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MORPHOGENETIC BASIS OF THE UNIFIED STATE REGISTER OF SOIL RESOURCES OF RUSSIA

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Nomenclature and taxonomic diversity of soils and their horizon-profile diagnostics/descriptions define morphogenetic soil indicators used in the Unified State Register of Soil Resources of Russia (with Russian abbreviation of EGRPR). Most of these soil indicators are of non-metric origin, i.e., established conventionally by agreement. Subject area of soil science includes a hierarchy of 5 types of soil objects (pit, profile, horizon, morphological element and sample), 380 indicators, 607 methods and 3019 values of the indicators.

Key words: unified state register of soil resources, soils, morphogenetic characteristics

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INTRODUCTION

Morphogenetic features of soils develop in the course of soil formation. They reflect the past and current soil processes and phenomena and serve as informational and methodological basis for modern soil science. Studying the morphological features of soil profile allows us to understand relationships between soil-forming factors and processes, to develop soil nomenclature and taxonomic identification, etc.

New soil information recourse was ratified in Russia in 2014 – "Edinyi gosudarstvennyi reestr pochvennykh resursov Rossii" – EGRPR (Unified State Register …, 2014). The EGRPR includes complete and unified digital data set on all soils of Russia, their properties and distribution.

The EGRPR concept comprises a model of spatial organization of soil cover, digital representation of soil data and systematization of soil features at different scales, i.e., soil recourses all over the country and within each of the Federal Subjects of Russia and soil-ecological regions (Stolbovoy and Molchanov, 2015). By a systemic approach the EGRPR interconnects and integrates the above elements into a unified

system, with the morphogenetic soil indicators playing a key role in providing consistent database on soils countrywide.

NOMENCLATURE AND TAXONOMIC DIVERSITY OF SOILS

The nomenclature of the EGRPR includes 205 soil units at different taxonomic levels. Soil features that determine soil taxonomic position are reflecting the integrated influence of soil-forming processes and factors. Therefore, the EGRPR represents a unified image of geographic diversity of soil taxa.

A soil unit is an integrated index of soil based on its combined characteristics. In the Russian school of soil science a priority is given to soil genetic features. In the EGRPR a soil unit is an identifier containing a brief description of distinguishing features of that particular soil. These units follow the Russian soil science tradition of hierarchical structure of soil names, beginning with type and continued to subtype, genus and species. The nomenclature and taxonomic diversity within the EGRPR is represented by 57 soil types, 107 soil subtypes, 47 soil genera and 11 soil species.

DIAGNOSTICS OF HORIZONS WITHIN A SOIL PROFILE

In EGRPR, the primary units of soil description and diagnostics are morpho-genetic horizons, with secondary importance being given to their additional features. The main morpho-genetic horizons are formed by leading soil-forming processes. These horizons are labelled by capital letters of the Latin script supplemented by Arabic digits (Table 1). They can be subdivided into sub-horizons by quantitative change in the main diagnostic features, e.g., $O1_1$, $O1_2$, $A2_1$, $A2_2$, etc.).

Transitional morpho-genetic horizons with a gradual change from one horizon to the other are labelled by the indices of respective horizons above and below, starting by the index of the horizon, which contributes more of its features to the transition horizon, e.g., A2B1 and A1B1.

Transitional morpho-genetic horizons having combined features of the horizons above and below are labelled by the indices of respective horizons above and below divided with a slash, e.g., A2/B1 and A1/B1.

A buried horizon is marked by square brackets, e.g., [A1].

