01.01 Soil Associations (Edition 2018)

Overview

Definition of Soil

Soil is the topmost layer of the crust of the earth formed on the surface by weathering and the influence of all other environmental factors. The mineral and organic substances of soil are pervaded with air, water and life forms. Natural soil originates through the combined interaction of parent material (basis rock), climate, water, relief, flora, and fauna. Depending on the conditions at each location and the developmental periods, different soil types with characteristic profiles and specific physical and chemical properties are formed.

Along with air, water, and sunlight, soil is the basis of life for plants and animals, including humans. Soil is not only a manufacturing base for foodstuffs, feeds, renewable raw materials and a source of raw material itself, but has, regarding its multiple functions, an outstanding importance in the ecosystem and is an important natural resource.

Soil is:

- natural habitat for animals and plants,
- part of the ecosystem and its material cycles,
- production basis for foodstuffs, feeds, and plants useful as raw materials,
- filter and storage depot for groundwater,
- location and supporter of constructed facilities,
- an influential element of nature and the landscape as well as
- an archive of natural and cultural history.

However, soil is translocated, altered, made impervious and destroyed by human activities (e.g. in agriculture or by construction of buildings).
Thus, soil represents a limited and non-renewable resource that must be protected and dealt with responsibly.

Soil Formation

Soil formation is a natural process beginning on the surface of the earth and continuing into the depths. Tab. 1 names factors and processes which lead to differentiations of soil structures and properties, and to the formation of various soil horizons (layers). Different soil types may thus be formed by combinations of soil horizons.

Soil-forming factors		**Soil development processes**
basis rock	solid rock	physical weathering
	loose rock	chemical weathering
climate	temperature	humus formation
	water	mineralizing
	wind	carbonate leaching (washouts)
surface formation	surface forms	clay muddying
	slope incline	podzolization
	exposure	gleying
vegetation	soil vegetation	nutrient transport

	shrub vegetation tree vegetation	erosion accumulation
soil fauna microflora		bio- and techno turbation
human interventions	material loss (e.g. crop harvest) melioration material input (e.g. fertilizer, pollutants) impervious soil coverage	

Tab. 1: Overview of soil-forming factors and soil development processes (according to Lieberoth 1982, amended)

Soil is formed from basis rock; it is a mixture of 3 components and 3 phases of solid, fluid, and gaseous constituents:

solids: minerals, including rock fragments of various sizes, oxides, salts, colloids, as well as organic materials,

fluids: soil solution with dissolved nutrients and other elements,

gases: soil air (oxygen, nitrogen, carbon dioxide).

Systematization of Soils

Soils are systematized in divisions, major soil groups, soil types, soil units, and soil forms. (Translator's note: Soil systems vary across countries and languages. This translation is based on the FAO/UNESCO system as much as is possible. The terms in parenthesis are common terms to assist non-specialist readers.)

The following divisions are differentiated according to groundwater level:

- terrestrial soils,
- semiterrestrial soils (semi-hydromorphic soils),
- hydromorphic soils (groundwater soils),
- sub-enhydrous soils (submerged soils) as well as
- bogs.

Tab. 2 demonstrates the classification at the example of the division of terrestrial soils and the major soil group of cambisols (brown soils) in particular. A detailed description of the soil classification can be found in the German Bodenkundliche Kartieranleitung (1982, 1994 and 2005).

Division	Major Soil Group	Soil Type	Soil Unit	Soil Form
terrestrial soils	cambisols (brown soils)	(typical) cambisol	normal type cambisol	...on glacial sand
			transitional type spodo-dystric cambisol	...on drift sand
			dystric cambisol	...on glacial sand
		luvisol		...on boulder marl
		podzoluvisol		...on boulder marl

Tab: 2: Soil classification according to the Bodenkundliche Kartieranleitung 1982 (Soil-scientific mapping guidelines)

Soil Types - Horizons

Soil types are considered stages of soil development often encountered under certain environmental conditions. They unify soils with the same or similar profile structures (horizon layers), due to similar processes of material transformations and translocations.

The most frequent soil types in Berlin are mineral soils with less than 30 percent by mass of organic substances. These soils are sometimes overlaid with organic horizons of varying thickness; H, L, or O horizons with more than 30 percent by mass of organic substances, especially in forests.

Soil types of mineral soils are categorized into the following horizons:

mineral topsoil horizon	- A horizon
mineral subsoil horizon	- B horizon
mineral undersoil horizon	- C horizon.

The **mineral topsoil A horizon** is characterized by the accumulation of organic substances and/or a loss of mineral substance; washouts of clay, humic materials, iron oxides and aluminum oxides. Material-specific accumulation and translocation processes enable further divisions of the A horizon. This differentiation in horizon terminology is indicated by a trailing lower-case letter; e.g., Ah, h stands for humus; Al, l stands for clay lessivation (washout).

The **mineral subsoil B horizon** is characterized by the accumulation of materials washed out of the topsoil horizon, as well as weathering and transformational processes, e.g., brunification, formation of clay, etc. This produces colours and material compositions different from that of the basis rock. Further differentiation of the B horizon parallels the A horizon, e.g. the v in Bv stands for weathered, brunified, clayey; whereas the t in Bt stands for accumulated clay.

The **mineral undersoil C horizon** is formed by the relatively unaltered basis rock underneath the soil.

The soil profile of soils characterized by several material translocational or transformational processes thus features several A and/ or B horizons layered on one another.

The horizon sequence indicates the horizon profile. The horizon profile is then used to differentiate soils into soil types.

Another factor in the formation of soil types is the influence of the groundwater level. The temporary or permanent effect of groundwater on soils affects how terrestrial and semiterrestrial soils form gley characteristics, e.g. rust and bleached spots. The depth of gley characteristics is applied in the naming of soil types, such as cambisols (brown soils):

< 40 cm	- dystric gleysol (brown gley soil)
40 - 80 cm	- eutro-gleyic cambisol (gleyic brown soil)
80 - 130 cm	- stagno-gleyed cambisol (gleyed brown soil)

Anthropogenic Alterations of the Soil

Anthropogenic alterations of the soil are increasing with progressing use of technologies and the use of ever larger areas.

Nowadays, there are hardly any untouched soils with horizon structures unaltered by humans. Soils are categorized as near-natural where horizon sequences remain largely unchanged in spite of influences by human use such as is the case with forest plantations, predominantly. Soils are categorized as anthrosols (anthric, anthropogenic soils, soils influenced by humans) when the horizon sequence has been destroyed. It has proven extremely challenging to categorize soils into these two groups, due to the difficulty in identifying the exact transition point to anthropogenic influences. The upper 20-30 cm of soils used for agriculture are usually mixed by plowing. Soils used for military training or for cemeteries can retain near-natural soils which can alternate with highly anthropogenic soils within small areas. The degree of anthropogenic influence and/or the degree of destruction is difficult to estimate without appropriate soil studies. The effect use has on the soil is also influenced by whether the whole area was used or not.

A developmental point of view sees soils as relatively "young" or "old". Soils relatively unaffected by use have a developmental period of up to several thousand years. The primary development of soils in the young moraine area around Berlin occurred in the Holocene period, which began about 12,000 years ago. A favourable climate, and the quick spread of vegetation connected with it, caused a stronger formation of soils. Various soil-forming processes took place during the long developmental period, and these processes are reflected in the formation of typical horizons. The horizon sequences of these soil types are thus much more greatly differentiated than those of "younger" soils.

Soil does not reproduce and is not reproducible. The use of soil is often linked with alterations of the original ecological conditions and this can lead to serious endangerment to the functional abilities of soil or even to its existence.

The **quantity** of soil as a natural resource is endangered by the progressive impervious coverage of soils. Industrial, commercial, traffic, and residential uses of soil are increasing more and more. Pervious soils once used agriculturally are found at the edge of the city; these soils have largely near-natural properties. Building construction caused soils to be translocated, mixed, made impervious over extensive areas and destroyed.

The **quality** of soils is altered by pollutants. Soils are permanently damaged by pollutant inputs from unregulated waste disposal, accidents, spills and leakages, improperly conducted storage depots, as well as emissions from industry, commerce, and traffic. Pollutant inputs can directly and indirectly endanger all organisms, including humans. The primary danger is uptake of pollutants through the food chain, but attention must also be given to the direct oral uptake of soils, especially by small children.

Soil can only store and filter a certain amount of pollutants. If soil storage and filter capacities are exceeded, pollutants can pass through soils and enter the groundwater.

These “area use” problems are more intense in metropolitan areas like Berlin based on e.g. the quantitative problem of impervious coverage, and the qualitative problem of material loads on soils from old contaminated sites and other pollutant inputs. The protection of the remaining near-natural soils is urgently necessary because soil does not reproduce; it cannot be manufactured, bred or grown. Strongly impaired soils can hardly ever be restored to their original quality.

Soil Protection

The discussion and considerations on soil protection at federal and state government levels in West Germany first really got underway at the beginning of the 1980s. Soil protection was first anchored in law in the Federal Soil Protection Act of 1998. This law was supplemented by a Berlin law in 2004.

The goal of the Berlin Soil Protection Act is "to protect the soil as the basis of life for humans, animals, and plants; to avert damaging alterations and to take precautions against the origin of new ones". Long-term effects to soil are to be avoided, and the natural functions of soil are to be protected.

A prerequisite for effective soil protection is knowledge about the spatial condition of soils, as well as impairments in their quantity and quality. In some cases, information on soil use, degree of impervious coverage and material load has been compiled in Berlin for decades. This information forms the basis for assessing the anthropogenic load on soils. A cadastre of impacts on soil was developed, and a Map of Degrees of Impervious Coverage, and a Map of Use were prepared.

To plan soil protection measures and to consider soil protection concerns at individual planning levels, it is necessary to determine soil value, suitability, and sensitivity. Complete data about distribution of soils and their ecological characteristics must be available. The Map of Soils may be used to derive ecological parameters in order to assess soil properties and functions.

Statistical Base

The first complete Map of Soil Associations for West Berlin was prepared by Grenzius in 1984, and the map was published in the Environmental Atlas (SenStadtUm 1985).

Soils in a landscape segment interact with neighbouring soils, air, water, and vegetation. Grenzius did not identify individual soil types, but rather combined soil types that interact with each other in a given landscape segment (geomorphic units) into soil associations. These soil associations were studied and evaluated for their location characteristics.

The present Map of Soil Associations was prepared for West Berlin based on the Map of Soil Associations and commentaries by Grenzius (Grenzius 1987), which define and describe soil associations. It was updated in 1990 for the first time. The assignment of soil associations, the definition of new soil associations and concept soil associations for East Berlin were enabled by a transposition concept (Aey 1991) based on conclusions by analogy, and with the aid of information from geologic and topographic maps, forest site surveys, detailed maps, aerial photography analyses, and information on land use and degrees of impervious coverage. Newer soil maps and an updated map of land use in West Berlin necessitated a reworking and updating of the Map of Soil Associations for West Berlin. For the first time, a soil map was created in the mid-1990s for the entire city (SenStadtUmTech 1998). It was updated in 2003. Changes in land use, updated data on impervious soil coverage and depth to groundwater, however, required further updates in 2008, 2012 and 2017. The results are thus presented here. Tab. 3 shows the data bases and preliminary information used throughout the developing process of the map.

