CLASSIFICATION OF URBAN SOILS IN RUSSIAN SOIL CLASSIFICATION SYSTEM AND INTERNATIONAL CLASSIFICATION OF SOILS

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Based on the example of St-Petersburg a genetic diversity of natural, human-transformed and anthropogenic soils has been thoroughly studied at the urbanized territory of this megalopolis. Under consideration are changes in components of the soil cover caused by the human activities along with the regularities in the soil cover formation that has being developed for several centuries from the beginning of the 18th century. It is also shown how changed the initial profile of natural soils accompanying the urbanization process with special emphasis on peculiar features of the soil formation at the urban territory. Among a great variety of surface bodies at this territory the soils were found out, the definition of which is given in Russian soil classification system and the WRB. The principles for classifying the urban soils are considered. The distinct morphological features of an introduced horizon are determined to give the comprehensive characteristics of human-transformed soils. Under discussion is the concept of "introduced horizon" composing of the human-modified material from the humus or organogenic horizons of natural soils and having the lower sharply expressed boundary with the parent rock. In Russian soil classification system it would be advisable to use a new order of "introduced soils" within the trunk of synlithogenic soils along with stratozems, volcanic, weakly developed and alluvial soils. In the WRB system it would be also possible to identify a new reference group of soils including the soils with the introduced horizon and underlying by any mineral substratum of natural or anthropogenic origin.

Keywords: urban soils, classification, soils, principles, introduced horizon

The study of urban soils is paid by increasing attention of scientists now in view of expanding the areas of urban territories, occupied by 3/5 of world population. The most urbanized States are Kuweit (98.3%), Bahrein (96.2%), Katar (95.3%), Malta (95%). In Northern and Western Europe the share of urban population makes up more than 80%. In Russia the urban territory is estimated at 4.3 mln hectares and accounts for 70% of townspeople. Such an unlimited expansion of towns leads to inevitable changes in global ecological potential of soils. The areas with actively functioning surface occupied by natural and agricultural lands are shortened to a considerable extent. For today, the forecasting consequences of urbanization for global changes in environmental functions of the soil cover is a pressing problem, the solution of which needs a better understanding of the position of urban soils in soil classification systems.

At present, there is no classification of urban soils in Russia and abroad. One of the reasons is the absence of common approaches to nomenclature and systematization of these soils. In soil classification of Russia published in 1977 and applied up to now the soils of urban territories are not considered at all [6]. An attention was paid to human-modified soils only in the latest Russian soil classification system (2004).

The study of urban soils assumes ever greater importance during the last decades and has been repeatedly discussed in the literature [1, 4, 5, 8–15, 18, 20–22]. Original approaches and schemes for nomenclature and diagnostics of urban soils have been proposed for Moscow [8, 13, 15], St-Petersburg [1, 2] and Perm [16]. The known publications of researchers from Germany [18–21] and the decisions of International working groups (SUITMA, INCOMMANTH, WRB) should be mentioned as well.

It is evident that the tasks relating to the placement of urban soils in classification must be solved taking into complete account the fact that the soil cover in towns cardinally differs from that in natural landscapes. The human-induced effects on soils of urban territories lead not only to insignificant changes in the soil properties but also to considerable transformation of the soil profile and “creation” of new soil forms.

The soil cover of any town is not uniform and characterized by its spatial and temporary heterogeneity. This is explained not only by a

great diversity of natural conditions; human interventions have an adverse effect on the soil cover at different stages of building and expansion of town boundaries including various parts of the town – the center, outskirts, forest-parks, industrial quarters,"sleeping" sectors [1]. In towns the human activity as one of the soil-forming factor exerts direct and indirect effects on soils and soil cover. The indirect influence is manifested through modification of soil-forming factors (precipitation, temperature, evaporation, vegetation, composition of parent materials), whereas the direct effects serve as a cause of soil oxidation, flooding, destruction of the soil profile and even its new formation or construction to be identical to natural one.

