Senate Department
for Urban Development,
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BERLIN

01.01 Soil Associations 2020

Introduction

Definition of Soil

Soil is the topmost layer of the earth's crust. It is weathered and formed on the surface through the influence of environmental factors. It consists of mineral and organic substances, filled with air, water, and life. Natural soils are created by the interaction of parent material, climate, water, relief, flora, and fauna. Depending on the specific site and soil formation periods, different types of soil develop with characteristic profiles and specific physical and chemical properties.

Along with air, water, and sunlight, soil is the basis of life for plants and animals, and humans. Soil is a raw material itself. It also provides the foundation for the production of food, feeds, and renewable raw materials. Beyond its role in production, soil holds exceptional importance within natural ecosystems due to its multifaceted functions, marking it as a vital natural resource.

Soil is:

- a natural habitat for animals and plants,
- part of the ecosystem and its material cycles,
- the foundation for producing food, feeds, and plant-based raw materials,
- a filter and storage depot for groundwater,
- a foundation, providing sites and support for structures,
- a shaping element of nature and the landscape as well as
- an archive of natural and cultural history.

However, soil is relocated, altered, made impervious and destroyed by human activity (e.g. in agriculture or building construction).

Thus, soil represents a limited and non-renewable resource that must be protected and handled responsibly.

Soil Formation

Soil formation is a natural process that begins on the earth's surface and extends gradually into the depths below. The factors and processes outlined in Table 1 result in variations in structure and properties depending on time, thereby leading to the formation of distinct soil horizons (layers). Different soil types may thus be formed by combinations of soil horizons.

<table>
<tr><th colspan="2">Soil-forming factors</th><th>Soil development processes</th></tr>
<tr><td>parent material</td><td>solid rock
loose rock</td><td rowspan="4">physical weathering
chemical weathering
humus formation
mineralising
carbonate leaching (washouts)
argillation (clay muddying)
podzolisation
gleying
nutrient transport
erosion
accumulation
bioturbation and anthroturbation</td></tr>
<tr><td>climate</td><td>temperature
precipitation
wind</td></tr>
<tr><td>relief</td><td>elevation
surface forms
slope incline
exposure</td></tr>
<tr><td>vegetation</td><td>soil vegetation
shrub vegetation
tree vegetation</td></tr>
</table>

soil fauna microflora		
human interventions	material loss (e.g. crop harvest) melioration material input (e.g. fertiliser, pollutants) impervious soil coverage	

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

Soil develops as a result of soil-forming processes in the parent material. It is a three-component and three-phase mixture of solid, liquid, and gaseous elements:

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

liquid components: soil solution with dissolved nutrients and other elements,

gaseous components: soil air (oxygen, nitrogen, carbon dioxide).

Systematisation of Soils

Soils are systematised 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.

Table 2 demonstrates the classification at the example of the division of terrestrial soils and the major soil group of cambisols (brown soils) in particular. The German Bodenkundliche Kartieranleitung (1982, 1994, 2005 and 2024; = KA3, KA4, KA5, KA6) describes the soil classification in detail.

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 KA5 (2005) (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 categorised into the following horizons:

mineral topsoil horizon	A horizon,
mineral subsoil horizon	B horizon, and
mineral undersoil horizon	C horizon.

The **mineral topsoil 'A horizon'** is characterised by an accumulation of organic substances and/or a loss of mineral substance; washouts of clay, humic materials, iron oxides and aluminium 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. Taking Ah as an example, h stands for humus, while l in Al represents clay lessivation (washout).

The **mineral subsoil 'B horizon'** is characterised by the accumulation of materials washed out of the topsoil horizon, as well as weathering and transformational processes, e.g. brunification and the formation of clay. This produces colours and material compositions different from that of the parent material. 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 indicates accumulated clay.

The **mineral undersoil 'C horizon'** is formed by the relatively unaltered parent material underneath the soil.

The soil profile of soils characterised by several 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 gley characteristics, e.g. rust and bleached spots, are formed in terrestrial and semiterrestrial soils. 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 categorised as 'near-natural' where horizon sequences remain largely unchanged in spite of influences by human use, such as is commonly the case with forest plantations. Soils are categorised as anthrosols (anthric, anthropogenic soils, soils influenced by humans) when the horizon sequence has been destroyed. It has proven extremely challenging to clearly categorise 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 ploughing. In areas used as military training grounds or cemeteries, near-natural soils, interspersed with (small) patches of highly anthropogenic soil, may be preserved. 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, improper storage as well as emissions from industry, commerce, and traffic. Pollutant inputs can directly and indirectly endanger all organisms, including humans. The primary concern is the uptake of pollutants through the food chain, but attention must also be given to the direct oral ingestion of soil, especially by small children.

Soil has a limited capacity to store and filter pollutants. If this capacity is exceeded, pollutants may pass through the soil unhindered and enter the groundwater.

In metropolitan areas like Berlin, issues related to land use, e.g. the quantitative problem of impervious coverage, and the qualitative problem of material contamination of the soil from old contaminated sites and other pollutant inputs, are particularly pronounced. Since soil is not renewable and heavily impacted soils can hardly ever be restored to their original quality, protecting remaining near-natural soils is imperative.

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.

Prerequisites for effective soil protection include knowledge about the spatial condition of the soils as well as impairments in their quantity and quality. In some cases, information on land use, degree of impervious coverage and material contamination of the soil has been compiled in Berlin for decades. This information forms the basis for assessing the anthropogenic impact on the soil. A cadastre of impacts on soil was developed, and a Map of Degrees of Impervious Coverage as well as a Land-Use Map 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. 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 (geomorphological units) into soil associations. These soil associations were studied and evaluated for their location characteristics.

The present Map of Soil Associations for West Berlin was initially developed based on the Map of Soil Associations and a commentary by Grenzius (Grenzius 1987), which defines and describes 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) drawing conclusions by analogy and referring to information from geological 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. The first soil map covering the entire city was created in the mid-1990s (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, 2017 and 2023. The results are thus presented here. Table 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
- Urban and Environmental Information System (ISU5) – Spatial Reference, 2020 and Land-Use Data, 2020 (Environmental Atlas)

Additional information for the entire area of Berlin:

- Geomorphological maps 1 : 100,000 and 1 : 200,000
- Geological 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 topographic maps) (1988)
- Topographic maps 1 : 5,000, 1 : 4,000
- Aerial photography 1 : 4,000, 1 : 6,000 and digital orthophotos – 20 cm (1990 – 2023)
- Data on current land uses and degrees of impervious soil coverage (as of: 2020 and 2021)
- 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 (Forestry site survey) 1 : 10,000 (East Berlin) (1992)
- Standortkundliches Gutachten für die Berliner Forsten (Westteil) (Site survey report for Berlin's forestry, West Berlin) - FSK Berlin-West (1991)
- Geological 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 and 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 2023)

Tab. 3: Data sources for 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 developing 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 had existed for East Berlin up to this point. The bases for the development of the Map Soil Associations of West Berlin were the trenches dug and borehole impacts conducted in all of West Berlin. These were carried out in forest plantations and agricultural areas under consideration of geomorphological-hydrological conditions, and, in populated areas, under consideration of land use. All occurring parent materials and most land uses, with the exception of those in industrial areas, were surveyed several times, and an appropriate soil-scientific mapping was carried out. Based on the analysis of this mapping, conclusions were derived for soil conditions in unmapped areas.

Many areas of the Map of Soil Associations in West Berlin have been confirmed by comprehensive soil-scientific studies, such as forests and farmland. The soil map is therefore verified for those areas. For areas with only few soil-scientific studies, the map is only partially verified. In East Berlin, sufficiently detailed soil mappings only existed for forest areas. The map in question is therefore only confirmed for these areas and serves as a concept map for all remaining areas. Mappings for further individual areas were added at a later stage. All derivations and classifications of soil associations for East Berlin, excluding the forests, had to rely on analogical inferences and any existing information. This included geological and topographic maps, soil maps, and data on land use, all of which varied greatly in accuracy, substance and age.

