Pedogenic processes in soils of urban, industrial, traffic, mining and military areas

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Soils within Cities

Global approaches to their sustainable management

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Global approaches to their sustainable management – composition, properties, and functions of soils of the urban environment

Editors:

Maxine J. Levin, Kye-Hoon John Kim, Jean Louis Morel, Wolfgang Burghardt, Przemysław Charzyński, Richard K. Shaw

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1 Introduction

1.1 The challenges for soils in the urban environment

Introduction

The vast majority of soils are now under human influence or in the urban environment and this is where almost 70% of human beings are expected to live by 2050 (Table 1.1-1). Surface areas strongly modified by human activities expanded very fast worldwide due to available efficient machinery and to monumental human projects that convert natural soil into urbanized surface without considering the loss of our Natural capital. Land Affected by Humans has increased 78% of the surface area of cities in Europe since the 1950's, with a loss of 10 000 km^2 of agricultural land per 10 years. About 2.3% of the European territory is now sealed representing 200 m^2 per citizen, and up to 250 ha are converted every day (http://ec.europa.eu/environment/soil/sealing_guidelines.htm).

Table 1.1-1. Percentage of Population residing in urban areas (United Nations 2011, in Burghardt et al. 2015).

Country/Year	1950	2000	2050
World	29.5	46.7	67.2
Japan	53.3	78.6	97.6
Germany	68.1	73.1	81.8
Nigeria	10.2	42.4	71.3

As a result, henceforth, humanity will thrive on strongly modified soils, and certainly mostly on artificialized soils. In urban areas soils are distinct from other areas by i) transformation through mixing, compaction, leveling, sealing, excavation and ii) exportation and input of soil and exogenous material (i.e., technogenic), wastes (organic, inert, toxic), and dredged materials (De Kimpe and Morel 2000). Also, some soils are designed to fulfill specific functions and provide a range of ecosystem services (e.g., transportation, water management, green infrastructures). In cities, deeply transformed soils coexist along with natural soils (showing only little changes except a very different environment), such as in urban forests.

"Urban soil" is often used to designate soils of anthropized areas. However, this definition is too restrictive to take into account all areas that are transformed by human activities. For that reason, SUITMA (*Soils of Urban*, *Industrial*, *Traffic*, *Mining and Military areas*) was proposed by Burghardt and Morel in 1998 to encompass all soils under strong human influence and to emphasize that the so-called "urban soils" are found in a large variety of strongly anthropized areas. "Military" was added in 2003 as those activities are of major impact on soils. However, if "SUITMA" better expresses the diversity of anthropized areas, each exhibiting specific features, in this book and in many other publications, "urban soil" is used with the generic meaning, making "SUITMA" and "urban soil" synonyms.

In this introductive chapter, we will briefly consider the challenges faced by urban humanity, and their consequences on soils. Then the general features of SUITMAs that will be described with more detail all along the book will be shortly given. Finally, the challenges that Soil Science faces regarding its role in urban areas will be addressed. The authors are well aware that those challenges are a view of soil scientists and that they should be challenged with views of other actors of the city environment (e.g., city planners). They are also aware of the necessity to adapt our semantic and scientific perspective to the urban environment to be understood and followed by the numerous stakeholders in charge of the development of sustainable cities.

Challenges for the urban environment

Building sustainable and enjoyable cities is one of the main expectations of humanity that involves a series of important challenges:

1. The increasing urban population produces an increasing demand in goods (food, water, energy). This leads to huge mass transfer from rural and mining areas towards cities; as a result, cities have long become a sink for elements, including energy and essential elements such as P (Nehls et al. 2014). Also, to minimize transport and reduce CO_2 emission, urban agriculture is a strong trend to produce food locally. In regions as in Africa, urban agriculture has been used for centuries, and probably represents a relevant model for city development.
2. Competition for land between agriculture and urbanization is also a major challenge. Cities need to increase their capacity to accommodate everyone; in a way they also preserve agricultural land. Brownfields are negligible regarding their total surface but are of considerable interest when considering their location, within the city borders. Being often seen as handicaps as they may conceal pollutants, they are a new resource for city development, provided appropriate restoration technologies are available. Also, belowground construction could be a trend to both expand urban surface and mitigate heat-island effect. If this trend was confirmed it would be necessary to design environments livable for permanent residence, i.e. in a complete artificial environment.
3. Climate change is a major issue that will probably affect cities more than rural environments. Mitigating heat waves, preserving urban vegetation, controlling green house gas emission, fighting against brutal floods are some of the major challenges faced by cities.
4. Biodiversity degradation or collapse is probably as important as climate change and closely related. Cities take this into account but, in general, in a way that mostly suits citizen expectations. Cities could have a prominent role in the general preservation of biodiversity within their borders, e.g., with the creation of specific habitats that favor organisms which contribute to the functioning of the urban ecosystem.
5. Finally, it is necessary to enable and stimulate healthier cities. Indeed, human health and social stability are important challenges for the prosperity of urban societies. Education and training, development of art, urban landscape, and preservation from transfer of contaminants are issues that receive much attention.

General features of SUITMAs

Soils of the urban ecosystem are under strong anthropic influence, and exhibit specific characteristics rather different than those of soils of natural environments. Composition, functioning, distribution and evolution of SUITMAs will be described in detail in the next chapters. The large diversity of soils in the urban environment is the result of the site history and management (e.g., transformation, excavation, input, changes of use), which makes soil classification and survey challenging operations (Fig. 1.1-1).

SUITMAs are now recognized in soil classifications or reference bases, e.g., *Technosols* and *Anthrosols* of the WRB 2006, and many belong to the Regosol group as young soils, with qualifi-

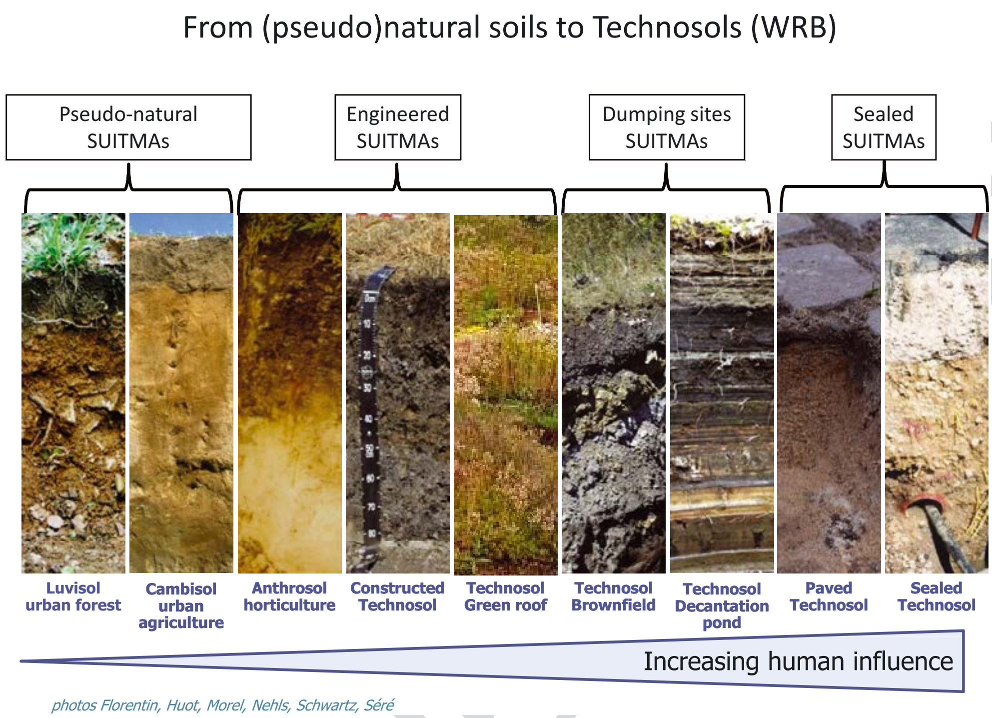

Fig. 1.1-1. Diversity of SUITMAs (after Morel 2015).

ers such like ekranic, linic (Charzynski et al. 2013) and recently proposed dialeimmic (Burghardt 2016). Urban soils were traditionally represented as white spots on maps or only depicted by the original natural soils. Nowadays, soil mapping of urban areas is generally based on soil functions in the city. For example, the New York City Soil Survey Staff (2005) proposed a map that stresses on a series of functions of open space to, e.g., management of municipal water and sewers, control of soil pollution, identification of wetlands and wildlife habitat, management of parks, control of runoff and stream flow in the urban environment.