Practically always the urban territory reveals the combined elements of the soil cover of natural landscapes, agrolandscapes, densely populated areas and industrial zones. In natural ecosystems preserved within the urban territory the different soils with weakly destructed profile are dominant; in agrolandscapes the agrogenically transformed soils prevail; at the densely populated territory are widespread the surface formations including asphalt covers, human-transformed soils, technogenic superficial formations, mineral ground. Thus, a spectrum of surface formations in towns is extending from natural soils characteristic of the given geographical zone to soils transformed in different extent and technogenic superficial formations.

For example, when compiling the soil map of St-Petersburg at 1:50000 scale it seemed possible to recognize 18 types and subtypes of natural soils, 13 human-modified soils and 4 anthropogenic soils [2]. The natural soils are presented by different stages of their development (from petrozems and psammozems to climax ones). The specific of soils in St-Petersburg is associated with the physical-geographical location in basins of the Neva river and the Baltic Sea and the town history since the time of human settling [1].

The soils of St-Petersburg reveal in their profile the features of century-old transformation induced by human activities. A primitive man has appeared in the area near the Neva stream in Neolithic epoch but his influence on soil was point and fragmentary by nature (Table). Probably, insignificant changes in the soil morphology were observed only at the territory of settlings occupied by fishers and hunters. Since the VIII–XI centuries the Neva stream became the most important wa-

Table. Changes in the component composition of the soil cover induced by the human activity at the territory of St-Petersburg

Period	New components in the soil cover	Character of changes in the soil cover
Neolithic–XIII	Surface-turbated	Point
XIII-XVIII	Surface-turbated, stratified, Abraded, agro natural	Fragmentary Expansion to natural soils
XVIII	Surface-turbated, stratified, Abraded, agro natural, introduced, Stratozems, oxidic-gley, agrozems	Over vast areas Expansion to natural and agricultural lands
XIX	Surface-turbated, stratified, Abraded, agro natural, introduced, stratozems, oxidic-gley, agrozems	Over vast areas Expansion to natural and agricultural lands
XX	Surface-turbated, stratified, Abraded, agro natural, introduced, stratozems Oxidic-gley Agrozems	Over vast areas Expansion to natural and agricultural lands

ter way between the people of Eastern and Northern Europe, what increased the load on the soil cover of this territory. The most drained soils near the rivers started to be intensively cultivated, thus transforming into stratified soils and at least into abrazems and stratozems. In 1500 the territory of today's St-Petersburg was occupied by 419 villages and the area of cultivated soils including such recent soils as agro-soddy podzols, agro-gray humus, agro-soddy podzolic ones. To the moment of the town foundation the soil cover proved to be considerably transformed: besides the cultivated soils with agro-horizon the vast areas were occupied by soils destructed in different extent.

The most radical changes in the soil cover have been taking place for a relatively short period of time (300 year). Since 1703 the point and fragmentary character of soil destruction revealed changes. The rise in soil surface was necessitated, on the one hand, by the position of historical center in St-Petersburg within the Neva delta on the other hand, by regular floods in town (the thickness of the cultural lay-

er reaches sometimes 4 m and more). Due to drainage work, roadways, avenues the area of destructed soils became augmenting and exceeding the areas of native soils. As a result, it seemed possible to study the soils with the artificially constructed humus layer.

In central part of the present-day megalopolis all the natural soils have been destructed and buried under the cultural layer. Dominant are newly constructed anthropogenic soils or stratozems (Fig. 1). As a rule, they have being developed on anthropogenic stratified substratum to be an underlying or soil-forming rock now and their formation has finished 100–150 years ago. Thus, we know exactly the time of the soil profile formation within the historical center of St-Petersburg. There are definite regularities in the development of the soil cover at the urban territory reflecting in the present-day image of this megalopolis.

Since the time of the town foundation the cultivated soils including agrozems or agro-natural ones were used for non-agricultural purposes and the buried arable soil horizons are often mentioned in publications devoted to studying the buried soils in St-Petersburg [9, 14]. The expansion of town to arable lands has being constantly accompanied by cultivation of new adjacent territories in order to advance the agricultural production and this process was continued for three centuries. The expansion of the urban territory at the expense of agricultural lands is envisaged in the General plan of St-Petersburg development to 2025. In outskirts covered with buildings in the 1960–1970s the soils display the traces of their former cultivation.

