Lecture Notes
Principles of Soil Classification

David G. Rossiter
Soil Science Division
ITC Enschede

09-February-2001

Contents

These are lecture notes that are slowly being worked into a more comprehensive explanation.

1 Principles of classification

- Why classify?
- Key concepts of classification

1.1 Why classify?

> "The purpose of any classification is so to organize our knowledge that the **properties of objects may be remembered** and their **relationships may be understood** most easily for a **specific objective**.
>
> "The process involves formation of classes by **grouping the objects** on the **basis of their common properties**.
>
> "In any system of classification, groups about which the **greatest number**, **most precise**, and **most important** statements can be made for the objective serve the purpose best." [9]

Classification helps us deal with **complexity**. There are too many objects to consider individually. If we can find some common properties or behaviour between them, we can make meaningful classes to help us organise our knowledge and simplify our decision-making.

We classify **individual** objects, for example soil profiles, by grouping them into **classes**, for example soil series. These classes then form other objects, that can in turn be classified into still more general classes, for example, reference soil groups. This is a **hierarchical** classification, and is common in soil science.

1.2 Key concepts

- Types of objects
  - Individuals
  - Populations
  - Sub-populations (strata)
- Issues regarding classes
  - Existence of **modal** ('typical') individuals
  - Measures of **similarity** in **state space**
  - Measues of **compactness** of classes
- Types of characteristics
  - **Differentiating**: used to defined classes
  - **Accessory**: consistently associated with a class; **co-variant** with differentiating characteristics
  - **Accidental**: not associated with the classes

- Categories in a hierarchy, levels of abstraction, principle of wholeness
- Ways of grouping
  - single category
  - hierarchical: sub-structures
  - multiple category: a class is part of several higher-level structures
- Principles of grouping
  - psychological
  - practical
  - Both apply to:
    * number of groups
    * balanced vs. unbalanced groups

2 Principles of soil classification

2.1 What is different about soils?

- There is really no soil 'individual' as a self-standing object
- Concept of the **pedon** as a discrete object within the soil **continuum**
- Therefore, the emphasis is on defining **mappable** classes rather than on optimal classification of individuals.
- There is no true inheritence or genetics as it is understood in biology

2.2 Major ways of classifying soils

There are various ways to organise a soil classification. A major distinction is between **natural** and **technical** approaches:

- **Natural** soil classifications group soils by some intrinsic property, behaviour, or genesis of the soils themselves, without reference to use
- **Technical** soil classifications group soils by some properties or functions that relate directly to a proposed use or group of uses.

Natural classifications:

- Group by **ecologic region**, e.g. "prarie soils", "boreal soils". Geographically-compact but may have diverse properties and function.
- Group by **presumed genesis**, i.e. the development pathway of the soil profile. These are called **genetic** soil classifications. The soil individual is considered as a natural body with its own history and ecology. This depends on the interpretation of landscape and soil genesis.

- Group by **similar properties**, working **bottom-up** from a set of individuals, to a set of classes, and then grouping the classes into super-classes. This can be done by:
  - Subjective judgement of the classifier
  - Numerical classification, usually multivariate

Technical classifications:

- Hydrologic response [5]
- Suitability classes (FAO Framework for Land Evaluation) [13]
- Land Use Capability (USDA LCC) [20]
- Fertility Capability Classification (FCC) [28] [26]
- Engineering group [23]

It would be very nice if the groups formed in these ways corresponded. For example, it might be expected that soils that had similar genesis would have similar properties and behaviour. The early soil classifiers thought that soils in an ecological region all had the same genesis and properties. But that is not always so.

3 International Soil Classification Systems

These are systems designed for universal application. They should classify any soil, and serve to **correlate** experiences on similar soils all over the world.

3.1 World Reference Base for Soil Classification

Background: This is the international standard soil classification system endorsed by the International Union of Soil Sciences [15, 11, 6]. It was developed by an international collaboration coordinated by the International Soil Reference and Information Centre (ISRIC) and sponsored by the International Union of Soil Science (IUSS) and the FAO via its Land & Water Development division. It replaces the FAO Legend for the Soil Map of the World [12, 14]

The WRB borrows heavily from modern soil classification concepts, including Soil Taxonomy, the legend for the FAO Soil Map of the World 1988, the Référentiel Pédologique and Russian concepts. As such, it is the result of 'pedo-political' negotiations.