SUITMAs have common features. They are mainly composed of coarse material (Burghardt et al. 2015), mostly of technic origin, urban waste (e.g., ash, bricks, coal, concrete, garbage, glass, gravel, oxides, plaster, plastic, rubble, sand, wood), and industrial waste (e.g., asphalt, ballast, dredged sediments, excavated bedrock, mine spoil, slag). They may contain organic and inorganic contaminants (e.g., hydrocarbons, metals). Technogenic materials often contain carbonates (concrete, mortar, lime) (Hiller 2000), and in many cases, they have properties of calcareous soils with high pH values (Kida and Kawahigashi 2015). SUITMAs used for horticulture or for waste and combustion residues disposal can be high in organic carbon. Black carbon is also a typical trait due to incomplete combustion of biomass and fossil fuel, and vehicle emissions (Nehls and Shaw 2010). From the high content of sand and gravel, SUITMAs have high water infiltration rates, but compaction is also a very common physical degradation of topsoil and subsoil that reduces infiltration (Burghardt 1996) and development of roots. Remarkably, SUITMAs can accommodate a large variety of organisms and are an efficient support for biodiversity (Pouyat et al. 2010, Santorufo et al. 2014).

Similar to natural soils, SUITMAs undergo pedogenic evolution that is closely dependent on parent material and environmental conditions (e.g., local climate). SUITMAs are young soils and often “polycyclic”. Evolution is remarkably fast as observed in former battlefields (e.g., Verdun) and slag fields (Burghardt et al. 2000), and in constructed soils (Séré et al. 2010). The specificity of pedogenesis in Technosols is due to the original mixtures of constituents, making possible the simultaneity of pedogenic processes, which coexist rarely in natural soils (Huot et al. 2015).

Challenges for Soil Science in the urban environment

Cities rely on soils but most people ignore how fundamental are soils for a more sustainable urban environment. Soil management in cities is almost exclusively the privilege of civil engineering, and soils remain probably a marginal component being considered when it comes to urban planning and urban management. This is largely due to Soil Science itself, as it has long ignored urban areas. Soils of urban areas were not considered as “real” soils until the pioneering works 40 years ago (e.g., Blume and Runge 1978).

In urban areas, soils are important in the daily life of citizens (transportation, housing, socio-economical activities, landscape shaping, health and social stability, human memory). They also play a major role for urban agriculture (e.g., horticulture, gardening, green roofs), green infrastructures (parks and street trees), and biodiversity (fauna, flora, microfauna). They are important for water cycle regulation (urban hydrology, infiltration, transport and sequestration of pollutants), the control of air quality (fine dust and pollutants) (Hoeke and Burghardt 2001), and the mitigation of local climate (heat-island effect) (Hoeke and Wolff 2011).

Among the primary issues are the functions of SUITMAs (Nehls and Wessolek 2011), and the ecosystem services they provide (Morel et al. 2014). SUITMAs are often built to fulfill specific functions (e.g., sealed soils for transportation of people and goods, constructed soils for ecosystem restoration and landscaping, green roofs and walls). But, underestimated, is the fact that SUITMAs may be the base for multifunctional characteristics in the urban ecosystem.

Actually, Soil Science is facing fundamental questions about the urban environment and its management. These questions are related to the functions of soils; the way sustainable cities can be built while preserving our soil capital; and how to get more ecosystem services from the same surface area. Hence, Soil Science should be capable to answer the question that could be asked by city planners: “*What soil(s) is(are) required to provide the expected services for citizens*?” and the following scheme should be built then implemented: *expected services > functions required > soil needed > soil engineering*.

Basic knowledge is then needed about objects and soil characteristics that notably differ from the ones that soil scientists are used to working with. This can contribute to understanding the functioning and evolution of SUITMAs in a very specific environment (e.g., local temperature), characterizing their functions and identifying their potential for ecosystem services, and finally helping in the mapping operations. With the soil management, it will provide solutions to important issues, e.g., food production potential, storm water infiltration, hazards and soil contamination, and urban heat mitigation. Also, other requirements will be met, such as reduction in the loss of arable land, reclamation of degraded and polluted soils (e.g., brownfields), health improvement, preservation of biodiversity, and conservation of archives of settlement history. As natural soils, SUITMAs undergo evolution under the influence of climatic and anthropogenic factors (e.g., temperature, compaction, reactive compounds, control of water input) and generate various distinctive features of pedogenesis. This evolution should be addressed to better manage the urban ecosystem.

Having a dedicated group within the IUSS helps to promote Soil Science in strongly anthropogenic areas, and increases the impact of soils science in the decision-making process for urban land management. It stimulates multi-disciplinary research and teaching for a better understanding and sustainable management of SUITMAs. However, the community should not be restrictive to soil science and should welcome other scientists dedicated to urban soil issues (e.g., geology, ecology, agronomy, horticulture, forestry, chemistry, physics) and actors of the urban management (e.g., economists, lawyers, geographers, policy-makers, engineers, artists, citizens). Also education strategies should be elaborated to promote awareness on urban soil ecological functioning. The SUITMA group is in constant movement as science makes progress and new generations take the lead. After more than 18 years of activity, SUITMA is recognized as a pioneer group, which has contributed to the increasing interest for soils observed worldwide in urban areas.

Finally, soil science should better communicate regarding the urban issues. SUITMA is now visible and can be an efficient vector for communication of soil science in the city. Dedicated journal and papers submitted to civil engineering journals are required. Books as this one and websites such are a good means to propagate information at a larger community than soil science itself, providing appropriate terminology is used.

Conclusion

SUITMAs are diverse, complex, distributed heterogeneously, and change rapidly with the city. They fulfill functions of the highest importance in the urban ecosystem and are "easily" manageable (soil design and soil construction). They are primary providers of ecosystem services that should draw the attention of city managers. Their economic value must be assessed. However, despite the growing awareness of their importance in urban areas, soils are still poorly valued for urban management (e.g., green infrastructures). Urban soil science covers all fields of traditional soil science, but it deals with a much larger number of soil uses and characteristics than occur in rural areas. It is necessary to increase knowledge on the properties, functioning, impacts and long-term evolution of soils under major human influence to better understand their role in anthropogenic areas, and better manage the urban ecosystem. Dialogue is essential between urban managers and soil scientists to improve the services that are expected from sustainable cities. Increase the impact of Soil Science in the decision-making processes for the sustainable management of the urban environment. Stimulate multidisciplinary research for understanding the urban environment, and share experiences and concerns from all over the world (e.g., case studies). This book is an initiative of IUSS fulfilled by the SUITMA working group. It is composed of a series of chapters, produced by colleagues who have shown interest over the years for urban soil issues, that cover many aspects of SUITMAs, including i) composition, properties, functions, evolution and classification of urban soils with examples of soil surveys, and ii) the management of soils in the urban environment with a special focus on soil sealing, urban agriculture, and the ecosystem services expected from urban soils.

