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Guidebook Tours G and H

Soilscapes of Berlin (West)
Raised Bogs in North-West Germany and the Netherlands

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Guidebook

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Natural and anthropogenic soils and environmental

problems within a metropolitan area

Raised Bogs

in

Natural and Cultural Landscapes

of the

Federal Republic Germany and the Netherlands

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Tour G

Soilscapes of Berlin (West)

by

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1. PREFACE

The major aim of the excursion in Berlin is to show the remarkable human impact on the soils and ecosystems in this metropolitan area. To meet the aims we try to compare the less altered natural soils and the soils under the characteristic urban use. The major alterations in the soils are due to the rapid almost uncontrolled growth of the town during the late 19th and the 20th century and the destruction during the second world war. Recently, many new environmental problems have been recognized to be induced by modern technologies. There are two major developmental pathways of our recent soils. One is through the formation of new anthropogenic parent materials (rocks), the other by strong anthropogenic influence on existing soils. In both cases, the influence on recent soil formation should be discussed.

This excursion was possible due to the great efforts of the Department of Ecology in the study of urban ecology since 1972, the year of the foundation of the department. This excursion guide has two precursors, the "Contributions to urban ecology, Berlin (West)" by H. SUKOPP et al. (1980) and "Typische Böden Berlins" by H.-P. BLUME et al. (1981). A lot of information has been taken directly out of these publications.

Within the Soils Units of the department many collegues have contributed to the field work, the analytical work, the drawing and typing especially K.H. Böttcher, S. Rautenberg, U. Förster, M. Facklam, G. Jakschik, D. Pfannschmidt, D. Stasch, J. Nierste, B. Marschner, U. Meier, J. Walzer and R. Conrad. Without their help the preparation of the excursion would have been impossible.

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Berlin, Dec. 1985

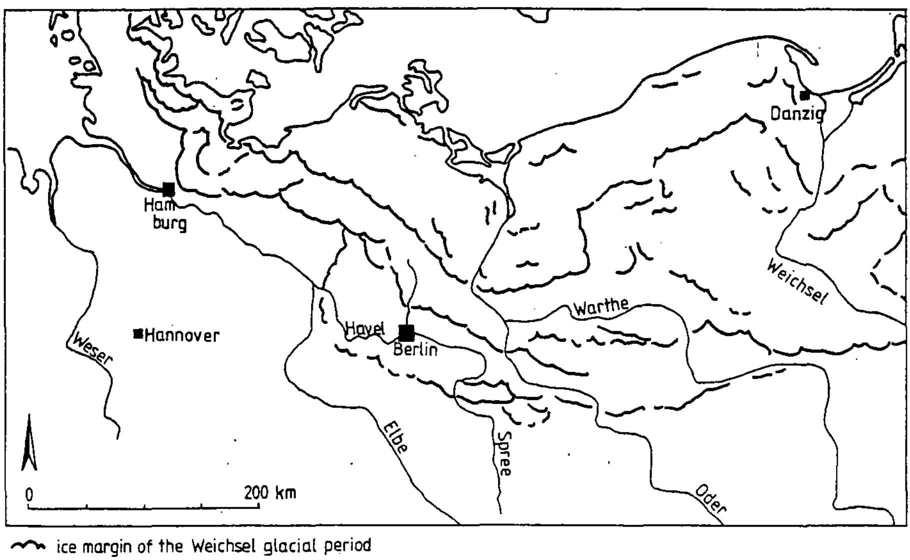
Karl Stahr

2. BERLIN - NATURAL ENVIRONMENT AND METROPOLITAN AREA

2.1 Location, size, climate

Berlin (52°31'N, 13°25'E) is located in the central part of the North-East German Lowlands. Consituted of the three western sectors, West-Berlin covers an area of 480 square kilometres. 31 square kilometres are occupied by open waters with a surface level of 30-31 metres a.s.l. The land surface has an average elevation of 32 to 50 metres a.s.l. The highest natural elevation is the Schäferberg (103 m) in the Forest of Düppel, whereas the Teufelsberg (120 m) in the Forest auf Grunewald has been constructed from the rubble of the ruins after the 2nd world war.

