UDK 631.47

O. Spaargaren

WORLD REFERENCE BASE FOR SOIL RESOURCES – ITS PRINCIPLES OF CLASSIFICATION AND POTENTIAL FOR CORRELATION

ISRIC – World Soil Information, the Netherlands

The World Reference Base for Soil Resources (WRB) is an international system for soil classification and correlation, recommended by the International Union of Soil Sciences. It has evolved from the Revised Legend of the Soil Map of the World, produced by FAO, and has been tested world-wide. Currently it is successfully applied as common language in the European Union, in regional and continental soil databases such as the Soil and Terrain (SOTER) databases for Latin America, Southern and Central Africa, and in many peer-reviewed journals of soil science.
Key words: WRB, correlation, principles of classification.

О. Спааргарен

ISRIC – Світовий ґрунтовий інформаційний центр, Нідерланди
СВІТОВА РЕФЕРАТИВНА БАЗА ҐРУНТОВИХ РЕСУРСІВ - ПРИНЦИПИ КЛАСИФІКАЦІЇ Й ПОТЕНЦІАЛ ДЛЯ КОРЕЛЯЦІЇ

Світова реферативна база ґрунтових ресурсів (WRB) є міжнародною системою для класифікації ґрунтів і кореляції, яка рекомендується Міжнародним товариством ґрунтознавства. Вона розвинулася на основі переглянутої легенди ґрунтової карти світу, створеної ФАО, і була перевірена в усьому світі. У наш час вона успішно застосовується як універсальна наукова мова в Європейському союзі, у регіональних і континентальних ґрунтових базах даних, таких як Ґрунт і Ландшафт (SOTER), база даних для Латинської Америки, Південної й Центральної Африки і в багатьох журналах з ґрунтознавства.
Ключові слова: WRB, кореляція, принципи класифікації.

The World Reference Base for Soil Resources (WRB) is an international effort to derive at a common language in classifying and correlating soils world-wide. It started in 1980 as International Reference Base for Soil Classification (IRB) during a meeting held in Sofia, Bulgaria. The initiative came from the United Nations Environmental Programme (UNEP), the Food and Agricultural Organization of the United Nations (FAO), and the International Soil Science Society (ISSS, now the International Union of Soil Sciences). In 1982 the IRB became a Working Group in the ISSS; it became the WG on WRB in 1992.

WRB has adopted the terminology as developed for the Legend and Revised Legend of the Soil Map of the World (FAO-UNESCO, 1974; FAO-UNESCO-ISRIC, 1990). Soil names are similar, although the precise definitions may have changed slightly. It uses diagnostic characteristics (diagnostic horizons, properties and materials) to identify soils; these characteristics are precisely defined and are similar or almost similar to those used in other major soil classification systems such as the US Soil Taxonomy. Where diagnostic definitions deviated largely, new names have been introduced to avoid confusion.

Over the years, the WRB Working Group has issued several editions. It started off with the draft World Reference Base for Soil Resources (ISSS-ISRIC-FAO, 1994), which was based on contributions of many soil scientists from all over the world. The format still followed largely that of the FAO Revised Legend, with soil units and subunits. Testing, both in the field and in journal articles showed that there was a great demand to introduce more subdivisions to suit local conditions; if that approach would have been followed, the system would have become unmanageable.

Consequently, the soil unit/subunit approach was abandoned and replaced by a system based on Reference Soil Groups (RSGs) and qualifiers (ISSS-ISRIC-FAO, 1998). This system had the advantage that the RSGs largely coincided with the major soils in the FAO Revised Legend and that qualifiers could be defined uniquely. This was a major deviation

---

from the Revised Legend in which some soil unit names combine different diagnostic criteria into one adjective. An example is the Mollic Gleysol, which can have a mollic A horizon or a eutric H horizon.

The 1998 WRB was widely tested in the field during tours in Argentine, China, Georgia, Germany, Ghana, Iceland, Italy, Kenya, Mexico, Namibia, Russia, South Africa, Tanzania and Vietnam. Advantages and disadvantages, correlations with other systems of soil classification, and proposals for revision were published in a number of journal articles (Krogh, Greve, 1999; Bockheim, Gennadiyev, 2000; Takahashi, Nanzyo, Shoji, 2004; Chabra, 2005; Nachtergaele, 2005). The publication has been translated in a number of languages (French, Georgian, Japanese, Latvian, Norwegian, Polish, Spanish and Vietnamese). A student edition with CD-ROM was prepared in 2001 for use in soil science education.