Table 1. The main morpho-genetic horizons of soils (Unified State Register…, 2014)

Index	Definition
	Organic horizons
O	Organic horizons. By volume, they contain more than 70% of organic matter with different rates of decomposition. Any minerals present are mostly a mechanical admixture. The horizons are usually at the soil surface or, if buried, anywhere within the soil profile. These horizons may form the entire soil profile (in the case of peat soil)
O1	Horizons formed mainly of well-preserved or slightly decomposed plant remains, which retain the main features of their initial composition.
O2	Horizons formed mainly of moderately decomposed plant residues, partially retaining their initial features (such as portions of plant fabric)
O3	Horizons formed by well-decomposed plant residues that have completely lost their initial features
	Organo-mineral horizons
AO	The upper organo-mineral horizons containing considerable quantities (30–70% by volume) of organic matter at different stages of decomposition. They usually have a mechanical mixture of organic and mineral material, which, however, could be easily separated
A1	The upper mineral horizons, which are usually the most dark-coloured within the soil profile. They contain well-humified organic material, which is formed in situ and closely linked to the mineral phase
	Mineral horizons
A2	Usually underlying horizons O, AO, or A1, but in heterogeneous profiles may occur under any horizon of the overlying profile. They are the most bleached and colorless horizons in the soil profile, and do not have the gleying characteristic of the G horizon
B	Mineral horizons, underlying horizons AO, A1, or A2 (or O horizon if the above-mentioned are lacking). They are identified by any differences of colour, structure, or texture in comparison with the overlying horizon A and underlining horizons G and C
G	Mineral gley horizons that reveal uniform or alternating bright blue, blue-grey, green, or rusty colours throughout the dominant part (not less than 70%) of the freshly cut surface
G1	Gley horizons with uniform or alternating bright blue and dark blue colours
G2	Gley horizons mottled with blue, grey-blue, and rusty tints
G3	Gley horizons, that have olive, green, or greyish-green colors

Index	Definition
C	Parent material, mostly unchanged by soil formation
D	Underlying rock, different from the soil parent material, underlies the soil profile, and has no features caused by soil forming processes
S	Horizons, cemented in both moist and dry conditions, may form an impermeable layer and resist sheet erosion. They are formed by the concentration of various chemical compounds (oxides of iron, silica, carbonates of calcium and magnesium, salts, etc.) Cementing the soil mass
K	Fragile, porous crusts, not more than 5 cm thick, forming the surface of the profile

Frozen, water-resistant and ice-cemented morpho-genetic horizons are labelled by the main horizon index with a special mark in front of it, e.g., ⊥BC.

Morpho-genetic horizons that have negative temperature at the time of description, but aren't water-resistant (with an optional presence of ice) are labelled by the main horizon index with a downward arrow in front of it, e.g., ↓BC.

Additional features of morpho-genetic horizons (presence of calcium carbonate, salinity, alkalinity, etc.), which result from secondary processes developed over a background soil-forming process, are given a lowercase letter behind the main horizon index, e.g., Bs – visible salt pedofeatures within the B horizon, Bsl – solonetzization (alkalization) within the B horizon, Aca – calcium and magnesium carbonate pedofeatures within the A horizon. If the secondary features reach their maximal degree of development, then their lowercase letter is underlined, e.g., B<u>ca</u>, B<u>m</u>, B<u>c</u>, etc. If there are several secondary features within the same main horizon, their respective lowercase indices are divided with commas, e.g., B1m,f,g.

Every soil profile has its specific sequence of morpho-genetic horizons from the top to the bottom, which is referred to as a "formula of soil profile structure". The guidelines for correctly presenting such formulas are set in the EGRPR.

MORPHOGENETIC CHARACTERISTICS OF SOILS

The morphogenetic characteristics of soils include their visually perceivable appearances and easily assessable (e.g. by tape measure) parameters. Sometimes they are supplemented by micromorphological

features being identified with more precise instruments of visual investigation, e.g., a polarizing microscope.

Definitions of the morphogenetic characteristics of soils used in the EGRPR are presented in Table 2 and definitions of morphogenetic elements of soils – in Table 3. Details describing soils in the system of the Unified State Register of Soil Resources of Russia is available in the Guidelines for soil description (Guidelines …, 2016).