The classification is based mainly on **soil morphology** which is thought to express **the effects of soil genesis**. A major difference with Soil Taxonomy (see below) is that soil climate is not part of the system, except in so far as the effects of climate affect soil properties. As far as possible, diagnostic criteria match those of existing systems, so that correlation with national and previous international systems is as straightforward as possible.

Classification Principles:

- A **practical** grouping into **reference groups** that share an **assemblage** of features which cause distinct **behaviour**, i.e. ecological function and implications for **soil management**.

  So, the reference groups are quite **distinct** and can serve as the basis for making general statements about soil suitability and management strategies.

- **Second-level** qualifiers are also based on **practical** considerations, allowing us to make more specific statements about soil behaviour.

- The system is **tested** in two ways:

  – Soils that behave similar should not be separated by the system; at the worst they should be in two reference groups with **intergrade** second-level.

  – Soils that are classified together in **national** systems should, if possible, stay together in the WRB. This allows the maximum utility from existing databases.

- **Soil Climate** is **not** taken into account, except insofar as it affects observable soil properties.

Structure: The WRB is a two-level classification:

1. **Reference Soil Groups** (30)

   Intermediate in conceptual level between Soil Taxonomy orders and suborders; Examples: Histols, Fluvisols, Luvisols

2. **Second-level subdivisions**

   Using any defined combination of 121 qualifiers. It is possible to use either a single qualifier (the most important) or all relevant qualifiers, depending on the degree of detail needed..

   Similar in detail to Soil Taxonomy great groups (one qualifier) or subgroups (multiple qualifiers).

   Examples: Leptic Umbrisols, Chromi-Vertic Luvisols.

The subdivisions do not take into account all possible differences among soil map units. In particular: climate, parent material, vegetation, depth of water table or drainage, and physiographic features such as slope, geomorphology or erosion are not considered as such, except insofar as they have affected soil morphology. These features can be used locally to defined mapping phases, but they are not considered soil properties to be classified as such.

Some detailed internal properties are also not considered at this level of detail, namely, substratum layers, thickness and morphology of solum or individual horizons. These can be used to define series or forms locally, for detailed soil survey.

Relation to local systems The WRB was **not** designed as a **map legend** to be used in **semi-detailed** or **detailed** mapping. It should be directly applicable for **reconaissance** (regional) and **compilation** (national, global) maps.

Many detailed soil properties that are important for land use and soil behaviour are not specified in sufficient detail in the two levels of the WRB. For detailed mapping and site characterisation, local

organisations or survey projects are expected to use **locally-defined** soil series, soil forms, or similar. The WRB is used to group these locally-defined soils for correlation and communication.

So, a soil survey using the WRB would also need a local classification. A typical structure is:

$$\text{WRB} \Longrightarrow \text{Soil Forms or Families} \Longrightarrow \text{Soil Series} \Longrightarrow \text{Mapping phases}$$

The families may well take into account soil or atmospheric **climate**, according to the aims of the survey.

3.2 Soil Taxonomy

Background

- Institutional: National Cooperative Soil Survey; later international advisory committees
- Historical: why developed, the problems they faced
- Timeline
    1. 1938 Great Soil Groups [22], 1949 revision
    2. 1951 decision for a new system (Guy Smith), 1950's approximations, 1960 '7th Approximation', detailed revision until ...
    3. 1975 'Green Book' [29]
    4. 8 revisions since, published as keys
    5. 1999 2nd full edition ('Magenta Book') [31]
- Fundamental structure criticised by Webster [34]

Objectives

- Organise **soil series** in increasingly-general groups for interpretations. Note that soil series were well-established from many years of detailed mapping.
- Support semi-detailed and reconaissance mapping directly with the defined classes
- Facilitate correlation within and among regions: the more similar the soils, the closer they should be in the classification
- Organise knowledge about soil relations

Structure

- Multicategoric, increasingly general as we go upwards
- Manageable numbers at each level
- Differentiating criteria observable or measurable, not inferred (but this was not always honoured)