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2.4 Functions of soils in the urban environment

Introduction

The world has experienced exceptional growth in urbanisation over the last decades. At present, approximately 54% of the world's population are urban dwellers (UN 2014). Today, urban areas cover ca. 6% of the total area of the European continent, and this value increases every 5 years by 0.34–0.50% (UN 2011). This clearly changes the perception of both cities and suburbs as a functional-spatial whole. Inside the contemporary urban organism, numerous functional transformations can be observed. The old industrial areas are eliminated and residential districts as well as service areas and new roads are built instead. Economic activity zones are created in the areas of suburbs. Some of the areas, especially those with defective building features are intended to function as parks and green areas. At present, of utmost importance are the functional-spatial changes occurring at the borderlines of urban developments, these changes are related to the urban sprawl phenomenon. Currently, cities expand both in reference to the development of new areas and also the pushing of their administrative borders in relation to their centres. In the first case, a consequence is substantial transformation of the soil functionality and the entire

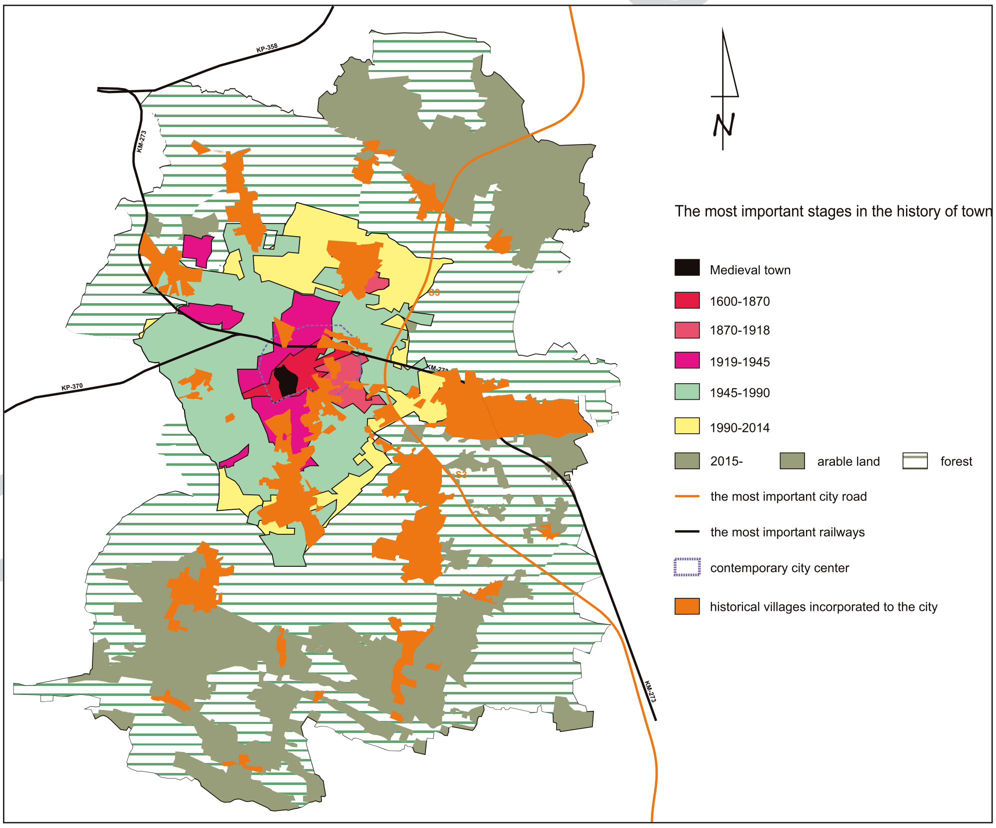

Fig. 2.4-1. Zielona Góra – the stages of the city growth against the background of the use of undeveloped areas.

natural environment. However, it is important to bear in mind that this takes place gradually, as the so called urban sprawl proceeds. An alarming phenomenon is the formation of vast wastelands before the final function is assigned to the areas of suburbs. Such wasteland areas in those cities whose growth is less dynamic or which are experiencing economic downturns may remain in this form for decades even. The second effect mentioned above results in the appearance of mainly agricultural and forest areas, not related to city development, within the city limits. In order to facilitate spatial planning, some cities seek very extensive outer areas which will be designated for development in the near or more distant future (Fig. 2.4-1). Until then, the soils which cover them continue with their current, mainly production and ecological functions.

Contemporary cites usually occupy areas which, time and again, have been transformed by man in different ways and to different extents (Fig. 2.4-1) – arable land, forest plantations, forest parks, former settlements, cemeteries, defensive structures, landfills, etc. (Greinert et al. 2013, Franck-Néel et al. 2015). This fact provides a distorted picture of the functionality of urban soils as different or same in relation to the natural areas. (Morel et al. 2015). Obviously, the situation also arises where cities reach those areas which are not useful from the point of view of agriculture and where features of the natural landscape have been preserved – this happens mainly in those cities located in mountain and foothill areas and cities adjacent to water bodies and forests. As a consequence of the presented origins, urban soils are affected by both the natural processes, which affect the natural environment, and man's activity.

History of soil functionality research

The issue of the fulfillment of specific functions by soils, in the conditions of the urbanised area, was outlined by Korndörfer (1996) based on the first act on soil protection in Baden-Württemberg drawn up in the year 1991. He defined cultural ecotopes as determinants of urban soils while preserving the functions of these soils. In the following years, numerous soil functionality models were created, being described by, among others: Larson and Pierce (1991), Doran and Parkin (1994), Karlen et al. (1994), Harris et al. 1996), Seybold et al. (1997) and Dailey (1997).

A complex assessment of soil functions was made by Blum (1993, 1997, 2005) who distinguished six main soil functions, including three ecological functions and three functions related to man's activity. The ecological functions of the soil include:
– food and other biomass production,
– environmental interaction: storage, filtering, and transformation,
– biological habitat and gene pool.

On the other hand, those soil functions which are related directly to man's activity include:
– source of raw materials,
– physical and cultural heritage,
– provision of a platform for man-made structures: buildings, highways.

In the Thematic Strategy for Soil Protection of the European Union (CEC 2006) the following soil functions were mentioned:
– biomass production,
– storing, filtering, and transforming nutrients, substances and water,
– biodiversity pool, such as habitats, species and genes,
– physical and cultural environment for humans and human activities,
– source of raw materials,
– acting as a carbon pool,
– archive of geological and archaeological heritage.

Soil functions in the contemporary city

Blume and Schleuß (1997) found that soils in urban areas serve primarily as land intended for development. Such an attitude dominates at present in city administration circles also (Morel et al. 2015). Fortunately, however, more and more often, city administrators are making more effort related to leaving large exposed areas where possible – used mainly to cultivate ornamental vegetation – between various structural forms. Therefore, the soils in these places fulfill a specifically understood biomass production function – as in this case its quantity does not matter so much as the state of the plants, which translates into the aesthetics of the place. Literature regarding the issue of the impact of the properties of Technosols on the growth and development of ornamental plants in cities has been rather scarce so far. Areas of cities also include typical agricultural lands – arable lands and allotments, on which the production function of the soil is of utmost importance. The production function of the soils dominates also in the areas of urban forests, those which have not been turned into park lands as a result of spatial planning. These areas are characterised by standard forest management aimed at timber harvesting.

Leaving uncovered places in cities is also extremely significant for other reasons; namely it affects the urban ecosystems. The soils fulfilll the role of the reactor for the physical, chemical and biological transformations of matter, both of the endogenous (being the effect of weathering of rocks and natural transport) and exogenous origin (introduced by man). In the majority of descriptions, particular attention is paid to the retention of toxic substances in the soils, which is explained by large settlements and thus is a risk for humans. Nevertheless, this element of the natural environment is fundamental to all the component circulation cycles. Due to the differences in their properties, urban soils differ from each other in terms of their capacities to store, exchange and decompose components, both those which are beneficial and harmful to the living organisms (Weber et al. 1984, Short et al. 1986, Burghardt 1996, Jim 1998).