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 the existing soil maps for East Berlin, especially those covering forest areas.

Due to the limitations of representing the spatial distribution of individual soil types in sufficient detail at a scale of 1:50,000, the methodology of soil associations proposed by Grenzius was maintained. This methodology involves selecting overarching geomorphological units to group spatially and materially connected soils into soil associations.

In conclusion, the whole map now serves as a **Concept Map with some verified areas** (partially verified concept map), 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, along with a soil typically indicative of material translocation (Grenzius 1987). In the map legend, soils of largely near-natural areas are connected by a “-“ to illustrate their relationship and linkage.

Near-natural soils are now found only in sparsely populated areas.

The structures of soils in populated areas have sometimes been heavily altered by human intervention. These anthrosols appear irregularly side by side and are connected in the legend by a “+”.

The legend is organised according to the degree of anthropogenic influence on and alteration of the soil. Near-natural soil associations are listed at the beginning; terrestrial soils are followed by 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.))

Boundary Delineation

Soil associations were delineated based on the terrain features of ridges and sinks. Neighbouring units may therefore share 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 method resulted in significant information loss, particularly in non-built-up and sparsely developed areas such as forests, agricultural areas, and settlement areas with low degrees of impervious soil coverage, these areas were subdivided further within the spatial reference of the Urban and Environmental Information System (ISU5) adhering to the boundaries of soil associations. Key factors in this subdivision included the boundaries of the geomorphological and geological units, contour lines, detailed soil type mappings, and boundaries of aggradations. Anthropogenic soil associations were delineated based on land use and the boundaries of aggradations or erosions. This additional subdivision of soil associations thus directly influences the formation of block segment areas within the spatial reference of the Urban and Environmental Information System (ISU5), and their regular 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 characterised 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 characterised by their distinctive soil types, geomorphological formation, substrate/ soil types, and the influence of water. They are minimally altered by humans.

The soil structure and soil associations of **anthropogenic soil associations** are not influenced by the topographical relief but rather by the type of use as well as the occurrence and type of aggradations. Certain transitional forms bear traces of various influences, including those from the parent material, geomorphology, groundwater levels, and partially natural soils. This is the case for soils at military training areas, former surface mining sites, cemeteries, and levelled sewage farms.

Table 4 presents the effects of human intervention on soils. It classifies the urban area into various soil association categories (anthropogenic soil associations) under consideration of historic and current land 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, earthy 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 30 cm ploughed, varying degrees of organic and mineral fertilisers, depending on crop: slightly 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 fertilised and irrigated
allotment gardens	soils partially relocated by house construction or replaced by anthropogenic aggradations of gravel and stone, garden areas altered by use of organic substances and digging (hortisols), heavy fertilisation, pH value in the neutral range, no original soils in gardens on aggradations or excavated areas, soils on debris (over landfill) heavy use of organic and mineral fertilisers, irrigated, sometimes contaminated by pollutants

cemetery	soils extensively altered by deep excavation and introduction of organic substances (necrosols), based on this and fertilisation and irrigation, pH values ranging from slightly acidic to neutral
outdoor bathing areas	soil erosion due to reed destruction and bathing activity, sometimes aggradations of sand, mostly raw soils, eutrophic soils due to nutrient-rich water
former airport	soils preserved during construction, present only in small areas, usually greatly altered typologically by levelling, some soils on debris aggradations
former sewage farm	soils altered during construction by levelling and irrigation of waste waters, accumulated nutrients, salts, and heavy metals, moderately low to acidic pH values, high degree of additional irrigation
park, mainly on aggradations; open areas in the inner city; hills of debris	no original soils remain, soil development on debris aggradation or relocated natural stone, sometimes irrigated, polluted, pH values in neutral range, largely water repellent ruderal soils
former military training area, gravel pit	hardly any original soils remain, raw soils due to excavation and relocation, raw soils, poor in nutrients
track facilities	no original soils remain, often old contaminated sites with high levels of herbicides
traffic areas, street edges, paths, squares	aggradations, 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 development (with yards)	some natural soils, depending on construction density, humus accumulation and eutrophication, additional systematic irrigation
residential areas, closed development in the inner city	hardly any or no original soils, depending on development type, some soils of construction and war debris, sometimes fertilised, irrigated, 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, 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), modified)

Soil Associations/ Collective Soil Associations/ Concept Soil Associations

Grenzius' classification of near-natural and anthropogenic soil associations for West Berlin was applied to East Berlin using available data and drawing parallels for similar regions, considering factors such as geomorphology, land use, and water conditions. Challenges arose for areas where soil associations could not be clearly derived based on the data available, or where new combinations of land use and geomorphology appeared that were not present or previously unidentified 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 information, concept soil associations and collective soil associations were developed. The soil associations used in the map thus exhibit three distinct levels of differentiation and designation:

1. **Soil Associations (SA)** – Soil associations in dependence on geomorphology and land 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 are groups of soil associations, as insufficient data for East Berlin does not allow for a differentiated categorisation of individual soil associations within the collective soil association.
3. **Concept Soil Associations** – Combinations of land use and geomorphology (e.g. levelled sewage farms) previously unidentified or absent in West Berlin at the time they were first recorded for East-Berlin. They have not yet been verified by soil studies.