The testing, proposals, and additional incoming data have resulted in a substantial revision of WRB in 2006 (IUSS Working Group WRB, 2006). First of all, the object classified in WRB was modified to the extent that WRB classifies «any material within 2 m from the Earth's surface that is in contact with the atmosphere, with the exclusion of living organisms, areas with continuous ice not covered by other material, and water bodies deeper than 2 m». Secondly, definitions of the diagnostic criteria were brought in line with the US Soil Taxonomy. Where major deviations remained, new names were coined. Thirdly, two new reference soil groups were added, viz. Stagnosols and Technosols. Finally, the qualifier level was split into two groups, prefixes and suffixes, to better structure the final soil name.

The structure of WRB and its principles of classification

1. Structure of the World Reference Base for Soil Resources

The World Reference Base for Soil Resources comprises 32 Reference Soil Groups (RSG). Each RSG has its own set of diagnostic criteria (combinations of diagnostic horizons, properties and/or materials) that permits the identification of the RSG. To ease the identification, the RSGs are brought together in a structured Key (*Table*).

Rationalized Key to the WRB Reference Soil Groups

1. Soils with thick organic layers: HISTOSOLS

2. Soils with strong human influence
   Soils with long and intensive agricultural use: ANTHROSOLS
   Soils containing many artefacts: TECHNOSOLS

3. Soils with limited rooting due to shallow permafrost or stoniness
   Ice-affected soils: CRYOSOLS
   Shallow or extremely gravely soils: LEPTOSOLS

4. Soils influenced by water
   Alternating wet-dry conditions, rich in swelling clays: VERTISOLS
   Floodplains, tidal marshes: FLUVISOLS
   Alkaline soils: SOLONETZ
   Salt enrichment upon evapo(transpi)ration: SOLONCHAKS
   Groundwater affected soils: GLEYSOLS

5. Soils set by iron/aluminium chemistry
   Allophanes or Al-humus-complexes: ANDOSOLS
   Cheluviation and chilluviation: PODZOLS
   Accumulation of Fe under hydromorphic conditions: PLINTHOSOLS
   Low activity clay, P-fixation, well structured: NITISOLS
   Dominance of kaolinite and sesquioxides: FERRALSOLS

6. Soils with stagnating water
    Abrupt textural discontinuity: PLANOSOLS
    Structural or moderate textural discontinuity: STAGNOSOLS

7. Accumulation of organic matter, high base status
    Typically mollic: CHERNOZEMS
    Transitional to drier climate: KASTANOZEMS
    Transitional to more humid climate: PHAEOZEMS

8. Accumulation of less soluble salts or non-saline substances
    Gypsum: GYPSISOLS
    Silica: DURISOLS
    Lime: CALCISOLS

9. Soils with a clay-enriched subsoil
    Albeluvic tonguing:ALBELUVISOLS
    High activity clay, low base status: ALISOLS
    Low activity clay, low base status: ACRISOLS
    High activity clay, high base status: LUVISOLS
    Low activity clay, high base status: LIXISOLS

10. Relatively young soils or soils with little or no profile development
    With acid dark topsoils: UMBRISOLS
    Sandy soils: ARENOSOLS
    Moderately developed soils: CAMBISOLS
    Soils with no significant profile development: REGOSOLS

Going through the Key and checking the diagnostics, one stops where the first (set of) criteria apply. To give an example, a soil has a high clay content, cracks when drying out, and has a layer within 100 cm from the surface that over a thickness of 25 cm has slicken-sides and wedge-shaped structural aggregates with a longitudinal axis tilted between 10° and 60° from the horizontal. This soil keys out as Vertisol, no matter what other types of soil come after in the Key.

Once a RSG is found, the classification continues with the identification of applicable qualifiers. In 2006 these have been split in prefix and suffix qualifiers. Prefix qualifiers comprise those that are typically associated with the RSG and the intergrades to other RSGs. All other qualifiers are grouped together as suffix.

The sequencing of the prefix qualifiers follows the rule that first the typically associated ones are listed, followed by the intergrade qualifiers in the order of the Key. Suffix qualifiers are listed as follows: (1) qualifiers related to diagnostic horizons, properties or materials, (2) qualifiers related to chemical characteristics, (3) qualifiers related to physical characteristics, (4) qualifiers related to mineralogical characteristics, (5) qualifiers related to surface characteristics, (6) qualifiers related to textural characteristics, including coarse fragments, (7) qualifiers related to colour, and (8) remaining qualifiers.

Prefix qualifiers are always put before the RSG; suffix qualifiers are always given between brackets behind the RSG. Combinations of qualifiers that indicate a similar status or that duplicate each other are not permitted, e.g. Calcaric (presence of free carbonates) and Eutric (high base status).

Unique in the system of classification according to WRB is the possibility to use specifiers with the qualifiers. They indicate the degree of expression (e.g. Hypo-: weak; Hyper-: extreme) or the depth of occurrence (e.g. Epi-: between 0 and 50 cm depth; Endo-: between 50 and 100 cm depth).