To determine the position of urban soils in classification systems, it is necessary to know what surface formations (natural, anthropogenically transformed, technogenic superficial formations, asphalt and the other artificial formations) should be considered as objects of classification.

In the soil classification of 2004 the artificially covered territories including those covered by asphalt are not objects of classification. This profile-genetic classification considers the soil as an exposed on the surface natural or natural-anthropogenic body developed due to interactions of processes leading to differentiation of initial mineral and organic materials in soil horizons. At the same time, the surface formations have to be considered in the WRB system because the objects of this classification are determined in a wider diapason.

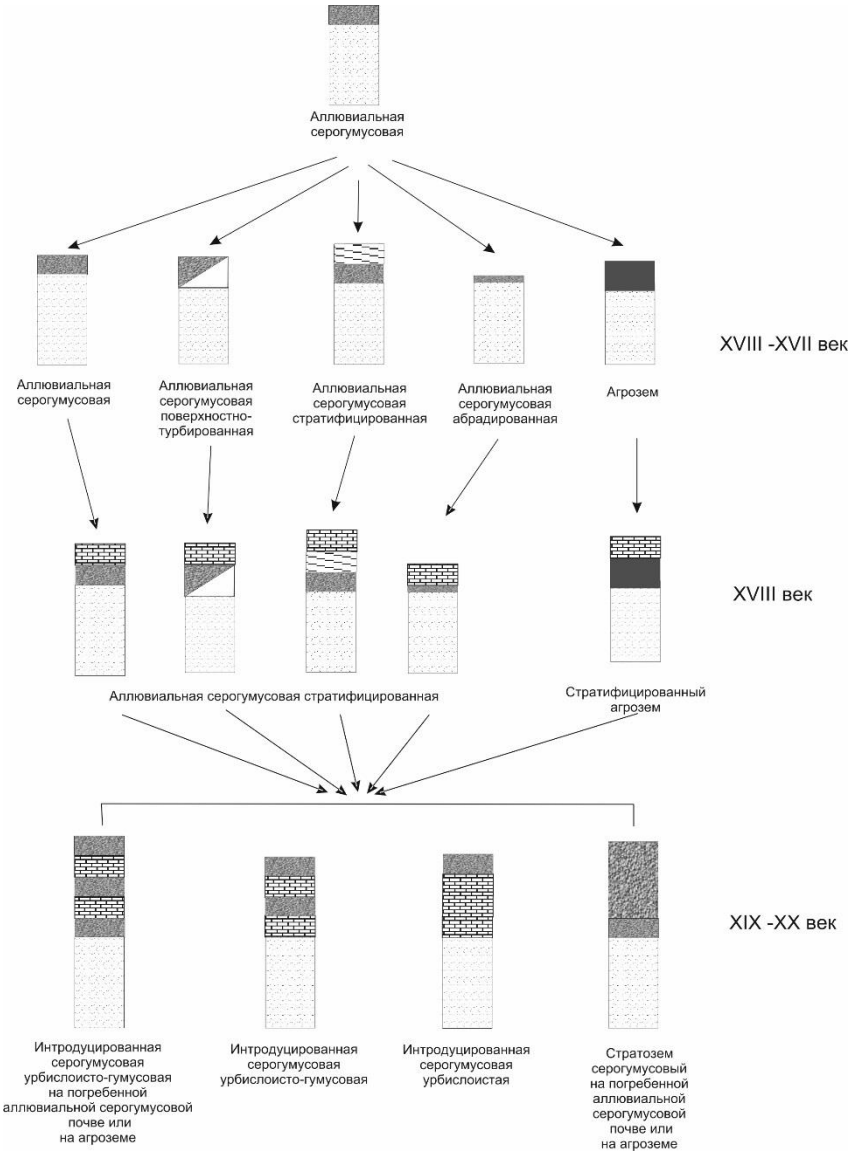

Fig. 1. Scheme of the profile transformation in natural soil at the urban territory.

