for crop growth. This soil quality can be derived from a combination of many soil properties: organic matter content, clay content and clay mineralogy, presence of weatherable minerals, pH, base saturation, and biological activity. A general evaluation of the natural fertility levels of major soil groups is given in Table 1, but wide variations exist within these major soil groups. Most crops thrive best on fertile soils, but some do yield reasonably well on moderately fertile soils (e.g., rice) and some produce well on quite infertile soils (e.g., millet or rye). Consequently, fertility levels of soils may have little influence on the land use, but will to a large extent determine the amount and distribution of chemical inputs required, which have an impact on the economic suitability and rentability of the land.

Table 7. Inherent soil fertility levels of major soil groups (adapted for Russia from World Soil Resources, 1993).

Fertility Level		
Low	Moderate	High
Soil Type		
Arenosols Planosols Podzols	Regosols Andosols Greyzems Podzoluivisols Histosols	Fluvisols Gleysols Vertisols Kastanozems Chernozems Phaeozems Cambisols

Reference

World Soil Resources. An explanatory note on the FAO World Soil Resources Map at 1:25,000,000 scale. 1993. World Soil Resources Reports, 66 Rev. 1, FAO, Rome, 66 pp.

Appendix: Technical Summary of Russian Soil Coverages and Databases

Source

General Characteristics

Stolbovoi V., I. Savin and B. Sheremet, Land Resources of Russia CD-ROM.

Soil Carbon Pools, CO2 and CH4 Emissions

Stolbovoi V., Land Resources of Russia CD-ROM.

Soil Reference Profiles

Stolbovoi V., I. Savin, B. Sheremet and L.Kolesnikova, Land Resources of Russia CD-ROM.

Technical Description

The soil coverage presented in the CD-ROM is a generalized version of the soil map of Russia at the scale 1:2.5 million (Fridland, 1988). The generalization procedure has passed through two types of aggregation: 1) generalization of the thematic content, and 2) a generalization of the mapping units or polygon geometry.

The generalization of the thematic content mainly deals with aggregation of soil classes presented in the map legend. Frequently, the process of scaling up soil information is based on vaguely defined arguments, like the notions of their representativeness, genetic unity, structure of soil cover patterns, the purpose the aggregated product will serve, etc. The generalization applied in the study has followed the principle of maximum identity with the original map. Only soils with minor extents have been ignored. The total soils number in the original soils map is 204. The revised version contains 163.

The second aspect, a generalization of mapping units, is due to the fact that polygons occurring at a larger scale cannot always be shown on a smaller scale. In this study, the soil mapping units were generalized in accordance with traditional rules of observational cartography stating that the minimal size of a mapped polygon should not be less than 1 square centimeter (cm2). The areas of soils belonging to the deleted polygons was added to similar soil of polygons remaining on the map. When necessary, the deleted soils are included in the neighboring soil mapping unit as an associated component. The total number of distinguished polygons is 1,329.

The soil naturalness coverage was created from a series of overlays and therefore is presented as an individual coverage. For more information on this coverage, refer to the soils description.

Table Definition

Soil profiles.dbf Soil adjusted characteristics.dbf	These databases both contain a field that links to the soil code in the soil coverage. In addition, they contain lat and long coordinates allowing them to be converted into a spatial coverage. For a complete description of these databases please refer to the soil description. For a description of the attributes see below.

Coverage Definition

Coverage	Data Type	Fields	Description
Soil	Poly	contour rus_code rus_tname eng_name wrb-tname wrb_tind wrb-name wrb-ind fao_code fao_tname fao_tind fao_name fao_ind us_tname us_name us_ind tawc drainage bulk_d cec ch4 ph nitrogen co2 rus_name mean0-30 mean0-50 mean0-100 mean0-200	database link link to russian classification russian soil class full description of russian class WRB soil class WRB acronym full description of WRB class WRB acronym FAO soil code FAO soil class FAO acronym full description of FAO class FAO acronym US soil class full description of US class US acronym Total Available Water Capacity soil drainage bulk density cation exchange capacity Methane production Topsoil acidity Nitrogen content CO2 respiration full description of russian soil class organic carbon 30cm organic carbon 50cm organic carbon 100cm organic carbon 200cm
Soil Naturalness	Poly	Impact	human impact on soil

Attribute Description

Soil Database Attributes from Soil_profiles.dbf and Soil_adjusted_characteristics.dbf

1. Soil ID in a WRB system
2. Lat - northern latitude (grad)
3. Long - longitude (grad)
4. Alt - altitude (m above sea level)
5. GWL-up the upper ground water level (cm)
6. GWL-down the lower ground water level (cm)
7. D-Rock - depth to hard rock (cm)
8. D-Oth.obs - depth for root penetration (permafrost, ground water table, compacted or saline horizons, etc.)
9. PM - parent materials
10. Land Use - main land uses and covers (tundra, forest, grassland, medow, bog, pasture, cropland
11. Horizon - identification of soil horizon according to the national nomenclature
12. Depth - lower boundary of the horizon extent (cm)
13. Clay - clay content (%)
14. esd - equivalent diameter of the sphere - 1 μm (upper limit)
15. Silt - silt content (%)
16. esd - equivalent diameter of the sphere - 10 μm (upper limit)
17. Sand - content of the 1st sand fraction (%)
18. esd - equivalent diameter of the sphere - 50 μm (upper limit)
19. Sand - content of the 2nd sand fraction (%)
20. esd - equivalent diameter of the sphere - 250 μm (upper limit)
21. Sand - content of the 3rd sand fraction (%)
22. esd - equivalent diameter of the sphere - 1000 μm (upper limit)
23. Stones - content of stones (% of soil volume)
24. Soil Color - color according to the Munsell Soil Color Charts
25. Structure - soil structure
26. C - carbon content (%)
27. cod - identification of method (A3 Turin method of wet combustion; A31 - ignition loss)
28. N - nitrogen content (%)
29. cod - identification of method (A4 wet digestion after Kjeldahl method)
30. CaCO3 - total CaCO3 content (%)
31. cod - A6 calcimeter method (%)[measures CO2 emitted]
32. AG - CaSO4*2H2O gypsum content (%)
33. cod - A10 extraction by 0.2N HCL and deduction of a mount extracted by 1:5 water solution
34. 35. pH(H2O) - acidity, pH 1:5 water solution

35. cod - method of acidity detection
36. EC - electro conductivity (dSm-1)
37. cod of the method of detection
38. ESP - content of exchangeable Na (%)
39. Ca - content of exchangeable Ca (mg-eqv/100g)
40. cod - neutral Ammonium Acetate extract
41. Mg - content of exchangeable Mg (mg-eqv/100g)
42. cod - neutral Ammonium Acetate extract
43. K - content of exchangeable K (mg-eqv/100g)
44. cod - neutral Ammonium Acetate extract
45. Na - content of exchangeable Na (mg-eqv/100g)
46. cod - neutral Ammonium Acetate extract
47. CEC - Cation Exchange Capacity (mg-eqv/100g)
48. cod - different method depending on soils (for details see Arinushkina, 1970)
49. BS - Base Saturation (%)
50. cod - ration of sum of exchangeable cations and CEC
51. TOT-POR - Total Porosity (%)
52. cod - (1 - bulk density/particle density)%
53. DB - Bulk density
54. cod - A29 - wet measurements in the field