2. Principles of classification in the World Reference Base for Soil Resources

Two basic principles govern the classification of soils in WRB:
1. The relationship between the soils and their dominant soil-forming processes;
2. The relevance of recognized soil properties to use and management of the soils.

The dominant soil-forming processes are recognized in WRB mainly at reference soil group level, also called the Reference Base. Clay translocation, a dominant soil-forming process in many regions in the world, is the common basis for recognition of five RSGs: **Luvisols**, **Alisols**, **Lixisols**, **Acrisols** and **Albeluvisols**. Discrimination between the groups depends further on their environmental setting: Luvisols and Alisols mainly in the temperate regions; Lixisols and Acrisols mainly in (sub-)tropical regions; Albeluvisols mainly in former peri-glacial regions.

Significant accumulation of organic matter is the common basis for five reference soil groups: **Histosols**, **Chernozems**, **Kastanozems**, **Phaeozems** and **Umbrisols**. Here the leaching (or hydrological) regime divides the five groups: Histosols as poorly drained members, accumulating organic debris without significant mineralization; Chernozems, Kastanozems and Phaeozems as well-drained members under non- or only slightly leaching conditions and strong mineralization and homogenization; Umbrisols as well-drained members under strong leaching conditions and strong mineralization and homogenization.

The result of this approach is that many soil reference groups in WRB reflect broad soil geographical regions in the world and more or less follow the classical principle of zonality.

The other basic principle, the relevance of recognized soil properties to use and management of the soils, is found back both at the RSG level as in further subdivisions, the qualifier level. For example, **Arenosols**, sandy soils with important regional relevance, are recognized at RSG level because of their low water-holding capacity and therefore their low productivity. Yet these soils are much sought after by farmers because of their easiness to cultivate. Recognizing these soils at the highest level is thus important in the light of food security issues, especially in the developing world.

Most qualifiers have a direct relation to use and management. A few examples: **Chromic** – reddish in colour – indicates high structural stability, good drainage and low vulnerability to degradation; **Siltic** – high content in silt-sized particles – stands for high vulnerability to degradation (particularly erosion and compaction); **Dystric** – low base saturation – indicates necessity for fertilization; **Petric** – an indurated layer – defines rooting restrictions.

The two basis principles have been translated, as far as possible, into diagnostic characteristics (diagnostic horizons, properties and materials) to serve as tool for recognizing the different soils.

Diagnostic characteristics are (a combination of) individual soil properties that have reached a certain degree of expression and that can easily be established either in the field or by laboratory analyses.

The combination of considerable accumulation of well-mineralized organic matter, resulting in good soil structure and dark colours, defines the mollic horizon which is supposed to be related to grass vegetation in under steppe-type climates. The mollic horizon thus forms the basis for recognizing Chernozems, Kastanozems and Phaeozems, the most common soils under these conditions. Ferralic horizons are supposed to be the result of long and extreme weathering, resulting in (almost) complete removal of all elements except those that are relatively immobile (Fe, Al). They identify the Ferralsols in the tropical regions. Prolonged wetness in soils leads to anaerobic conditions and a reducing regime. In such a regime, iron is mobilized and redistributed, leading to mottling when oxidized again. Thus gleyic (oxidation mottles along pores or on ped faces, reduction colours in the soil matrix) or stagnic (reduction mottles along pores or on ped faces, oxidation colours in the soil matrix) colour patterns develop. These properties are used to identify Gleysols and Stagnosols. Additions of fresh alluvial, lacustrine or marine deposits results in stratification and, often, an organic matter content that decreases irregularly with depth because of intervals in the sedimentation process. This defines the diagnostic fluvic material and the Fluvisols.

Potential for correlation

Correlation requires good knowledge of the systems used, comparable definitions and insight, and the availability of sufficient relevant data. To correlate national systems to WRB it is needed that the various diagnostics and classes can be determined. Here lies a major problem with Eastern European countries.

For texture WRB uses the standard ISO classes: 2–1.25 mm very coarse sand, 1.25–0.63 mm coarse sand, 0.63–0.2 mm medium sand, 0.2–0.125 mm fine sand, 0.125–0.063 mm very fine sand, 0.063–0.02 mm coarse silt, 0.02–0.002 mm fine silt, and <0.002 mm clay. As texture is widely used in establishing the classes, e.g. Vertisols must have 30 % clay above the vertic horizon (which also requires 30 % or more clay), Arenosols must have a weighted average texture of loamy sand or coarser in the upper meter, argic horizons are defined on a percentage increase in clay content, a cambic horizon must have a texture in the fine earth fraction of very fine sand, loamy very fine sand or finer, these basic data need to be known.