As a rule, the soils in parks, graveyards and public gardens are human-made soils being completely corresponded to determination of classification objects, they have been considered in the WRB and the soil classification of Russia published in 2004.

In Russian soil classification system (RS) the soils, the profiles of which reflect results of anthropogenic effects are recognized at different taxonomic levels – from orders to subtypes. In the WRB system two reference soil groups are distinguished to show the human-induced changes in their morphological image and properties: Anthroposols and Technosols and a number of qualifiers. However, not all the surface formations are considered as soils in the recent classification systems.

Principles of urban soils classification The experience gained in studying and mapping of soils in St-Petersburg showed that the soils of urban territories should be considered in classification systems taking into complete account the following principles:

to apply common approaches to classification of solid-phase bodies exposed on the surface and formed the soil cover in town;

to consider as objects of classification not only natural and anthropogenically transformed soils but also the human-made formations with the introduced material of the humus or organogenic horizon;

to take into consideration the features reflecting the anthropogenic transformation degree of the soil profile; the human activity as a soil-forming factor leads to soil destroying or its burying, to mixing or transporting the material of soil horizons;

to take into account not only the horizon sequence but also the presence or absence of genetic interactions between them (a sharply expressed transition from one layer to the other in the absence of similar features between these layers – removal and accumulation of the substance);

to admit that in the urban ecosystem the profile-forming process taking place under the influence of natural factors is frequently accompanied by constant or periodical input of new materials into the soil surface, thus providing the rise of the soil profile towards the day surface and its stratification;

to recognize that the features inherited from native soils should be considered as priorities to diagnose the horizons of anthropogenic

soils and to determine their position in classification at the type level in Russian soil classification and qualifiers in the WRB system.

The placement of urban soils in RS and WRB. To determine the placement of urban soils in the above classification systems let us consider the possible changes in the initial profile of natural soils due to urbanization process (Fig. 2). There are four types of changes in the soil profile induced by human activities: mixing of soil horizon, cutting and removal of the topsoil, soil burying and "construction" of a new soil profile.

In the course of building the soils prove to be buried but their typodiagnostic horizons of initial soils remain unchanged. In case of covering the soil profile by the layer of natural or artificial materials of 40 cm thick the soil bodies are formed to be classified at a subtype level: humus-, arti-, urbi- and toxi-stratified soils in RS (Fig. 2a, 2б). In the WRB system the qualifier Novic is used for these soils (Fig. 3.1). The soils in which the major part of the profile is represented by the humus stratified layer consisting of introduced materials are combined into the order of stratozems in RS (Fig.2a). In the WRB they are named as Anthrosols (Fig. 3.2, 3.3). The qualifier Urbic is applied for the stratified soil containing more than 20% of artefacts and about 35% of debris. The soil bodies preserved their natural form under the asphalt cover are classified as Ekranic in the WRB system (Fig. 3.4). From our point of view, in Russian soil classification they should be considered as buried soils of appropriate genetic types because such soil bodies are found to be isolated and have no functions of biogeomembranes. Being isolated from the environment these soils cannot absorb the metabolism products, transform and transport pollutants; they are incapable to fulfill the sanitary, water- gas- and thermo-regulating functions.

The soil studies in St-Petersburg showed that the buried natural soils are found to be at a great depth being covered not only by asphalt but also the anthropogenic layers of different thickness.

