Soil classifications: Their origin, the state-of-the-art and perspectives

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Abstract
The classification of soils originated from three main sources: from early empirical soil surveys, from folk soil classifications and from scientific theory of pedology. The first soil classifications reflected their origin in different extent, and still remain certain features of their initial sources. The actual situation in soil classification is discouraging, mainly due to the diversity of national soil classifications, extreme complexity of developed soil taxonomies and, as a result, to the loss of public interest in soil classification. Recently suggested roadmap to the Universal Soil Classification seems to be the main challenge in the recent history of soil classification.

Key Words
History of pedology, soil diagnostics, classification structure.

The origin of soil classification

People were managing soils for ages. Of course, from the very beginning of the agrarian civilization they noted that the soils are different (Yaalon 2008). This knowledge then was then used by the governors for evaluating land value and, consequently, the taxes. The earliest known soil classification system in the world can be find in an ancient Chinese book *Yugong* (2,500 y.b.p.), where soils of China were classified into three categories and nine classes based on soil color, texture and hydrologic features; the classification was used for land evaluation (Gong Zitong 1994). Ancient name for Egypt – *Kemet* means fertile black alluvial soils, while *Deshret* means red desert land. About 3,000 y.b.p. different arable soils had different cost in Egypt: "*nemhuna*" soils cost 3 times more than "*sheta-teni*" soils (Krupenikov 1981). This tradition continued in newer times. For example, in Russia a systematic survey of folk soil knowledge was started in the 16th century, when special books were created to evaluate soil resources of the state; these books were prepared by interviewing the peasants about the quality and productivity of their lands. These books mainly included short characteristics of soils, like *poor sandy soil*, *clayey stony soils, fat loams* etc. Later, in 19th century, the survey became more regular, and perennial data were published in a series of books "Materials on Statistics of Russia", where a number of local folk soil names for soils were listed. The materials were also used for preparing first soil maps of Russia, which, in fact, were based on ethnopedological survey.

Somewhat different approach existed in Western Europe and the United States in 18th – 19th centuries. Agronomic science developed independently from folk knowledge; farmers' perception was very conservative, while progressive agronomy could answer the challenges of growing population with new technologies and the use of fertilizers. Thus, the "progressive" scientific knowledge was somewhat opposed to "conservative" traditional knowledge. The soil was studied both in the field and in laboratories, and it was classified by *ad hoc* empirical parameters, such as texture, visible or measured organic matter percentage, and nutrients content. This agrogeological approach was soon extended from surface samples to a sequence of layers during seminal early soil surveys in the United States (Simonson 1989). However, these works lacked a scientific basis, a theory that explained the origin and distribution of soils. The methods and even terminology were borrowed from relative scientific disciplines, such as sedimentary geology and agronomy. The classification was not systematized; it was just a nominal list for individual groups of soils. In the US, the folk classification was not aggregated in the "scientific" taxonomy also because of the absence of the sources of indigenous knowledge: the native population has been displaces and generally not very interested in soil agriculture, and newcomers did not develop yet a system of soil knowledge.

In Russia, the development of soil classification was somewhat different. In 1883 Russian geologist presented his doctoral thesis "Russian Chernozem" (Dokuchaev 1967) that proposed a scientific theory of soil formation. The approach was not completely new: earlier a number of workers already suggested the

system of vertical soil horizons (Darwin to be noted as the most well-known scientists who used A/B/C/D sequence of soil horizons). Also Dokuchaev's theory on soil dependence on climate and other environmental factors repeated some ideas of earlier researchers, such as Lomonosov, Thaer and Hilgard. However, only after Dokuchaev's works a holistic theory was created, explaining the genesis and geographical distribution of soils. Thus, the first classification of Russian soils was based on the overall theory of soil genesis and soil geography. The influence of folk soil knowledge on Russian classification is often disregarded. The names of soil types were mainly borrowed from folk soil classifications: the words *chernozem*, *solod*, *solonetz*, *rhendzina* were used by Russian, Ukrainian and Polish peasants for ages. However, not only the words were accepted, but also the central concepts of soil units, the archetypes were included in the classification.

The existing scientific classifications developed from these three main sources: folk knowledge, empirical soil study and from scientific theory. Every soil classification has elements of indigenous concepts, empirically collected data and of scientifically-based grouping. It is expected that the combination of these three components should lead to harmony. Unfortunately, it just causes a kind of historical bias that complicates actual scientific classifications.

