

Classification of urban soils in the World Reference Base for Soil Resources

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11–September–2004

Paper presented at **EUROSOIL 2004**
Freiburg im Bressgau (D)



Soil classification : caution – danger ahead!



Topics

1. What is “soil”?
2. What is “urban soil”?
3. WRB history and objectives
4. Proposals to **better accomodate urban soils in the WRB**
5. Next steps: **towards WRB 2006**

Status

- A continuation of the work presented at SUITMA 2003 . . .
- . . . taking into consideration comments received and work by others during the past year
 - * papers from Soil Classification 2004 meeting
 - * ICOMANTH circular letter #5
- But, **this presentation is not a definitive proposal**; in particular the definitions and qualifiers are **not worked out in detail**.
- It is to **stimulate discussion** and **clarify concepts**
- **Detailed proposal to follow “soon”**

What is “soil”?

- Traditional definitions of soil as a **natural body**
 - * “pedological prejudice” against recognizing human influence and dealing with technical or unweathered materials
- These have difficulties outside of “natural” areas (and even within them), so ...
- Replace the question: **“What is soil?”** ...
- ... with the question: **“What should soil survey map?”** (Nachtergaele 2004)
- Answer: **the Earth’s epidermis**, not including deep water or structures

Functional definition of soil

- The soil is the **functional interface** between atmosphere, hydrosphere, biosphere, lithosphere (& anthrosphere)
 - * **Environmental models must consider the entire epidermis**
 - * We map and characterise surfaces that are largely **rock**, ...
 - * ... largely **pavement or structures**, ...
 - * ... **freshly-exposed earthy material** from excavation, construction, or natural disasters ...

Thus we avoid arguments about what exactly is soil, and rather focus on a classification that can segment the epidermis in order to **map** and **characterise** it.

These are soils and should be classified (1)



Essen-Altenessen (D), Hövelstraße;
DBG June 2002 P2a



Essen-Kray (D); DBG June 2002 P1

These are soils and should be classified (2)



Leirhnjukar (Krafla) (IS)
sulfurous muds



Leirhnjukar (Krafla) (IS)
fresh lava flow

Even these?



Eirikstair (IS)
reconstructed house of Eirik the Red



Reykjavík (IS)
City hall

What do we mean by “urban” soils?

- The term “urban soils” is simply a shorthand for **any soils that occur in urban or industrial areas** (Burghardt 1994, Sobocka 2003)
 - * All soils in urban areas affect the life of the city, so all are included in the general concept of “urban soils”
- These are **more-or-less human-affected** (“anthropogenic”); in urban zones even ‘natural’ soils are likely to be affected by human activities
- Similarly, in industrial zones, not only technogenic soils
- N.b. this is *not* a **classification category**, only a **discussion category**

Urban soils



Soil remediation on abandoned gas factory, Enschede (NL)



CaO slag, Essen (D)

Urban soils



Mine spoil, Faulquemont, Lorraine (F)



Revegetated street, Nancy (F)

Urban soils



Luxembourg Gardens, Paris (F)



Municipal golf course, Ithaca, NY (USA)

Not urban soils



Terraces constructed by heavy machinery, planted to olives near Malaga (E)



Excavated and levelled dune sands, sub-irrigated for vegetables near Aveiro (P)

Soil classification

- The process of grouping **soil individuals**, defined by the *pedon* concept, into *classes*
- Classes should provide **maximum information** with respect to **defined objectives** (Cline 1949)
- Objectives in this case are those of the **WRB**

The World Reference Base for Soil Resources (WRB)

This is the **official international soil classification system** (IUSS → ICSU)

- **Objective 1: Correlation** of soil individuals to exchange experiences in soil studies, especially among **national systems** at the **higher categorical levels**
- **Objective 2:** Provide a common language to discuss the **world and regional soil geography**
- **Objective 3:** Provide a ready-made **mapping legend** at regional and world scales
 - * not intentional but “by popular demand”
- **The WRB should play these roles in urban soils**