Preliminary information:

- Bodengesellschaften Berlin (West) (West Berlin soil associations) - Map 1 : 50,000 (1985)
- Grenzius, R. 1987: Die Böden Berlins (West) (West Berlin soils), Dissertation
- Fahrenhorst, C., Haubrok, A., Sydow M. 1990: Übernahme der Bodengesellschaftskarte Berlin in das Umweltinformationssystem Berlin und Zuordnung von Bodeninformationen (Integrating the Map of Soil Associations of Berlin into the Urban and Environmental Information System of Berlin and assigning soil information)
- Aey, W. 1991: Konzept zur Erstellung einer Bodenkarte von Berlin (Concept for preparing a soil map of Berlin)
- Gerstenberg, J. H. 2017b: Erstellung von Karten zur Bewertung der Bodenfunktionen (Preparing maps for the evaluation of soil functions), commissioned by the Senate Department of Urban Development and Housing, Berlin 2017

Additional information for the entire area of Berlin:

- Geomorphic maps 1 : 100,000 and 1 : 200,000
- Geologic maps 1 : 25,000
- Geological overview map (GÜK) of Berlin and surrounding areas (1 : 100,000)
- Topographic maps 1 : 25,000 of various ages
- Topographic maps 1 : 10,000 (military topographical maps) (1988)
- Topographic maps 1 : 5,000, 1 : 4,000
- Aerial photography 1 : 4,000 and 1 : 6,000 (1990 - 2011)
- Data on current use and degrees of impervious soil coverage (as of: 2015 and 2016)
- Map on Depth to Groundwater 1 : 50,000 (as of: May 2009)
- Map on Ecological Condition of Shores and Banks 1 : 50,000 (1994)

Detailed information:

- Forstliche Standortserkundung (forest site survey) 1 : 10,000 (East Berlin) (1992)
- Standortkundliches Gutachten für die Berliner Forsten (Westteil) (forest site survey of Berlin's forests, West Berlin) - FSK Berlin-West (1991)
- Geologic maps 1 : 10,000
- Mittelmaßstäbige Landwirtschaftliche Standortkartierung (MMK) (medium-scale mapping of agricultural sites) 1 : 100,000 and 1 : 25,000 (1976)
- Map of Sewage Farms 1 : 30,500 (1993)
- Maps of Building Damage 1945, 1 : 10,000 und 1 : 25,000
- Detailed mappings from nature conservation legal protection procedures
- Soil-scientific analyses by the Soil Science Department of the Technical University of Berlin (TU)
- Soil-scientific analyses by the Geography Department of the Humboldt University of Berlin (HU)
- Altlastenkataster (Cadastre of old contaminated sites) (as of: December 1993 East Berlin, September 1994 West Berlin)

Tab. 3: Basis of the map of soil associations of Berlin

Methodology

Developing the First City-wide Map of Soil Associations

Starting Point

Aey (1991) wrote a guide on how to prepare a Concept Map of Soil Associations for the entire city. This guide was based on: the method described by Grenzius (1987) for preparing a Soil Association Map for West Berlin, and the Map of Soil Associations by Grenzius, which was transferred into the spatial reference system of the Urban and Environmental Information System (Informationssystem Stadt und Umwelt, ISU) by Fahrenhorst, Haubrok, and Sydow (1990). No Soil Association Map of this or a similar kind existed for East Berlin. The bases for the development of the soil association map of West Berlin were the excavations and drilling stock samples conducted in all of West Berlin. These were conducted in forest plantations and agricultural areas under consideration of geomorphological-hydrological conditions, and, in populated areas, under consideration of uses. All basis rock and most uses, with the exception of industrial areas, were surveyed several times, and appropriate soil-scientific mapping was carried out. Based on the analysis of this mapping, conclusions were derived for soil conditions in unmapped areas.

The comprehensive soil-scientific studies used for the Map of Soil Associations in West Berlin have verified the Soil Map for many areas, such as forest and agricultural areas (farmland). The map is only verified partially, however, for areas linked to fewer soil-scientific studies. Such detailed soil mapping for East Berlin, however, only existed for forests. The present map is thus to be regarded as a verified map only for these areas and as a concept map for all remaining areas. Mappings for further individual areas were added at a later stage. All derivations and determinations of soil associations for East Berlin – excluding forests – had to be derived from existing material, such as geologic and topographic maps, soil maps, and data on land use, etc. The accuracy, content, and age of this material varied greatly.

More precise classification models for soil associations, as well as the definition of new soil associations not described by Grenzius, were enabled both by maps and soil studies conducted in West Berlin after the publication of the West Berlin Soil Association Map, and existing soil maps for East Berlin, particularly for forest areas.

Since a scale of 1 : 50,000 does not allow the spatial distribution of individual soil types to be differentiated in sufficient detail, Grenzius' methodology for soil associations was retained which involves the selection of unifying geomorphological units. Soils of spatial and material coherence are combined as soil associations.

In conclusion, the whole map should be considered a **Concept Map with some verified areas** (partially verified concept map) only, which **exclusively focuses on pervious soils**.

Naming

The naming of the soil associations was based on the interactions of characteristic soils. The first and last soil of each soil association were specified, and, usually, one of the soils that characterizes material translocations (Grenzius 1987). This interacting system, or the link between soils in areas still extensively near-natural is characterized in the map legend by "-".

Near-natural soils are found only in loosely populated areas.

The structures of soils in populated areas have sometimes been greatly altered by human intervention. These anthrosols appear randomly next to each other and are connected in the legend by "+".

The legend is structured according to the degree of anthropogenic influence on and alterations of the soil. Near-natural soil associations are listed at the beginning; first the terrestrial soils, followed by the semi-terrestrial soils. Soil associations of anthropogenic aggradations and erosion are listed at the end. (Translator's note: "aggradation" describes soils and materials which have been placed somewhere by natural processes (glaciers, water flows) or human actions. Anthropogenic aggradations include deep landfills (waste and debris depots, etc.), and shallow landfill of upper layers (playgrounds, building construction sites, street construction, etc.))

Drawn Borders

Borders were drawn between soil associations following reliefs in ridges and sinks. Neighbouring units can hence display the same starting and concluding elements. The area delineation of soil associations also had to conform to the Berlin Digital Spatial Reference System based on block and block segment areas of homogeneous use. If this process led to great losses of information, particularly in non-built-up and loosely built-up areas such as forests, agricultural areas, and settled areas with low degrees of impervious soil coverage, these block map areas were divided further, according to the borders of the soil associations. The decisive factors in these cases were the borders of geomorphological and geological units, contour lines, soil types (detail map), and aggradation borders. The factors for the delineation of anthropogenic soil associations were land use and the borders of aggradation or erosion. The further subdivision of soil associations thus directly influences the formation of block segments in block maps 1 : 5,000 and 1 : 50,000 (ISU5 and ISU50, Spatial Reference Environmental Atlas) and their continuous updates.

Near-natural and Anthropogenic Soil Associations

Determining factors for soil development are parent material, prevailing soil type, relief (slope, sink, channel, gradient etc.), water and climate conditions, as well as the degree of human influence. Anthropogenic influences are characterized by aggradation of natural soil material and non-natural materials (e.g. war debris, construction debris, slag and cinders), and erosion of natural soil. Important measures for anthropogenic alterations in soil include present and previous use, and the degree of impervious soil coverage. The map only shows pervious soils, independent of the degree of impervious soil coverage. The latter is used only to support the analysis of the degree of anthropogenic alterations of pervious soils in this area.

Near-natural soil associations are characterized by typical soil types, geomorphological structures, substrate/ soil types, and the influence of water. There are few alterations caused by humans.

The soil structure and soil associations of **anthropogenic soil associations** are not influenced by the topographical relief but rather by type of use, as well as the occurrence and type of aggradations. Some transitional forms still retain the characteristics of parent material, geomorphology, groundwater levels, and some natural soils. This is the case at military training areas, former surface mining sites, cemeteries, and levelled sewage farms.

Tab. 4 presents the effects human intervention has on soils. It classifies the urban area into various soil association categories (anthropogenic soil associations) under consideration of historic and current uses, damage to buildings in the Second World War, the type of construction, and the degree of impervious soil coverage.

Landscape segments and land uses	Effects on soils
bog	usually dried, soiled upper part, sometimes acidic, sometimes with accumulated heavy metals in the upper centimetres
forest	topsoil disturbed by planting, accumulated heavy metals in topsoil and organic layer, soil strongly acidic
farmland (agricultural field)	top 3 dm plowed, varying degrees of organic and mineral fertilizers, depending on crop: little to clearly increased pH value compared to forest plantations, sometimes with accumulated heavy metals
landscape park/ park	landscape park - similar to forest, some highly acidic soil parts, other parts with somewhat increased pH values from caretaking measures, structures sometimes altered by decorative landscaping measures, sometimes replaced by anthropogenically aggraded gravel and stone parks - natural soils alternating with soils formed by aggradation with higher nutrient and pollutant contents, sometimes fertilized and watered
allotment gardens	soils partially translocated by house construction or replaced by anthropogenic aggradations of gravel and stone, garden areas altered by use of organic substances and excavations (hortisols), heavy fertilization, pH value in neutral range, no original soils in gardens on aggradations or excavated areas, soils on debris (over landfill) heavy use of organic and mineral fertilizers, watered, sometimes polluted
cemetery	soils extensively altered by deep excavation and introduction of organic substances (necrosols), based on this and fertilization and watering, pH values ranging from slightly acidic to neutral
outdoor water	soil erosion after destruction of reeds and water recreation, sometimes

recreation	aggradations of sand, mostly raw soils, eutrophic soils due to nutrient-rich water
airport	soils retained after construction exist only in small areas, usually greatly altered typologically by grading, sometimes soil on debris aggradation
sewage farm	soils altered during construction by grading and irrigation of waste waters, accumulated nutrients, salts, and heavy metals, pH values ranging from moderately low to acidic range, high degree of additional watering
park, mainly on aggradations; open areas in the inner city; hills of debris	no original soils exist, soil development on debris aggradation or translocated natural stone, sometimes watered, polluted, pH values in neutral range, largely water repellent ruderal soils
military training area, gravel pit	hardly any original soils, raw soils from excavations and translocation, raw soils, poor in nutrients
track facilities	no original soils, often old contaminated sites with high levels of herbicides
traffic areas, street edges, paths, squares	aggredations, impervious soil coverage, reduction of water uptake and gas exchange, penetration of salts, lead, and cadmium (traffic), oil , gas, heat (defective pipelines) etc.
residential areas, loose construction (with yards)	some natural soils, depending on construction density, humus accumulation and eutrophication, additional planned watering
residential areas, closed construction in the inner city	hardly any or no original soils, depending on construction type, some soils of construction and war debris, sometimes fertilized, watered, polluted, pH values ranging from neutral to (extremely) alkaline, pollutant inputs
industrial locations and technical supply facilities	hardly any natural soils, production-specific pollutant inputs, aggradations (construction and war debris, ashes, slags and cinders), compacted soils

