Int. Agrophysics, 2006, 20, 129-134

INTERNATIONAL
Agrophysics
www.ipan.lublin.pl/int-agrophysics

Technosols and other proposals on urban soils for the WRB (World Reference Base for Soil Resources)

A. Lehmann

Institute of Soil Science, Hohenheim University, D-70593 Stuttgart, Germany

Received March 24, 2006; accepted April 12, 2006

A b s t r a c t. Urban soils are defined as soils which are severely influenced by various human activities, but not only by cultivation. These soils have assumed particular significance because they extend over large areas, are intensively used and are increasingly relevant in the consideration of land-use patterns. However, urban soils can bring about both considerable benefits and extreme risk for urban living. Therefore, an effective way of handling taxonomy for urban soils must be taken into account in spatial planning. The taxonomy of urban soils must take into consideration the fact that urban soils are mostly young soils, normally showing only weak signs of soil genesis. In contrast herein urban soils are often characterized by easily differentiable substrate-linked features. Since the early stages of soil genesis are mainly influenced by substrate properties, reasonable taxonomic differentiation of urban soils can be obtained by restricting consideration to substrate-linked properties. Proposals which were first presented during a session on Anthropogenic soils classifica- tion at the 2nd International Conference on Soil Classification in July 2005, in Petrozavodsk (Russia) are reflected here.

K e y w o r d s: urban soils, soil taxonomy, World Reference Base for Soil Resources (WRB), land-use

SIGNIFICANCE OF URBAN SOILS

Urban soils make significant contributions to the quality of life in urban areas. In fact there are no other soils used with such an intensity in terms of the number of users per unit of area as urban soils. Urban soils are also an object of great interest because in the predictable future it is anticipated that the size of urban areas will continue to increase (UN, 1995). Furthermore, urban soils perform a number of beneficial functions. The benefits of urban soils are similar to these of natural soils, but a high number of humans are affected by these profits. This applies in a specific way in fragile urban environments rather than in more natural rural areas. The meaning of each beneficial function can differ substantially between different cities and between different parts of the world. The beneficial functions of urban soils can be divided into four groups namely: hazard prevention, provision of renewable sources of water and food, contributions to urban infrastructure and to environmental quality and cultural heritage.

Hazard prevention:
– protection against rainstorm damage and flooding events by allowing water infiltration;
– decomposition of organic contaminants *eg* fuel by soil-borne microorganisms;
– retention and immobilization of contaminants.

Provision of renewable resources:
– plant products for food supply;
– groundwater for water supply.

Contribution to the performance of urban infrastructure:
– medium for alternative storm water management;
– site for recreation and sports activities.

Functions with relevance to environmental quality and to the cultural heritage:
– dust entrapment;
– sequestration of carbon in nongaseous state;
– buffering of climate, mainly through cooling by evaporation;
– media for ruderal vegetation and sites for public and private green space;
– archives of prehistoric and historical information.

Functions of soils which lead to the destruction of the soil, such as sites for housing and transportation, are not listed below because they contradict soil protection. It is,

Corresponding author's e-mail: as@uni-hohenheim.de

however, also important to be aware of dangers which may emanate from urban soils. These dangers are:

- contamination of groundwater;
- damage to organisms' health as a result of consuming contaminated soil *eg* by direct uptake by eating contaminated vegetables or through inhaling contaminant-laden dust;
- emission of trace gases implicated in climate change;
- damage to housing, transportation links or other infrastructural constructions by events such as landslip and flooding caused by restricted infiltration.

As a consequence of the high functionality of urban soils, a practicable taxonomy for urban soils is necessary for the identification, protection and future management of urban soils. Such a classification should be applicable on a world-wide scale (AKS, 2002).

A brief history of identifying and studying urban soils in a pedological way is given below to draw a picture of the increasing significance and awareness of these soils.

until the 1970s
Russian, German and American soil scientists first examine urban soils, see (Blume, 1975; Pettry and Coleman, 1973; Zemlyanitskiy, 1963).

1990s Knowledge on urban soils becomes less restricted to aspects of soil pollution. In addition to the examination of a reasonable number of urban soils using pedological methods aspects of land-use and soil protection are considered by soil scientists
The portion of the world population living in urban areas exceeds 40%.

1995 The French pedological framework defines two types of urban soils (Baize, 1998).

1997 A manual for the description of urban soils (AKS, 1997) is developed by a working group of the German Pedological Society.