WRB Structure

- Two categorical levels:
 1. **Reference Groups** (30): reflect **major soil forming environments and processes**
 - * e.g. Ferralsols, Spodosols, Chernozems, Luvisols, Acrisols
 - * *Anthrosols* where human influence (esp. for agriculture) is the main soil-forming factor
 - * *Regosols* for raw or disturbed soils
 - * ≈ Soil Taxonomy (USA) *great groups*, not including soil climate
 2. **second level**: named **qualifiers**
 - * e.g. Thionic Cambisols (**strong** property), Leptic Cambisols (**intergrade**), Skeletic Cambisols (**weak** property)
 - * Can be used in combination, e.g. Eutri-skeletic Cambisols
 - * ≈ Soil Taxonomy (USA) *subgroups*, not including soil climate

What the WRB does *not* classify

- **(Agro-)climate** or **soil climate** (except as reflected in measureable soil properties)
- **Detailed profile morphology** (→ **series**)
- **Site morphology**, e.g. land form
- **Substrates**, except if they dominate soil behaviour at an appropriate categorical level
 - * **Arenosols**
 - * **Siltic** Chernozems Kastenzozems, Phaeozems, and Albeluvisols
 - * not consistently defined (Jahn)
- **Transient** properties

Scale (cartographic detail)

- **World** soil map at 1:5M: Minimum Legible Area (MLA) = 625 km²; Minimum Legible Width (MLW) \geq 15 km
- **Continental** soil map at 1:1M: MLA = 25 km²; MLW \geq 3 km
- **Regional/country** soil maps at 1:100k – 1:200k: MLA = 0.25 – 1 km² (25 – 100 ha); MLW \geq 300–600 m

This is the most detailed scale that WRB was designed for

- An “urbanized” WRB would be used to give **meaningful names** to map units **at these scales: No more “white holes” on the soil map!**

Mappable areas at 1:100 000



Akureyri (IS); area \approx 400 ha



Woeste Hoeve (NL), A50 ; width \approx 150 m (exaggerate on the map)

Categorical detail

- **Categorical** detail should match **cartographic** detail
- Map units should be named by one **dominant** class or an **association** of a few classes
- **Not all soil differences can be named at this level of detail**
- **Resist the temptation to put too much into WRB**

Categorical detail: Example from the USA

- **39 series** of Lithic Dystrudepts (ST) \approx **Dystri-Leptic Cambisols** (WRB)
- **19** of these in mesic temperature regime (cool temperate)
- \rightarrow *19 different shallow 'brown acid forest soils' of cool temperate climates only in USA*
- **Important differences**: series defined by texture, mineralogy, parent material, detailed horizon organisation and thickness
- **We must accept the same situation in urban soils** when using the WRB to discuss and map them.
- Separate proposal for **Reference Soil Series** (Jahn) for detailed mapping

WRB History

- 1974, 1988: **FAO Soil Map of the World** (1:5M) legends
- 1980: International Reference Base (**IRB**) project → WRB
- 1998 (Montpellier IUSS): **FAO Soils Bulletin 84**
 - * Official status with IUSS
- 2002 (Bangkok IUSS): **FAO World Soil Resources Report 94**
 - * Updated list of qualifiers relevant to urban soils
 - * Explains geographic and pedologic rationale
- **WRB Forum**: working group to evaluate proposals
- **2006** (Philadelphia IUSS): **new version** to be presented to IUSS

WRB Classification Principles

- Classify based on **diagnostic horizons**, **materials**, and **properties** of the soil itself
 - * Use **field morphology** as much as possible
 - * Minimum use of laboratory tests; allow **field indicators** in place of tests if possible
- Do not classify on **transient properties**
- Keep well-established limits from **national systems** if possible (especially Soil Taxonomy, since it is used in many countries as a national system)
- Keep **traditional names** if possible

Problems with classification of urban soils in WRB 2002

Presentation at **SUITMA 2003**; subsequent comments

1. Importance of urban soils not reflected by “own” group
2. Technogenic soils are grouped with those from natural materials
3. No explicit provision for pavements, coarse rubble or ballast
4. Definitions intended for natural soils; must infer when confronted with technical or human-transported materials
5. No provision for contaminated soils
6. Other problems with Anthrosols as currently defined

Proposals

These are based on much previous work by a.o.