Tab. 4: Landscape segments, land uses and their effects on soils (according to Blume et al. 1978 and Grenzius 1987)

Soil Associations / Collective Soil Associations / Concept Soil Associations

The near-natural and anthropogenic soil associations defined for West Berlin by Grenzius were transposed onto East Berlin with the aid of existing data bases, and inferred conclusions for comparable areas, such as geomorphology, use, water conditions, etc. Problems occurred in areas where soil associations could not be derived and thus classified based on existing data bases, or where combinations of uses and geomorphology appeared that were not considered or did not exist in West Berlin. Examples of these areas are former sewage farms, sinks in plateaus, and mapped end moraines podzols. Besides the soil associations included in the Soil Association Map of West Berlin, the availability of appropriate mapping was used to develop new soil associations. In the case of insufficient pre-existing information, concept soil associations and collective soil associations were developed. The soil associations used in the map thus have three different levels of differentiation and characterization:

1. **Soil Associations (SA)** - Soil associations in dependence on geomorphology and use. These can be verified by field studies in the form of detailed maps, key profiles, and soil profile studies.
2. **Collective Soil Associations (CSA)** - These soil associations are collective, as insufficient data material for East Berlin does not allow for a differentiated categorization of individual soil associations within the collective soil association.
3. **Concept Soil Associations** - are soil associations which do not exist or which have not yet been verified in West Berlin. They are a combination of use and geomorphology, such as levelled sewage farms. They have not yet been verified by soil studies.

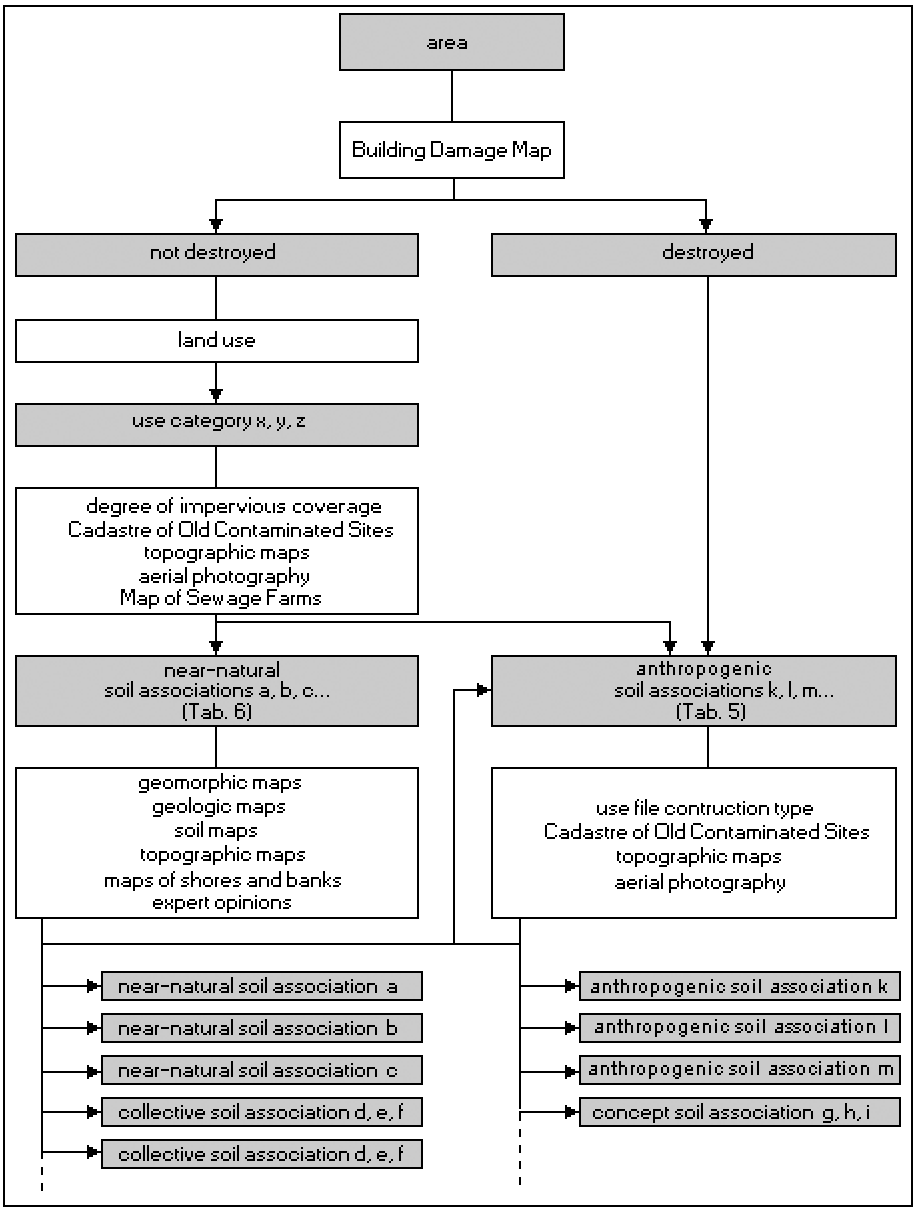

Fig. 1: Diagram demonstrating the classification process of soil associations

Categorization of Soil Associations

The categorization of soil associations was carried out in several steps:

1. The actual use of each area was extracted from the land use data record. Each type of use category was linked to a specific model pattern on which the categorization of soil associations was based (cf. Fig. 1).

2. Areas were defined as having mainly naturally developed soils or highly anthropogenic soils. Land use and degree of impervious coverage were used as criteria to pinpoint the extent of anthropogenic alterations of soils. Other factors of determination were existing data material such as the cadastre of old contaminated sites, geologic and topographic maps of various ages, building damage maps, etc. (cf. Tab. 5).

3. For areas with hardly altered soils without aggradations or erosion, and a degree of impervious coverage of < 30 %, or a degree of impervious coverage of < 25 % at new, large area construction areas, soil associations were categorized into near-natural soils according to the model pattern in Tab. 6.

4. Areas with a degree of impervious coverage of ≥ 30 %, or ≥ 25 % at extensive areas of new constructions, were classified as highly anthropogenic soil associations, depending on the type of use and the type of construction (cf. Tab. 5).

Use category	Possible soil association (SA)
independent of use (excluding industry), heavily destroyed (> 50 % of building substance destroyed)	SA 2500 [52]
residential area	according to construction type: degree of impervious coverage (IC) >= 30%, SA 2483 - 2486 [50], 2490 [51]; ds >= 25 % in newly constructed large settlement areas, concept SA 2487 - 2489, 7777 [50a], 2482 [50aR], near-natural SA in the case of settlement, single house or village construction and ds < 30 %
mixed area	according to character, construction type and ds, SA 2540 [57], 2483 - 2486 [50], 2490 [51], 2487 - 2489, 7777 [50a], 2482 [50aR], or near-natural SA
core area	according to character, construction type and ds, SA 2540 [57], 2483 - 2486 [50], 2490 [51], 2487 - 2489, 7777 [50a], 2482 [50aR], or near-natural SA
industrial/ commercial area	SA 2540 [57]
public service and other special uses	according to character and construction type, SA 2540 [57], 2483 - 2486 [50], 2490 [51], 2487 - 2489, 7777 [50a], 2482 [50aR]; ds < 30 % near-natural SA or SA 2430/2440/2441 [42/43/43a]
utility area	according to character and construction type, SA 2540 [57], 2483 - 2486 [50], 2490 [51], 2487 - 2489, 7777 [50a], 2482 [50aR]; ds < 30 % near-natural SA
weekend cottage area	near-natural SA or SA 2483 - 2486 [50]
traffic area (excl. streets)	SA 2470 [49], concept SA 2487 - 2489, 7777 [50a]
construction site	concept SA 2487 - 2489, 7777 [50a], 2482 [50aR] or near-natural SA
forest	near-natural SA, except in the case of aggradations
body of water	no SA
meadows and pastures	near-natural SA, or sewage farm SAs
farmland	near-natural SA, or sewage farm SAs
park, green space	near-natural SA, SA 2483 - 2486 [50], 2487 - 2489, 7777 [50a], 2482 [50aR] or disposal site SA
city square, promenade	SA 2483 - 2486 [50], 2487 - 2489, 7777 [50a], 2482 [50aR], 2490 [51], 2500 [52]
cemetery	SA 2390 to 2420 [38 to 41]
allotment gardens	near-natural SA; in the case of aggradations concept SA 2471 [49a], SA 2483 - 2486 [50], or disposal site SA
fallow area / ruderal area	near-natural SA; in the case of aggradations, depending on aggradation type also SA 2540 [57], 2483 - 2486 [50], 2487 - 2489, 7777 [50a], 2510 [53], 2530 [55], and 2470 [49] are possible
camping ground	near-natural SA, except in the case of aggradations
sport facility, outdoor swimming pool (including water sports, tennis, riding, etc.)	near-natural SA, or SA 2487 - 2489, 7777 [50a] when ds ≥ 30 %
tree nursery, horticulture	near-natural SA, or SA 2483 - 2486 [50], SA 2487 - 2489, 7777 [50a]
surface mining, gravel pit	SA 2450 [47], 2460 [48]
levelled sewage farms, sewage farms	SA 2560 [60], 2580 [62], 2590 [63], concept SA 2482 [50aR], 1131 [12a], 1141 [13a]
waste disposal site	SA 2510 [53], 2530 [55]
IC = degree of impervious coverage, SA = soil association	[ ] = old description

Tab. 5: Classification guidelines for soil associations, in dependence on use category and degree of impervious coverage

The classification rules presented in the figures and tables are general guidelines. It was often impossible to classify soil associations precisely, based on insufficient information on current land use or the degree of impervious coverage. Decisions hence had to be made on a case-by-case basis. The classification of soil associations in residential areas considered the construction type; the historical land use was also significant. Residential areas located on sites with previous industrial used were considered industrial areas, e.g., the Thälmannpark residential unit. Waste disposal sites, military locations, sewage farms, and other aggradations were analyzed also based on information such as maps, the Cadastre of Old Contaminated Sites, aerial photography, expert opinions, etc.

Near-natural soil associations were determined following the process presented in Tab. 6, if it had been ruled out that soils were greatly altered by human influence.