Particle size classes in many Eastern European countries are conform the Russian system: 1–0.5 mm coarse sand, 0.5–0.25 mm medium sand, 0.25–0.05 mm fine sand, 0.05–0.01 mm coarse silt, 0.01–0.005 mm medium silt, 0.005–0.001 mm fine silt, and <0.001 mm clay. Not only is the fine earth fraction itself different (<2 mm in ISO, <1 mm in the Russian system) but also the subdivision is incomparable.

Attempts have been made in the past to overcome these problems in correlation (Stolbovoi, 2000; Batjes, 2000) but without success. An additional problem lies in what is considered as fine earth fraction. This part of the soil is used for other analyses as well (e.g. cation exchange characteristics, pH, soluble salts, calcium carbonate content). Although one may state that the contribution of the fraction 2–1 mm in the soil to the cation exchange characteristics is negligible, and therefore the figures according the Russian system can be used to correlate to WRB, this is not the case with soluble salts and calcium carbonate content. As these latter two are important characteristics of many soils in Eastern Europe, additional problems in correlation arise.

The World Reference Base for Soil Resources is as much as possible built up on easily verifiable field characteristics; in fact it is often possible, with some experience, to classify the soil quite precisely in the field. Then correlation between WRB and other systems is quite feasible.

Another difficult issue is correlation in mapping. Soil maps give, by definition, a generalized picture of the soil distribution. When classifying soil profiles, the current WRB is capable of indicating most of the soil's properties some way or another, and in most cases the result is a quite satisfactory and informative soil name. However, when generalization is required, important information may not show, depending on how the generalization is carried out.

WRB recommends that for small-scale maps (world, continental or regional) only the prefix level is used, and at larger scale one or two additional suffixes would be used to stratify the soil units. If this approach is taken, important information on certain soil characteristics may not be revealed. Some examples: WRB 2006 recognizes acid sulphate soils only at suffix level (Thionic), and on small-scale maps they would then be shown as Haplic Histosols, Fluvisols and Gleysols. Similarly, Chromic Luvisols – important Mediterranean soils – will most likely become Cutanic Luvisols on small-scale maps, thereby loosing the difference between the Central European Luvisols and the Mediterranean ones.

CONCLUSION

WRB with its in-built soil geography component is well-suited as tool for correlation with Ukrainian soils. However, obstacles like differences in classes and related analytical data have to be overcome. A soil analytical correlation project under the auspices of the European Union and the Academies of Sciences in former USSR republics is highly recommended; only then we are to achieve a harmonized soil database for the European continent.

At the same time, rearranging the qualifier lists in WRB may be needed to better link WRB to existing soil maps, particularly small-scale maps. It is also needed to better express essential differences in soils for wise use of this non-renewable natural resource.

REFERENCES

Batjes NH. 2000. Soil data derived from SOTER for environmental studies in Central and Eastern Europe (ver. 1.0). Report 2000/02a, ISRIC, Wageningen. 30 p.

Bockheim JG & Gennadiyev AN. 2000. The role of soil-forming processes in the definition of taxa in Soil Taxonomy and the World Soil Reference Base. Geoderma 95 (2000): 53-72.

Chabra R. 2005. Classification of Salt-Affected Soils. Arid Land Research and Management 19: 61-79.

FAO-UNESCO. 1974. Soil Map of the World 1 : 5 000 000. Volume 1. Legend. UNESCO – Paris. 59 p.

FAO-UNESCO-ISRIC. 1990. FAO-UNESCO Soil Map of the World. Revised Legend. World Soil Resources Report 60. Food and Agriculture Organization of the United Nations – Rome. 119 p.

ISSS-ISRIC-FAO. 1994. World Reference Base for Soil Resources. Draft. Wageningen/Rome. 161 p.

ISSS-ISRIC-FAO. 1998. World Reference Base for Soil Resources. World Soil Resources Reports 84. Food and Agriculture Organization of the United Nations – Rome. 88 p.

IUSS Working Group WRB. 2006. World reference base for soil resources 2006. World Soil Resources Reports 103. Food and Agriculture Organization of the United Nations – Rome. 128 p.

Krogh L & Greve MH. 1999. Evaluation of World Reference Base for Soil Resources and FAO Soil Map of the World using nationwide grid soil data from Denmark. Soil Use & Management 15 (3): 157-166.

Nachtergaele F. 2005. The «soils» to be classified in the World Reference Base for Soil resources. Eurasian Soil Science 38 (Suppl. 1): 13-19.

Stolbovoi V. 2000. Soils of Russia: Correlated with the Revised Legend of the FAO Soil Map of the World and the World Reference Base for Soil Resources. International Institute for Applied Systems Analyses - Laxenburg. 109 p.

Takahashi T, Nanzyo M & Shoji S. 2004. Proposed revisions to the diagnostic criteria for andic and vitric horizons and qualifiers of Andosols in the World Reference Base for Soil Resources. Soil Science and Plant Nutrition 50 (3): 431-437.