- DBG Arbeitskreis Stadtböden
- SUITMA members (esp. in E Europe)
- WRB leadership
- ICOMANTH committee of Soil Taxonomy (USA)
- UK (Hollis, BGS), literature

I have been asked by the WRB leadership to coördinate a **common proposal** aiming at WRB 2006.

Evaluating proposed changes to the WRB

- Are **soil individuals** (from actual databases) placed into more **homogeneous groups** in feature space, with respect to properties, function and genesis?
 - * “Hard cases make good law”
- Are **map units** with the new names **purier**?
- Are **soil names** more **connotative** (lead to clearer communication with the general public)?
- Are **classification principles of the WRB** respected?

The “Technosol” idea

Sentiment is strong (SUITMA 2003, Soil Classification 2004) for a **new reference group** to separate at least some of the urban & industrial soils.

Key questions for “Technosols”:

- Defined by **materials**, **human activity**, or **both**? (i.e. narrow or wide interpretation)
- **What kind of materials?** Newly-synthesized (not occurring in nature); processed natural materials; reworked natural materials? Organic materials?
- **How much pedogenesis** to allow?
- **Placement in the key**; importance relative to other groups
- Which second-level **qualifiers**, especially strong property

The name “Technosols”

- The “techno” root has several derivations in English
- The meaning here is closest to “technique” (something built by humans, using some method or technique) . . .
- . . . *not* “technogenic” (\approx “artificial”) . . .
- . . . *not* “technical” (opposite of “general” or “conceptual”).
- “Techno” is preferred to “Urbo” (or “Urbi”) because these soils occur outside of cities.
- “Techni” will be used for “artificial” material

Conceptual differentiation of Technosols (1)

- **Exclude** soils with significant pedogenesis formed on natural materials by natural processes (28 reference groups for these)
- **Exclude** raw soils formed on *undisturbed* natural materials, or natural materials disturbed by natural processes (*Regosols*)
 - * Add qualifier(s) for limited urban influence
 - * (Could add a qualifier for colluviation)
- **Exclude** soils profoundly affected by human activity substantially *in situ* for **agricultural purposes** (*Anthrosols*, perhaps renamed)
 - * Terracing
 - * Deep plowing
 - * Intensive manuring with non-processed material

Conceptual differentiation of Technosols (2)

- **Include** soils from **industrial artifacts** whose properties are dominated by the material
- **Include** soils from **transported** and **heavily reworked** natural or technical materials whose properties are dominated by these actions
- **Include** soils **severely and non-transiently compacted** by urban & industrial activities
- **Include** pavements & other **sealed** soils
- **Include** soils freshly-exposed by **excavation**

Conceptual differentiation of Technosols (3)

- **Exclude** soils where the “urban” influence does not dominate the soil properties:
 - * Not enough “foreign” material; or
 - * Material has transformed so its properties are close to natural materials
- **Exclude** soils on excavated sites with any significant pedogenesis (as shown by diagnostic horizons other than *ochric*)
- **Contamination** *by itself* does not qualify a soil in the Technosols
 - * E.g. heavy metal pollution by flooding in Fluvisols or by airborne deposition in any reference group

Not Technosols



streetcar right-of-way,
Ithaca, NY (USA)
abandoned for 70 years; frost heave,
erosion, colluviation



sand path, Enschede (NL)
compaction is temporary, material is
local

Map units in urban & industrial areas

The definition should lead to:

- In **industrial zones**: Mostly Technosols
- In **cities**: Associations of Technosols and Anthrosols, with larger parks or agricultural areas as inclusions of “natural” reference groups

New definitions

1. Artifacts
2. Human transported materials (HTM)
3. Human compacted materials (HCM)
4. Urbic & Technic soil materials
5. Technosols

Artifacts

- **Concept:** something in the soil recognizably made by humans
- Useful to identify colluviation, human occupation, and industrial processes
- Suggested definition:

“Solid or liquid material created or substantially modified by humans, usually for practical purposes as part of a manufacturing process.”