How we lost our way in broad daylight

Due to historical reasons, almost every school of pedology has its own classification. In fact, more than one natural soil classification can exist, i.e. there is no unique "true" classification to be discovered. The existence of numerous national soil classifications is a serious problem of perception of soil science by other specialists. To some extent it is related to the differences in soil cover in different countries that leads to distinguishing different archetypes as a basis for classification. Modern biology and geology originated in medieval time in Europe, and later was distributed all over the world in a "semi-mature" state. Soil science was distributed in a rudimentary state, and was often developed independently in different countries. Sokolov (1978) noted that the lack of a uniform classification resulted from the fact that soil science was relatively young and similar to an "infant disease" it would be overcome in the near future. Some researchers proposed the US Soil Taxonomy as a world classification; others hoped that the Soil Map of the World Legend by FAO-UNESCO (or, later, WRB) would replace national classifications. However, the period of the 90-th dashed these hopes. National schools did not try to integrate, but intensified activities to update and revise their classifications. In these years new versions of classifications were proposed in New Zealand (Hewitt, 1992), China (Gong Zitong 1994), Australia (Isbell 1996), Russia (Shishov *et al.* 1997), France (AFES 1998) and Brazil (EMBRAPA 1999). However, what resulted was the development of improved quantitative diagnostics to support the designation of units and their classification in hierarchical systems.

Apart of the variety of classifications there are a number of other problems that aroused with the progress of soil classifications, which are extreme complexity, costly and time-consuming diagnostics, and ambiguous, complex and confusing terminology. Each of the problems can be explained in its historical perspective. The complexity resulted from the need to compress soil data for mapping; every soil polygon had to represent as much information, as possible. In fact, developed soil classifications practically replaced soil names by brief soil descriptions. Every soil name was meaningful, and a complete soil name included practically all the soil characteristics important for pedologists. In parenthesis we should note that this information was often useless for practical users, because soil features important for agriculture, such as nutrients availability and hydrophysical characteristics, were usually variable and taxa-independent. The uncontrolled growth of information saturation of classifications resulted in their extreme complexity. Even the authors of soil classifications already cannot classify a soil without consulting their manuals. Is it what we wanted?

The extensive diagnostics needed for soil allocation in the taxonomic scheme is somewhat related to the complexity of classifications. Also it was logical continuation of a generally productive approach that declares that we should classify soils by the measurable attributes and not on the basis of our doubtful ideas on soil genesis. Initially the task seemed simple: we had to find soil properties that corresponded to certain central concepts of soils (archetypes). However, soon it was discovered that the properties that seemed to be the most evident for a certain group, are not unique and might be found in some other groups. It is useful to consider the concepts of divergence and convergence (Rozanov 1977). Divergence means that soils formed under similar conditions in different places commonly exhibit variable properties due to local factors. Convergence means that different pedogenic processes under different environmental conditions might lead to similar soil properties and morphology. For example, such processes as podzolization, clay eluviation and surface gleying generally lead to the formation of a bleached, clay depleted surface horizon. Thus, the

presence of a bleached surface horizon cannot be used as an only diagnostic criterion for soil classification. Less evident, every time more and more sophisticated criteria were proposed to delimitate soil groups. Nowadays a user of soil classification applies long and complex definitions for allocating soils in taxonomic groups even without clear understanding of the origin and significance of these criteria.