Geomor-phology	**Soil type/ substrate**	**Morphological division**	**CSA**	**Distinct characteristics from other SAs**	**SA 1:1**	**Additional information**	***Concept SA*/ SA**
plateau	• (boulder) marl			• sand (on BM) < 0.8 m	1010 [1]	• used as a sewage farm at point of mapping	*1131 [12a]*
						• influenced by sewage farm water, low-lying location	1130 [12]
				• clayey sink fill	1120 [11]		
		• fluvioglacial meltwater channel		• peat	1270 [27]		
	• fine sand on (boulder) marl	• dune		• fine sand < 2.0 m	1080 [8]		
	• (glacial) sand			• sand (on BM+G47) 0.8 - 2.0 m	1020, 1030 [2, 3] *		
				• sand > 2.0 m	1070 [6]	• used as a sewage farm at point of mapping	*1141 [13a]*
						• influenced by sewage farm water, low-lying location	1140 [13]
		• fluvioglacial meltwater channel		• without peat	1050 [7]		
				• fossil gley, dried lower bog	1290 [29]		
				• lower bog	1300 [30]		
		• plateau slope, end moraine slope			1060 [5]		
		• fluvioglacial meltwater channel with alluvial dynamic			1280 [28]		
end moraine (oser/ kames)	• (glacial) sand with (boulder) marl			• calcaro-dystric histosol (lime slope bog), dystric gleysol (slope gley)	1180 [17]		
	• (glacial) sand/ gravel			• dystric cambisol (rusty brown soil)	1040 [4]		
				• podzol	1110 [72]		
sink	• (glacial) sand on (boulder) marl			• sand < 2.0 m		geolog. map 1 : 25,000	*1021 [2a]*
	(boulder) marl			• sand < 2.0 m + peat		geolog. map 1 : 25,000	*1022 [2b]*
	• (glacial) sand			• sand > 2.0 m		geolog. map 1 : 25,000	*1072 [6b]*
glacial spillway (Urstromtal) / outwash plain	• sand				1160 [15]		
				• peat		geolog. map 1 : 25,000	*1164 [15d]*
				• limey	1150 [14]		
		• lowland		• turf (some dry)	1260 [26]		

Geomor-phology	Soil type/ substrate	Morphological division	CSA	Distinct characteristics from other SAs	SA 1:1	Additional information	*Concept SA*/ SA
				• lime accumulation	1240 [23]		
		• dead ice sink			1250 [25]		
		• meltwater channel with dune		• peat	1230 [22]		
		• meltwater channel without dune		• peat + half-bog		geolog. map 1 : 25,000	*1231 [22a]*
		• shallow channel		• limey	1220 [21]		
	• sand on (boulder) marl			• sand < 2.0 m		geolog. map 1 : 25,000	*1021 [2a]*
				• sand < 2.0 m + turf		geolog. map 1 : 25,000	*1022 [2b]*
dune	• fine sand	• no bog (GOK > 40 m)	1090, 1100 [9, 10]	• podzol	1090 [9]		
				• no podzol	1100 [10]		
		• with bog			1200 [19]		
		• low dune on valley sand or drift sand cover, remote from groundwater (GOK < 40m)			1190 [18]		
		• dune on valley sand, slope, near to groundwater			1210 [20]		
river lea	• sand			• calcaric regosol (para-rendzina of lime mud)	1310 [31]		
	• sand		1360, 1370 [33, 34]				
	• sand + peat		1320, 1330 1340 1350 [24, 32, 35, 36]				
1 : 25,000 Blatt Bernau und Königs-Wusterhausen							
BM = boulder marl, GOK = ground level							

Tab. 6: Classification of soil associations of natural lithogenesis (according to Aey 1991)

Typical landscape segments with characteristic soil types, key profiles and the most important ecological properties exist for almost all soil associations.

Presentation within the map

For the map, soil associations, concept soil associations, and collective soil associations were aggregated into groups of uniform colour. Geomorphic uniformity was decisive for the formation of near-natural soil association groups. Land use was decisive for the formation of anthropogenic soil association groups.

Update of the Map in 2003

Due to the modified geometry of the basic map (splitting or merging of areas) and update of land use and impervious soil coverage, the map had to be revised after a decade in 2003.

For all new areas, the soil association of the existing map was adopted, if a clear geometric mapping was possible, no major change of land use had taken place and the degree of impervious soil coverage was close to that of the old soil association. In the case of a land use change from built-up to open space use, the old soil association was also maintained.

In the case of a land use change from open space to a built-up use combined with impervious coverage, an anthropogenic soil association was assigned. This was also the case if excessive impervious soil coverage was recorded.

All other new areas were assigned a soil association by expert opinion.

Since its creation in 1998, the map of soil associations was supplemented with the essential and additional differentiation of the soil association BG 50 (regosol + calcaric regosol + hortisol) and BG 50a (calcaric regosol + loose lithosols + regosol), depending on the different parent materials including glacial sand, drift sand, fluvial sand and boulder marl. The assignment process was based on the geological overview map of Berlin and surrounding areas 1: 100,000 (GÜK 100). With this, the number of units in the legend increased to 76. In addition, a four-digit ID was introduced to distinguish the soil associations. Each soil association and its characteristics are stored in the soil database under their ID. The map at hand has a scale of 1 : 50,000 and is an overview map used by public planning agencies in determining goals and measures. Detailed statements about individual lots cannot be inferred, as they would require project-specific detail maps.

Update of the Map in 2008

Due to the modified geometry of the map basis (splitting and merging of areas - as of December 31, 2005) and update of land use and impervious soil coverage, the map had to be revised and updated once again in 2008.

The methods to record new areas, detect changes in land use or impervious soil coverage numbers exceeding class limits were the same as used in 2003.

Soil association 1251 [c] (transitional eutric histosol - histo-humic gleysol - dystric gleysol, dead-ice sink in ground moraine flat upland), an oligotrophic transitional histosol located in the Düppeler Forst area, was newly defined.

Furthermore, the findings of the following large-scale soil-scientific mappings from the Geography Department of Humboldt-University of Berlin were integrated into the map (Makki and Bíró 2008):

- sewage farms Blankenfelde,
- nature protection area and landscape protection area Johannisthal,
- landscape protection area Tiefwerder Wiesen as well as
- Tempelhof airport.

Update of the Map in 2012

Due to the modified geometry of the map basis (splitting and merging of areas - as of December 31, 2010) and update of land use and impervious soil coverage, the map had to be revised and updated once again in 2012.

The methods to record new areas, detect changes in land use or impervious soil coverage numbers exceeding class limits were the same as used in 2003.

Furthermore, the findings of the following large-scale soil-scientific mappings from the Geography Department of the Humboldt-University of Berlin were integrated into the map (Kissner 2010):

- Königsheide.

Update of the Map in 2017

Due to the modified geometry of the map basis (splitting and merging of areas - as of December 31, 2015) and update of land use and impervious soil coverage, the map had to be revised and updated once again in 2017.

The methods to record new areas, detect changes in land use or impervious soil coverage numbers exceeding class limits were the same as used in 2003. See Gerstenberg (2017a) for a comprehensive description of the methods.

In addition, the results of various individual mappings by the Soil Science Department of the Technical University of Berlin and the Chair of the Geography of Soils of the Geography Department of the Humboldt University of Berlin were included (Böhme 2009, Makki et al. 2014a, Makki et al. 2014b, Godbersen 2007, Edelmann 2014). By incorporating the results of the research project "Berlin's peatlands and climate change " (Klingenfuß et al. 2015, Gerstenberg 2014), the location/ extent of peat soil associations and their characteristics could be defined in more detail.

The soil association 2441 [43a] (calcaric regosol + regosol + loose lithosols on military training area on (glacial outwash plain) moraine area of sand containing war debris and construction) was added as a new association. It is a part of the former military training area Parks Range in Lichterfelde Süd.

Map Description

Soils vary greatly in their ecological properties, depending on parent material, grain size composition, humus contents, relief profiles and depth to groundwater.

Important parameters that characterize the ecological properties of soils are: usable field capacity, aeration, cation exchange capacity, pH values, effective rooting depth, and summer moisture.

Usable field capacity is a measure for the amount of water in soil available to plants. This includes slowly moving seepage water and retained water in the coarse and medium pores of soil. Soil water in the fine pores (dead water) is subject to high water tension and cannot be absorbed by plants. The amount of water stored in the soil is determined by pore volume, pore size distribution, grain size composition, and humus levels.

Aeration of the soil includes gas exchange by diffusion between the atmosphere and soil. Aeration is critical for the growth of plant roots and the existence and activity of soil organisms. The intensity of gas exchange depends on pore volume, particularly the number of coarse pores, as well as their continuity. Other factors are grain size composition, structure, and the water content of the soil.

Cation exchange capacity is the number of exchangeable cations bound to clay minerals and humus materials in the soil; e.g. Ca^{2+}, Mg^{2+}, K^+, Na^+, NH_4^+, H^+. Cation exchange capacity gives indications of the soil's ability to bind and store nutrients. This binding capacity, or nutrient storage capacity, depends on the type and amount of clay minerals, humus amounts, and pH values. Current actual nutrient levels in the soil can thus be lower than potential nutrient levels. The potential (i.e. maximum) cation exchange capacity for soil is given as a pH value of 8.2, and the effective cation exchange capacity for the current actual pH value of the soil is determined. Effective cation exchange capacity, air and water conditions, biological activity, and redox properties, etc. are important factors for an evaluation of nutrient levels actually available in the soil.

The **pH value** allows for direct and indirect determinations of various processes and properties of soils, including weathering processes; soil formation processes, such as podzolization or clay translocation; species range and activity of soil organisms; humic material formation; structural stability; soil acidification; and the silting (mud filling) process.

Summer moisture represents the water supply useable for the effective root area in critical dry periods during the main vegetation growth period. The figure takes into consideration usable field capacity, climate, relief, and groundwater.

Effective rooting depth is the depth in the soil where plants can draw water. Anthrosols can restrict rooting by impenetrable layers, e.g. concrete, lack of air, or the formation of methane, for example in waste disposal site soils.

Soil Types

The **near-natural soils** in Berlin with a long developmental history and relatively uninfluenced by use are: luvisols (para-brown soils), podzoluvisols (leached soils), cambisols (brown soils), dystric cambisols (rusty-brown soils), spodo-dystric cambisols (podzol brown soils), podzols, gleysols, and histosols (bog soils). Histosols (bog soils) appear almost only in the less densely populated and unpopulated outer edges of the city.

Luvisols (para-brown) and podzoluvisols (leached soils) are the most predominant soils in the sandy overlayered Barnim and Teltow boulder marl plateaus. They are dealkalized to a depth of 1 - 2 m. Podzoluvisols (leached soils) occur mainly in forest areas. The greater humus and clay contents in the topsoil give luvisols (para-brown soils) a distinctively greater nutrient supply than podzoluvisols (leached soils). Luvisols have a medium to high storage capacity for water and nutrients and are well aerated. The pH values of topsoils in forest plantation areas are usually low at 3 - 4; with soil acidification by humic acid, fulvic acid and "acid rain". The pH values of agricultural soils are higher because of fertilizers and liming. The nutrient supply of forest plantation soils in the shallow root zone down to 0.3 m depth is very low to moderate; on farmland it is low to elevated. The nutrient supply in the deep root zone down to 1.5 m depth is medium to high because of the increase in pH (Grenzius 1987). Podzoluvisols (leached soils) have a greater nutrient supply in the subsoil - Bt horizon - than topsoils with little clay. Water storage capacity and aeration are sufficient. Luvisols (para-brown soils) are good locations for agricultural plants, particularly in Rudow, Mariendorf, Lichtenrade (Teltow plateau), Kladow (Nauen plate), Hohenschönhausen, Hellersdorf, Weißensee, and Pankow (Barnim pleateau).