Implications of the definition of Artifacts

- “Material”: exclude spade marks etc.; these are not artifacts in themselves, but rather evidence of human disturbance
- “Liquid”: include chemicals of industrial origin
- Do *not* include mined material or transported soil; the change in properties is from the transportation (loosening, compaction, mixing) but not in the material itself (see HTM and HCM, below)
- **Human influence must be documented**

Examples of artifacts

- Natural materials minimally processed: organic garbage, carcasses
- Processed natural materials: pottery, bricks
- Synthetic materials not found in nature: slag, plastic
- Natural chemical materials: creosote
- Synthesized chemical materials: refined hydrocarbons

Artifacts



SUITMA 2000 Profile 7
coal ash; brick rubble



Reykjavík (IS)
water pipe; paving

Size & continuity

1. **Particulate**: < 2 mm and not arranged or compacted into a layer; example: coal ash, lead shot, industrial dust
2. **Discrete**: ≥ 2 mm and not arranged or compacted into a layer; example: construction rubble
3. **Liners**: (nearly-)continuous layer; example: asphalt; rubber or plastic sheeting (landfill liners)

ICOMANTH restricts liners to > 18 cm depth; no reason for this if we are going to classify streets

A new soil material: “Human-transported materials” (HTM)

- Concept: Any material intentionally brought to the current pedon from “outside”, usually with the aid of machinery.
- Can be for agricultural purposes (e.g. mine spoil revegetation)
- Restrict to material *not* from the immediate area (ditching, terracing, land shaping)
- This is a **parent material** for pedogenesis (by analogy to WRB **fluvial soil material**, colluvium)

Human-transported materials



Topsoil for reclamation, *HTM*:
Laneuveville-dévant-Nancy (F)



Not HTM: Soil excavated by deep
ditching, Miðadalir (IS)

Suggested definition of Human-transported materials (HTM)

“Any solid or liquid material moved horizontally into a pedon from a source area outside of its immediate vicinity by intentional human activity,

usually with the aid of machinery,

and without substantial reworking by natural forces.”

Implications of the definition of HTM

- The restriction to “intentional” excludes dusts
- “Liquid” → include sludges and manures
- It must still be where it was deposited by humans Otherwise it is a different substrate, e.g. colluvium *from HTM*.
- If reworked *in situ* (e.g. by frost or wind) the human influence is reduced → Regosols
- “immediate vicinity” excludes ditching, terracing etc. within one field; these are dealt with in Anthrosols
- No explicit list of materials is needed in this definition

Identification of HTM

- **Field** identification
 1. Strongly-contrasting with underlying material
 2. Signs of deposition processes after transportation (voids, compaction, aia . . .)
- But may be partly identified by **historical evidence**, e.g. site plans

This latter is otherwise not allowed in WRB (e.g. fluvic soil material only from morphology, not from records of flooding).

A new soil material: “Human-compacted materials” (HCM)

- Concept: materials **substantially** and **non-transiently compacted** by **human activity**
- “**Substantially and non-transiently compacted**”: limits to be defined; probably by reference to the natural state of the material (e.g. 20% higher bulk density); after review of studies to find when compaction becomes so marked as to dominate soil behaviour
- “**by human activity**”: must be documented by field or historical evidence
- **Exclude** fragipans, dense glacial tills etc. ; these are not caused by humans

New soil materials: “Technic” and “Urbic”

These after the proposal of Lehmann.

They are intended to differentiate **two types of human intervention**:

1. more-or-less natural material that has been affected by humans, other than for productive agriculture → “*urbic*”;
2. non-natural materials created by humans → “*technic*”

Technic soil material

“Technic soil material:

Material created as the result of a technical process,

with properties substantially different from those of natural materials.”