- Define by clear class boundaries, which should be natural boundaries in property space; as opposed to using central concepts
- Define all soils that may be encountered in soil survey; routine use by man should not change the classification (only the mapped phase)
- Use new names and define them precisely, to avoid confusion with older systems. E.g. confusing, inconsistent use of word 'podzolic', so use Spodosol (same root, new word)
- Classify soils as they occur, not concepts. The system fits the observed relations.
- Soil moisture & temperature 'regimes' are extremely important for interpretations, also they co-vary with many soil properties, so they are used for soil classification

4 Classifying with WRB

1. Assemblages of characteristics: which **diagnostic horizons** are present? (both surface & subsurface)

   E.g. 'mollic horizon', 'cambic horizon'

2. Assemblages of characteristics: diagnostic soil properties & materials as required by the keys

   E.g. 'alic properties', 'abrupt textural change'; 'fluvic soil material'

3. Reference soil groups: single-level binary-elimination key

   Structure of a binary-elimination key ('other soils having...'); reading a key (pay attention to *and* and *or*)

4. Second-level subdivisions:

   (a) List of possible second-level names for each reference group
   (b) Description of criteria for each second-level name
   (c) Can use one (most important) or all applicable

5. Procedure to follow

   (a) Pre-conception OK, to get some idea of where we might end up and to avoid blunders, however . . .
   (b) Must follow the **exact wording** of the keys to classify
   (c) Determine diagnostic surface and subsurface horizons and their thicknesses
   (d) Follow the key to the **reference groups**; during this you may be asked to determine if the soil satisfies certain **diagnostic criteria** such as the presence of soil properties or materials
   (e) For each possible second-level name of the reference group, see if the soil meets the criteria. List them in priority order.

5 Classified Bibliography

5.1 Principles of soil classification

- Cline [9]
- Butler [8]

5.2 International systems

- World Reference Base: Keys [15]; Introduction [11]; Atlas [6]
- Soil Taxonomy: System [31]; Keys only [30]; Text [7]
- FAO [12, 14]

5.3 National systems

- Australia [19]
- Canada [24]
- England & Wales [1]
- France [3] (English); [2] (French)
- Germany [16]
- Russia [32]
- South Africa [17, 18]

5.4 Technical

- Fertility Capability Classification [28, 27, 26]
- Topsoil Classification [21]
- Hydrology of Soil Types (HOST) [5]
- Land Capability Classification [20] (USA), [4] (UK)

5.5 Numerical methods (ordination)

- de Gruijter [10]
- Webster & Oliver [33]

5.6 World Wide Web Links

- *Compendium of On-Line Soil Survey Information* [25]

A References

References

[1] B W Avery. *Soil classification for England and Wales: higher categories*. Soil Survey Technical Monograph 14. Cranfield University, Soil Survey & Land Research Centre, Cranfield, England, 1980.

[2] D. Baize and M.C. Girard, editors. *Référentiel pédologique 1995*. Institut National de la Recherche Agronomique, Paris, 1995.

[3] D. Baize and M.C. Girard, editors. *A sound reference base for soils: The "Référentiel Pédologique"*. Institut National de la Recherche Agronomique, Paris, english translation by hodgson j.m., eskenazi n.r., & baize d. edition, 1998.

[4] J S Bibby, H A Douglas, A J Thomasson, and J S Robertson. *Land capability classification for agriculture*. Macaulay Land Use Research Institute, Aberdeen, 1991 edition, 1991.

[5] D. B. Boorman, J. M. Hollis, and A. Lilly. Hydrology of soil types: a hydrologically-based classification of the soils of the united kingdom. Technical Report 126, UK Institute of Hydrology, 1995.

[6] E M Bridges, N H Batjes, and F.O. Nachtergaele, editors. *World reference base for soil resources : atlas*. ACCO, Leuven, 1998.

[7] S.W. Buol, F.D. Hole, R.J. McCracken, and R. J. Southard. *Soil genesis and classification*. The Iowa State University Press, Ames, IA, 4th edition, 1997.

[8] B.E. Butler. *Soil classification for soil survey*. Monographs on soil survey. Oxford Science Publications, Oxford, 1980.

[9] M.G. Cline. Basic principles of soil classification. *Soil Science*, 2:81–91, 1949.

[10] J.J. de Gruijter. *Numerical classification of soils and its application in survey*, volume 855 of *Agricultural Research Reports*. PUDOC, Wageningen, 1977.

