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The Soil Classification course in Russian universities: an important ingredient of education

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Abstract. The teaching of soil classification in the universities of Russia is being discussed as a comparatively new experience in the education of environmental science students. The lecture course (24–30 academic hours) changes in response to the inevitable changes in soil classification systems. In the introduction, the objectives and structure of soil classifications are outlined, and then a brief overview of the most well-known national systems is given, which is also important for understanding the difficulties, origin and problems of the International WRB system. The latter is the central point of the lecture course: its principles are explained, the main diagnostic features of Reference Soil Groups are communicated, and students are trained to use system basing on the descriptions of soil profiles and analytical data relating to them. As a result, students give WRB names to soils either by correlating with a name from the national system, which is familiar to them, or by looking at soil profile photos; in both cases morphological and analytical data are clarified by the teacher. Chernozem is used as an example for training. In the conclusion, the reasons to know soil classifications are specified, and they are differentiated for soil scientists, geochemists and geographers.

Key words:
teaching soil classification, national and international systems, Chernozems, students specialisation, potential users of classification

Introduction

Studying soil classification as a special discipline is essential now in the university education system for training soil science, geography, agronomy and environmental sciences students. Classification of soils, as any classification system, is a mirror showing the development of science at the time the system was created. Two famous aphorisms are worth recalling at this point. The first, "Show me your classification system, and I shall tell you how advanced is your science" was said by Walter von Kubiëna – outstanding scientist, the "father" of micromorphology (1938), and author of an original soil classification that may be regarded as a predecessor of the German classification system. The famous Guy Smith, who initiated the American Soil Taxonomy in the 1950s said that "You must remember that a classification is a creation of man and is a reflection of the state of knowledge at that time and the uses that were intended at that time." Moreover, in this phrase, the targeted aspect of soil classification may be recognised.

At present, in the time when global international soil classifications appear, the national systems tend to correlate with them. Therefore, knowledge becomes required in many fields of pedology and environmental science for an adequate understanding of the locations of study objects both in the region of a particular study, and globally; in other words, soil classification is required for harmonisation of data, both experimental data and those used in conducting surveys and compiling maps. One recent example of the international positioning of soil classifications is the proposal to consider WRB soil names in the same way as the Latin names of animal and plant species in the Linnaean system.

The purpose of this paper is to share the experience we gained while teaching this innovative course. Emphasis is put on the WRB and its correlation with the new Russian system.

Teaching soil classification in several universities in Russia

We shall discuss the official position of the block of knowledge concerning soil classification: as a special lecture course, or as part of any other courses in the academic plans of three universities. Another aspect is the structure of the course and the information given to students.

History and official status of the lecture course. In the USSR, the discipline of Soil Classification was introduced into academic plans for soil science students in the mid-1980s as a special lecture course. Such courses were supervised by methodological commissions and/or faculties' academic councils, and the course names, programmes, durations and schedules therefore varied between universities. However, they were introduced in several universities. Another way to acquaint students with soil classification systems was to include appropriate sections into other academic courses. For example, in Moscow Lomonosov State University, there is a special lecture course entitled "Systematics and classification of soils" at the Faculty of Soil Science; at the Faculty of Geography, information on soil classification was presented in the courses "Methods of soil-geochemical research" and "Soils of the World"; in Leningrad State University, the special course was named "Current problems of soil systematic and classification" (Fedorova, Schastnaya 2006); and in Rostov-on-Don Southern Federal University (since 1988) it is simply "Soil classification". Two institutions – Rostov-on-Don and Moscow University, Faculty of Soil Science – have each published *manuals* for this lecture course (Dobrovolskiy, Trofimov 1996; Bezuglova 2009). In recent years, with the adoption of the two-level high school system, the situation remained the same for Bachelors, while future Masters must now listen to a course of lectures on national and authorial classification systems, and the international one – WRB – in particular. Thus, lectures on soil classification have now become an indispensable element of education for students specialising in soil science and environmental sciences.

The contents and most important sections in the lecture course: These are discussed with the example of Moscow Lomonosov University, faculties of Geography and Soil Science; the lecture courses mostly coincide.