Such material is by definition human-transported, since it is not native to any pedon.

Property differences can be in composition, coherence, reaction . . . These must be documented in each case; no comprehensive list can be given in WRB.

Urbic soil material

“*Urbic soil material:*

Non-*technic* (q.v.) human-transported material;

***or* human-compacted material (q.v.)”**

***or* material exposed by complete excavation of the solum with no diagnostic horizons other than an *ochric* horizon”**

This combines three concepts in one definition.

A new reference group: the Technosols

“Soils containing at least 20% (by volume) *technic* and/or *urbic* soil materials to a depth of 100 cm or a lithic or paralithic contact, whichever is shallower.

TECHNOSOLS (TS)”

- The proportion of material must begin at the surface; this allows shallow covers by dusts, flooding or colluviation
- Implication: if qualifying by HCM, this must be 20% of the profile
- N.b. current definitions of *lithic* or *paralithic* refer to hard or broken rock; this is taken to mean natural rocks, not technic materials

Excavations

Note that natural materials exposed by **excavation** are *not* considered urbic soil materials, and therefore not in the Technosols, *unless* it is “substantially and non-transiently compacted” during the excavation process.

The floor of an open-cast mine worked by heavy machinery would probably be urbic (compacted), but subsoil left after mining for topsoil with light equipment would not be.

Non-compacted excavations are *Anthropic Regosols* as currently defined (perhaps a less-confusing name than Anthropic can be found).

Excavations as urbic material



No: house foundation in Tertiary glacially-compacted clay, de Lutte (NL)



Yes: housing project on old Vitesse FC grounds, Arnhem (NL)

Placement in the key

This is placed **first** in the key, even before Histosols (HS) and Anthrosols (AN); also before the Leptosols (LP) and Cryosols (CR)

- Avoids re-defining other groups to exclude technical material (which may be contaminated)
- Technic or urbic material has more influence on soil properties, function etc. than the shallow depth or skeletal material (LP) or frozen condition (CR).
- Little conflict between AN and TS; but if “Anthrosols” are on technical material this should be emphasized (e.g. revegetated mine spoil)
- HS from dredgings, fly ash etc. may be contaminated and so preferably mapped with TS

Qualifiers for Technosols

Not yet worked out in full; several (contradictory) proposals; must place in the framework of this definition of Technosols

strong expression : the main reason for placement in the Technosols, e.g.

Technic : dominated by technic material other than pavement

Urbic : dominated by non-compacted urbic material (HTM)

Sealic : pavements (“Ekranosols”)

Compactic : compacted but not sealed (further as *epi-*, *endo-*)

Histic : organic transported materials

intergrades as documented; arenic, hyperskeletal, cryic, andic, gleyic, cambic . . .

weak expression : lithic, skeletal, . . .

special features : e.g. toxic

Detailed mapping

The above proposals do *not* address medium- and large-scale mapping, nor detailed correlation of soil studies.

This is addressed by the proposal of **Jahn** & colleagues (this meeting) to define **Reference Soil Series** in the framework of WRB, also for Technosols:

1. **Soil form**

2. **General profile**

- (a) **general texture** (with modifiers suggested by ICOMANTH)
- (b) **substrate** from detailed lists prepared by a.o. Hiller & Meuser, ICOMANTH

Thus WRB can form the basis for (semi-)detailed mapping without becoming too detailed itself.

Next steps: Towards WRB 2006

- Full paper of this talk, with proposal, sent to all interested parties for comment
 1. urban & industrial soil specialists (SUIMTA mailing list)
 2. WRB Forum correspondents; WRB leadership
 3. ICOMANTH leadership (for further dissemination)
- Test proposed new classes and revised definitions against their databases and maps
- Suggestions for revision by end October 2004;
- Formal proposal to WRB leadership by end November 2004
- **Updated WRB IUSS 2006** (Philadelphia)

Soil classification : handle with care!