[11] J.A. Deckers, F.O. Nachtergaele, and O.C. Spaargaren, editors. *World reference base for soil resources : introduction*. ACCO, Leuven, 1998.

[12] FAO. *Soil map of the world*, volume 1 : Legend. Food and Agriculture Organization of the United Nations, Rome, 1974.

[13] FAO. *A framework for land evaluation*. Soils Bulletin 32. Food and Agriculture Organization of the United Nations, Rome, Italy, 1976.

[14] FAO. *Soil map of the world : revised legend*. World Soil Resources Report 60. Food and Agriculture Organization of the United Nations, Rome, 1990.

[15] FAO. *World reference base for soil resources*. World Soil Resources Report 84. Food and Agriculture Organization of the United Nations, Rome, 1998.

[16] Arbeitskreis für Bodensystematik der Deutschen Bodenkundlichen Gesellschaft. Systematik de böden un der bodenbildenden substrate deutschlands. *Mitteilungen der Deutschen Bodenkundlichen Gesellschaft*, 86:1–180, 1998.

[17] Soil Classification Working Group. *Soil classification: a binomial system for South Africa*. Department of Agricultural Technical Services, RSA, Pretoria, 1977.

[18] Soil Classification Working Group. *Soil classification: a taxonomic system for South Africa*. Department of Agricultural Development, RSA, Pretoria, 1991.

[19] R F Isbell. *The Australian soil classification*. Australian Soil and Land Survey Handbook. CSIRO, Collingwood, Victoria, Australia, 1996.

[20] A.A. Klingebiel and P.H. Montgomery. *Land capability classification*. USDA Agricultural Handbook 210. US Government Printing Office, Washington, DC, 1961.

[21] Land and Water Development Division. Topsoil characterization for sustainable land management. Draft, FAO, 1998 1998.

[22] United States Department of Agriculture. *Soils and Men*. Yearbook of Agriculture 1938. US Government Printing Office, Washington, DC, 1938.

[23] Gerald W. Olson. Soil survey interpretation for engineering purposes. Technical Report FAO Soils Bulletin 19, FAO, 1973 1973.

[24] Agriculture Canada Expert Committee on Soil Survey. *The Canadian system of soil classification*. Publication 1646. Canadian Government Publishing Centre, Ottawa, 2nd edition, 1987.

[25] David G Rossiter. A compendium of on-line soil survey information: Soil classification for soil survey, 30-January-2001 2000.

[26] Christopher Smith, Russell Yost, José Benites, and Freddy Nachtergaele. Fertility capability classification (fcc) system - 3rd approximation: the algorithm and an application. In Alain Ruellan, editor, *16th World Congress of Soil Science*, volume CD-ROM, page Paper No. 862, Montpellier, France, 1998. International Society of Soil Science (ISSS).

[27] Christopher W. Smith. *The Fertility Capability Classification System (FCC) - 3rd Approximation: A technical soil classification system relating pedon characterization data to inherent fertility characteristics*. Ph.d., North Carolina State University, 1989.

[28] P.A Sánchez, W. Couto, and S.W. Buol. The fertility capability soil classification system: interpretation, applicability and modification. *Geoderma*, 27(4):283–309, 1982.

[29] Soil Survey Staff. *Soil taxonomy: a basic system of soil classification for making and interpreting soil surveys*. Agricultural Handbook 436. US Department of Agriculture Soil Conservation Service, Washington, DC, 1975.

[30] Soil Survey Staff. *Keys to Soil Taxonomy*. US Government Printing Office, Washington, DC, 8th edition, 1998.

[31] Soil Survey Staff. *Soil taxonomy: a basic system of soil classification for making and interpreting soil surveys*. Agricultural Handbook 436. US Department of Agriculture Soil Conservation Service, Washington, DC, 2nd edition, 1999.

[32] Vladimir Stolbovoi. *Soils of Russia: correlated with the revised legend of the FAO soil map of the world and World Reference Base for Soil Resources*. RR-00-13. International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria, 2000.

[33] R. Webster and M.A. Oliver. *Statistical methods in soil and land resource survey*. Oxford University Press, Oxford, 1990.

[34] Richard Webster. Fundamental objections to the 7th approximation. *Journal of Soil Science*, 19:354–366, 1968.