In view of stable soil resources which are subject to transformations to a lesser extent, parks constitute important urban areas (Greinert 2015). The soils within park areas fulfill all of the already mentioned ecological functions by serving as stabilisers of much larger areas than the park areas per se. In order to strengthen these functions, a large majority of infrastructural functions are being limited on purpose.

Currently, great emphasis is placed on those issues related to the concept of ecosystem services (Costanza et al. 1997, De Groot et al. 2002, Fisher et al. 2009). In this context, urban soils are described as essential (Morel et al. 2015); this covers such functions as production of food, transport, retention and treatment of water, storage of carbon, reduction of air pollution, regulation of climate elements, source of biodiversity and formation of areas for ornamental and recreational purposes (McPhearson 2011, Gómez-Baggethun et al. 2013, Franck-Néel et al. 2015). All this, as a result, translates into an improvement in human health and optimisation of the functioning of a city.

The covering of huge areas with an impermeable surface of asphalt or concrete plates, called soil sealing is one of the most frequently discussed problems in urban ecology (Prokop et al. 2011, Piotrowska-Długosz and Charzyński 2015, Kostecki and Greinert 2016). The total surface of roads, pavements and buildings means that Ekranic Technosols are of relatively high importance in urban areas. In the area of Zielona Góra, the aggregated unsealed areas were smaller in the case of villa developments than among multi-family residential developments (Greinert 2003, Kostecki and Greinert 2016). This is caused by the small areas of individual building plots – often covering 2 or 3 acres, which include: the building, the access road, parking space and the pavement. In such cases, a drastic decrease in the water retention capacity of these areas is noticeable, which results, among other things, in the flooding of houses during heavy rainfalls (Scalenghe and Ajmone Marsan 2009). Covered soils are also characterised by significantly limited ecological functionality which is still important in view of the commonly present tree and bush plantings within the roadside green belts (Greinert and Drozdek 2015, 2016).

Many urban soil functions are a resultant of their chemical properties as frequently described in the literature (Charzynski et al. 2013, Capra et al. 2015). Very common is the pollution of soil with heavy metals, oil derivatives, salinity and alkalization; this limits the possibility of the occupancy of the areas by organisms and has a negative impact on the health condition and appearance of ornamental plants (Grigatti et al. 2007, Drab et al. 2009, Greinert et al. 2009). The presence of pollution in the soils of areas used as children playgrounds may also contribute to an increase in the incidence of various diseases directly attributable to the consumption of soil (Ryan et al. 2004, Ren et al. 2006, Ahamed and Siddiqui 2007). Historically, urban soils were also polluted with human and animal excretions (Franck-Néel et al. 2015), which is currently a less relevant limiting factor for the functionality of areas.

An interesting function of urban soils is their capacity to preserve objects of the cultural heritage of man. In the context of impact on the natural environment, the presence of artefacts in the soils is often treated as a symptom of their degradation caused by littering. In most of the anthropogenic transformed soils, the presence of waste materials has been noted. These are miscellaneous materials with various properties and impact potential. An admixture of wastes in soil as a consequence of building activity is a typical, widespread situation. Admixtures change the morphology, properties and functions of soils and dominate the soil-forming processes and the soil evolution route. While studying the soil cover of the city of Essen, Meuser (1996) noted technogenic materials, mostly rubble, in 70% of sites. Blume and Runge (1978) noted 56% of brick parts in the Rendzina soil from rubble in Berlin. Nehls et al. (2013) reported that the fine soil fractions of the urban soils of Berlin contained 3 to 5% of bricks, while the coarse fractions contained up to 50%.

In the context of the preservation of the cultural heritage of man, Necrosols, i.e. cemetery soils are of an exceptional nature (Sobocka 2003, 2004, Charzyński et al. 2010, Majgier and Rahmonov 2013). Their function is the safe preservation of human or animal remains or such decomposition of these remains which does not pose any threat to the natural environment, including ground and surface waters. For this purpose, usually soils with poor grain size distribution are selected whereas the ground water table is located at a considerable depth (Majgier and Rahmonov 2013).

The urbanosphere as a habitat of contemporary cities is subject to constant changes caused by human impact. Therefore, it is of particular interest to scientists from different fields. In contemporary ecology, urban areas are described as very complex, especially now, when large new areas are incorporated into cities. As a result, urban areas have varying features (Bradshaw 2003, Cadenasso and Picket 2008) and are characterised by a complexity of their soil cover (Greinert 2003, Pickett and Cadenasso 2009, Charzyński et al. 2013a). Soils of urban areas can be slightly transformed (without any consequences to soil classification), or the extent of transformations is so large that completely technogenic soils develop. Special attention should be paid to the uniqueness of the spatial and vertical distribution of soil parent rocks and the high contribution of technogenic materials therein. Their properties and degree of differentiation strongly influence the state of urban soils (Siem et al. 1987, Morel et al. 2005, Pickett and Cadenasso 2009, Huot et al. 2013).

The functionality of urban soils is often determined by the possibility of providing for the needs of plants growing on them. This characteristic is usually defined as soil fertility. Native soils are not characterised by high fertility which ensures good conditions for growth and the development of certain foreign species with clearly different requirements. Both in the past and at present, urban soils have been modified and transformed by gardeners to create urban greenery (Huinink 1998). The preparation of these sites for demanding ornamental plant species involves replacing the surface soil layer (in many cases the underlying ones also) with a garden soil