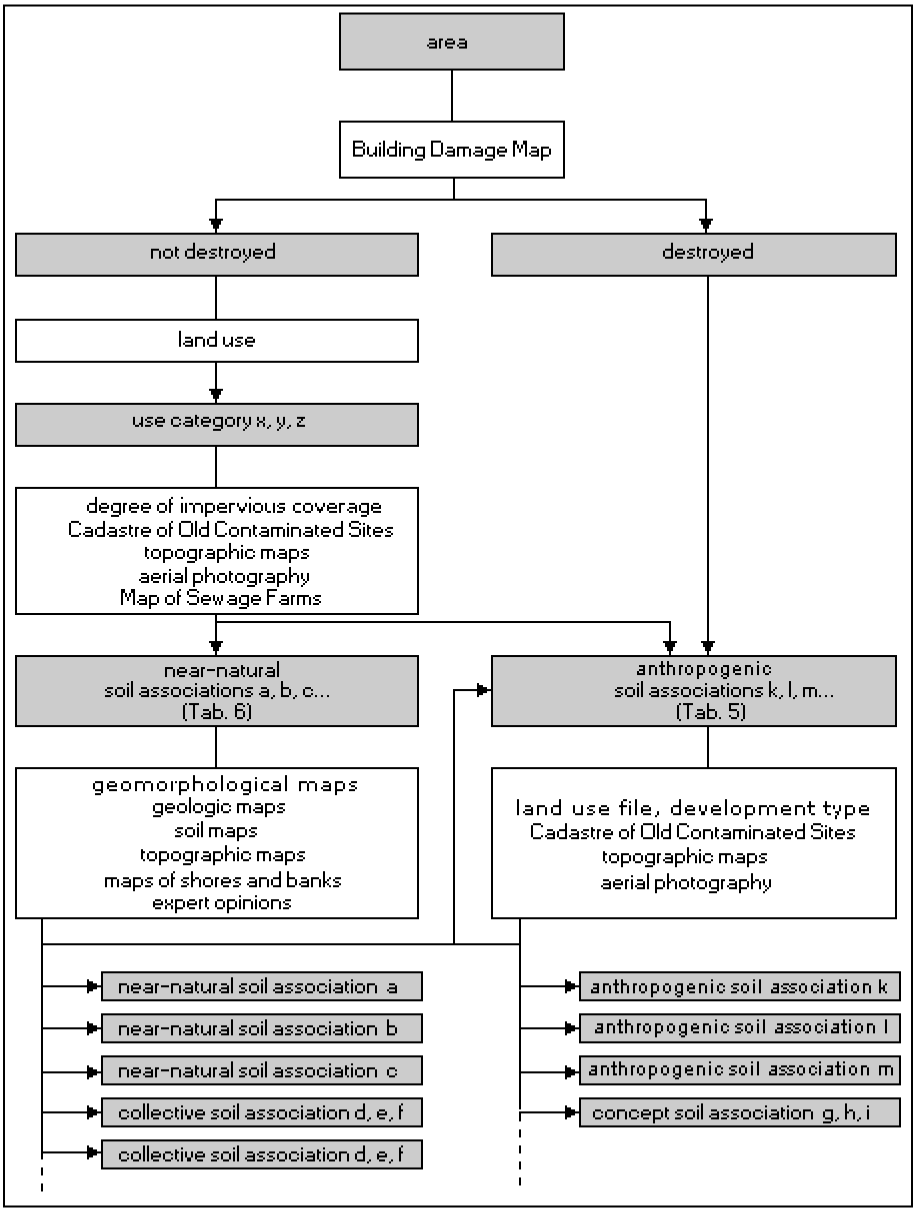

Fig. 1: Diagram demonstrating the classification process of soil associations

Categorisation of Soil Associations

The categorisation 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 decision tree on which the categorisation 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 the soils. Other key factors included available data such as the Cadastre of Old Contaminated Sites, geological 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 < 35 %, soil associations were categorised into near-natural soils according to the decision aid in Table 6.

4. Areas with a degree of impervious coverage of ≥ 35 % were classified as highly anthropogenic soil associations, depending on the type of land use and the type of development (cf. Tab. 5).

Land-use category	Possible Soil Association (SA)
independent of use (excl. industrial use) if heavily destroyed (> 50 % of building stock destroyed)	SA 2500 [52]
residential area	according to type of development: degree of impervious coverage (IC) >= 35 %, SA 2483 – 2486 [50], 2490 [51]; IC >= 25 % in newly constructed large settlement areas, Concept SA 2487 – 2489, 7777 [50a], 2482 [50aR], near-natural SA in the case of settlement, single-family home or village development and IC < 35 %
mixed-use area	according to character, type of development and IC, SA 2540 [57], 2483 – 2486 [50], 2490 [51], 2487 – 2489, 7777 [50a], 2482 [50aR], or near-natural SA
core area	if IC >= 35 % and heavily destroyed during the War (> 50 % of the building stock destroyed) SA 2500 [52], otherwise SA 2490 [51], or near-natural SA if IC < 35 %
industrial/ commercial area	SA 2540 [57]
public service and other special uses	according to character and type of development SA 2540 [57], 2483 – 2486 [50], 2490 [51], 2487 – 2489, 7777 [50a], 2482 [50aR]; IC < 35 % near-natural SA or SA 2430/2440/2441 [42/43/43a]
utility area	if IC >= 35 % SA 2540 [57], if IC < 35 % 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, SA 2540 [57], 2483 – 2486 [50], 2487 – 2489, 7777 [50a], 2510 [53], 2530 [55], and 2470 [49] are also 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] if IC ≥ 35 %
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]
former, now levelled 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	[ ] = previously used Soil Association number

Tab. 5: Classification guidelines for soil associations based on land use 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, due to 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 development type as well as previous land uses. Residential areas located on sites formerly used for industrial purposes were considered industrial areas, e.g. the Thälmannpark residential unit. Waste disposal sites, military locations, sewage farms, and other aggradations were analysed also based on information such as maps, the Cadastre of Old Contaminated Sites, aerial photography, and expert opinions.

For soils that were confirmed not to have been heavily altered by humans, near-natural soil associations were assigned according to the process outlined in Table 6.

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]	• former sewage farm	*1131 [12a]*
				• sand (on BM) < 0.8 m		• 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) 0.8 - 2.0 m	1020 [2] *		
				• sand > 2.0 m	1070 [6]	• former sewage farm	*1141 [13a]*
						• influenced by sewage farm water, low-lying location	1140 [13]
		• fluvioglacial meltwater channel		• without peat	1050 [7]		
				• fossil gley, earthy low-moor bog	1290 [29]		
				• low-moor bog	1300 [30]		
		• plateau slope, end moraine slope			1060 [5]		
		• fluvioglacial meltwater channel with alluvial dynamic			1280 [28]		
	• meltwater sand on glacial sand			• podzol	1110 [72]		
				• calcaro-dystric histosol (lime slope bog), dystric gleysol (slope gley)	1180 [17]		
	• meltwater sand on glacial sand, partially boulder clay/ marl				1030 [3]		
end moraine (oser, kames)	• (glacial) sand/ gravel			• dystric cambisol (rusty brown soil)	1040 [4]		
sink	• (glacial) sand on (boulder) marl			• sand < 2.0 m		geological map 1 : 25,000	*1021 [2a]*
				• sand < 2.0 m + peat		geological map 1 : 25,000	*1022 [2b]*
	• (glacial) sand			• sand > 2.0 m		geological map 1 : 25,000	*1072 [6b]*
glacial spillway/ outwash plain	• sand				1160 [15]		
				• peat		geological map 1 : 25,000	*1164 [15d]*
				• limey	1150 [14]		

Geomor-phology	Soil type/ substrate	Morphological division	CSA	Distinct characteristics from other SAs	SA 1:1	Additional information	*Concept SA*/ **SA**
		• lowland		• peat (sometimes earthy)	1260 [26]		
				• lime accumulation	1240 [23]		
		• kettle hole			1250 [25]		
		• meltwater channel with dune		• peat	1230 [22]		
		• meltwater channel without dune		• peat + half-bog		geological map 1 : 25,000	*1231 [22a]*
		• shallow channel		• limey	1220 [21]		
	• sand on (boulder) marl			• sand < 2.0 m		geological map 1 : 25,000	*1021 [2a]*
				• sand < 2.0 m + turf		geological map 1 : 25,000	*1022 [2b]*
dune	• fine sand	• without bog (ground level > 40 m)	1090, 1100 [9, 10]	• podzol	1090 [9]		
				• without podzol	1100 [10]		
		• with bog			1200 [19]		
		• flat dune on valley sand or drift sand, remote from groundwater (ground level < 40m)			1190 [18]		
		• dune on valley sand, slope is close to groundwater			1210 [20]		
river floodplain	• 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 (Map sheet covering the Bernau and Königs-Wusterhausen area)							
BM = boulder marl, [ ] = previously used soil association number							

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

Typical landscape segments with characteristic soil types, key profiles and their most important ecological properties have been defined for almost all soil associations.

Presentation on the map

Groups with uniform colour schemes were formed from the soil associations, concept soil associations, and collective soil associations for a clear presentation on the map. The grouping of near-natural soil associations was based on geomorphological units, while anthropogenic soil associations were grouped according to land use.

Update of the Map in 2003

Due to changes in the geometry of the initial map (splitting or merging of areas) and updates in 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, provided that a clear geometric assignment was possible, there had been no major change in land use, and the degree of impervious soil coverage fell within the definition of the previous soil association. In the case of a land use change from built-up to open space use, the previous soil association was also maintained.

If there was a change in land use from open space to built-up, along with an increase in impervious coverage, an ‘anthropogenic’ soil association was assigned. This was also the case if the impervious soil coverage increased and exceeded the category threshold.

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

An important addition compared to the Soil Association Map from 1998 is the additional differentiation of the Soil Association SA 50 (regosol + calcaric regosol + hortisol) and SA 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, Geological Overview Map). 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. The soil associations and their 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 to determine goals and measures for state planning purposes. Detailed statements about individual lots cannot be inferred, as they would require project-specific detailed maps.

Update of the Map in 2008

Due to changes in the geometry of the base map (splitting and merging of areas – as of December 31, 2005) and updates in land use and impervious soil coverage, the map had to be revised and updated once again in 2008.

The same methods from 2003 were applied here to record new areas, detect changes in land use or in the category of impervious soil coverage.