Cambisols (brown soils) develop on the sandy areas of the Barnim and Teltow boulder marl plateaus, on the lower slope of plateaus, moraine hills, and end moraines. Cambisols develop particularly well as colluvial (transported) formations in the sometimes silty medium and fine sands of the Berlin glacial spillway, the Panke-Tal, and in the sinks of dune landscapes. Stagno-gleyed and residual stagno-gleyed cambisols, and eutro-gleyic cambisols occur mainly in the glacial spillway, depending on earlier and current groundwater levels.

Cambisols are deeply rootable and well aerated. They have a low, sometimes medium water storage capacity at lower slopes of end moraines through water inputs and deposits of clay. They are dry locations for shallow-rooted plants and fresh locations for deep-rooted plants. The stagno-gleyed and eutro-gleyic cambisols of the glacial spillway, however, were moist locations before the groundwater level sank. Cambisols usually have a moderate nutrient storage capacity, but the actual nutrient supply of cambisols with low pH values used for forests and grain production is very low to moderate. The nutrient supply is higher with greater humus contents and pH values, such as found in vegetable crop and horticultural areas.

Dystric cambisols (rusty brown soils) are found on the glacial sands of the Nauen plate (Gatow-Kladow), and the Barnim and Teltow plateaus. Dystric cambisols are also the predominant soils of the end moraines in the Düppeler Forst, in Grunewald (Havelberge), in the Köpenicker Forst (Müggelberge), the Gosenberge, and the Seddinberg. Dystric cambisols are also formed in valley sands remote from groundwater, such as in the Forst Jungfernheide, and dystric cambisols, along with spodo-dystric cambisols (podzol brown soils). They are the predominant soils in dunes in the Spandau, Tegel, and Köpenick forests.

Both dystric and spodo-dystric cambisols are deeply rootable and well aerated. They possess a low to moderate usable field capacity and a medium nutrient storage capacity. They are very dry to dry and are very nutrient-poor locations. Their water and nutrient storage capacities are increased by interstratifications of silt in the subsoil, and by horticultural use, or in the vicinity of bogs (gleyed spodo-dystric cambisols or stagno-gleyed dystric cambisols, and dystric gleysols or spodo-dystric cambic gleysols).

The formation of **podzol soils** requires special climatic conditions, such as low temperatures and high precipitation. Podzol soils develop on fine-grained, lime-free and sandy substrates. They only appear at a few locations in Berlin forests; mainly at the northeast slopes of dunes in the Tegel Forst (cf. Grenzius 1987), the Püttberge in the Köpenicker Forst (cf. Smettan 1995), and in part of the end moraine formation of the Seddinberg.

Podzol soils are usually deeply rootable and well aerated, but in spite of their medium to high water and nutrient storage capacity, they are nutrient-poor and dry soils.

Gleysols form from sandy or silty substrate at locations with high groundwater levels. Gleysols appear in sinks of valley sand levels in the Spandau Forst. They are dependent on relief profiles and are often associated with stagnic gleysols (wet gleys), histo-humic gleysols (turfy moulder gleys) and histosols (bogs). Together, they form the soils of the sinks in the dunes in the Spandau Forst and in the Forstrevier Schmöckwitz south of Seddinsee; the meltwater channels such as the Kuhlake, Breite Fenn, Rudower Fließ, Tegeler Fließ, Wuhle, Neuenhagener Mühlenfließ, and the Krumme Laake; the dead ice sinks of the Großer Rohrpfuhl and the Teufelsbruch in Spandau, and the dead ice sink Teufelssee in Köpenick.

The ecological properties of gleysols differ greatly depending on the parent material, humus contents, groundwater level, and the nutrient supply in the groundwater. Residual gleysols are also found in Berlin in areas of lesser depth to groundwater where groundwater levels have sunk. The residual gleysols have typical gley characteristics in profile structure, but their ecological properties differ very greatly from gleysols.

Gleysols are usually moist topsoil locations for shallow-rooted plants, and wet subsoil locations for deep-rooted plants. The available air supply is inversely proportional to the water level of the soil. This results in poorly aerated subsoil and, depending on water levels, a well to poorly aerated topsoil (sometimes alternately dry to wet), and medium rootability. Gleysols have a large to high nutrient storage capacity and a moderate to high nutrient supply, depending on humus contents. The nutrient supply is higher if additional nutrient inputs occur by way of the capillary uptake of eutrophied groundwater.

Residual gleysols are dry to very dry, well aerated into the subsoil, deeply rootable locations with generally medium to higher water capacities. The nutrient supply is low to medium, depending on humus contents and pH values. Nutrient input from groundwater is usually lacking.

Histosols (bog soils) have a high water level, are very poorly aerated, and only shallowly rootable. Histosols have a very high water storage capacity and a medium to higher nutrient storage capacity. They are undrained, near-natural locations with varying nutrient supplies.

Bog soils are subject to drying and mineralization when groundwater levels sink. Their properties relevant for plants are thus changeable. Dried boggy (histosols) and peaty moulder soils (histo-humic soils) that appear in the glacial spillway, such as in allotment garden areas along the Teltow and Neukölln canals, and in Treptow along the edge of the Teltow plateau, are deeply rootable, well aerated, and moist locations, in contrast to intact bog soils.

Loose lithosols (raw soils of loose material), regosols, and calcaric regosols (para-rendzinas) are relatively young soil formations, compared to soils that have developed for hundreds or thousands of years. They develop on young aggraded areas of eroded natural rocks, and at areas of anthropogenically aggraded materials.

Natural soil erosion occurs naturally, for example, by the action of wind or water on the slopes of dunes, as well as on kames (short moraines crosswise to the flowing direction of the ice), and moraine hills. Anthropogenic soil erosion is caused by human use of soil. Soil inputs can occur both through natural translocation processes and through anthropogenic aggradations. Aggradations are differentiated into aggradations of natural material, such as soil excavation and gravel, and aggradations of artificial substrates such as war debris, construction debris, slags and cinders, etc.

Loose lithosols, regosols and calcaric regosols (para-rendzinas) of anthropogenically aggraded material undergo the same soil development as natural rock. The various parent material is described by the soil form, e.g. regosol of glacial sand, regosol of war debris, etc. (Grenzius 1987).

The soils of the Berlin urban area are characterized by intensive anthropogenic interventions resulting from settlement, demolition of buildings, damage incurred during the Second World War, as well as construction. There are large-area aggradations of war debris, slag and cinders, and building materials, as well as eroded areas due to construction of streets and railway lines, and the surface mining of gravel, sand, and clay. This has led to the wide distribution of loose lithosols, regosols, and calcaric regosols in the Berlin urban area.

Loose lithosols (raw soils of loose material) appear mainly on eroded areas of natural rock in the outer urban area. They develop where dystric cambisols (rusty-brown soils) and cambisols (brown soils) of glacial, valley, and drift sands have been removed by use, such as at military training areas and surface mining sites. Near-natural soils can still be found in small parts of areas impaired to a lesser degree.

Larger military training areas are located in Heiligensee at Baumberge, in the Grunewald, and in the Köpenick Forst at Jagen 161. Surface mines in the Berlin urban area are located at Kaulsdorfer Seen, the Kiessee Arkenberge in Pankow, the Tegeler Flughafensee, and the Laszinssee in Spandau.

Ecological properties are marked by natural undersoil and groundwater levels, e.g., loose lithosols created by erosion of dystic cambisols are well-aerated, usually dry, and nutrient-poor soils.

Loose lithosols (raw soils of loose material) at aggradation areas of anthropogenically transported rock (war debris, construction debris, railway track crushed rock, industrial crushed rock) are found at open areas throughout the entire densely-populated urban area, such as the inner city; at all areas greatly damaged or destroyed during the Second World War (soil association 52); and at industrial, and commercial locations. Loose lithosols also appear at war and construction debris disposal sites like the Eichberge in Köpenick, Arkenberge in Pankow, Teufelsberg in Grunewald, Trümmerberg in Friedrichshain, Volkspark Prenzlauer Berg, and at railway tracks throughout the entire urban area. Loose lithosols are less common at aggraded or translocated natural rock, such as landfill bulwarks at military training areas, including firing ranges.

The ecological properties of these loose lithosols are determined by the aggraded material. Loose lithosols of sands and artificial substrates form very dry to dry locations; tar or concrete layers in the undersoil form locations of periodic moisture. Aeration and thus oxygen supply are good; rootability is restricted by high stone contents; rootability is deep in rock-free, sandy soils. Nutrient supply and storage capacity is low to high, according to basis rock and use.

The formation of **regosols** (cf. Grenzius 1987) is a result of natural erosion (water and wind) and anthropogenic induced erosion (in Berlin often a high pedestrian load on slopes) of the loose lithosols on kames, moraines, or dune sands. The soil formation process is continuous. Humus accumulation in the Ah horizon results finally in regosols. These regosols appear, for example, on the steeper slopes along river Havel in Grunewald, in the Düppeler Forst, and on the slopes of the Müggelberge. Soil aggradation and erosion by the construction and closing (levelling) of sewage farms in the north of the boroughs Pankow, Weißensee, and Hohenschönhausen also influenced the formation of regosols from natural materials. These are soil associations 2560 [60], 2580 [62], 2590 [63].

Regosols of sandy, lime-free aggradations develop mainly in more densely built-up urban areas, including smaller green areas and park facilities. They are usually poor in nutrients. Humus accumulation in the topsoil improves the nutrient supply. They often have a low water storage capacity, good aeration, and a deep to medium rootability, depending on the stone content.

Calcaric regosols (para-rendzinas) develop from loose lithosols of limey substrate. Calcaric regosols of natural origin develop on eroded areas of marl pits which have been left open, on translocated marl, such as at foundation excavations, and on eroded slopes of bodies of water and channels of boulder marl plateaus.

Calcaric regosols developed in the bottomland of the Bäke at the Landgut Eule, and at Albrechts Teerofen from lime mud or disturbed shallow water sediments. This material was excavated for the Teltow canal and redeposited (cf. Grenzius 1987).

Calcaric regosols of anthropogenic aggradation material occur all throughout the entire densely built-up urban area at sites filled with war debris or construction debris; at all areas of heavy war damage with debris aggradations; and at railway facilities. Calcaric regosols are also found along the many landfill banks and bottomlands of the Havel and Spree rivers and their lake-like broadenings.

The higher clay levels of boulder marl calcaric regosols show an increased nutrient storage capacity, and a medium to high usable field capacity. Calcaric regosols of war debris are nutrient-poor and dry. Aeration is good, the rootability of war debris calcaric regosols is shallow because of the stone content. Calcaric regosols of lime muds are fresh, well to poorly aerated locations that are rich in nutrients, depending on the groundwater level.