Fig. 1 Berlin, geographical location



The climate of Berlin has oceanic as well as continental influences and the moisture regime is at the limit between semihumid to semiarid. Climatic data recorded at the station of the Free University at Dahlem show an average annual precipitation of 590 mm and an average annual temperature of 8.9°C. The regional variability is shown in figures 2 and 3.

Fig. 2: Mean air temperature (^{o}C) 1978 in Berlin

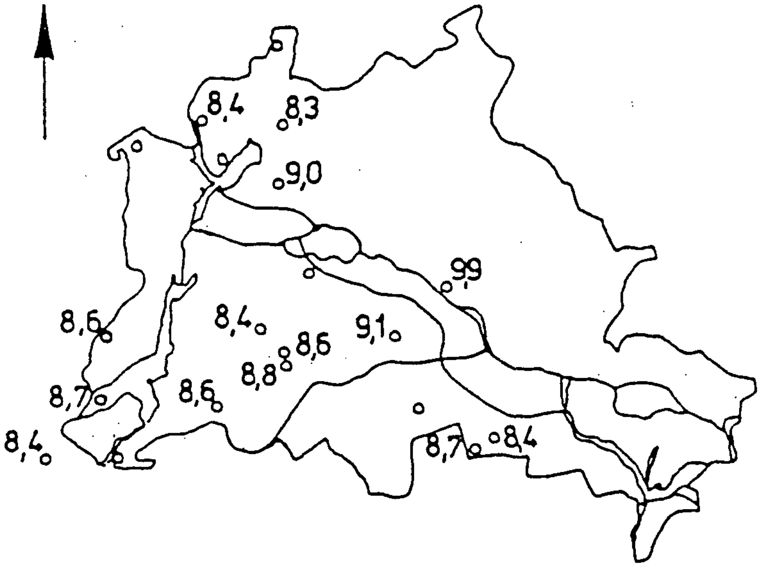
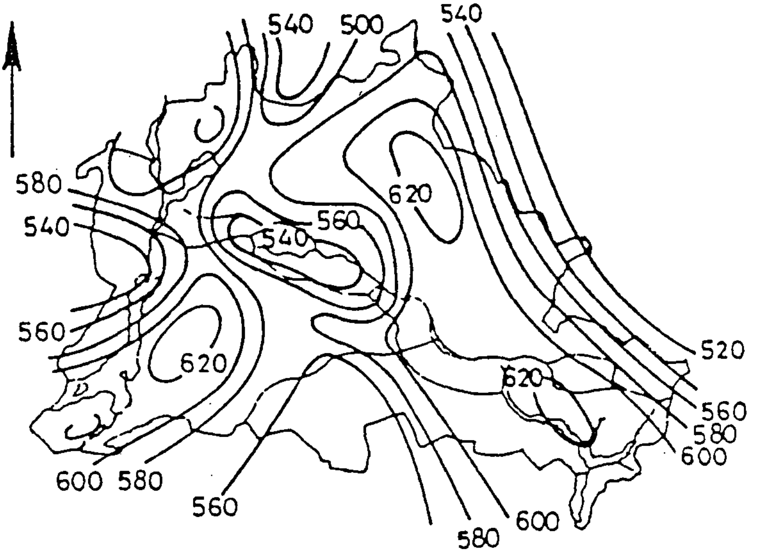


Fig. 3: Mean annual precipitation in Berlin (SCHLAAK 1977)



At Dahlem the mean daily average maximum temperature is 12.9°C, the minimum 5.1°C. As an average, there are 6 hot days, 33 summer days, 79 days with frost and 23 ice days registered per year. The soil surface is frozen on 107 days a year.

Tab. 1 Climatological data of different places from the Berlin climatological survey (average for the year 1983)

station	Pfauen-insel	Gatow	Grune-wald	Dahlem	Charlotten-burg
air temperature °C	10.1	10.0	9.8	9.9	11.0
mean max. temperature	14.1	14.0	14.0	13.9	14.4
mean min. temperature	6.7	6.1	5.8	5.9	7.3
mean daily temp. range	7.4	7.9	8.2	8.0	7.1
hot days (all day > 25°C)	10	14	12	11	12
summer days (average > 25°C)	53	58	52	53	55
frost days (average < 0°C)	64	77	78	73	49
ice days (all day < 0°C)	15	14	15	14	13
precipitation (mm)	605.4	579	606.9	611.6	-