Due to uprooting of wood vegetation or land leveling only the uppermost part of the soil profile is subject to destruction. Such soils are classified as turbated at the subtype level in types of natural soils (Fig.2e). The prolonged mixing of the topsoil by different mechanical treatments leads to the formation of soils that are classified as agronatural and agrozems in RS (Fig. 2e) and Anthrosols in the WRB sys-

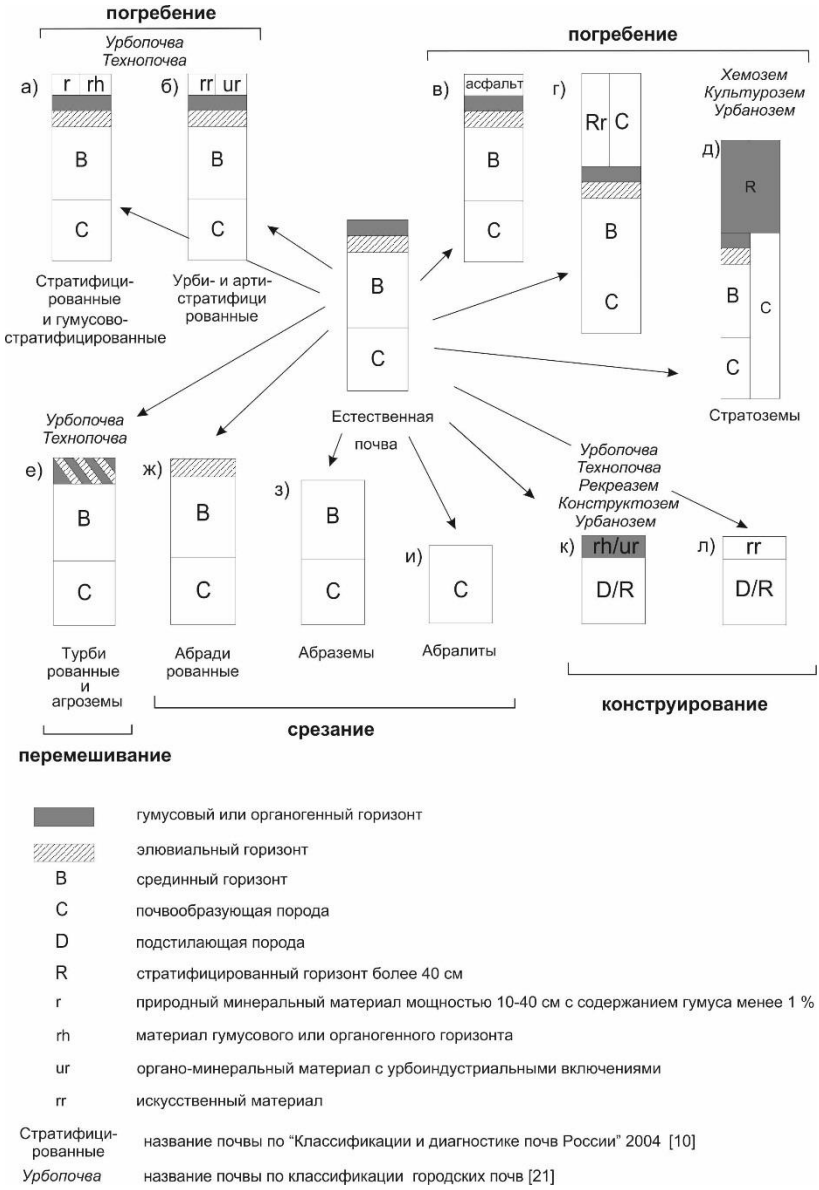

Fig. 2. Types of changes in the soil profile under direct effects of human activities in Russian soil classification system.

tem (Fig. 3,7; 3,8). As a result of topsoil cutting the abraded soils are formed (Fig.2ж). In case of deep cutting when the soil mid-horizon is exposed on the day surface these soils are referred to the order of abrazems (Fig.2з). Not frequently the soil seems completely disappeared. In this case abraliths are recognized to be a technogenic superficial formation that is not considered in the scope of RS. The introduced layer of the artificial material or bedrock can be also referred to technogenic superficial formations or Technosols in the WRB system [8, 23].

Thus, in the WRB system the variants 1–3 and 7–9 (Fig. 3) are recognized as the soils of different reference groups with qualifiers Novic, Urbic, Ekranic, Antric. The variants 4–6 are Technosols. The variant 10 is the rock.