Selected Soil Associations

Currently, there are 78 distinct soil associations. In the following, some characteristic soil associations (SA) will be described. A more detailed description of soil associations was developed by Grenzius (1987). The depicted landscape segments originate from Grenzius' dissertation (1987).

Soil association	Soil types that characterize the soil association	Use/ formation	Frequency [%]
1010	luvisol - arenic cambisol	ground moraine plateaus of boulder marl	7.150
1020	dystric cambisol - luvisol - colluvial cambisol	moraine (hill) of glacial sands, usually over marl	1.695
1021	dystric cambisol - luvisol - colluvium/ luvisol	sandy sink fill on plateaus and valley sand over marl	0.431
1022	dystric cambisol - luvisol – dried eutric histosol	sandy sink fill on plateaus and valley sand on marl with peat	0.256
1030	dystric cambisol - colluvial cambisol	moraine (hill) of glacial sands, partially on marl	1.091
1040	dystric cambisol - regosolic cambisol - colluvial cambisol	end or push moraine of glacial sands	1.770
1050	dystric cambisol - chromic cambisol - colluvial cambisol	fluvioglacial meltwater channel of glacial sands	0.433
1060	dystric cambisol - regosol - colluvial cambisol/ gleysol	end or push moraine and plateau slope of sand	1.026
1070	dystric cambisol - colluvial cambisol	(outwash plain on) moraine surface of glacial sands	3.941
1072	dystric cambisol - colluvial cambisol	sandy sink fill, partially on marl	0.252
1080	podzoluvisol - arenic dystric cambisol - dystric cambisol	dunes on ground moraine plateaus of boulder marl	0.277
1090	spodo-dystric cambisol - podzol - colluvial dystric cambisol	dunes of fine sand	1.070
1100	spodo-dystric cambisol - dystric cambisol - colluvial dystric cambisol	dunes of fine sand	0.986

Soil asso-ciation	Soil types that characterize the soil association	Use/ formation	Frequency [%]
1110	podzol - regosolic-cambisol - colluvial cambisol	end or push moraine of glacial sands	0.031
1120	stagnic gleysol - stagno-gleyic luvisol - stagno-gleyed luvisol	clayey sink fill	0.043
1130	luvisol (sometimes influenced by groundwater) - arenic dystric cambisol (sometimes influenced by groundwater)	ground moraine plateau of boulder marl	0.133
1131	gleyic luvisol - gleyic arenic dystric cambisol (used as a sewage farm at the time of mapping)	ground moraine plateau of boulder marl	0.084
1140	residual eutro-gleyic cambisol (cambisol with gley characteristics)	moraine (hill) of glacial sands, sometimes on marl	0.097
1141	dystric cambisol - eutro-gleyic cambisol (used as a sewage farm at the time of mapping)	moraine (hill) of glacial sands, sometimes on marl	0.126
1150	eutro-gleyic cambisol - calcaric eutro-gleyic cambisol - calcaro-gleyic cambisol	valley sand of medium and fine sands	0.226
1160	dystric cambisol - stagno-gleyed cambisol - eutro-gleyic cambisol	valley sand of medium and fine sands	13.606
1164	stagno-gleyed cambisol - gleysol - dried eutric histosol	valley sand of medium and fine sands	1.095
1170	eutro-gleyic cambisol - gleysol - histo-humic gleysol	basin in valley sand	0.024
1180	dystric cambisol - dystric gleysol - calcaro-dystric histosol	end or push moraine of glacial sands with interbedded marl	0.225
1190	spodo-dystric cambisol - stagno-gleyed dystric cambisol	drift sand on valley sand areas	1.835
1200	dystric cambisol - podzol gleysol - oligotrophic transitional histosol	deflation basin in valley sand with dunes	0.640
1210	dystric cambisol - stagno-gleyed dystric cambisol - eutro-gleyic dystric cambisol	valley sand with dunes	0.128
1220	dystric gleysol - calcaric dystric gleysol - calcaric gleysol	flat valley sand channels of medium and fine sands	0.083
1230	dystric cambisol - stagnic gleysol - histo-humic gleysol	meltwater channels in valley sand with dunes	0.037
1231	eutro-gleyic cambisol - gleysol - eutric histosol	meltwater channels in valley sand areas without dunes	1.413
1240	stagno-gleyed dystric cambisol - calcic gleysol - dried eutric histosol	lowland in valley sand with valley bog peat	0.161
1250	dystric gleysol - histo-humic gleysol - mesotrophic histosol	dead ice sink in valley sand	0.066
1251	eutric histosol - histo-humic gleysol - podzol gleysol	dead ice sink in ground moraine plateau	0.002
1260	dried (fluvi-eutric) histosol	(river) lowland with valley bog peat in valley sand	1.839
1270	dried (fluvi-eutric) histosol - dried histo-humic gleysol - gleysol	fluvioglacial meltwater channel of sand (in boulder marl flat upland area) with lower bog peat	0.309
1280	eutrophic fluvi-eutric histosol - fluvic histo-humic gleysol - eutro-gleyic dystric cambisol	fluvioglacial channel of sand with lower bog peat	0.402
1290	dystric cambisol - colluvium/ residual gleysol - dried eutric histosol	fluvioglacial meltwater channel of glacial sands	0.328
1300	dystric cambisol - stagnic gleysol / eutric histosol - dried transitional histosol	fluvioglacial meltwater channel of glacial sands	0.164

Soil asso-ciation	Soil types that characterize the soil association	Use/ formation	Frequency [%]
1310	calcaric regosol - calcaro-gleyic regosol - calcaric gleysol	dried fluvisol (lea) with lime mud over sand	0.056
1320	fluvic gleysol - fluvi-stagno gleysol - eutrophic fluvi-eutric histosol	river lowlands in valley sand with valley bog turf	0.162
1330	colluvial cambisol - eutrophic fluvi-eutric histosol - calcic fluvisol	slope-influenced river lea of layered sands	0.266
1340	dystric cambisol - dystric fluvisol - mesotrophic fluvi-eutric histosol	river lea of layered sands	0.015
1350	fluvisol - fluvi-stagnic gleysol - mesotrophic fluvi-eutric histosol	river lea of layered sands	0.002
1360	dystric cambisol - fluvic gleysol - calcic fluvisol	slope-influenced river lea of layered sands	0.067
1370	fluvisol - calcaric fluvi-mollic gleysol - raw fluvisol	river lea of layered sands	0.009
1380	colluvial cambisol - raw fluvisol - submerged raw fluvisol	river lea of layered sands	0.082
2390	necrosol + cambic hortisol + luvisol	cemetery on ground moraine plateau of boulder marl	0.605
2400	necrosol + cambic hortisol + dystric cambisol	cemetery on ground moraine plateau of glacial sands	0.405
2410	necrosol + cambic hortisol + spodo-dystric cambisol	cemetery on drift sand area of fine sands	0.205
2420	necrosol + eutro-gleyic cambic hortisol + gleysol	cemetery on valley sand of medium and fine sands	0.357
2430	loose lithosols + cambisol / dystric cambisol + gleysol	military training area on valley sand area (with dunes)	0.134
2440	loose lithosols + cambisol / dystric cambisol + dystric cambisol	military training area on (glacial outwash plain) moraine area of glacial sands	0.150
2441	calcaric regosol + regosol + loose lithosols	military training area on (glacial outwash plain) moraine area of glacial sand and war debris and construction debris	0.085
2450	loose lithosols (raw soil)	surface mining on kames or (glacial outwash plain) moraine sands	0.117
2460	loose lithosols + loose lithic gleysol + submerged raw fluvisol	surface mining on valley sand	0.099
2470	lithosol + calcic regosol + calcaric regosol	railway tracks on aggraded and eroded surfaces	2.873
2471	(loose) lithosols + calcaric regosol + hortisol	allotment garden on aggraded and eroded surfaces	0.153
2482	calcaric regosol + loose lithosols + regosol	settlements on areas once used for sewage farms, partially on aggraded surfaces	1.377
2483	regosol + calcaric regosol + hortisol	settlements on valley sand, partially on aggraded surfaces	5.011
2484	regosol + calcaric regosol + hortisol	settlements on glacial sands, partially on aggraded surfaces	1.265
2485	regosol + calcaric regosol + hortisol	settlements on boulder marl, partially on aggraded surfaces	4.786
2486	regosol + calcaric regosol + hortisol	settlements on drift sand, partially on aggraded surfaces	0.369
2487	calcaric regosol + loose lithosols + regosol	settlements on valley sand, partially on aggraded surfaces	4.819
2488	calcaric regosol + loose lithosols + regosol	settlements on glacial sands, partially on aggraded surfaces	1.148
2489	calcaric regosol + loose lithosols + regosol	settlements on boulder marl, partially on aggraded surfaces	5.031

Soil asso-ciation	Soil types that characterize the soil association	Use/ formation	Frequency [%]
2490	loose lithosols + humic regosol + calcaric regosol	dense inner city construction; not destroyed during war, on aggraded surfaces	4.707
2500	loose lithosols + regosol + calcaric regosol	inner city, on aggradation	4.780
2510	calcaric regosol + calcic regosol + loose lithosols	war debris hill, construction debris site and landfill	1.164
2530	reductosol + loose lithosols + regosol	waste disposal site (primarily domestic waste)	0.524
2540	loose lithosols + regosol + calcaric regosol	industrial area on aggraded or eroded surfaces	9.953
2550	humic regosol/ eutro-gleyic cambisol + hortisol/ gleysol + calcaric regosol / fluvisol	aggradation on (river) bank areas and in channels	0.917
2560	regosol + dystric-eutric regosol + gleyic regosol	levelled sewage farm on glacial sand	1.044
2580	regosol + luvic regosol	levelled sewage farm on boulder marl	1.940
2590	regosol + dystric-eutric regosol + gleyic regosol	levelled sewage farm on valley sand / outwash plain sand	1.322
3020	podzol - dystric cambisol - colluvial dystric cambisol	(collective soil association of dunes without bordering bog) dunes of fine sand	0.127
3030	fluvic gleysol - fluvi-eutric histosol	(collective soil association of river lea with peat) river lea of layered sands	0.091
3040	calcic fluvisol - fluvic gleysol	(collective soil association of river lea without peat) river lea of layered sands	0.071
7777	calcaric regosol + loose lithosols + regosol	settlements on drift sand, partially on aggraded surfaces	0.236

Tab. 7: Soil association and its characteristic soil types, use/ formation and frequency. The frequency for collective associations 3020, 3030 and 3040, cannot be directly compared with others, as it encompasses several soil associations.