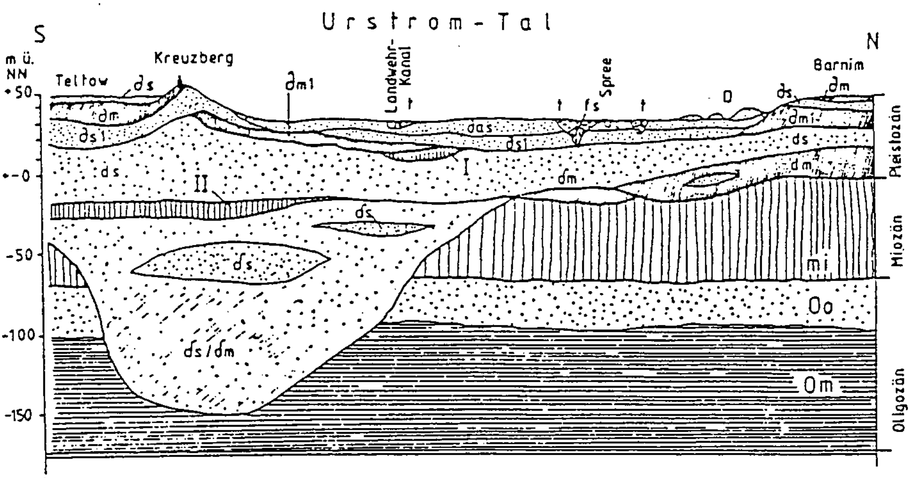
The agriculture areas on the plains (Gatow/Rudow) and the City (Charlottenburg) have more continental influences than the forests (Grunewald) and lake side areas (Pfaueninsel).

2.2 Geology, petrography and landscape structure development

The underground of Berlin consists of mesozoic and tertiary sediments (FREY 1975). These rocks do not occur as parent material of our soils because of an quarternary unconsolidated sediment cover of a thickness of 20 to 100 m (Fig. 4)

The glacial till of the moraine plains has a high bulk density due to the former ice load. The till is poor in coarse pores and, therefore, has a low water permeability. The lime content varies between 7 and 20%. The clay content is similar, but is considerably reduced towards to the plate margins. The dominant minerals of the clay fraction are illite, kaolinite, smectite, vermiculite together with mixed layer minerals and iron oxides (ALAILY 1984). The coarser fractions contain mainly quartz, feldspars, micas with a quartz maximum in the sand fractions. As a result of various processes, especially wind action, the

Fig. 4: Geological transect through Berlin (from BLUME et al. 1981)



D	Dune sand	
t	Fen peat	Holocene
fs	Sapropel and calcareous mud	
δas	Fluvioglacial outwash sands	
δs	Cover sand	
δm	Upper till	Weichsellian glacial period
δsl	Lower sand (frontal apron and gravel)	
δml	Lower till	
I	Sapropel and sand	Interglacial I
ds	Sand and gravelly sand	
dm	Till (partly 3 sand layers separated by 3 till layers)	Saalenian glacial period
II	Paludina bed, sand and clay	Interglacial II
δs	Gravel and sand	Elsterian glacial period
δm	Till	
mi	Lignite, clay and sand	Miocene
Oo	Sand	Upper Oligocene
Om	Septarian clay (Rupelian clay)	Middle Oligocene

tills are commonly overlain by some decimeters of cover sands.

The sandy moraines are considerably reduced in lime, clay and silt but are rich in medium and coarse sand in comparison to the till. These materials are mainly deposited in the pushed terminal moraines (e.g. Grunewald, Forest Düppel). In the northwest of the Grunewald these sands are virtually free of stones and partially stratified. They have been called therefore "kames" sands (ASSMANN 1957). In the upper decimeters the moraine sands have also incorporated wind blown fine sands. In places there are stone pavements preserved, which have been formed by wind erosion in the late glacial period.

The fluvioglacial outwash-sands are well sorted, highly permeable, medium to fine sands with very low clay, silt and lime contents. The mineral distribution is similar to the tills, but the high sand contents results in a strong dominance of quartz. In some places, silty, calcareous or layers of coarse sand occur (DÜMMLER et al. 1976).

The texture and mineralogy of the wind blown sands is very similar to the outwash sands but, in general, they are better sorted, with the fine sand fraction dominating. They are less compacted than the outwash sands which increases their permeability.