1998 Publication of the first pedological compendium on urban soils (Stroganova *et al*., 1998).

1998 Foundation of the ISSS-Working Group 'Urban Soils - Soils of Urban, Industrial, Traffic and Mining Areas' (SUITMA).

2000 The first international conference on soils of urban, industrial, traffic and mining areas (SUITMA) takes place in Essen (Germany) (Burkhardt and Dornauf, 2000).

2005 The WRB-soil group 'Technosols' is proposed by the author of this paper during a session on Anthropogenic soils classification at the 2nd International Conference on Soil Classification in Petrozavodsk, Russia.
In excess of 50% of the world's population lives in urban areas.
The proportion of land under construction increased at twice the rate of population growth during the last two decades.

The last 30 years of research on urban soils provides a substantial base for the development of a taxonomic scheme for urban soils on the global scale. However, further collection and dissemination of existing data on urban soils would be beneficial, as well as more research on urban soils, especially those under tropical and cold climates. Essential work on the relation between soil taxonomy, soil evaluation and planning procedures is actually done by the EU-financed (INTERREG IIIB Alpine Space Programme) project TUSEC-IP (see www.tusec-ip.org).

SPECIFICATION OF URBAN SOILS

The term 'urban soil' is understood by soil scientists, planners and citizens, often without any further explanation. But there is no accordance if all soils within city boundaries or within conurbations are urban soils. A more pedological definition for urban soils is given:

Urban soils are those strongly influenced by human activities such as construction, transportation, manufacturing processes, industry, mining, rural housing and similar activities. Activities such as agriculture, sylviculture and horticulture are specifically excluded. The term urban soil is substantiated here with proposals for definitions of soil materials, a soil group and qualifiers. These definitions take into account that the main sites of human civilisation are cities, whereas the influence of cities extends far beyond city boundaries. Natural soils within cities or conurbations could not be included, because the principal of WRB system for soil correlation relates to soil or substrate properties and soil processes (ISRIC, 2002). Soils formed by agricultural use are also excluded from urban soils, because they are already subsumed by the soil group *Anthrosols*. Anthropogenic activities that form urban soils are listed below:

<u>addition of matter</u> by man, which could be solid *eg* rubble, waste, liquid *eg* petrol, sludge or gaseous *eg* natural gas from pipelines, methane from anaerobic decomposition of organic wastes, of either anthropogenic or natural origin. The addition of matter is often accompanied with deep mixing of the soil and levelling of the soil surface resulting in alkalinization, contamination, deoxidation, and fertilization – also by the addition of organic matter;

<u>covering</u> a special form of addition, mostly with natural soil material, *eg* to allow plant growth above deposits of wastes;

<u>sealing</u> an anthropgenic crust which builds the soil surface, mainly a special form of addition of matter for roads, parking areas and buildings;

<u>loss of material</u> mechanically, *eg* by digging and transportation or by leaching as a consequence of irrigation, or loss of water by drainage;

<u>loosening</u> mechanically, or as consequence of material addition like ashes or other skeletal material;

<u>compaction</u> technically or simply by application of weight.

An attempt for the taxonomic acknowledgement of urban soils within the WRB rules is presented below. The proposal is based mainly on discussions with the German Pedological Society's working group on urban soils and with members of the WRB. The proposal uses the prefixes 'techni-' and 'urbi-' to distinguish between two intensities of anthropogenic changes. 'Techni-' denotes more intensively changed soils where most of the soil material is significantly altered by technological procedures, and 'urbi-' denotes less perturbed soils where the typical urban land-use has significantly changed the soil dynamics.The proposed soil group Technosol shows numerous similarities to soil types which are already introduced in the French and Russian frame or system for soil classification.

PROPOSALS FOR THE CLASSIFICATION OF URBAN SOILS IN THE WRB

Redefinition and definition for soil materials

Urbic soil material (redefinition):

Soil material showing evidence of urban and related activities such as settlement, construction, traffic, industry, and mining. Evidence is visible as signs of soil scalping, shifting, or tipping (Scalping means removal of the upper part of a soil, extending down to subsoil, thus creating a new soil surface. Shifting means the transportation of soil material to another place using technical or other instruments. Tipping means deposition of soil material in one place using technical instruments or other instruments). Artefacts* have a content of less than 20% by volume.

Technic soil material:

Soil material showing evidence of urban, industrial and related activities. Evidence is visible by a content of artefacts by volume equal to or more than 20%.

Definition of the soil group 'Technosols'

Technosols: having technic soil material with an artefact content by volume of more than 50% for a depth of at least 10 cm, starting within 10 cm from the soil surface.