Near-natural Soil Associations

SA 1010 [1] Luvisol (para-brown soil) - arenic cambisol (wedged sand-pit brown soil)
(ground moraine flat upland area of boulder marl)

This soil association combines soil types with plateaus withboulder clay or marl as parent material. Shrinkage created wedges filled with sand; this was then overlaid with drift sand. A mixture of drift sand with boulder marl led to the formation of the glacial cover sand. Luvisols developed on the 1 - 3 m deep wedged sand-pits of arenic cambisols (wedged sand-pit brown soils) where the boulder clay and marl was covered with a thin glacial sand cover.

This soil association is particularly found at the Teltow and Barnim boulder marl plateaus.

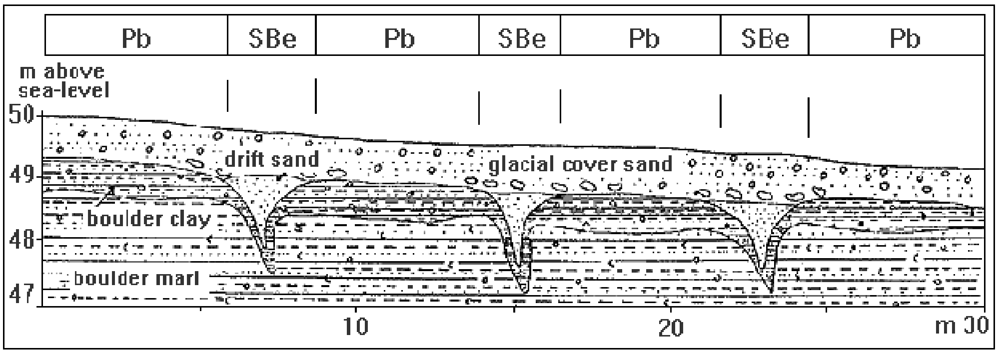

Fig. 2: Luvisol (para-brown soil) - arenic cambisol (wedged sand-pit brown soil)
(soil association of the ground moraine plateau of boulder marl)

SA1070 [6] Dystric cambisol (rusty brown soil) - colluvial cambisol (colluvial brown soil)
(outwash plain over) moraine area of glacial sands

This soil association comprises dystric cambisols on the sandy, morphologically relatively flat area of the boulder marl plateaus and the ground moraines of the Teltow (Grunewald, Düppler forest) and Barnim plateau. The upper 2 metres of glacial sand do not contain boulder clay or marl.

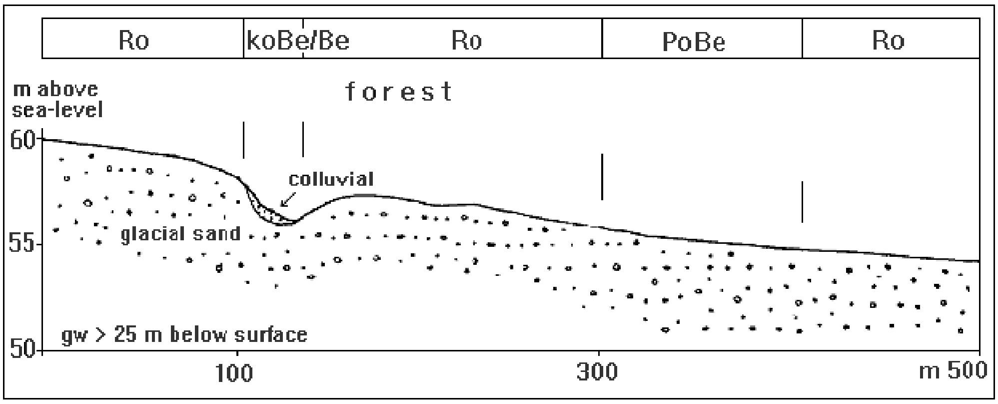

Fig. 3: Dystric cambisol (rusty brown soil) - colluvial cambisol (colluvial brown soil)
(soil association of moraine areas (outwash plain) of glacial sands)

Dystric cambisols also appear at the kames formations of the Grunewald forest, from Lübars to Arkenberge, and in the end moraine formations in Gatow and Müggelberge, where they have a different spatial relationship (geomorphological unit). This is why, this geomorphological unit was included with another soil type in another soil association, SA 1040 [4]).

Another soil association, SA 1020 [2] or 1030 [3], is of dystric cambisols on relatively higher moraine hills of glacial sands with some boulder marl or boulder clay remainders within the first two metres of the glacial sands.

SA 1090 [9] Spodo-dystric cambisol (podzol brown soil) - podzol - colluvial dystric cambisol (colluvial rusty brown soil)
(dunes of fine sand)

SA 1100 [10] Spodo-dystric cambisol (podzol brown soil) - dystric cambisol (rusty brown soil) - colluvial dystric cambisol (colluvial rusty brown soil)
(dunes of fine sand)

Soil associations 1090 [9] and 1100 [10] are dunes several metres thick, remote from groundwater, as well as larger dune areas with terrain heights of over 40 m above sea level. They differ primarily in the presence of podzols. They appear mainly in the Tegel and Frohnau forests, but in the Köpenicker Forst as well. No statements can be made about the presence of podzols without soil profile studies. These two soil associations in East Berlin were partially listed as collective soil associations, unless maps were available (Standortskarten des Forstbetriebes Ost-Berlin, Smettan 1995) (Site Maps of East Berlin Forest Management), in which case they were listed separately.

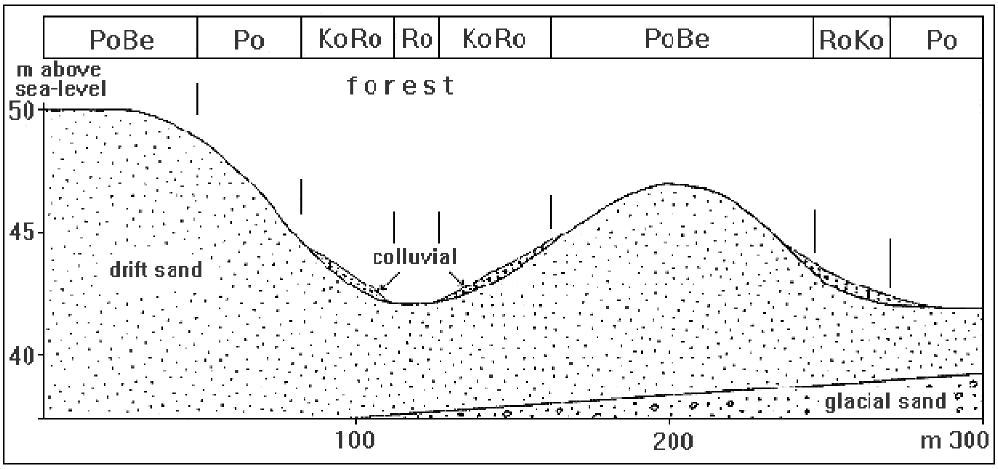

Fig. 4: Spodo-dystric cambisol (podzol-brown soils) - podzols - colluvial Dystric cambisols (colluvial rusty brown soil) (soil association of dunes of fine sand)

SA 1160 [15] Dystric cambisol (rusty brown soil) - stagno-gleyed cambisol (gleyed brown soil) - eutro-gleyic cambisol
(valley sand areas of medium and fine sand)

This soil association is widely distributed in the Berlin glacial spillway (Urstromtal). The Berlin Urstromtal is the last meltwater valley of the Frankfurt phase of the Weichselian glaciation. The medium and fine sands transported and deposited in the valley by meltwater formed the parent material for the formation of cambisols and dystric cambisols. Varying groundwater levels caused the formation of gley properties, such as rusty spots, in various depths. These are represented by the soil types stagno-gleyic cambisol and eutro-gleyic cambisol. Groundwater levels sank in this century because of groundwater removals by the Berlin Waterworks. Gley properties are often only residuals today, i.e. groundwater levels today are deeper than the gley characteristics they once produced. This soil association is present particularly in the Spreetal in Köpenick, and in the valley sand areas of forests in Spandau, Tegel and Jungfernheide.

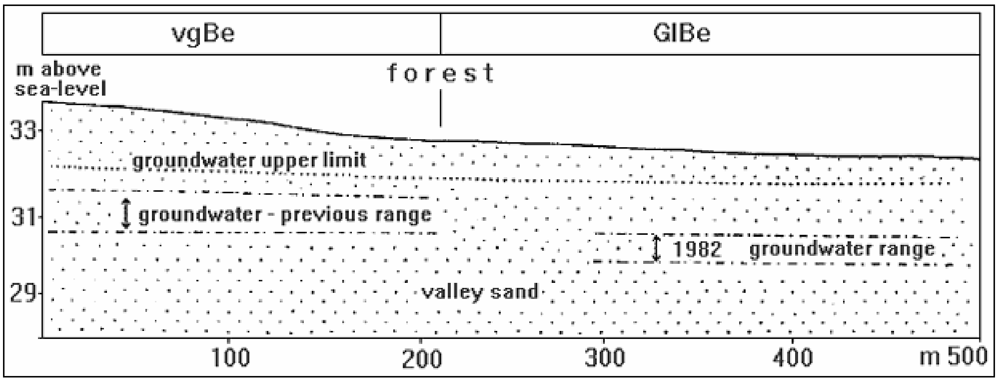

Fig. 5: Stagno-gleyed cambisol (gleyed brown soil) - eutro-gleyic cambisol (gleyic brown soil) (soil association of valley sand areas of medium and fine sand in the Spandauer Forst)

SA 1231 [22a] Eutro-gleyic cambisol (gleyic brown soil) - gleysol - eutric histosol (lower bog)
(meltwater channels in valley sand areas without dunes)

The great pressure from the weight of the glaciers melted ice at their bottom layers. The runoff of this meltwater produced subglacial meltwater. Great amounts of meltwater produced in the warm periods between ice ages flowed into the valleys and with their erosive force created - at times deep - subglacial meltwater channels. The channels in the vicinity of groundwater bogged or silted up after the last ice age. Many of these channels, particularly in the Berlin inner city, were landfilled and/or built upon, and are not visible today.

Such fluvioglacial meltwater channels within valley sand areas are found in parts of the Wuhle, the Neuenhagener Mühlenfließ, Spekte-Lake, the Egelpfuhlwiesen, and the Breite Fenn. Histo-humic gleysols (peatymoulder gleys) and valley bog peat formed directly in the middle of these channels, depending on groundwater levels. Also depending on groundwater levels, eutro-gleyic, eutro-gleyic dystric, stagno-gleyed and stagno-gleyed dystric cambisols were formed towards the channel edges.