The alluvial river sediments are mostly sands and do not differ very much from the outwash sands of the Urstromtal from which they are derived. On the margins of terminal moraines and tills they are coarser and more variable. Under bogs and on the bottom of fresh water lakes, precipitated lime with up to 80% $CaCO_3$ and a silty texture is found (see Tab. 2) (NEUMANN 1976).

The area of Berlin was formed during the last glaciation (Weichselian) and the late and post glacial phases.
The moraine plateaus of Teltow in the South, Barnim in the North and Nauen to the West are separated by the broad, flat "Berlin-Warschau-Urstromtal" in which now the Spree river flows. The Havel river crossing this valley flows in an old meltwater channel (Fig. 5).

During the Weichselian, two thick ice lobes pushed southward beyond Berlin. The present day chain of Havel lakes runs along the icestream boundary. During this phase older glacial sediments together with their soil cover were largely removed and the Berlin Urstromtal, preformed in earlier ice ages, was also overlain. Beneath and above the ice, meltwaters flowed towards the Urstromtal of

Tab. 2 Examples for the properties of typical sediments in the Berlin region (from BLUME et al. 1981 changed)

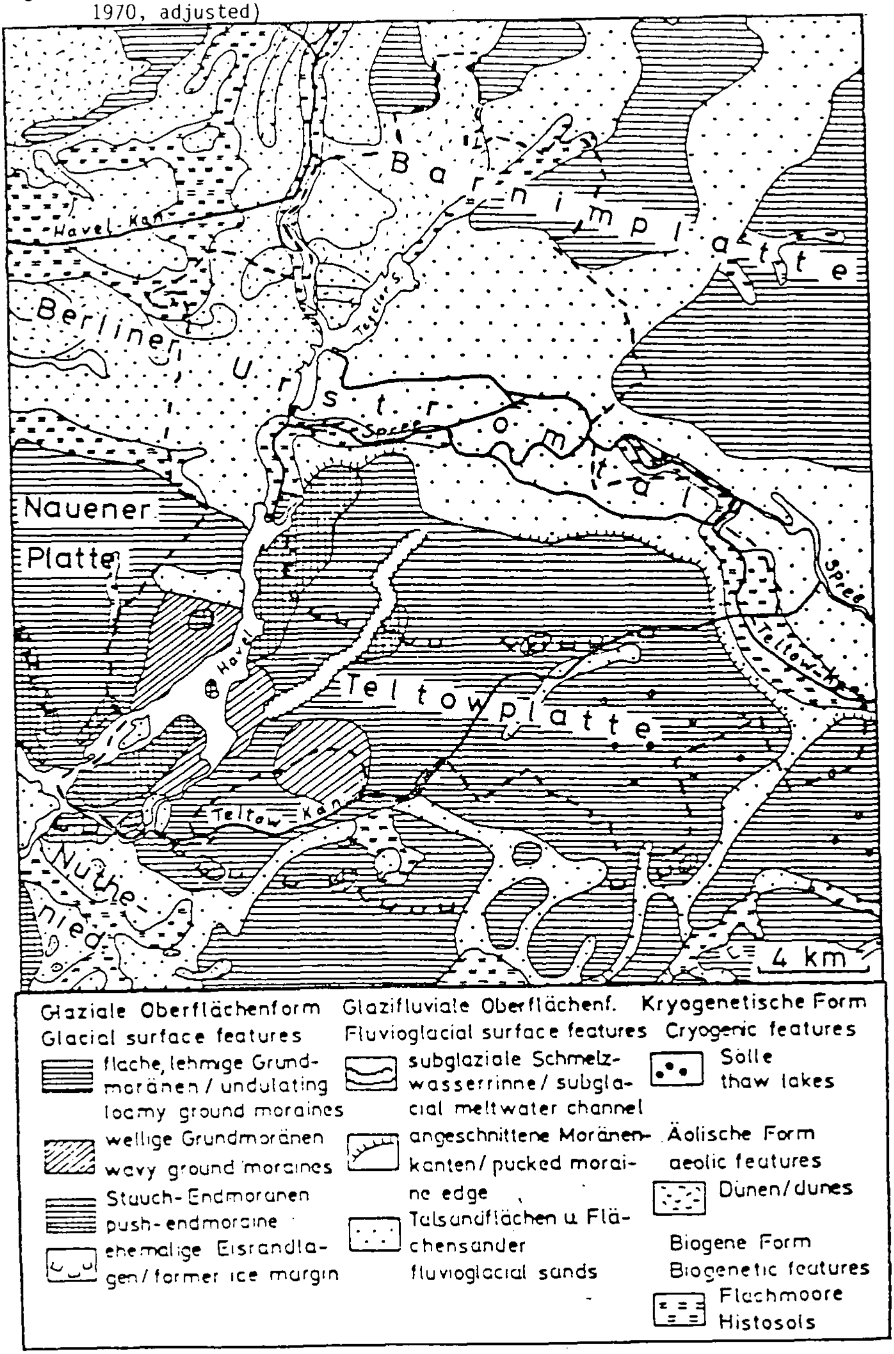
Sediment	Bulk density kg/dm^3	Saturated water conductivity cm/d	Pore volume Vol.% total	coarse	medium	fine
1. Till (boulder clay)	1.87	2	31	7	15	9
2. Coversand	1.75	70	33	13	16	4
3. Moraine sand (boulder sand)	1.65	260	38	34	3	1
4. Outwash sand	1.57	600	40	32	5	3
5. Outwash silt (glacial)	1.62	160	39	27	10	2
6. Dune sand	1.50	2000	43	36	5	2
7. Alluvial sand	1.64	1700	41	33	4	4