Soil Association 1251 [c] (transitional eutric histosol - histo-humic gleysol - dystric gleysol, kettle hole 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 the 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
- Tempelhofer Feld (former Tempelhof airport).

Update of the Map in 2012

Due to the changes in the geometry of the base map (splitting and merging of areas – as of December 31, 2010) and updates in land use and impervious soil coverage, the map had to be revised and updated once again in 2012.

The same methods from 2003 were applied here to record new areas, detect changes in land use or in the category of impervious soil coverage.

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 changes in the geometry of the base map (splitting and merging of areas – as of December 31, 2015) and updates in land use and impervious soil coverage, the map had to be revised and updated once again in 2017.

The methods from 2003 were largely applied here to record new areas, detect changes in land use or in the category of impervious soil coverage. 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 incorporated (Böhme 2009, Makki et al. 2014a, Makki et al. 2014b, Godbersen 2007, Edelmann 2014). By integrating the results of the research project '*Berliner Moorböden im Klimawandel*' (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 debris) was added as a new association. It is a part of the former military training area 'Parks Range' in Lichterfelde Süd.

Update of the Map in 2022/23

Due to the changes in the geometry of the base map (splitting and merging of areas – as of December 31, 2020) and updates in land use and impervious soil coverage, the map was revised and updated once again in 2022/23.

The methods from 2003 were largely applied here to record new areas, detect changes in land use or in the category of impervious soil coverage.

In addition, the results of various individual mappings were incorporated (Grottke 2015, Schmalisch 2017, Kayser 2019, Fell und Fell 2020, Hoffmann 2021, Tost 2021). By integrating the results of the NatKEV project (Kaufmann-Boll 2022), the assignment of bog soil associations and their characteristics could be defined in more detail.

The location and extent of operational and levelled sewage farms as well as existing and former war debris hills and waste disposal sites, were revised. Geomorphological units of the soil associations were adjusted based on the GK25. An additional unit, 'meltwater deposition of the plateau', was added, and landscape-related soil associations were assigned to it.

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 characterise the ecological properties of soils are available water capacity, aeration, cation exchange capacity, pH values, effective rooting depth, and summer moisture.

Available water capacity is a measure for the amount of water in soil available to plants. This includes slowly moving seepage water and water retained in the coarse and medium pores of the 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 the 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 the 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^+. The 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 levels, and pH values. Actual nutrient levels present in the soil may thus be lower than the potential maximum nutrient levels. The potential (i.e. maximum) cation exchange capacity for soil is determined based on a pH value of 8.2, and the effective cation exchange capacity on the current pH value of the soil. Effective cation exchange capacity, air and water conditions, biological activity, and redox properties, are important factors in assessing the actual nutrient availability of the soil.

The **pH value** plays an important role in shaping the soil, influencing both directly and indirectly a range of processes and properties, including weathering processes; soil formation processes, such as podzolisation or clay translocation; diversity and activity of soil organisms; humic material formation; structural stability; soil acidification; and the silting (mud filling) process.

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.

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 available water capacity, climate, relief, and groundwater.

Soil Types

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) are near-natural soils that occur in the Berlin area. They have a long developmental history and have been minimally influenced by human activity. 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 sand-covered Barnim and Teltow boulder marl plateaus. They are decalcified down to depths of 1 to 2 m. Podzoluvisols (leached soils) occur mainly in forest areas. The higher humus and clay contents in the topsoil offer luvisols (para-brown soils) a distinctively greater nutrient supply compared to podzoluvisols (leached soils). Luvisols have a medium to high capacity for storing water and nutrients and are well aerated. As a result, luvisols provide ideal planting conditions for agriculture, particularly in Rudow, Mariendorf, Lichtenrade (Teltow plateau), Kladow (Nauen plate) as well as Hohenschönhausen, Hellersdorf, Weißensee, and Pankow (Barnim plateau). In forest areas, topsoil pH values are typically low (pH 3 to 4, due to soil acidification from humic and fulvic acids as well as 'acid rain'). Farmland, however, has higher pH levels due to fertilisation and liming practices. The nutrient supply of forest 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 topsoil with little clay. Water storage capacity and aeration are sufficient.

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 Valley, 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 previous and current groundwater levels.

Cambisols are well aerated and allow for deep root development. They have a low, sometimes medium water storage capacity at lower slopes of end moraines through water inputs and deposits of clay. They provide a dry environment for shallow-rooted plants and provide adequate moisture for deep-rooted plants. The stagno-gleyed and eutro-gleyic cambisols of the glacial spillway, however, were once moist locations until the groundwater level receded. Cambisols generally exhibit a moderate nutrient storage capacity However, in practice, cambisols with low pH values used for forestry and grain production often have very low to moderate nutrient availability. The nutrient supply increases with higher humus content and pH values, such as found in areas used for vegetable crops and horticulture.

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 soil type in the push moraines of Pichelsberg in Charlottenburg-Wilmersdorf. Additionally, they develop on valley sands without groundwater, such as in the Forst Jungfernheide, and, along with spodo-dystric cambisols (podzol brown soils), serve as the predominant soils in the dunes of the Spandau, Tegel, and Köpenick forests. Both dystric and spodo-dystric cambisols allow for deep root development and are well aerated. They possess a low to moderate available water capacity and a medium nutrient storage capacity. They are very dry to dry environments and extremely poor in nutrients. The capacity to store water and nutrients is increased in these soils if there are silt deposits in the subsoil, if they are used for horticulture, or if they are located 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 specific 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 the Berlin forests; mainly on the northeast slopes of dunes in the Tegeler Forst (cf. Grenzius 1987), and the Püttberge in the Köpenicker Forst (cf. Smettan 1995).

Podzol soils usually allow for deep root development and are well aerated, but in spite of their medium to high water and nutrient storage capacity, they are nutrient-poor and dry.

Gleysols develop in locations with high groundwater levels from sandy or silty substrates. They occur in sinks within the sand plains in the Spandau Forst. Due to the relief, they are often associated with stagnic gleysols (wet gleys), histo-humic gleysols (peaty half-bog 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 kettle holes of the Großer Rohrpfuhl and the Teufelsbruch in Spandau as well as the kettle hole Teufelssee in Köpenick.

The ecological properties of gleysols vary greatly, depending on the parent material, humus contents, groundwater level, and the availability of nutrients in the groundwater. In Berlin, relict gleysols can also be found in areas with a low depth to groundwater, where the groundwater level has decreased. While these relict gleysols exhibit typical gley characteristics in their profile structure, their ecological properties differ significantly from gleysols.

Gleysols usually provide moist topsoil locations for shallow-rooted plants, and wet subsoil locations for deep-rooted plants. The available air supply is therefore inversely proportional to the water level of the soil. This results in a poorly aerated subsoil and, depending on water levels, a topsoil that ranges from well to poorly aerated. The topsoil may sometimes be wet or periodically dry with a medium level of rootability. Gleysols have a relatively high to high nutrient storage capacity and a moderate to high nutrient supply, depending on humus levels. The nutrient supply increases if eutrophied groundwater introduces additional nutrients through capillary uptake.

Relict gleysols are dry to very dry locations that are well aerated into the subsoil and allow for plants to form deep roots. They usually exhibit a medium to high capacity to store water. 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 allow for shallow roots. Histosols have a very high water storage capacity and a medium to high nutrient storage capacity. They are undrained, near-natural sites with varying nutrient levels. Bog soils often undergo peat humification and mineralisation due to groundwater lowering, resulting in altered conditions for plant growth.

In contrast to intact bog soils, earthy bog soils (histosols) and half bog soils (histo-humic soils) are relatively well aerated and moist locations that allow for plants to grow deep roots. They occur 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.

The soil types loose lithosols (raw soils of loose material), regosols, and calcaric regosols (para-rendzinas) are relatively young soil formations, compared to soils with development periods of hundreds or thousands of years. They develop on both young erosion surfaces from naturally occurring rocks, and areas composed of anthropogenically aggraded materials.