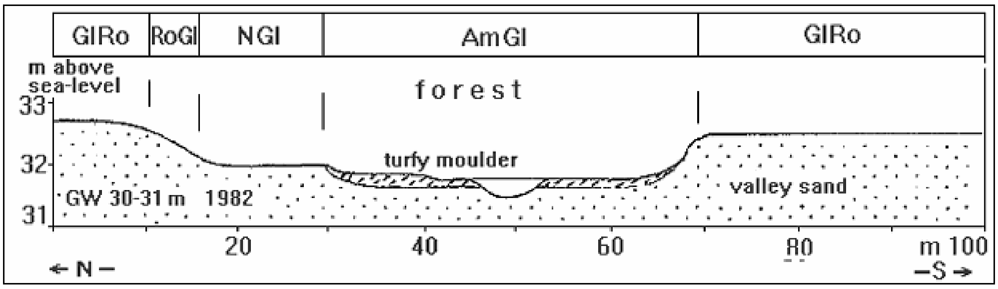

Fig. 6: Eutro-gleyic cambisol (gleyic brown soil) - gleysol - eutric histosol (lower bog) (meltwater channels in valley sand areas without dunes)

Anthropogenic Soil Associations

SA 2420 [41] Necrosol + eutro-gleyic cambic hortisol (gleyic brown horticultural soil) + gleysol (cemetery on valley sand areas of medium and fine sands)

This soil association is comprised of valley sand soils. The use as cemeteries brings certain anthropogenic influences. Necrosols are defined as soils resulting from excavations for graves. The unused cemetery areas of valley sands still retain residual eutro-gleyic cambisols and gleysols. The long-term input of humus develops humic regosols, horti-gleyic cambisols, and hortisols (horticultural soils).

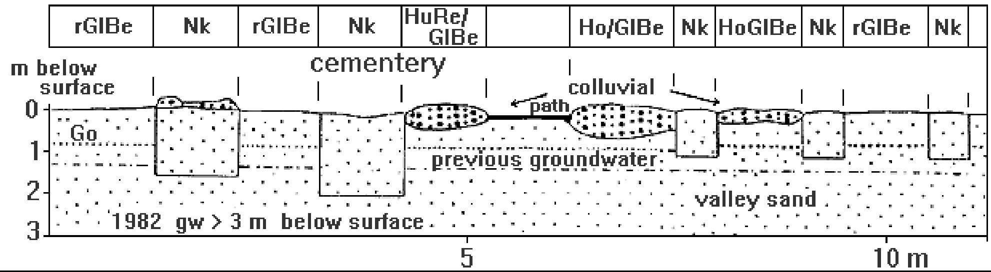

Fig. 7: Necrosols + eutro-gleyic cambic hortisol (gley brown horticultural soil) + gleysol (soils of cemeteries on valley sand areas of fine and medium sands)

Other anthropogenic uses have extremely altered soils so that once natural soils were extensively destroyed, or covered by other materials.

SA 2470 [49] Lithosol + calcic regosol + calcaric regosol (para-rendzina)
(railway tracks on aggraded and eroded surfaces)

This soil association includes soils used for railway facilities and railway stations. The trackbeds are of coarse gravel of various materials; the embankments are of sand, war and industrial debris are also used as fill. Lithosols, loose lithosols, calcaric and calcic regosols are mainly formed, depending on the soil substrate.

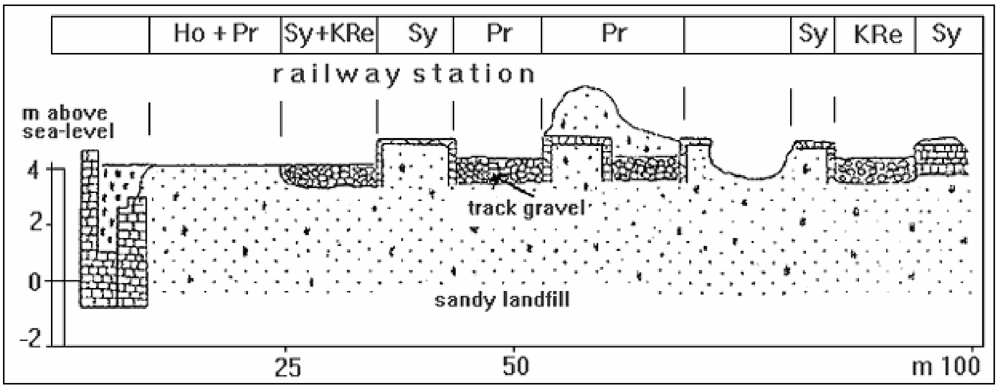

Fig. 8: Lithosol + calcic regosol + calcaric regosol (soils of railway facilities on aggraded or eroded surfaces; Potsdamer Güterbahnhof (freight station))

SA 2490 [51] Loose lithosol (raw soil of loose material) + humic regosol + calcaric regosol (para-rendzina)
(dense inner city construction; not destroyed during the Second World War; on aggraded surfaces)

This soil association characterizes soils within areas of uniform construction built before the Second World War, undestroyed or only lightly damaged. The degree of impervious soil coverage is high. Soils in the rear courtyards used currently or previously as yards are characterized by humic topsoils and were able to develop into humic regosols, hortisols, and humic calcaric regosols. Other back courtyard areas lightly covered by debris formed loose lithosols (raw soils of loose material) and regosols.

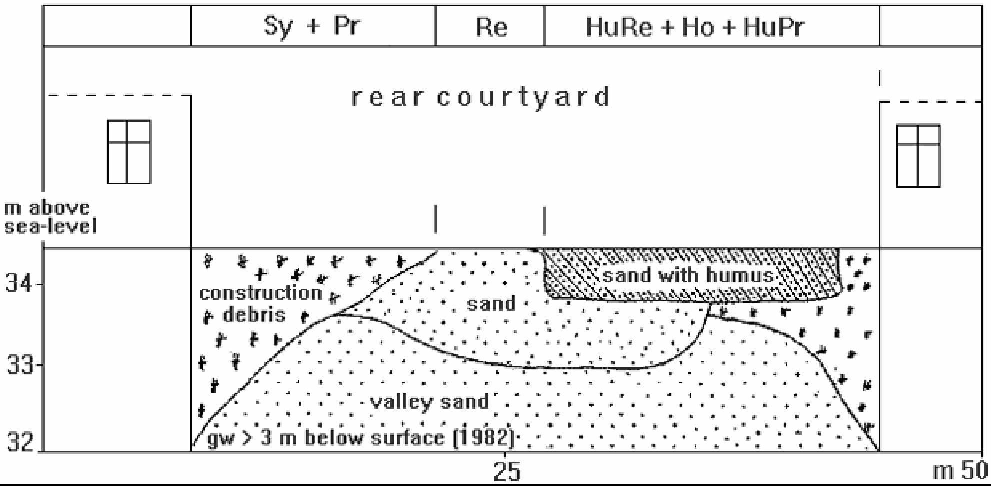

Fig. 9: Loose lithosol (raw soil of loose material) + humic regosol + calcaric regosol (soils of dense inner city construction; not destroyed in the Second World War; on aggraded surfaces)

SA 2500 [52] Loose lithosol (raw soil of loose material) + regosol + calcaric regosol (para-rendzina)
(inner city on aggradation/landfill)

This soil association describes soils of the previously densely constructed inner city, completely destroyed in the Second World War. Most war debris remained where it fell. Many surfaces without buildings have a soil layer composed partially or completely of war debris and/ or construction sand. This thickness of this layer is from a few tenths of a metre up to 2 metres deep (cf. Grenzius 1987). Fig. 10 shows how these surfaces develop lithosols and calcaric regosols. Surfaces without war debris develop lithosols and regosols.

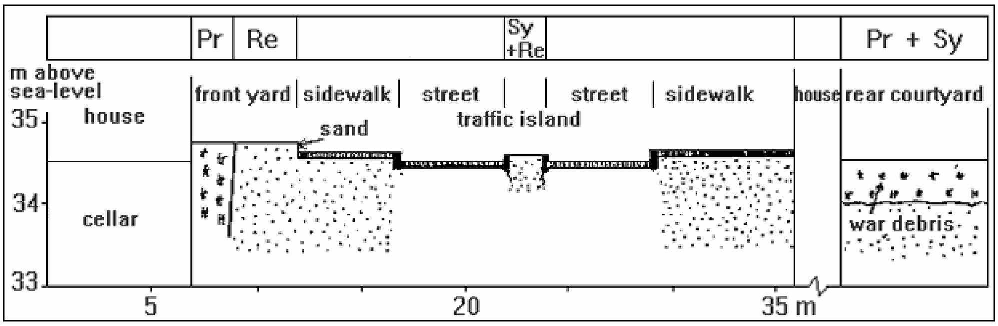

Fig. 10: Loose lithosol (raw soil of loose material) + regosol + calcaric regosol (para-rendzina) (soils of the inner city on aggradations)

The Map of Soil Associations was prepared from existing data of the most various kinds. The map gives an overview of the near-natural and anthropogenic soil associations to be expected, depending on the parent material, geomorphology or landscape segment, groundwater level, and use. The soil association category allows the derivation of main soil types, as well as site characteristics such as aeration, rootability, field capacity, usable field capacity, nutrient storage capacity, and potential and effective cation exchange capacity as a measure for nutrient storage capacity (cf. Grenzius 1987).

Soil types and ecological properties may be derived with a certain probability using additional information, such as topographic maps and the current groundwater level, as well as the soil association in a terrain without a map. Using this method, statements about gleysols or residual gleysols, and thus of moist or dry locations, can be made only under consideration of current groundwater levels.

Soils are a basic natural element and co-determinants of the diversity of flora and fauna at the site. Seldom, unaltered, and only slightly altered soils are considered in the demarcation of protected areas.

The Map of Soil Associations is suitable for deriving site characteristics, and for making evaluations regarding soil protection and soil functions. Environmental Atlas Maps 01.06 document soil-scientific characteristic values, Maps 01.12 present an analysis of soil functions and Maps 01.11 outline criteria to derive these functions.

Po	=	podzol
Be	=	cambisol (brown soil)
Pb	=	luvisol (para-brown soil)
SBe	=	arenic cambisol (wedged sand-pit brown soil)
Ro	=	dystric cambisol (rusty brown soil)
PoBe	=	spodo-dystric cambisol (podzol brown soil)
koBe	=	colluvial cambisol (colluvial brown soil)
KoRo	=	colluvial dystric cambisol (colluvial rusty brown soil)
RoKo	=	dystric cambisol colluvium (rusty brown colluvium)
vgBe	=	stagno-gleyed cambisol (gleyed brown soil)
GlBe	=	eutro-gleyic cambisol (gleyic brown soil)
rGlBe	=	residual eutro-gleyic cambisol (gleyed brown soil)
GlRo	=	eutro-gleyic dystric cambisol (gley rusty brown soil)
RoGl	=	dystric gleysol (rusty brown gley soil)
NGl	=	stagnic gleysol (wet gley)
AmGl	=	histo-humic gleysol (peaty moulder gley)
Nk	=	necrosol
Re	=	regosol
KRe	=	calcic regosol
HuRe	=	humic regosol
Ho	=	hortisol (horticultural soil)
HoGlBe	=	horti-gleyic cambisol (horticultural gley brown soil)
Pr	=	calcaric regosol (para-rendzina)
HuPr	=	humic-calcaric regosol (humic para-rendzina)
Sy	=	loose lithosol (raw soil of loose material) / lithosol
/	=	on
+	=	and

Tab. 8: List of soil type abbreviations used in figures 2 - 10 (according to Grenzius 1987)

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