The terminology used in soil classifications may be divided into two groups: traditional (indigenous and common folk terms) and artificial terms. The principle of including folk soil names (*podzol*, *chernozem*, *gley* etc.), as well as stylized terms (*krasnozem*, *burozem*) in scientific classifications was used by Dokuchaev and his followers. Dokuchaev did not collect these terms himself rather he used soil names from existing publications such as the "Statistic Materials of Russia" which contained numerous folk names for soils. He understood that folk names could not be converted directly into scientific terms (Krasilnikov 1999) but should be determined more strictly because in folk tradition different soils could be grouped under the same name, or the same soil was named differently in other localities. As a result, scientific terms, which have originated from folk terminology, often differ significantly in their meaning from the original concept. The other option for constructing scientific soil terminology was to apply completely new artificial names. It was first proposed by Guy Smith (Banfield 1984) while preparing the 7th Approximation, a new American soil classification system. Guy Smith considered that old traditional soil names were confusing, and with the help of philologists developed a completely new system of soil terminology; a wide group of philologists participated in the development of soil nomenclature that was mnemonic (Heller 1963). In addition, the levels in the taxonomy are recognizable by the number of syllables of the base words and the "ic" ending of modifiers. The idea was brilliant and could work very well if the system remained the only artificial nomenclature. Unfortunately soon a number of "clones" of the US classification terminology appeared, and now some of the artificial terms cause almost the same confusion as traditional ones. For example, the name Histosols is used both in the US Soil Taxonomy and in the classifications of Cuba, China and in World Reference Base; the problem is that the definitions and diagnostic criteria for this group vary in different classifications. Attempts to avoid confusion by modifying slightly the names, like in Australian classification (Isbell 1996) (*Vertosols* instead of *Vertisols*, *Podosols* instead of *Spodosols*) only increased the chaos. Some modified terms, once used in one national classification, were then introduced independently in the other classifications, also with different definitions. The same term *Vertosols* used in Australian soil classification was also used in Chinese and Romanian taxonomies. Actually there are more than 3,000 soil names only on the highest levels of world soil taxonomy, most of them absolutely inexplicable for non-specialists.

Out of the dead end

The crisis of soil classification resulted in serious doubts of the perspectives of soil classification at all. Currently soil classification has moved from the nucleus to the margin of the attention of soil science community as environmental issues of terrestrial ecosystems have gained prominence. In the last decades developments in digital mapping now facilitate combining various information layers, somewhat replacing traditional soil classification based maps. Even in soil genesis and soil geography studies researchers commonly speak in terms of pedogenetic processes and particular soil characteristics rather than the use of formal soil names. For many purposes mathematical ad-hoc classifications work better than more general basic classifications. Does it mean that we should leave soil classification behind?

To answer this question we should remember the functions of classification in natural sciences in general and in soil science in particular. These functions are: arrangement of our knowledge about the Universe, development of common language for the communication among the specialists, presentation of soil information in a compact form (e.g. for mapping) and simplification of education. The development of technology produced novel methods of visualization of soil information. The GIS-based soil maps include several layers with soil properties, important for the users, instead of extensive soil names, which need explanation. Definitely the use of digital soil maps is a big challenge in soil geography that reduces the importance of classification for practical soil mapping. However, the other functions of soil classification cannot be replaced by high technology. Soil classification is a mirror of our knowledge about the soil, and the structure of soil classification depends on our current system of concepts and ideas about soil genesis, geography and functioning. Then, the communication among the scientific community requires common language. We use names in our everyday activity, and we need them in science. To a great extent the existence of specific terminology determines the identity of science. Without soil classification all the pedology may be reduced to chemistry, physics and biology. Finally, the education on any level requires simple systems of presentation of information. If we teach the students on the basis of independence of soil

properties, they would be easily confused and lost in the chaos of soils. Classification permits simple and structured explanation of soil phenomena.

However, the present situation is very unfortunate. We believe that a Universal Soil Classification System should be accepted. Soil classification harmonization and, finally, acceptance of a uniform classification is a priority task in pedology. The main features of the future soil classification should be its simplicity, flexibility, universality, clear terminology and functionality. It should have options both for expert and expert-independent diagnostics and a convenient structure for databases and GIS.

There are a number of obstacles, both objective and subjective, on the way to the Universal Soil Classification. The clog of traditions and habits is very strong. Most people honestly believe that their classification system is the best just because they are used to it from studentship. The possible option is introducing the Universal Soil Classification in university programs as a parallel system. Also certain ambitions of national schools of pedology exist. Most people believe, may be correctly, that they know their local soils much better than external specialists. The only way to overcome this problem is wide international cooperation, something like that existed when the FAO map was prepared. One of the strongest arguments against the acceptance of uniform soil taxonomy was that the change of classification would make obsolete all the existing soil maps made with older national systems. However, an introduction of a new national classification system, usually quite different from the older one, would lead to the same problem. We propose developing a long-term road map for the Universal Soil Classification: we should avoid claiming that the national schools of pedology should immediately change their classifications. The best way is using a natural change of old outdated systems that occurs every 20-25 years. We should propose accepting a universal system instead developing a new national classification.

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