Natural soil erosion occurs as a result of natural processes, such as wind or water erosion on dune slopes, as well as on kames (short moraines perpendicular to the flow direction of the ice), and moraine hills. Anthropogenic soil erosion is a result of human activity on the soil. Soil inputs can occur both through natural translocation processes and through anthropogenic aggradations. Aggradations can be classified into those involving natural materials, such as soil excavation and gravel, and those involving artificial substrates such as war debris, construction debris, slags and cinders.

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

The soils of the Berlin urban area bear the marks of extensive human activity caused by settlement, the demolition of buildings, damage incurred during the Second World War as well as construction. On the one hand, there are large-scale aggradations of war debris, slag and cinders, and building materials, while on the other hand, there are areas eroded due to the construction of roads and railway lines as well as surface mining of gravel, sand, and clay. As a result, loose lithosols, regosols, and calcaric regosols are common in the Berlin urban area.

Loose lithosols (raw soils of loose material) on eroded areas of natural rock are mainly found 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 eroded due to specific land uses, such as is the case for military training areas and surface mining sites. Near-natural soils can still be found in small, less impacted military training areas.

Larger military training areas are located in Heiligensee at Baumberge, in the Grunewald, and in the Köpenicker 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 depend on the natural undersoil and groundwater levels, e.g., loose lithosols created by erosion of dystric cambisols are well-aerated, usually dry, and nutrient-poor.

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 in 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 2500); and at industrial, and commercial locations (Soil Association 2540). 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 as well as along railway tracks running throughout the entire urban area. Loose lithosols are less common on aggraded or transported natural rock, such as embankments 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 technogenic 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, however, in rock-free, sandy soils. Nutrient supply and storage capacity is low to high, according to parent material and use.

Regosols develop from the loose lithosols found in areas where erosion occurs naturally or due to human activity, such as on kame, moraine, or dune sands and form due to humus accumulating in the Ah horizon (cf. Grenzius 1987). These regosols are commonly found on the steeper slopes of Grunewald along the Havel, 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 of Pankow, Weißensee, and Hohenschönhausen also influenced the formation of regosols from natural materials. These are represented by soil associations 2560 [60], 2580 [62], 2590 [63].

Regosols of sandy, lime-free aggradations develop mainly in 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 availability of nutrients. Regosols often have a low water storage capacity, good aeration, and allow for deep to medium root development, 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 relocated marl, such as at excavation sites, and on eroded slopes of bodies of water and channels of boulder marl plateaus.

In the Bäke lowland near Landgut Eule and Albrechts Teerofen, calcaric regosols developed from lime mud that was dredged up and then redeposited during the building of the Teltow Canal, or from disturbed shallow water sediments (cf. Grenzius 1987).

Calcaric regosols formed by anthropogenic aggradation develop on areas filled with war or construction debris. This includes the entire densely built-up urban area, areas that suffered extensive destruction during the War and were subsequently filled with debris, as well as railway areas. Calcaric regosols are also found along the many landfill banks and lowlands of the Havel and Spree rivers and their lake-like broadenings.

The higher clay levels of calcaric regosols of boulder marl exhibit an increased capacity to store nutrients, and a medium to high available water 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 Asso-ciation	Soil types that characterise the Soil Association	Use/ formation	Frequency [%]
1010	luvisol - arenic cambisol	ground moraine plateaus of boulder marl	5.757
1020	dystric cambisol - luvisol - colluvial cambisol	moraine (hill) of glacial sands, usually over marl	1.529
1021	dystric cambisol - luvisol - colluvium/ luvisol	sandy sink fill on plateaus and valley sand over marl	0.358
1022	dystric cambisol - luvisol – dried eutric histosol	sandy sink fill on plateaus and valley sand on marl with peat	0.277
1030	dystric cambisol - colluvial cambisol	meltwater sand on glacial sand, partially boulder clay/ marl	1.047
1040	dystric cambisol - regosolic cambisol - colluvial cambisol	end or push moraine of glacial sands	1.724
1050	dystric cambisol - chromic cambisol - colluvial cambisol	fluvioglacial meltwater channel of glacial sands	0.450
1060	dystric cambisol - regosol - colluvial cambisol/ gleysol	end or push moraine and plateau slope of sand	1.009
1070	dystric cambisol - colluvial cambisol	meltwater sand on glacial sand	3.774
1072	dystric cambisol - colluvial cambisol	sandy sink fill, partially on marl	0.225
1080	podzoluvisol - arenic dystric cambisol - dystric cambisol	dunes on ground moraine plateaus of boulder marl	0.270
1090	spodo-dystric cambisol - podzol - colluvial dystric cambisol	dunes of fine sand	1.040
1100	spodo-dystric cambisol - dystric cambisol - colluvial dystric cambisol	dunes of fine sand	0.969
1110	podzol - regosolic-cambisol - colluvial cambisol	meltwater sand on glacial sand	0.031
1120	stagnic gleysol - stagno-gleyic luvisol - stagno-gleyed luvisol	clayey sink fill	0.018
1130	luvisol (sometimes influenced by groundwater) - arenic dystric cambisol	ground moraine plateau of boulder marl	0.127
1131	gleyic luvisol - gleyic arenic dystric cambisol	ground moraine plateau of boulder marl (former sewage farm)	0.089
1140	residual eutro-gleyic cambisol (cambisol with gley characteristics)	moraine (hill) of glacial sands, sometimes on marl	0.090
1141	dystric cambisol - eutro-gleyic cambisol	moraine (hill) of glacial sands, sometimes on marl (former sewage farm)	0.129
1150	eutro-gleyic cambisol - calcaric eutro-gleyic cambisol - calcaro-gleyic cambisol	valley sand of medium and fine sands	0.391
1160	dystric cambisol - stagno-gleyed cambisol - eutro-gleyic cambisol	valley sand of medium and fine sands	12.873
1164	stagno-gleyed cambisol - gleysol - dried eutric histosol	valley sand of medium and fine sands	0.994
1170	eutro-gleyic cambisol - gleysol - histo-humic gleysol	basin in valley sand	0.024
1180	dystric cambisol - dystric gleysol - calcaro-dystric histosol	meltwater sand on glacial sand	0.179
1190	spodo-dystric cambisol - stagno-gleyed dystric cambisol	drift sand on valley sand areas	1.523
1200	dystric cambisol - podzol gleysol - oligotrophic transitional histosol	deflation basin in valley sand with dunes	0.638
1210	dystric cambisol - stagno-gleyed dystric cambisol - eutro-gleyic dystric cambisol	valley sand with dunes	0.129
1220	dystric gleysol - calcaric dystric gleysol - calcaric gleysol	flat valley sand channels of medium and fine sands	0.081