The following qualifiers are proposed for the use with Technosols: skeletic, episkeletic, endoskeletic, sealic, endocompactic, ruptic, toxic, pestic, humic, thionic, calcaric, haplic or any other qualifiers which are used with Regosols and Cambisols and which are not proposed to be deleted (see below).

The order of the first soil groups in the key should be as follows: Technosols, Anthrosols, Histosols, Cryosols, ... The other soil groups follow in the known order.

*liquid or solid material which has experienced a technical process, *eg* bricks, ashes, wastes, sewage sludge, also mined material

Additionally, all qualifiers proposed below should be used with Technosols. This with exception of the proposed qualifiers *technic* and *urbic*.

Renaming of the soil group Anthrosol

Agrosol or Cultisol should be used instead of Anthrosol to preserve the self-explanatory character of the names of the Soil Groups if the soil group Technosol is introduced. Proposed definitions of qualifiers should be used in combination with the WRB-soil groups as shown in Table 2:

urbic: having urbic soil material for a depth of at least 50 cm;

technic: having technic soil material for a depth of at least 10 cm;

endocompactic: (1) having anthropogenic subsoil compaction starting within 200 cm from the soil surface and with a bulk density of at least 0.9 g cm^{-3} in a soil from pure clay; this bulk density boundary has to be calculated 0.1 g cm^{-3} higher for every 10% decrease in clay content;

epicompactic: (2) having a surface compaction forming an anthropogenic crust;

sealic: (3) having a surface sealed with construction material or having a similar surface.

Adaptation of qualifiers and proposed qualifiers

humic: (4) having more than 18% of organic carbon (by weight) to a depth of 50 cm from the soil surface in Technosols (text module to be included into the existing definition before the last comma);

urbihumic: (5) having urbic soil material with more than 1% of organic carbon (by weight) for a depth of at least 10 cm, starting within 200 cm from the soil surface;

urbiruptic: (6) having urbic soil material for a depth of at least 50 cm, with one or more substrate discontinuities, starting within 200 cm from the soil surface;

techniruptic: (7) having urbic soil material for a depth of at least 50 cm, with one or more substrate discontinuities, starting within 200 cm from the soil surface;

pestic: having known toxic artefacts *eg* slag or petrol within 50 cm from the soil surface

urbiskeletic: (8) having urbic soil material with between 40 and 90% of coarse fragments added to the soil by anthropogenic activities to a depth of 100 cm from the soil surface;

techniskeletic: (9) having technic soil material with between 40 and 90% of coarse artefacts to a depth of 100 cm from the soil surface.

Deletion of qualifiers

Spolic, garbic, because the proposed qualifiers *urbic, humic, technic and pestic* provide similar soil properties.

Deletion of a soil material

anthropogeomorphic soil materials.

Tables 1 and 2 are an attempt to evaluate the usefulness of the proposed qualifiers in combination with each soil group. This evaluation is mainly based on personal experience of the author. Contributions and suggestions of others are most welcome.

The following **short headings** in Table 1 signify that the definitions of the respective soil group do not oppose a possible combination of the soil group with the proposed qualifiers 'urban' or 'technic' if the requirements given below are met.

For the heading '**general**': The definition of the soil groups mentioned in this column allows the combination with ”urbic” or ”technic”. If ”general” is not met the column '**in some cases'** or '**in young soils**' or '**maximal depth'** has to be regarded.

For the heading '**in some cases**': The genesis of the soils specified here took place mainly in transported ”urbic” or “technic” soil material.

For the heading '**in young soil**': The in situ genesis of these soils could take place in 'urbic' or 'technic soil material', mostly within 50 to 100 years.

For the heading '**maximal depth**': A combination of the regarded soil groups with the qualifiers 'urbic' or ”technic” is possible if the 'urbic' or 'technic soil material' does not exceed the given depth.

The heading '**description**' signifies for the regarded soil groups that at least one example is known by the author for which 'urban' or 'technic' could be met.

'**Spatial meaning**' considers the area which is occupied by the regarded urban soil.

'**Special meaning**' regards to the significance of the soil in points like health care, sustainable soil use, spatial planning.

The column with the heading '**significance of proposed qualifiers'** shows if the proposed qualifiers could be combined with the listed soil groups. A number is assigned for each proposed qualifier. The definitions of the qualifiers referring to these numbers are given in the chapter 'Proposals for the classification of urban soils in the WRB, in the left column of the previous page'.