Within the framework of RS all the variants have their placement in the classification or they are not objects of classification. There is the other variant – the human-constructed anthropogenic soil, in which the introduced humus or peat horizon rests on the natural or artificially constructed mineral substrates. The man being one of the soil-forming factors cannot construct the soil in classical (scientific) sense.

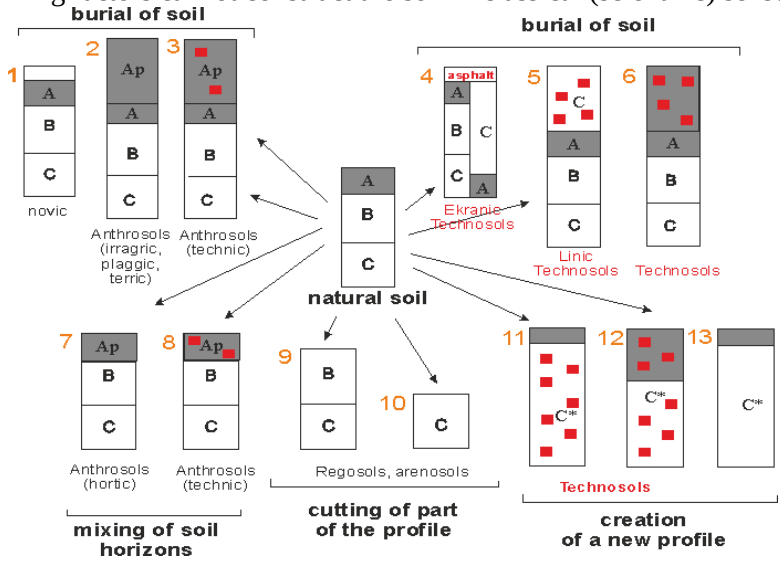

Fig. 3. Types of changes in the soil profile under direct effects of human activities in the WRB system.

Proceeding from the purposeful function, for example - to provide the growth and development of crops, the man creates a physical model of the root layer but not a real soil profile. In agrolandscapes he changes the chemical composition, properties and regimes of soil in order to use efficiently its most important function – the soil fertility. In this case the genetic soil profile is changed insignificantly. To implement this purpose at the urban territory the man is obliged to construct a soil-like formation with the fertile root layer introducing the organo-mineral or organogenic material. As a rule, this material is taken from the adjacent territories and introduced into the remained horizons of the initial soil or the artificially constructed mineral layer. Thus, the biologically active part of soil from its natural area is transported in the urban territory. Although the soil formation as a specific immanent form of energy movement starts after the stabilization of the day surface on all the mineral and organo-mineral substrates the hundred years are required to develop the system of genetic horizons in the soil.

In a new human-made soil profile the major morphological features permitting to identify the type of newly formed horizons remain unchanged. At the same time, some human-modified properties can significantly differ from initial properties of these horizons in natural soils. The material transported into the human-constructed soil may be named as introduced one; this term is widely adopted in biology and the input of material from the humus (peat, peat-mineral) horizon into the urban soil is a specific technogenic introduction like the plant introduction. As a result, the soils with the introduced horizon are formed and have morphological features that are inherited from the initial soil on the one hand but on the other hand they are attributed with human-induced effects.

The introduced humus or organogenic horizon containing the human-modified material from humus or organogenic horizons of natural or anthropogenically transformed soils has a sharply expressed boundary with the mineral substratum – the underlying rock of different composition. A distinctive feature of underlying rocks is their heterogenous composition and configuration. They contain a significant amount of inclusions – artefacts of different composition, size and volume characterized by the presence of geochemical barriers and gradients of water permeability, heat conductivity and water-holding capaci-

ty. It is worthy of note that the humus or organogenic horizon in these soils rests on the underlying rock that is not the parent material. The majority of such new soils have no typomorphic features characteristic of natural soils. The system of mineral-energy exchange is not balanced in the profile of these soils and the absence of genetic interactions between the layers evidences the initial stage of the soil profile development.