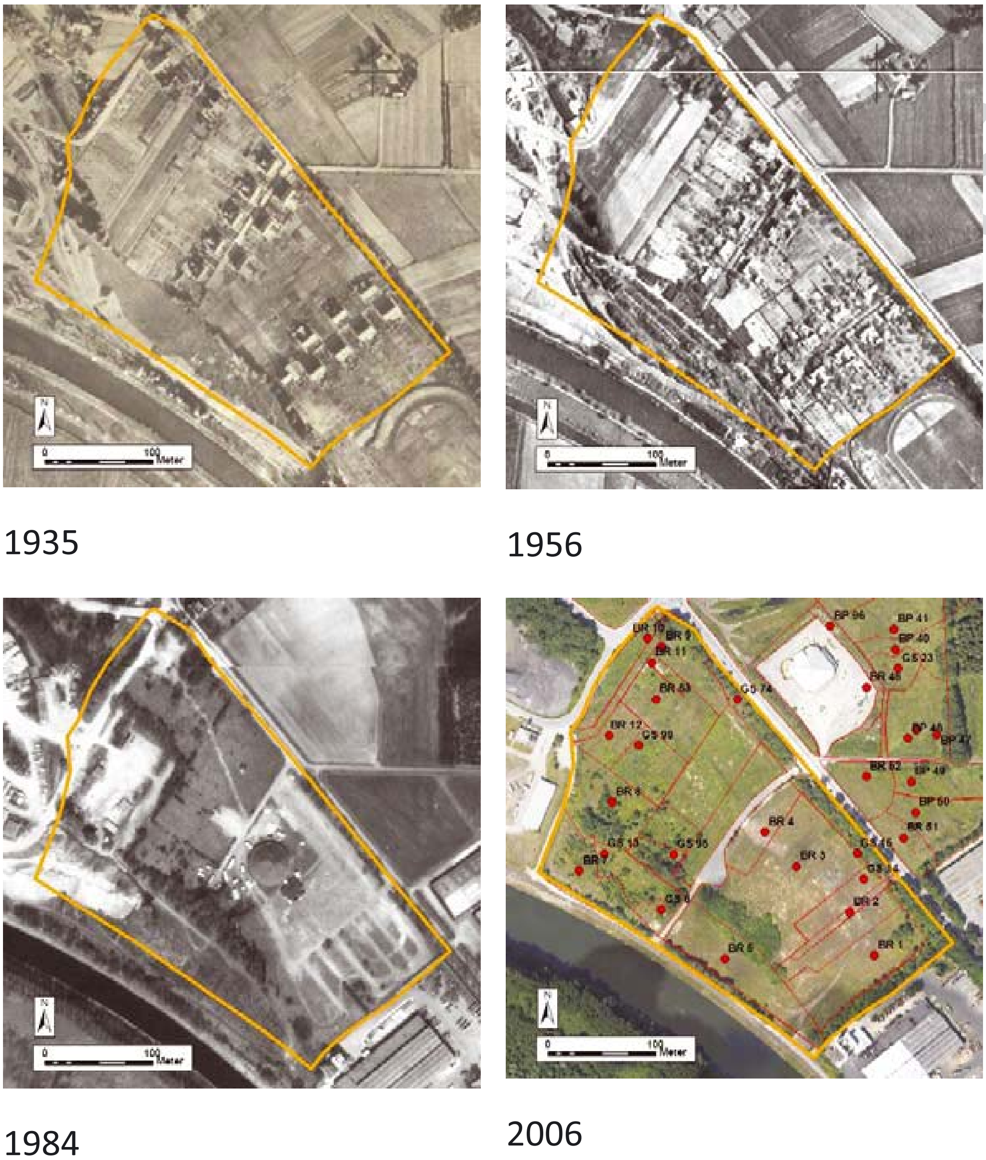

Fig. 5.2-7. Section of historical land use from 1935 until 2006 to select soil survey sites (Fachhochschule Osnabrück 2009 with permission of Environmental Agency, city of Osnabrück).

An essential part of a research project performed from 2006 until 2009 to assess soil functions in a northern district of Osnabrück dealt with an urban soil survey (Fachhochschule Osnabrück 2009). Before starting the survey, the time sequence of land use was documented by aerial images to decide upon the exact investigation sites for surveying. A selection of images dating from 1935, 1956, 1984 and 2006 reveal the changes in land use from first settlements along two roads in 1935 surrounded by agricultural land, followed by an intensified settlement in 1956

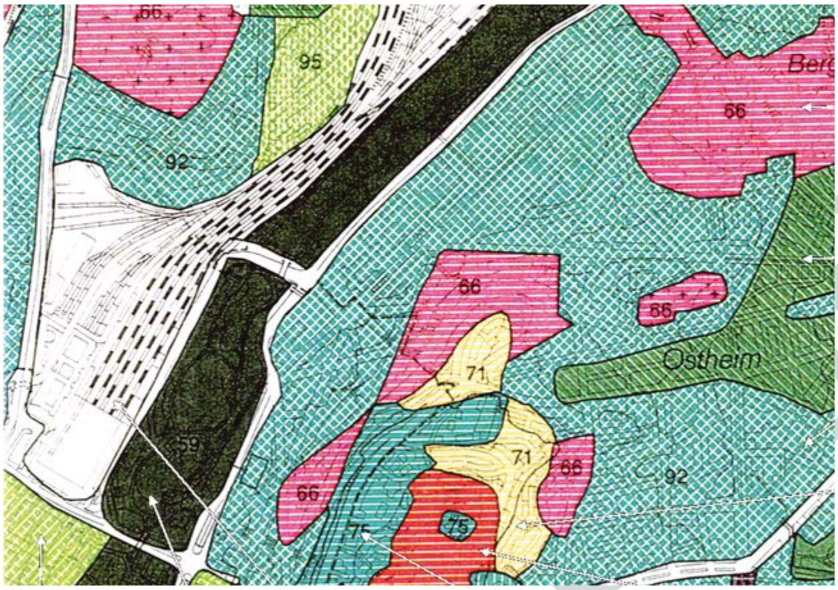

Fig. 5.2-8. Extract of urban soil map of Stuttgart with soil groups Technosol, Regosol, Cambisol and Colluvisol (based on Holland et al. 1997; modified and illustrated). Annotation: Designation of soil group «Colluvisol» according to German soil taxonomy and not in coincidence with WRB soil group (FAO 2014).

with private gardens to a demolition of the houses and conversion of the land to an commercial, leisure and industrial plot in 1984. The year 2006 shows the movement of the circular building (leisure center) to the north and the left behind open-space which is planned as an industrial park. Additional information, e.g. testimony of contemporary witnesses, soil maps, geological maps, was provided and considered to create the concept soil map. It turned out, that high amounts of coarse material can be expected in the topsoil. Therefore, it was decided to use percussion drilling equipment and soil pits to conduct the survey. Moreover, the survey sites were not planned along a geometric grid but closely depending on the land use history. The survey sites are marked with red dots representative for each delimited area in Figure 5.2-7.

At each survey site, the relevant information of the site and soil properties were documented in the survey according to the target soil function assessment. Generally, each survey takes a number of key properties about site and soil into account which are essential to draw urban soil maps and to assess SUITMAs:

a) site information
date of surveying, profile number, position (GPS), method of surveying, anthropogenic land forms, current land use, vegetation, surface sealing

b) soil properties
parent material (kind and amount of [technogenic] substrates), horizon symbol, depth of horizons, texture, coarse fraction, colour and mottling (if present), humus content, carbonate content, groundwater table, soil group

The tables and figures to assess these soil properties are published in the German guideline for soil description (Arbeitsgruppe Boden 2005, FAO 2006). To fullfill the demands of **urban soil surveying,** specific aspects explained in the German guidelines for Urban Soil Mapping (Arbeitskreis Stadtböden 1989/1997) are included, such as anthropogenic landforms, surface sealing or technogenic substrates.

The final and third step of **urban soil maps** lead to maps which depict soil groups in combination with specific parent material. An example from Stuttgart is presented in Fig. 5.2-8 (Holland et al. 1997). It demonstrates that despite heterogeneous origin and translocated parent materials the soil group Calcaric Regosols (loess and construction rubble) dominates the landscape. Technosols and technic Regosols are distributed close to the railway station. The former valley with linear structure east of the railway tracks carries «Colluvisol» consisting of deposited various technic parent materials but also natural translocated materials of coarse clayey-loamy marlstone fragments orginating from recultivated wine yards. Only a few areas are still covered with «natural» soils like Cambisols.

In fact, **soil maps of soil groups are not the final step** itself because (digital) urban soil maps provide information for various applications in planning and construction processes. Mostly, calculations of certain soil properties (e.g. infiltration capacity) and methods to assess soil functions (e.g. soil quality for food production) are of interest. Consequently, urban soil surveying in Germany is currently conducted «on demand» and therefore limited to project related mapping. On the one hand surveying is performed in a huge scale (e.g. 1:5,000) as part of urban construction planning with many drillings covering the whole small planning area (a few hectares). On the other hand, on a medium scale of 1:50,000 as part of rural planning of a district (many square kilometers) only a few sites can be inspected. Here, the soil survey is conducted if the concept soil map reveals contradicting (soil) information. For example, the topographical map shows a deposited area but the soil map shows a Histosol even though Technosols are more likely.

In summary, the knowledge about computing soil maps is mature but only few surveyors are experienced in «on-site mapping». Consequently, the quality of urban soil surveying varies enormously. In Germany it is still an urgent task to recruit urban soil experts to share their SUITMA experiences with experts in other fields such as planning, engineering, landscape architecture, and natural sciences (biology, ecology etc.).

Final personal comment

Many aspects and contributions in this chapter step back to the applied SUITMA research and surveying of our precious colleague and friend Dr. Silke Hoeke who unexpectedly died in May 2016, 49 years young. It is our deep desire to dedicate our contribution to this book to her and her honourable and passionate work for SUITMAs in Germany and worldwide!

The authors thank Wolfgang Burghardt for his valuable annotations to this chapter.