The **'over all evaluation'** shows a sum-up for all evaluated aspects with regard to their weighting. Soil groups which did not reach the value of 1 could be regarded as not

T a b l e 1. Evaluation of the meaning of the proposed qualifiers in combination with the WRB soil groups – under general and particular aspects

Short heading (see the text above for explanations)	General	In some cases	In young soils	Maximal depth (cm)	Description	Spatial meaning	Special meaning
Maximum points for the final evaluation in Table 2	2	0.5	1	0.5*	1	1	1
Histosols							
Anthrosols	X				X	X	X
Andosols	X						
Arenosols	X					X	X
Vertisols	X				X	X	X
Fluvisols		X	X	50	X		X
Gleysols			X	50	X		X
Leptosols		X		topsoil			
Regosols	X				X	X	X
Cambisols	(X)	X	rare	>25			
Plinthosols, Ferralsols	X					X	X
Luvisols, LX, AC, AL, Solonetz			rare	100+		X	X
Nitisols		X		100		X	X
Solonchaks	X						
Gypsisols, Calcisols	X						
Durisols				100		(X)	
Chernozems, KS, PH	X						
Albeluvisols				topsoil			
Umbrisols	X						
Cryosols	X		X			X	X

*no points are given if the 'depth of boundary' is the depth of the topsoil; LX: Lixisols, AC: Acrisols, AL: Alisols, KS: Kastanozems, PH: Phaeozems; (X): for Camibsols: met the words of the definition but not the central meaning of the definition, for Durisols: were they are covered with gravel for road construction (gravel roads); +: in Luvisols 100 or 200.

T a b l e 2. Evaluation of the meaning of the proposed qualifiers in combination with the WRB soil groups – evaluation of proposed qualifiers and over all evaluation

Short heading (see the text above for explanations)					Significance of proposed qualifiers					Over all evaluation – concerns Tables 1 and 2
Evaluation					Each fully relevant combination = **0.1** point					The highest evaluated soil groups are typed in **bold**
Histosols			3			6	7	8	9	0.6
Anthrosols*	1	2	3	4	5	6	7	8	9	**5.9**
Andosols	1	2	3	4	5	6	7	8	9	2.9
Arenosols	1	2	3	4	5	6	7			**4.6**
Vertisols	1	2	3	4	5	6	7	8	9	**5.9**
Fluvisols	1	2	3	4	5					**4.5**
Gleysols	1	2	3	4	5	6	7			4.2
Leptosols	1	2	3	4	5	6	7	8	9	1.4
Regosols	1	2	3	4	5	6	7	8	9	**5.9**
Cambisols	1	2	3	4		6	7	8	9	1.5
Plinthosols, Ferralsols	1	2	3	4	5	6	7	8	9	**4.8**
Luvisols, LX, AC, AL, Solonetz, Planosols	1	2	3	4	5	6	7	8	9	3.4
Nitisols	1	2	3	4	5	6	7	8	9	3.9
Solonchaks	1	2	3	4	5	6	7	8	9	2.9
Gypsisols, Calcisols	1	2	3	4	5	6	7	8	9	2.9
Durisols	1	2	3	4	5	6	7	8	9	1.4
Chernozems, KS, PH	1	2	3	4	5	6	7	8	9	2.9
Albeluvisols, Podzols	1	2	3	4	5					0.5
Umbrisols	1	2	3	4	5	6	7	8	9	2.9
Cryosols	1	2	3	4	5	6	7	8	9	**5.4**

*up this proposal a number of Anthrosols will key as Technosols, LX: Lixisols, AC: Acrisols, AL: Alisols, KS: Kastanozems, PH: Phaeozems.

relevant as urban soils. Soil groups which are evaluated higher than 1 and less than 4.5 key out as relevant in urban areas. The introduction of the proposed qualifiers is highly recommended for the soil groups which reach 4.5 or more points. At least, most soil groups could have a top soil from 'urbic' or 'technic soil material'.

CONCLUSION

The inability to key out urban soils using international soil taxonomies, namely the WRB-system (Dudal *et al.*, 2002), will only be overcome by amen- ding existing soil taxonomies. The discussions necessary for the development of a taxonomic soil classification for urban soils have begun and the proposal given here arises from these early discussions which should be continued. This result should be transferred to WRB-experts who will bring suitable proposals together and introduce the outcome into a new version of the WRB.

ACKNOWLEDGMENTS

I want to thank Wolfgang Burghardt, Peter Schad and Karl Stahr for discussion and their highly valuable contributions. Special thanks are extended to Dr. Emma Tilston for her patient help in improving the wording of the manuscript.

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