The introduction to the course comprises information on the types of soil classification in terms of their hierarchy, authors or status, and purposes; according to the latter approach, systems may be divided into "basic" and "applied" ones. The importance and universal character of basic systems is emphasised, as well as the possibility for diverse applications. Interpretation of separate aspects of a basic system gives birth to particular systems, where soils are grouped in accordance with their properties and/or potential uses, such as organic carbon content and/or reserves, soil acidity, base saturation, redox conditions, texture, density classes, etc. As for applied purposes, they may be agricultural, ecological, ameliorative, or many others. Such soil groupings may be derived either from a comprehensive knowledge of soil classes in the systems, or from the factual data that should be categorised taking into account the appropriate taxonomic units.

This part of the course ends with a "game". Each student, or small team, receives a list of soils (20 to 25), whose taxonomic position presumes 3 (sometimes 4 or 5) soil properties, and these soils should be grouped in several ways at 2 or 3 taxonomic levels. The first grouping corresponds to a basic soil classification – genetic or ecological-genetic; the other groupings should be targeted at some applied issues, such as: suitability for a certain crop; ease of plowing, i.e. fuel consumption depending on texture; (im)mobilisation of pollutants, e.g. heavy metals; or erosion hazard. Soils may also be categorised by their properties, such as organic carbon reserves, texture, secondary carbonates, manifestations of cryogenic features, and so on. The tested assemblages of soils may comprise either low taxa of a soil type (Table 1), or several high-taxa units with contrasting properties. It is supposed that students already have enough knowledge about the soils that should be grouped.

The next section of the lecture course deals with the basic national systems. It is preceded by brief information on particular features of the most popular scientific schools in soil science inherent to the countries whose classification systems will be discussed, namely, USSR/Russia, France, Germany, USA, Canada and China. For example, in the French school soil evolution is emphasised, and this is implemented in the sequence of profile types (AC-A(B)C-ABC, etc.) as one of the milestones in the former classification of G. Aubert and Ph. Duchaufour (1967). Complementary to the evolutionary approach, A. Ruellan's idea of "couvertures pédologiques" explains the interest in soil horizons and their spatial patterns; hence, genetic-diagnostic horizons are numerous and related to the environment in recent system (Référentiel Pédologique 1995). German pedologists were particularly interested in hydrological regimes and parent materials and the former is illustrated by introduction of Pseudogleys, Stagnogleys and Hanggleys into soil nomenclature, and the classes of "Semisubhydrische und Subhydrische" soils into the national system (Grundsätze et al. 2005).

Pedogenetic traditions were always very strong in our country, as well as the approach to soil-forming agents, and zonality was the dominant conceptual background for any kinds of activities related to soils. That is why the early Russian systems, and the official one of 1977 in particular, displayed a strong bias to the factors of climate and biota. In the recent system – soil classification of Russia, versions 2004 and 2008 – there is a clear shift to soil properties as differentiating criteria, and the system is termed "substantive-genetic".

A short final control test is proposed: several soil names are mentioned, and students have to guess to which national school these names belong. Example are taken from old systems and given in English translation (deliberately without capitalising): ranker, meadow solonetz, yellow-red tropical soil, rendzina, calcimorphic soils, alfisols, aridisols, gray-brown podzolic, sol lessive, pseudogley, soddy-podzolic, pelosol, braunerde, reductosol, meadow-boggy soil, podzol, grey forest soil, and so on.

The most important and voluminous part of the lecture course concerns the characterisation of basic classification systems – the WRB primarily (IUSS Working Group WRB 2014), and the national ones; some authorial classifications may also be included. The information communicated by the lecturer for

Table 1. Test on grouping chernozems according to objectives (type) of classification

Chernozems to be grouped	
1. Chernozems leached medium-humus L	12. Chernozems Trans-Baikalian low-humus LS
2. Chernozems typical medium-humus L	13. Agrochernozems typical medium-humus L
3. Chernozems leached low-humus L	14. Chernozems southern medium-humus L
4. Chernozems typical medium-humus CL	15. Chernozems Pre-Caucasian low-humus CL
5. Chernozems Moldavian low-humus L	16. Chernozems southern low-humus LS
6. Agrochernozems leached low-humus SL	17. Chernozems podzolised high-humus CL
7. Urbochernozems leached low-humus L	18. Chernozems ordinary medium-humus L
8. Chernozems Ukrainian medium-humus L	19. Chernozems ordinary low-humus SL
9. Chernozems podzolised medium-humus L	20. Urbochernozems ordinary L
10. Chernozems podzolised gleyic L	21. Agrochernozems ordinary medium-humus L
11. Chernozems typical very high-humus CL	22. Chernozems leached high-humus CL