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The phyto-P-mining concept

For phyto-P-mining (Fig. 9.2.2-4), plants are grown to extract phosphorus from planting substrates, which were newly constructed from waste materials (Nehls et al. 2015) or from existing urban soils where they are still available and appropriate. Phyto-P-mining is not a single-purpose concept but must be understood as a surplus benefit of secondary urban greening, a re-greening of former grey city structures. It is especially suitable to exploit P from materials with comparable low P concentrations – too low for technical approaches but sufficient to grow plants. In terms of maximum P extraction the use of P hyperaccumulators, in other words species and plant communities with high P extraction and luxury consumption like rape (*Brassica napus*) would be preferable. However, the plant or plant community should be chosen according to the primary function of the secondary urban green such as climatic regulation (shade, cooling by transpiration), food production (contaminant exclusion), ornamental purposes or suitability to architecture as well as site specific conditions such as climate, light and water availability. For phyto-P-mining, vertical green seems to be promising as it can reach higher biomass to ground area (rooted volume) ratios and thus higher extractions than horizontal green.

The concepts to use the extracted P could be transferred from phytoremediation and hyperaccumulation of heavy metals by plants (e.g. Schwartz et al. 2003). This approached is now called

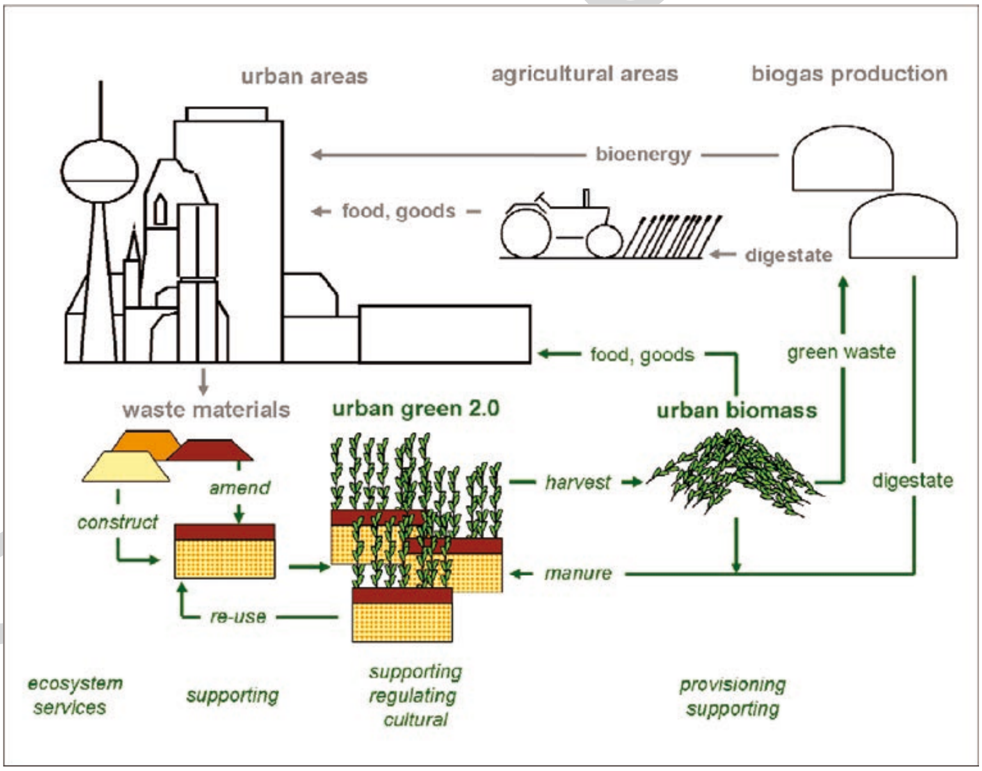

Fig. 9.2.2-4. The phyto-P-mining concept integrated into existing matter, energy fluxes and infrastructures (grey arrows and objects). Waste materials are used as planting substrates for a high number of secondary urban greens. The concept offers opportunities for biogas production and subsequent urban internal cycling as well as export of nutrients back to agricultural land (new matter and energy fluxes in green).

agromining (Morel 2013) and has been developed for metals like nickel, which is recovered from biomass (Simonnot et al., this book). To make the process profitable, Li et al. (2003) discussed to exploit the target metal but also to use the biomass for bioenergy production. Thus the biomass produced from urban green, which was installed for other purposes (e.g. ornamental) becomes a resource itself. In the case of phyto-P-mining, the final use of the biomass should be the production of biogas or wood pellets. Both would guide matter and energy into established flow chains and existing infrastructures. In Germany, there were 8856 biogas plants already installed in 2016 and another 150 prognosticated for 2017 (Biogas e.V. 2016). They are then delivering about 15% of the electricity demand of Germany.

With P concentrations in the biomass of 5 to 7×10^{-3} g g^{-1} and 3 to 4×10^{-3} g g^{-1} for rape and hop (*Humulus lupulus*), respectively both extract about 2 g P m^{-2} year^{-1}. For hop, grown in containers, one can expect much higher extraction rates. Assuming a planting substrate container of 1 m^3 per plant (7 m high, 1.5×10^3 g dry matter wt.), hop would extract up to 6 g P m^{-2} year^{-1} and thus up to 3 times the amount of horizontal plants, as discussed above.

The accruing amounts of biogas digestate (AD) and its P contents are intensively discussed topics in the bioenergy community. Mokry and Kluge (2009) found that the amount of AD is usually about 75% of the input for fresh green plant materials. The total P content of the digestate is usually 1.5 to 2×10^{-3} g g^{-1} of which 60 to 70% are water soluble.

Zirkler et al. (2014) and Möller and Müller (2012) found P accumulations of 16 to 25% in the AD compared to the plant biomass, which is proportional to the dry mass reduction through digestion, while the availability of P was 20 to 47% lower than that of the undigested material. Such data is not yet available for *Humulus lupulus* or other climbers like *Hedera helix*, *Parthenocissus tricuspidata and Fallopia baldschuanica*.

The direct application of ADs as manures in agriculture is already in practice (Mokry and Kluge 2009). Alternatively, P and other nutrients could be extracted and concentrated from the residues. Such techniques (Kuroda et al. 2012) are nowadays investigated due to rising amounts of digestate. The digestates of urban biomass could be used as fertilizers in (urban) agriculture and thus contribute to close nutrient cycles inside cities and between cities and their rural surroundings. Thus, not only the production of planting substrate but also the production of food and other plant products as well as the production of energy and fertilizers offer the possibility to enhance the economic benefits of phyto-P-mining.

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10 Key initiatives on soil awareness by Global Soil Science Communities: World Soil Day, International Year of Soils 2015 and International Decade of Soils 2015–2024

Introduction

All of us recognize that the soil plays a key role, not only in securing food, but in maintaining ecosystem integrity and the well-being of our human population. However, soil is not an infinite resource since its formation takes a long time but its loss can be a quick process. Our soils are under threat, particularly in urban areas. For many decades urban areas have grown rapidly and the pressures on the soil – often high-quality soils in floodplains where people settled centuries ago – have increased significantly. Numerous drivers and types of soil degradation that threaten soil health are constantly in our sight: climate change, desertification, deforestation, water shortage, erosion, urban expansion, pollution, sealing and compaction, etc. The results of soil degradation are evidently exerting detrimental effects on our life and ecosystem health.

To cope with soil degradation, sustainable soil management is the key to securing and maintaining soil, food and water, as well as the health of humans and ecosystems. However, how many actually know about sustainable soil management and how important it is? In the real world, many people are still treating soil like dirt lying under their feet, even though soil scientists are convinced that such an assumption is a fatal mistake since our lives rely on soil. Although the public may think that soil is a ubiquitous and infinite resource, it is a fragile and nonrenewable one.