Soil Asso-ciation	Soil types that characterise the Soil Association	Use/ formation	Frequency [%]
1230	dystric cambisol - stagnic gleysol - histo-humic gleysol	meltwater channels in valley sand with dunes	0.040
1231	eutro-gleyic cambisol - gleysol - eutric histosol	meltwater channels in valley sand areas without dunes	1.278
1240	stagno-gleyed dystric cambisol - calcic gleysol - dried eutric histosol	lowland in valley sand areas with low-moor bog peat	0.004
1250	dystric gleysol - histo-humic gleysol - mesotrophic histosol	kettle hole in valley sand	0.067
1251	eutric histosol - histo-humic gleysol - podzol gleysol	kettle hole in ground moraine plateau	0.003
1260	dried (fluvi-eutric) histosol	(river) lowland with low-moor bog peat in valley sand	1.672
1270	dried (fluvi-eutric) histosol - dried histo-humic gleysol - gleysol	fluvioglacial meltwater channel of sand (in boulder marl flat upland area) with low-moor bog peat	0.290
1280	eutrophic fluvi-eutric histosol - fluvic histo-humic gleysol - eutro-gleyic dystric cambisol	fluvioglacial channel of sand with low-moor bog peat	0.434
1290	dystric cambisol - colluvium/ residual gleysol - dried eutric histosol	fluvioglacial meltwater channel of glacial sands	0.302
1300	dystric cambisol - stagnic gleysol / eutric histosol - dried transitional histosol	fluvioglacial meltwater channel of glacial sands	0.147
1310	calcaric regosol - calcaro-gleyic regosol - calcaric gleysol	dried fluvisol (floodplain) with lime mud over sand	0.056
1320	fluvic gleysol - fluvi-stagno gleysol - eutrophic fluvi-eutric histosol	river lowlands in valley sand with low-moor peat	0.174
1330	colluvial cambisol - eutrophic fluvi-eutric histosol - calcic fluvisol	slope-influenced river floodplain of layered sand	0.258
1340	dystric cambisol - dystric fluvisol - mesotrophic fluvi-eutric histosol	river floodplain of layered sand	0.015
1350	fluvisol - fluvi-stagnic gleysol - mesotrophic fluvi-eutric histosol	river floodplain of layered sand	0.002
1360	dystric cambisol - fluvic gleysol - calcic fluvisol	slope-influenced river floodplain of layered sands	0.065
1370	fluvisol - calcaric fluvi-mollic gleysol - raw fluvisol	river floodplain of layered sand	0.009
1380	colluvial cambisol - raw fluvisol - submerged raw fluvisol	river floodplain of layered sand	0.080
2390	necrosol + cambic hortisol + luvisol	cemetery on ground moraine plateau of boulder marl	0.603
2400	necrosol + cambic hortisol + dystric cambisol	cemetery on ground moraine plateau of glacial sand	0.366
2410	necrosol + cambic hortisol + spodo-dystric cambisol	cemetery on drift sand area of fine sand	0.204
2420	necrosol + eutro-gleyic cambic hortisol + gleysol	cemetery on valley sand of medium and fine sand	0.351
2430	loose lithosols + cambisol / dystric cambisol + gleysol	military training area on valley sand area (with dunes)	0.136
2440	loose lithosols + cambisol / dystric cambisol + dystric cambisol	military training area on meltwater sand and glacial sand	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 meltwater sand and glacial sand	0.111
2460	loose lithosols + loose lithic gleysol + submerged raw fluvisol	surface mining on valley sand	0.086

Soil Asso-ciation	Soil types that characterise the Soil Association	Use/ formation	Frequency [%]
2470	lithosol + calcic regosol + calcaric regosol	railway tracks on aggraded and eroded surfaces	2.702
2471	(loose) lithosols + calcaric regosol + hortisol	allotment garden on aggraded and eroded surfaces	0.140
2482	calcaric regosol + loose lithosols + regosol	settlements on former sewage farm, partially on aggraded surfaces	1.413
2483	regosol + calcaric regosol + hortisol	settlements on valley sand, partially on aggraded surfaces	6.390
2484	regosol + calcaric regosol + hortisol	settlements on meltwater sand and glacial sand, partially on aggraded surfaces	1.393
2485	regosol + calcaric regosol + hortisol	settlements on boulder marl, partially on aggraded surfaces	6.422
2486	regosol + calcaric regosol + hortisol	settlements on drift sand, partially on aggraded surfaces	0.460
2487	calcaric regosol + loose lithosols + regosol	settlements on valley sand, partially on aggraded surfaces	4.778
2488	calcaric regosol + loose lithosols + regosol	settlements on glacial sand, partially on aggraded surfaces	1.136
2489	calcaric regosol + loose lithosols + regosol	settlements on boulder marl, partially on aggraded surfaces	4.934
2490	loose lithosols + humic regosol + calcaric regosol	dense inner city construction; not destroyed during war, on aggraded surfaces	4.712
2500	loose lithosols + regosol + calcaric regosol	inner city, on aggradation	4.762
2510	calcaric regosol + calcic regosol + loose lithosols	war debris hill, construction debris site and landfill	1.204
2530	reductosol + loose lithosols + regosol	waste disposal site (primarily domestic waste)	0.602
2540	loose lithosols + regosol + calcaric regosol	industrial area on aggraded or eroded surfaces	9.668
2550	humic regosol/ eutro-gleyic cambisol + hortisol/ gleysol + calcaric regosol / fluvisol	aggradation on (river) bank areas and in channels	0.934
2560	regosol + dystric-eutric regosol + gleyic regosol	levelled sewage farm on meltwater sand over glacial sand	1.267
2580	regosol + luvic regosol	levelled sewage farm on boulder marl	2.356
2590	regosol + dystric-eutric regosol + gleyic regosol	levelled sewage farm on valley sand / outwash plain sand	1.468
3020	podzol - dystric cambisol - colluvial dystric cambisol	(collective soil association of dunes without bordering bog) dunes of fine sand	0.124
3030	fluvic gleysol - fluvi-eutric histosol	(collective soil association of river floodplain with peat) river floodplain of layered sand	0.095
3040	calcic fluvisol - fluvic gleysol	(collective soil association of river floodplain without peat) river floodplain of layered sand	0.071
7777	calcaric regosol + loose lithosols + regosol	settlements on drift sand, partially on aggraded surfaces	0.238

Tab. 7: Soil associations and their characteristic soil types, use/ formation and frequency.

The frequency for Collective Associations 3020, 3030 and 3040, cannot be directly compared with each other, as they contain multiple soil associations.

Near-natural Soil Associations

SA 1010 [1] Luvisol (para-brown soil) - arenic cambisol (wedged sandpit brown soil)
(Ground moraine plateau of boulder marl)

This soil association combines soil types with plateaus with boulder 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 to 3 m deep wedged sandpits of arenic cambisols (wedged sandpit brown soils) where the boulder clay and marl was covered with a thin layer of glacial sand.

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

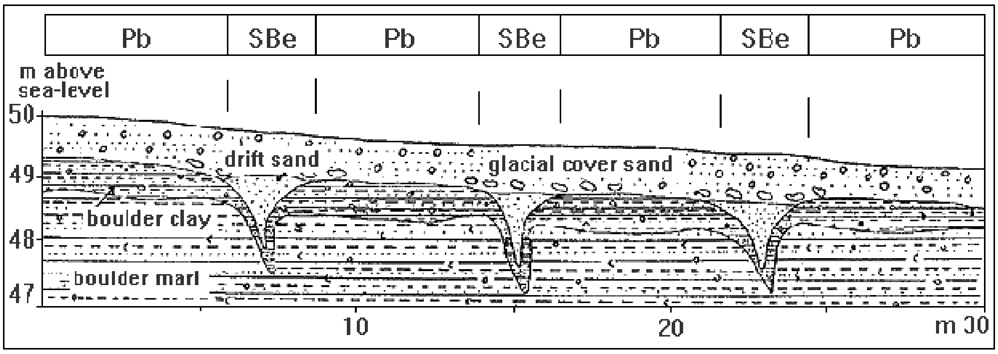

Fig. 2: Luvisol (para-brown soil) - arenic cambisol (wedged sandpit brown soil)
(Soil Association of the Ground Moraine Plateau of Boulder Marl)

SA1070 [6] Dystric cambisol (rusty brown soil) - colluvial cambisol (colluvial brown soil)
(Meltwater sand on glacial sand)

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, Düppeler Forst) and scattered across the Barnim plateau. The upper 2 metres of glacial sand do not contain boulder clay or marl.