Conventions for texture classes: L – loam, SL – sandy loam, LS – loamy sand, CL – clay loam. Note: the geographic names of chernozem subtypes include both soil regimes and profile features. Objectives: 1) basic; 2) applied to various uses: fertility classes, erosion hazard, resilience to pollution, etc.

each system is arranged in the following scheme (obligatory and *optional items):

- objects to be classified and *definition of soil;
- principles of the system and *history of its development;
- taxonomic structure – number of levels, with criteria for each;
- diagnostic tools (if any) – horizons, properties, materials; *their designations;
- rules to construct the soil name, *sequence of formative elements or qualifiers.

The information about classification systems is given by the lecturer and illustrated by examples. They are followed by tests – naming a soil in each system – and may be implemented in two ways (Photographs of soil pits are very desirable):

1. Full name. This is time-consuming and should result in the soil name up to the low taxonomic level, or containing maximum information on the soil. To produce a full name, the student receives data on a soil profile: environment; morphology, including arbitrary subdivision into horizons; and analytical data – pH, Corg, content of carbonates/gypsum/soluble salts.
2. Short name. A simpler and less time-consuming test, which results in naming the soil at a rather high taxonomic level based on the following information: environmental conditions, including the location of the profile; landscape; parent material; landform; plant community; and genetic horizons and properties. In this case, knowledge of soil geography is helpful.

Examples of two types of names in the WRB system: (1) Dystric Folic Glossic Stagnic Albic Retisol (Loamic, Cutanic, Differentic, Novic); (2) Stagnic Albic Retisol (Loamic).

Correlation between systems: this is a very difficult task, and the results may be ambiguous. Moreover, different principles of classification make the result uncertain. Correlation may be based on pedogenetic concepts taking into account soil-forming agents and looking for "central images". This approach is more suitable for high-level taxa. Using soil properties (primarily diagnostic horizons) it may be possible to correlate soils at lower levels, although the definition of horizons and their quantitative boundaries frequently do not coincide. It is most reliable to perform the correlation procedure in the system correlated in the field at the soil pit, and this is the way the WRB was created. Sometimes, it may be helpful to overlay soil units on maps compiled in different systems. Presumably, the majority of correlations made apply the pedogenetic approach. As an example, a rather simple case of naming chernozems in four systems is given (Table 2), which illustrates the difference in classification principles and nomenclature.

Objectives for studying soil classification

Overall objectives for students. Any science tends to systematise its study objects. Grouping or categorising objects contributes to a better understanding of their essence and the bonds between them, and to summarising the knowledge accumulated. The latter point is of special significance for students, because when studying soil classifications the student has to activate the information received earlier in other subjects, such as chemistry or physics. Understanding the place that soil systems and soil properties have in the landscape and taxonomic position minimises formal memorisation of the huge volume of facts a student receives. As a consequence, the arrangement of data on soils in classification systems makes it easier to access computer databases and work in search systems.

Particular objectives for students: why do soil scientists, geographers (physical geography, landscape science), and ecologists need soil classification?

Future soil scientists should be interested in working with various soil classifications more than any other students, because soil is their immediate professional matter. They need this knowledge to participate in international workshops, joint research programmes, training courses and scientific schools for young specialists, and to adequately understand the publications of colleagues from other countries. Presumably, properties-oriented systems are preferable for soil science students. Basing on the information on soils they have already received, it is easy for them to apply such systems. Properties-oriented systems are more suitable for experimental research: the programme of experiments

Table 2. Naming chernozems in different classification systems

Local classification	Classification and Diagnostics of Soils of the USSR,1977	Classification and Diagnostics of Soils of Russia, 2004	WRB, 2014/2015
Chernozem ordinary	Chernozem ordinary	Chernozem segregationary	Haplic Chernozem
Chernozem southern	Chernozem southern	Chernozem texturally-carbonate	Chernozem (Tonguic)
Chernozem-like sandy and loamy sandy soil (seropeski)	Chernozem southern weakly differentiated	Excluded from chernozems	Arenosols (Humic) or Chernozem (Arenic)
Chernozem of north-Azov province	Chernozem ordinary carbonate	Chernozem migrational-segregationary	Chernozem (Pachic)
Chernozem of Pre-Caucasus province	Chernozem ordinary carbonate	Chernozem migrational-segregationary	Chernozem (Pachic)
Chernozem primitive	Chernozem under-developed	Chernozem texturally-carbonate shallow, low-humus	Skeletic Chernozem or Mollic Leptosol
Chernozem of terrace	Chernozem ordinary and southern residual-meadow	Chernozem quasigleyic	Gleyic Chernozem (Oxyaquic)