The issues on the importance of soil need to be discussed not only within soil scientist communities but also among various stakeholders related to soils. Soil scientists should provide knowledge and information to meet such needs and challenges. This has become even more important because the levels of technology, knowledge and information available today are quite different, underscoring the need for more communication and collaboration. Soil in the 21st century has to meet the societal needs not only for food, fiber and shelter for humans but also for energy, water, climate change abatement, biodiversity, environmental health and ecosystem services, etc. On the other hand, soil science faces more traditional challenges as coping with population growth, soil degradation, decreases in crop productivity, shortages of arable land for food, and human malnutrition, etc.

The field of soil science is mushrooming by leaps and bounds due to the growing interest in such diverse needs and challenges. In addition, many emerging state-of-the-art technologies being developed by other fields will be available for us to integrate into soil science. We are in the presence of an explosion of information and knowledge in many fields of science. Thus the implementation of soil science should be global, intergovernmental, inter-organizational, and multidisciplinary, adopting the holistic integrations of research, policy and strategic plans.

Soil awareness matters in enhancing the importance of soils. This is the challenge that we can overcome only if various stakeholders work together. In this regard, the International Union of Soil Sciences (IUSS), as a global soil science community with 60,000 soil scientists and 75 member countries, must play a strong leadership in connecting various stakeholders in science, knowledge, policy and information of soils. As a strong partnership between UN FAO and IUSS, IUSS has already envisioned the importance of soil awareness several decades ago, and will support enhancing the global soil awareness. In this chapter, we introduce key global soil initiatives emphasizing the importance of soil awareness, such as World Soil Day (December 5^{th}), International Year of Soils (IYS) 2015 and International Decade of Soils (IDS) 2015–2024. Through those initiatives, all importance is on soil awareness and the key issue is to connect all stakeholders together through the initiatives.

Background resolutions

At the Council meeting of the 17^{th} World Congress of Soil Science (WCSS) in 2002, IUSS made a resolution that proposed the WSD as of December 5^{th}. Since then, or before or close to 2013, when the UN General Assembly designated the WSD and IYS 2015 (see attachment), there were many resolutions or declarations on the importance of soil on which to base the WSD and IYS 2015. Typical examples include: FAO World Soil Charter (WSC) in 1981 and the revised WSC in 2015; Report of the United Nations Conference on Environment and Development, Rio de Janeiro, 3–14 June 1992, vol. I, Resolutions adopted by the Conference (United Nations publication, Sales No. E.93.I.8 and corrigendum), resolution 1, annex I and II; US Senate Resolution in 2008 (S. RES 440, the 110^{th} Congress, 2D Session); later on followed by the Jeju Soil Declaration during the 20^{th} WCSS in 2014; and the Vienna Soil Declaration in 2015 during the closing ceremony of the IYS2015 and the IUSS EC meeting. There are even more proclamations proposed by various stakeholders or professional societies such that a complete listing is not feasible in this chapter. One may visit websites to get such resources in detail: www.iuss.org, www.fao.org/global-soil-partnership/en/, www.soils.org. http://globalsoilweek.org etc. All of these efforts were to emphasize soil as an essential natural resource, and soil professionals are playing a critical role in managing global soil resources.

World Soil Day: December 5^{th}

The International Union of Soil Sciences (IUSS) in 2002 in Bangkok, Thailand, during the 17^{th} World Congress of Soil Science, made a resolution proposing the 5th of December as World Soil Day (the birthday of his majesty King Bhumibol) to celebrate the importance of soil as a critical component of the natural system and as a vital contributor to human wellbeing. Under the leadership of the Kingdom of Thailand and within the framework of the "Global Soil Partnership". FAO has supported the formal establishment of the World Soil Day as a global awareness raising platform. The World Soil Day was endorsed unanimously during the FAO Conference in June 2013. Finally, the requested official adoption took place at the 68th UN General Assembly in December 2013 and was published (see attachment). During the 68^{th} UN General Assembly, the World Soil Day was declared 5^{th} of December (http://www.fao.org/global-soil-partnership/en/). At present, most of the member countries of IUSS celebrate December 5^{th} as the World Soil Day (http://www.iuss.org; http://www.fao.org/global-soil-partnership/en/).

International Year of Soils 2015

On April 24, 2013 at the 146th FAO Council, FAO member countries endorsed the request from the Kingdom of Thailand in the framework of the GSP for the proclamation of the International Year of Soils 2015. The IYS has served as a platform for raising awareness on the importance of sustainable soil management as the basis for food systems, fuel and fiber production, essential ecosystem functions and better adaptation to climate change for present and future generations (http://www.fao.org/global-soil-partnership/en/).

Outcomes of WSD and IYS 2015

Since designation of WSD and IYS2015 by the UN, IUSS with its member societies, FAO-GSP and other soil related institutes or organizations, have organized many events to celebrate the WSD and IYS2015. According to the UN FAO resources (http://www.fao.org/global-soil-partnership/en/), nearly one thousand events in nearly 100 countries were held to recognize such important initiatives. Many symposia, seminars, articles, publications, video clips and policies with different languages have been published in following up those events. The FAO-GSP proposed the activities with the title of 'IYS2015 and beyond' emphasizing sustainable soil management as a key tool for the sustainable development goals. The most important outcome from WSD and IYS 2015 is the enhancement of soil awareness in every category and dimension. Various meetings such as Global Soil Week, Global Soil Security, Global Soil Partnerships, regional or international symposia etc. will add the synergies to the enhancement of soil awareness in the future.

International Decade of Soil 2015–2024

In the Vienna Soil Declaration of Dec. 7, 2015, the IUSS has identified the key roles played by soils in addressing the major resource, environmental, health and social problems which humanity is currently facing (www.iuss.org). Given this situation, the IUSS believes that it is incumbent on IUSS members to not only maintain the level of activity generated in IYS 2015 but to increase the momentum and the extent of our contributions on these issues as we move towards the Centenary of the IUSS formation in 2024. In the course of the highly successful conference 'Celebration of International Year of Soils 2015 – Achievements and Future Challenges' the International Decade of Soils 2015–2024 was proclaimed by Rainer Horn, IUSS President. The Executive Committee and the Council of the USS will play a pivotal role in setting overall objectives and directions during this period. However, it is essential that all Divisions, Commissions, Working Groups, National, Regional and individual Members but also experts of related fields of expertise accept the challenge to undertake activities to ensure that the significance of soils in maintaining healthy life and environment remain continually at the forefront of political and scientific planning and decision making. The International Decade of Soils shall thus be a continuation of the efforts made during the International Year of the Soils 2015. It will be marked by a number of activities on the national and international levels.

World Soil Day and International Year of Soils

Resolution adopted by the General Assembly on 20 December 2013 [on the report of the Second Committee (A/68/444)]
United Nations A/RES/68/232
Sixty-eighth session
Agenda item 25

The General Assembly

Reaffirming General Assembly resolutions 53/199 of 15 December 1998 and 61/185 of 20 December 2006 on the proclamation of international years, and Economic and Social Council resolution 1980/67 of 25 July 1980 on international years and anniversaries, particularly paragraphs 1 to 10 of its annex on the agreed criteria for their proclamation, as well as paragraphs 13 and 14, stating that an international day or year should not be proclaimed before the basic arrangements for its organization and financing have been made.

Noting that soils constitute the foundation for agricultural development, essential ecosystem functions and food security and hence are key to sustaining life on Earth.

Recognizing that the sustainability of soils is key to addressing the pressures of a growing population and that recognition, advocacy and support for promoting sustainable management of soils can contribute to healthy soils and thus to a food-secure world and to stable and sustainably used ecosystems.