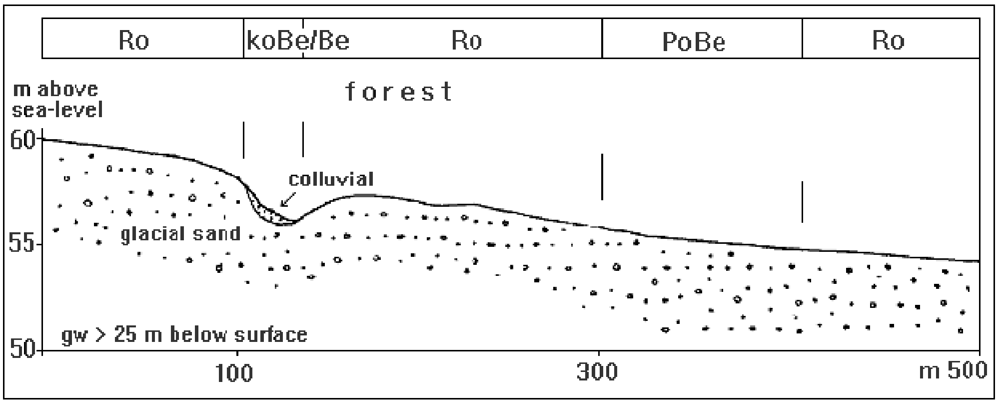

Fig. 3: Dystric cambisol (rusty brown soil) - colluvial cambisol (colluvial brown soil)
(Soil Association of Moraine Areas of Glacial Sands)

Dystric cambisols also occur in the push moraine formation in Pichelsberg. Here, they have a different spatial reference (geomorphological unit), however. For this specific geomorphological unit, dystric cambisols were therefore incorporated into other soil associations (SA 1040 [4] and 1060 [5]) along with another occurring soil type.

Dystric cambisols have their own soil associations, designated as SA 1020 [2] and 1030 [3]. These soils also occur on moraine hills consisting of glacial sands of varying heights. Sometimes, remnants of boulder marl or boulder clay can be found within the upper two metres of the glacial sand.

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, with some occurrences in the Köpenicker Forst. Soil profile studies would be required to determine the presence of podzols. In East Berlin, these two soil associations were sometimes grouped together in 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.

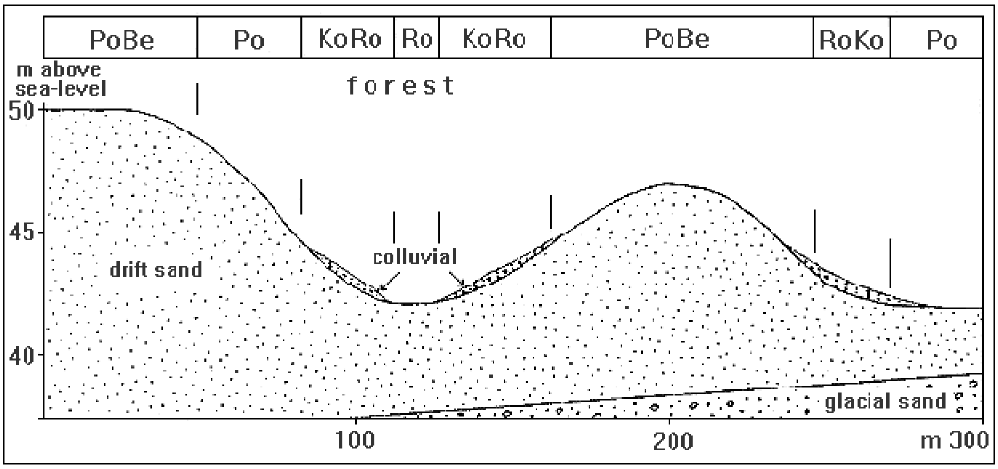

Fig. 4: Spodo-dystric cambisol (podzol-brown soils) - podzols - colluvial Dystric cambisols (colluvial rusty brown soil)
(Soil Association of Dunes of Fine Sand)

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, which 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 served as the parent material for the formation of cambisols and dystric cambisols. Varying groundwater levels contributed to the development of gley properties, such as rusty spots, at various depths. These properties are represented by the soil types stagno-gleyic cambisol and eutro-gleyic cambisol. Since the 20th century, groundwater levels have been lowered due to the groundwater extraction by the Berlin Waterworks. As a result, gley properties are often only remnants today, meaning that groundwater levels today are deeper than the gley features they once produced. This soil association is primarily found in the Spreetal in Köpenick, and in the valley sand areas of the forests in Spandau, Tegel and Jungfernheide.

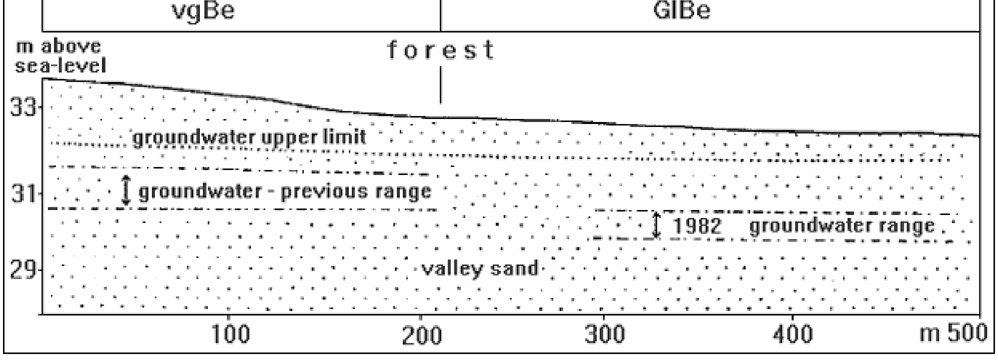

Fig. 5: Stagno-gleyed cambisol (gleyed brown soil) - eutro-gleyic cambisol (gleyic brown soil)
(Soil Association of Valley Sand Areas of Medium and Fine Sand in the Spandauer Forst)

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

The subglacial meltwaters formed during the glacial period due to the high pressure of the glacier on its bed as well as the meltwaters formed during interglacial periods as a result of climate warming, flowed into the large glacial spillways. They created, at times deep, (subglacial) meltwater channels through their erosive force. Channels close to groundwater filled with sediment and peat after the last Ice Age. Many of these channels, especially in the area of Berlin's inner city, were anthropogenically filled and built upon and are therefore no longer visible today.

Such fluvioglacial meltwater channels within valley sand areas occur in parts of the Wuhle, the Neuenhagener Mühlenfließ, Spektelake, the Egelpfuhlwiesen, and the Breite Fenn. Depending on the groundwater level, Histo-humic gleysols (peaty half-bog gleys) and low-moor bog soils formed directly in the middle of these channels. Also depending on groundwater levels, eutro-gleyic, eutro-gleyic dystric, stagno-gleyed and stagno-gleyed dystric cambisols were formed towards the edges of the channels.

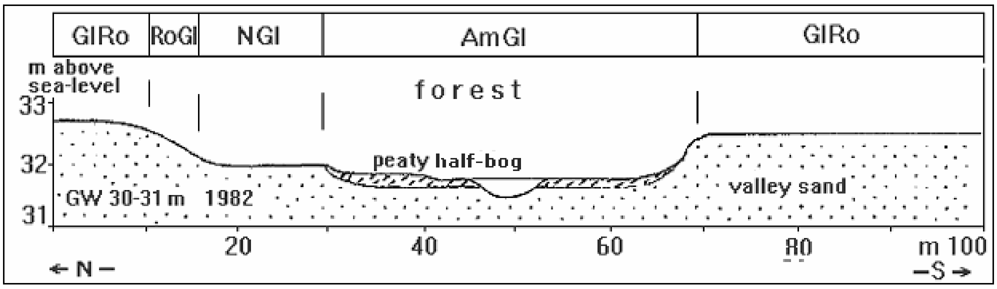

Fig. 6: Eutro-gleyic cambisol (gleyic brown soil) - gleysol - eutric histosol (low-moor bog) (Meltwater channels in valley sand areas without dunes)

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 consists of soils found in valley sand areas, which have been influenced by humas due to their use as cemeteries. Soils resulting from deep excavation during grave digging are termed necrosols. In the unused sections of the cemetery that are located on valley sand, remnants of eutro-gleyic cambisols and gleysols can still be observed. Over time, continuous organic matter input has led to the development of humic regosols, horti-gleyic cambisols, and hortisols (horticultural soils).