may be coordinated with the characteristics of diagnostic horizons and properties, and the results (as well as deviations from those expected) may be explained by these characteristics. When revealing and analyzing soil-forming processes, i.e. soil genesis, the properties-oriented approach permits indications to be found (among the criteria of diagnostic tools) that prove the occurrence of certain processes, because processes and properties are closely interrelated. Finally, properties-oriented systems offer more possibilities for a maximally complete soil name: thus, in the Russian system several qualifiers (process-based adjectives) may be used to indicate the diversity of properties, and the taxonomic unit is "a complex subtype". The same approach is used in WRB by combinations of qualifiers: 188 for 32 Reference Soil Groups. However, traditional "hand-made" soil maps or computer maps are compiled by overlaying spatial data on soil-forming factors using factor-genetic soil classification systems.

Soil maps always served as major sources of information for the assessment of soil resources. Calculating areas occupied by "these or those" soils was the first step in this sphere, and this has been done more than once for the world as a whole, and for countries, administrative divisions, etc. It is quite obvious that the results – i.e., areas occupied by soils differing in quality – strongly depended on the perception of soil units, which is to say, on the principles of soil classification and differentiating criteria. For example, according to *Atlas…* (ISSS Working Group RB 1998) the most widespread soils in the world are Leptosols, which are identified by the occurrence of hard rock at a depth of 25 cm; if this limit is shifted downwards, for example, to 30–35 cm, Leptosol areas will strongly increase. Moreover, including soil properties in classification systems facilitates compilation of particular or applied maps, like those in the "Global Soil Map project", as well as maps of soil functions or soil services, which are important and novel items in the soil resources inventory (FAO and ITPS 2015).

Objectives for students of physical geography and landscape science. Specialists in physical geography and landscape science in Russia are accustomed to the old factor-genetic system of 1977. On one hand, the old system is a better fit for compiling and using small-scale maps, which mostly have the zonal framework; such are all the maps of soil-geographic regionalisation of the country, including the recent one. Still more vital is this preference for soil maps in national atlases or complex atlases of large areas, because one of their principles is the correspondence between "natural" maps – vegetation, soils, Quaternary deposits, geology, etc. In some atlases, soil names are supplemented with landscape names, e.g. "red soils of savanna", "brown soils of Mediterranean subtropics" (Physico-geographical World Atlas 1964), or legends of soil maps are arranged in accordance with zones (map of Russian Federation, 1:2,500,000). On the other hand, large-scale surveys in landscape science include soils as an obligatory ingredient of their elementary spatial units – facies. Each facies must be individual in terms of landform, substrate, plant community, erosion/accumulation processes and soil unit. With the properties-oriented classification system, it is easier to differentiate the soils within facies by soil properties, whereas looking for interrelations between soil properties and environment requires reference to factor-genetic systems. Factor-genetic systems have less potential for accounting for the results of human impacts on soils, whereas properties-oriented systems have the appropriate nomenclature and criteria for anthropogenically modified soils. Thus, this group of studies requires general knowledge of both types of classification systems.

Objectives for ecologists. Response reactions and resilience of soils to anthropogenic impacts are milestones for ecologists assessing human effects on the environment and providing various specialised expertises. Most commonly they are concerned with pollution of soils and waters by heavy metals, hydrocarbons, organic municipal wastes, products of mining industry, etc. To forecast and/or minimise the harmful effects of these and other toxicants, they need to know soil properties, and they can find them in properties-oriented systems. The following information on soils may be expedient for them. When sampling topsoils, it is reasonable to know which are the diagnostic horizons with their blocks of properties sampled, how far the results of analyses may be extrapolated, whether the samples taken are typical of the study area, and which geochemical migration/accumulation processes cause the removal or accumulation of toxicants in soils.

Thus, teaching soil classification is important for students specialising in soil science, geochemistry, physical geography, ecology, and the volume of information is dictated by both their academic background and purposes in using soil classification.

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