FORMAL MODEL OF PRESENTING THE MORPHOGENETIC CHARACTERISTICS

As shown above, the morphogenetic characteristics of soils registered in the EGRPR are derived from the nomenclature and taxonomic diversity of soils and their profile descriptions. Such approach to choosing the morphogenetic characteristics of soils is based on soil research data. Indeed, the soil cover is a continuous mantle, not subdivided by distinct boundaries into soil taxonomic units. Our concepts of soil variety are always conventional and based on classifications being accepted and study methods being practiced in field and laboratory. A close relationship between the nomenclature and taxonomic diversity of soils and their profile descriptions/diagnostics makes the EGRPR truly unified, with soil morphogenetic indicators proving for integrity and interconnection.

There is a formal mathematical expression of soil morphogenetic description in the EGRPR (Unified State Register…, 2014). There is a logical sequence, where each soil object is described by the associated set of soil indicator values and the whole soil is expressed as a tree of associated sets of indicator values within an area of soil objects:

$$S = \Sigma(V_{[pID][p,0,0]}) + \Sigma(V_{[hID][p,h,0]}) + \Sigma(V_{[eID][p,h,e]}) + \Sigma(V_{[sID][p,h,s]}),$$

where S – soil, V – value of soil indicator, [pID], [hID], [eID], [sID] – soil indicator identification indices for respective objects (p – profile, h – horizon, e – element of soil morphology, s – sample), [p,0,0], [p,h,0], [p,h,e], [p,h,s] – saved indices of sets of soil objects:

profile {pID | pID(ObjectTypeID=P)},
horizon {hID | hID(ObjectTypeID=H)},
element of soil morphology {eID | eID(ObjectTypeID=E)},
sample {sID | sID(ObjectTypeID=S)}.

Such interpretation allows establishing and expressing relationships between the soil structure objects and their indicators through

Table 2. The morphogenetic characteristics of soils and their definitions

Morphogenetic characteristics	Definitions
Moisture	Morphological assessment of the degree of soil moisture
Colour	Morphological feature of soils (visual assessment)
Texture	Field determination of soil texture (tactile assessment)
Stoniness	Determination of stoniness as a mass percentage of stones (>3 mm) in soil
Mineralogical composition	Characteristics of the composition of mineral skeleton of soil
Homogeneity of structure	Degree of homogeneity/heterogeneity of soil structure
Structure	Shape and size of structural units of soil
Density	Morphological determination of soil hardness
Porosity	Morphological characteristics of porosity within soil aggregates and total soil mass
Fissures	Morphological description of fissures between soil aggregates
Upper boundary of effervescence	The upper boundary of effervescence upon reaction with 10% HCl
Lower boundary of effervescence	The lower boundary of effervescence upon reaction with 10% HCl
Intensity of effervescence	Morphological description of the intensity of effervescence upon reaction with 10% HCl
Character of effervescence	Morphological description of the character of effervescence upon reaction with 10% HCl
Tree roots	Indication of a presence of tree roots within soil horizon
Shrub roots	Indication of a presence of shrub roots within soil horizon
Grass roots	Indication of a presence of grass roots within soil horizon
Prevailing size of roots	Morphological detection of the prevailing size of roots, mm
Abundance of roots	Morphological detection of the abundance of roots
Mycelium	Morphological description of fungal mycelium appearance
Algal film	Indication of a presence of algal film on soil aggregate faces
Boundary shape	Morphological characterises of the lower boundary of soil horizon
Transition	Morphological description of transition to the horizon below
Upper depth of horizon	The upper depth of soil horizon, cm
Lower depth of horizon	The lower depth of soil horizon, cm
Thickness of horizon	The thickness of soil horizon, cm