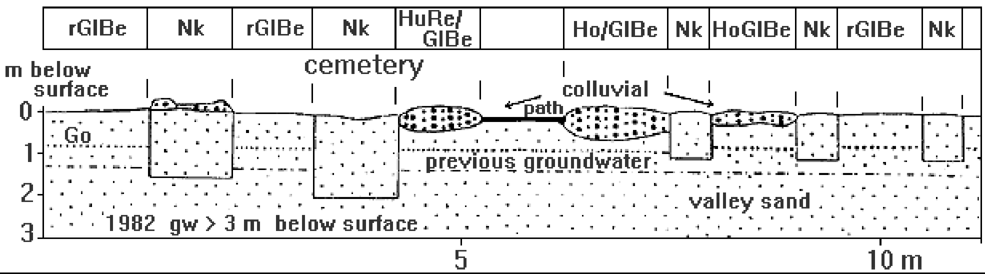

Fig. 7: Necrosols + eutro-gleyic cambic hortisol (gley brown horticultural soil) + gleysol (Soils of cemeteries on valley sand areas of fine and medium sands)

Soils subjected to other anthropogenic uses have been significantly altered by human influence, leading to the extensive destruction or covering of natural soils with 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 composed of coarse gravel of various materials; railway embankments consist of sand or were filled with war and industrial debris. Depending on the soil substrate, lithosols, loose lithosols, calcaric and calcic regosols have primarily formed.

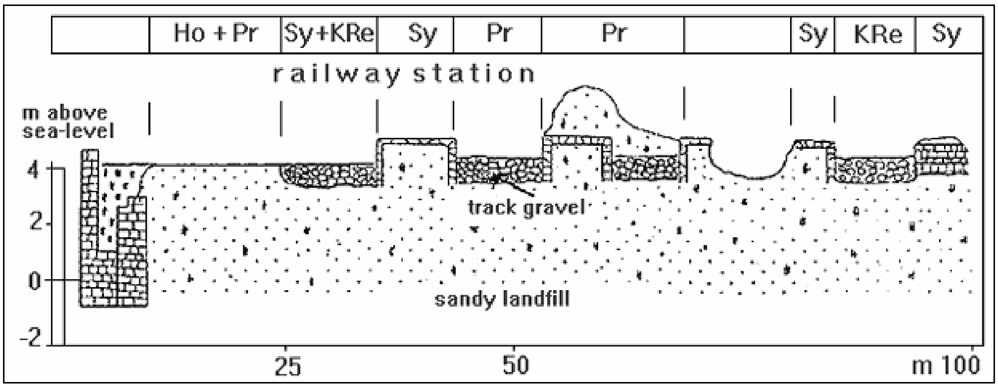

Fig. 8: Lithosol + calcic regosol + calcaric regosol
(Soils of railway facilities on aggraded or eroded surfaces; Potsdamer Güterbahnhof (freight station))

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 refers to soils within the urban area characterised by closed development, constructed prior to the Second World War and largely preserved or minimally damaged. The degree of impervious soil coverage is high. Soils found in the rear courtyards, which were or are still used for gardening, are characterised by humic topsoil and have evolved into humic regosols, hortisols, and humic calcaric regosols. In other areas of the rear courtyards, which may be covered with debris in individual cases, loose lithosols (raw soils of loose material) and regosols form.

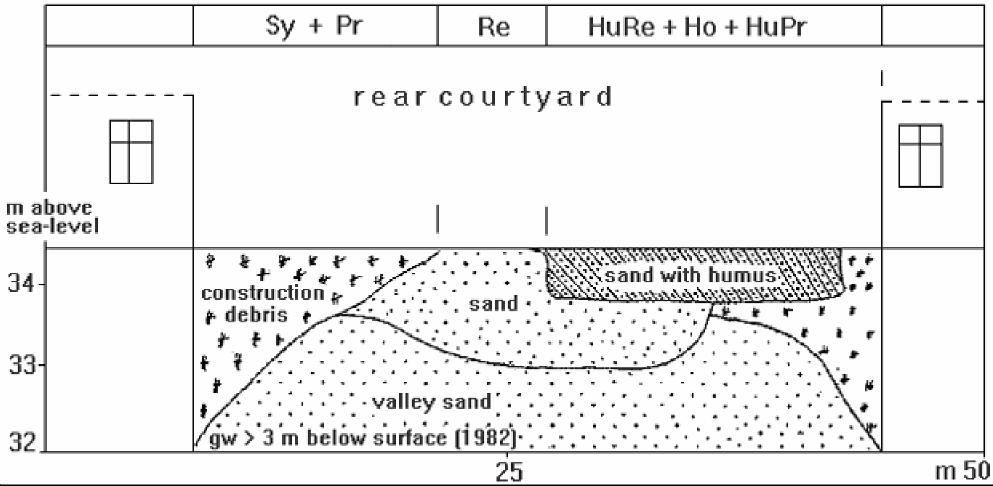

Fig. 9: Loose lithosol (raw soil of loose material) + humic regosol + calcaric regosol
(Soils of dense inner city construction; not destroyed in the Second World War; on aggraded surfaces)

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. The thickness of this layer ranges from a few decimetres up to 2 metres (cf. Grenzius 1987). Figure 10 shows how lithosols and calcaric regosols develop on these surfaces. On areas without war debris, lithosols and regosols form.

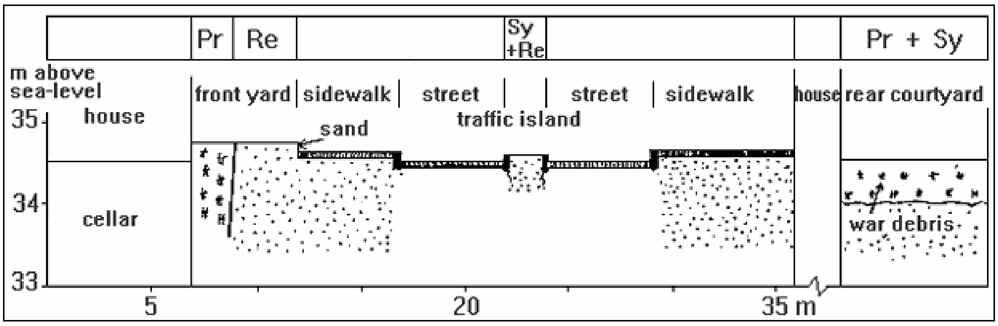

Fig. 10: Loose lithosol (raw soil of loose material) + regosol + calcaric regosol (para-rendzina) (Soils of the inner city on aggradations)

The Map of Soil Associations was compiled from various existing data sources. The map provides an overview of the near-natural and anthropogenic soil associations likely to be present, based on factors such as parent material, geomorphology or landscape segment, groundwater level, and land use. From the soil associations, the main soil types and additional site characteristics may be inferred. This includes aeration, rootability, (available) water capacity, and nutrient storage capacity as well as potential and effective cation exchange capacity as an indicator of the nutrient storage capacity (cf. Grenzius 1987).

With additional information, such as topographic maps and current groundwater levels as well as information on the soil associations, it is possible to deduce the soil type and ecological properties of a location with relative certainty, even in the absence of a map. Information about (remnants of) gleyed soils and therefore wet or dry sites, can only be inferred based on current groundwater levels.

As essential components of the landscape, soils significantly influence the diversity of flora and fauna of an area. Therefore, rare or minimally altered soils are prioritised in the designation of protected areas.

In addition to deriving site properties, Soil Association Map 01.01 is also useful for gaining insight into soil protection and soil functions. Maps 01.06 of the Environmental Atlas document soil-scientific characteristic values, Maps 01.11 outline criteria for deriving soil functions, and Maps 01.12 present an analysis of soil functions, from which Map 01.13 of ‘Planning Advice for Soil Protection’ is derived.

Po	=	podzol
Be	=	cambisol (brown soil)
Pb	=	luvisol (para-brown soil)
SBe	=	arenic cambisol (wedged sandpit 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	=	relict 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 half-bog 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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