Recalling the Rio Declaration on Environment and Development,[1] Agenda 21,[2] the Programme for the Further Implementation of Agenda 21,[3] the Johannesburg Declaration on Sustainable Development,[4] the Plan of Implementation of the World Summit on Sustainable Development (Johannesburg Plan of Implementation)[5] and the commitments made therein and the outcome document of the United Nations Conference on Sustainable Development, entitled “The future we want”.[6]

Recognizing the economic and social significance of good land management,including soil, particularly its contribution to economic growth, biodiversity, sustainable agriculture and food security, eradicating poverty, women’s empowerment, addressing climate change and improving water availability, and stressing that desertification, land degradation and drought are challenges of a global dimension and that they continue to pose serious challenges to the sustainable development of all countries, in particular developing countries,

Recognizing also the urgent need, at all levels, to raise awareness and to promote sustainability of the limited soil resources, using the best available scientific information and building on all dimensions of sustainable development.

Noting that World Soil Day and the International Year of Soils can contribute to raising awareness of desertification, land degradation and drought, in line with the objective of the United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa.[7]

1 Report of the United Nations Conference on Environment and Development, Rio de Janeiro, 3–14 June 1992, vol. I, Resolutions Adopted by the Conference (United Nations publication, Sales No. E.93.I.8 and corrigendum), resolution 1, annex I.
2 Ibid., annex II.
3 Resolution S-19/2, annex.
4 Report of the World Summit on Sustainable Development, Johannesburg, South Africa, 26 August–4 September 2002 (United Nations publication, Sales No. E.03.II.A.1 and corrigendum), chap. I, resolution 1, annex.
5 Ibid., resolution 2, annex.
6 Resolution 66/288, annex.
7 United Nations, Treaty Series, vol. 1954, No. 33480.

Recognizing that, for these reasons, an international year and world day on the same issue on soil could exceptionally be proclaimed at the same time without constituting a precedent.

Recalling resolutions 4/2013 and 5/2013 adopted on 22 June 2013 by the Conference of the Food and Agriculture Organization of the United Nations at its thirty-eighth session.[8]

1. Decides to designate 5 December as World Soil Day and to declare 2015 the International Year of Soils;
2. Invites all Member States, the organizations of the United Nations system and other international and regional organizations, as well as civil society, non-governmental organizations and individuals, to observe the Day and the Year, as appropriate;
3. Invites Governments, relevant regional and international organizations,non-governmental organizations, the private sector and other relevant stakeholdersto make voluntary contributions for the observance of the Day and the Year;
4. Invites the Food and Agriculture Organization of the United Nations, mindful of the provisions contained in the annex to Economic and Social Council resolution 1980/67, and within the framework of the Global Soil Partnership, to facilitate the implementation of the Day and the Year, in collaboration with Governments, the secretariat of the United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa and other relevant regional and international organizations, civil society and the general public, and also invites the Food and Agriculture Organization of the United Nations to keep the General Assembly informed of the progress made in the implementation of the present Resolution, including on the evaluation of the Day and the Year;
5. Stresses that the cost of all activities that may arise from the implementation of the present resolution should be met from voluntary contributions, subject to the availability and provision of voluntary contributions;
6. Requests the Secretary-General to bring the present resolution to the attention of all Member States in order to encourage them to carry out activities to commemorate World Soil Day and the International Year of Soils.

71st plenary meeting
20 December 2013

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8 See Food and Agriculture Organization of the United Nations, document C 2013/REP.

Soils within Cities

Global approaches to their sustainable management

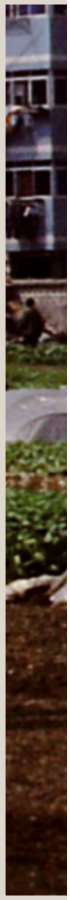
Editors: M.J. Levin, K.-H.J. Kim, J.L. Morel, W. Burghardt, P. Charzyński, R.K. Shaw
IUSS Working Group SUITMA

As the proportion of people living in urban areas has been and still is increasing, ***Soils within Cities: Global approaches to their sustainable management*** undertakes to shed light on the role and importance of soils in cities, and stresses the need to consider and manage this unique component of the urban ecosystem on our way to build sustainable cities.

Edited on behalf of the International Union of Soil Sciences, this book is the result of a joint effort of the international SUITMA (Soils of the Urban, Traffic, Mining and Military Areas) working group of IUSS.

Thirty-four short contributions comprehensively highlight key aspects and characteristics of soils of the urban ecosystem and the problems and challenges associated with them.
The authors lay out the fundamentals of soil science applied to anthropized environments (environments degraded by human activity), including composition, properties, and functions of soils of the urban environment, their pedogenic evolution, classification and mapping.
Furthermore, contributions present examples of actual urban soil surveys conducted in the US, Poland, Germany and Russia. Approaches to managing soils of the urban environment with focus on brownfields, soil sealing and urban agriculture, and the management of soil sealing are described.
A separate chapter is dedicated to the ecosystem services urban soils can provide, including sustaining and controlling water quality and quantity, providing C and P storage capacity, supporting biodiversity, pollution problems, and pointing out ecosystem services that even contaminated industrial and mine soils are able to provide.

"Soils within Cities" is aimed at expanding our view of soils of our planet, and having them taken into consideration for human well-being. It provides city planners and managers with a special reference that can serve to offer citizens a better life in the long run.



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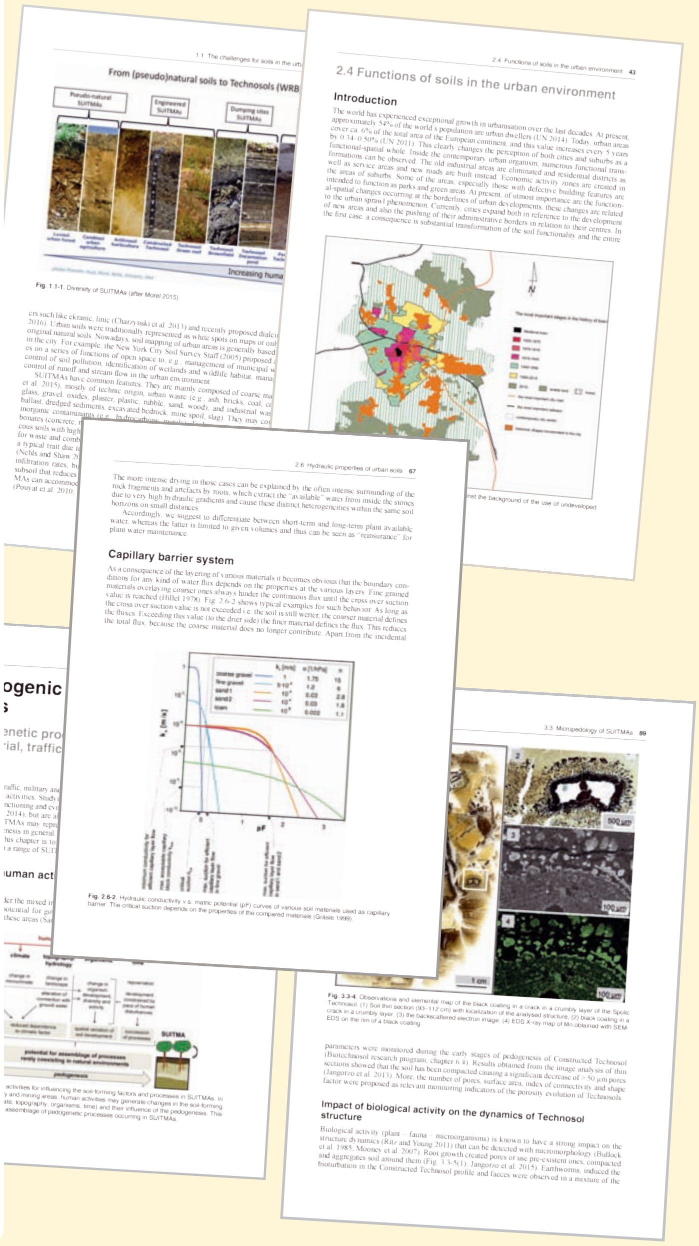

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