Suggestions to have new taxa in Russian soil classification The specific features of the soil formation process under urban conditions is that the soil profile becomes rejuvenated as resulted from constant or periodical anthropogenic input of humus material into the soil surface. Having evaluated the age of urban soils one should take into consideration that the age of introduced humus horizons as well as the underlying mineral stratum can make up several hundred years whereas the age of the proper soil profile doesn't reach sometimes a year. In megalopolis the soil-forming process has no principal differences from that in natural landscapes but the velocity of the soil development is much higher under urban conditions.

The morphological-genetic analysis of the profile, its form, composition and properties serves as a basis for classification of soils with the introduced horizon. At the territory of St-Petersburg the soil profile at a depth of 100 cm is taken into consideration, i.e. in the lower boundary where the soil formation processes are manifested to differentiate genetic horizons in natural soils. To classify the urban soils, it is necessary to take into account the thickness of the humus or organogenic horizon, the genetic interaction between the layers and their correspondence to profile-forming processes characteristic of soils in the natural zone, the origin and composition of the topsoil. Bearing in mind the specific of anthropogenic soils and peculiar features of soil formation under urban conditions, we propose to create in RS a new order of introduced soils in the trunk of synlithogenic soils along with stratozems, volcanic, weakly developed and alluvial soils. This order can embrace the soils in which the introduced humus or organogenic horizon less than 40 cm thick (I) rests on the mineral substratum (D) derived from the material of the *in situ* natural soil or human-deposited material. If the introduced horizon of less than 40 cm in thickness rests on the undestructed soil or the mid-horizon, this soil is classified as a

humus-stratified subtype in the appropriate type. The introduced horizon more than 40 cm thick makes possible to diagnose this soil as stratozem. In the order of introduced soils 6 soil types are recognized according to the character of the humus or organogenic horizon and the specific features of mineral substratum. The subtypes are distinguished owing to the underlying substratum having the features that serve as evidence of mechanisms responsible for its formation.

Typical soils (*in situ*) I-D: the underlying mineral substratum has no features of mechanical translocation. The typical introduced soils are developed when the introduced horizon is spread over the soil-forming rock remained from the destructed soil.

Urbostratified soils I-RDur: these soils reveal a clearly expressed stratification with a great share of inclusions – remnants of construction materials. The thickness of the underlying urbostratified mineral substratum can reach several meters, the subtypes of these soils are characteristic of territories repeatedly subjected to building works.

Urbointroduced soils I-RD: the underlying mineral stratum is heterogenous and contains artefacts; indistinct bedding serves as evidence of the material stratification. The soil subtypes are formed at a place of building and routine repairs of underground communications. The underlying mineral stratum is about 2 m thick and rests on the natural bedrock.

Urbostratified-humus soils I-RDur[h]: these soils are characterized by the clearly expressed bedding with inclusions of buried introduced humus layers. In St-Petersburg the gray-humus urbostratified-humus subtypes of these soils are identified in public gardens and parks in central part of town. The area of these soils among the asphalt covers occupies from 5 to 20% of the entire territory. They have been developed on anthropogenic stratified deposits – the “cultural” layer of 4 m in thickness. The simple component composition of these soils speaks about their origin. During several centuries the introduced humus horizon has been periodically overlaying by the layer consisted of building debris to be transformed into a new horizon that later was covered by the introduced material again, etc. Thus, the major part of soils in quarters of the “old town” is represented by introduced gray-humus urbostratified-humus soils.

Water-accumulative soils (aquazems) I-Daq: the underlying mineral stratum is homogeneous in composition and has fine bedding. In the coastal area the fluvial sediments are predominated, as a rule, they are stratified and like as alluvial deposits.

Besides the above subtypes so specific for the type of introduced soils it is feasible to identify the subtypes according to natural features, for instance, gley formation, carbonate content, ferrugination, etc.

In the WRB system it would be possible to have a new reference group including the introduced soils underlying by any mineral substratum.

The united classification scheme with inclusion of natural, human-transformed and proper anthropogenic soils permits to consider the diversity of soils and their spatial and temporary changes in the soil cover of any megalopolis or town.

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