Table 3. Definitions of morphogenetic elements of soils

Morphogenetic elements	Definitions
Plant debris	Morphological characteristics of plant debris
Degree of decomposition of plant debris	Morphological characteristics of the degree of decomposition of plant debris
Abundance of plant debris	Morphological characteristics of the abundance of individual types of plant debris
Minimal size of plant debris	The minimal size of individual types of plant debris
Maximal size of plant debris	The maximal size of individual types of plant debris
Faunal remains	Morphological characteristics of types of faunal remains
Abundance of faunal remains	Morphological characteristics of the abundance of individual types of faunal remains
Minimal size of faunal remains	The minimal size of individual types of faunal remains
Maximal size of faunal remains	The maximal size of individual types of faunal remains
Shape of soil peds	Description of shapes of soil peds (structural units)
Films on ped faces	Appearance of films on ped faces
Minimal size of peds	The minimal size of prevalent peds
Maximal size of peds	The maximal size of prevalent peds
Rock fragments	The presence of rock fragments (stones)
Roundness of rock fragments	Morphological characteristics of roundness of rock fragments
Abundance of rock fragments	Morphological assessment of the abundance of rock fragments
Minimal size of rock fragments	The minimal size of prevalent rock fragments
Maximal size of rock fragments	The maximal size of prevalent rock fragments
Inclusions	Morphological identification of inclusions, their genesis and composition
Abundance of inclusions	Morphological characteristics of the abundance of individual types of inclusions
Minimal size of inclusions	The minimal size of individual types of inclusions
Maximal size of inclusions	The maximal size of individual types of inclusions
Pedofeatures	Morphological description of pedofeatures' types
Composition of pedofeatures	Morphological assessment of the composition of pedofeatures
Abundance of pedofeatures	Morphological assessment of the abundance of individual types of pedofeatures

Morphogenetic elements	Definitions
Minimal size of pedofeatures	The minimal size of individual types of pedofeatures
Maximal size of pedofeatures	The maximal size of individual types of pedofeatures
Units with coatings	Morphological description of soil structural units covered with coatings (cutans)
Cover of coatings	Morphological assessment of the percentage cover of coatings on the surface of soil structural units
Minimal size of coatings	The minimal size of coatings
Maximal size of coatings	The maximal size of coatings
Shape of pores	Morphological description of the shape of pores
Connectivity of pores	Morphological assessment of the pore connectivity
Orientation of pores	Morphological characteristics of pore orientation
Abundance of large pores/fissures	Morphological assessment of the abundance of large pores/fissures (more than 3 mm wide and more than 1 mm in diameter)
Abundance of small pores/fissures	Morphological assessment of the abundance of small pores/fissures (less than 3 mm wide and less than 1 mm in diameter)

logical formulas. Precise positioning of each set of soil morphogenetic data in the EGRPR digital format gives us a possibility to restore soil descriptions in visually available form without information loss and distortion. The precision of descriptions supplied by their authors is being controlled and supported by complete meta-data on the subject area of soil science, i.e., the *Universum*[1] of soil cosmos (pedosphere) including an entire range of soil objects with an entire diversity of their properties and features. The subject area is also a sphere of theoretical development of soil science that can be realised only within the area of soil objects, their morphogenetic characteristics and other parameters.

[1] *Universum, summa rerum* (lat. meaning “universe”, “the world”) is a philosophical concept of objective reality in time and space. In the context of this article, it is applied to soil cosmos (pedosphere) in time and space.

CONCLUSIONS

1. The EGRPR is an innovative national soil information resource, being a system for organizing spatially-distributed morphogenetic characteristics and other parameters of soils.

2. The unified morphogenetic characteristics of soils in the EGRPR play a key role in ensuring the unity of soil information base of our country. The set of morphogenetic characteristics is determined by the nomenclature and taxonomic diversity of soils and descriptions/diagnostics of their horizons and profiles. There are 57 types, 107 subtypes, 47 genera and 11 species of soils. The EGRPR as a system represents an integrity of diverse soil taxa (conceptual morphogenetic images of soils) within a geographical continuum of soil morphogenetic properties.

3. In digital format the EGRPR opens a possibility for restoring soil descriptions in visually available form without information loss and distortion. The precision of descriptions supplied by their authors is being controlled and supported by complete meta-data on the subject area of soil science, which includes a hierarchy of 5 types of soil objects (pit, profile, horizon, morphological element and sample), 380 indicators, 607 methods and 3019 values of the indicators.

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