Sediment	Grain size distribution (carbonate free) weight %						Chem.-mineralogical properties weight %o			
	gravels	sand coarse	sand medium	sand fine	silt	clay	Carbonates	Fe-Oxides	HCl-soluble K	HCl-soluble P
1. Till (boulder clay)	5	5	25	31	22	14	140	5	1.6	0.3
2. Coversand	6	4	32	38	22	4	0	3	0.8	0.3
3. Moraine sand (boulder sand)	2	6	64	25	3	1	10	0.4	~0.5	~0.2
4. Outwash sand	< 1	1	15	80	3	1	2	0.2	~0.4	~0.2
5. Outwash silt (glacial)	< 1	< 1	4	57	38	1	100	0.4	1.2	0.3
6. Dune sand	< 1	< 1	16	82	1	1	10	0.3	0.4	0.1
7. Alluvial sand	< 1	37	57	2	2	2	5	1.5	0.3	0.2

"Potsdam-Baruth". The main meltwater channels lead to erosion beneath the ice, thereby forming the modern Havel valley and the Grunewald lake chain, for example (FRANZ et al. 1970).

After the ice melting during the Brandenburg phase, level ground moraines of till emerged which overlie the sandy deposits of older tills (BÖSE 1979). Their clastic silicatic content are derived from weathered rock materials of the mature land surface of the Fennoscandian Shield. These components are mixed with sedimentary components of the Baltic regions. The $CaCO_3$-content, in particular,

Fig. 5: Geomorphology of the Berlin region (after FRANZ & SCHNEIDER & SCHOLZ 1970, adjusted)



is derived from Cretaceous sediments (ASSMANN 1957). Between the icestream boundaries, mainly sands and gravels have been pushed together and form convex push moraines. They form the present-day characteristic landscape of the hilly Grunewald and Forest Düppel.

During the thawing of the ice sheets, ice residues were covered by debris and fluvioglacial sediments. The melting down during the terminal phase of the glacial period resulted in a great number of kettle holes on the ground moraines, whisch subsequently became small pools. Also, parts of the hollows in the original river-bed of the Havel (e.g. Tegel Lake, Heiligensee, Teufelsbruch in the Spandau Forest) are believed to be kettle holes.

During the Pommeranian phase Berlin was free of ice at that time. The meltwatery from the ice margins further north used the Berlin Urstromtal and deposited the fine-grained fluvioglacial sands. Under the influence of presumably arid, high arctic climatic conditions, during the winter a network of frost cracks (2-10 m mesh) two to three meters deep developed within the moraines. These cracks were subsequently filled by windblown sands (BLUME & HOFFMANN 1977). Later on, the surfaces of the moraines were covered with windblown sand and subsequently altered by cryoturbation processes. The alteration of the processes of dune sand accumulation, cryoturbation and wind erosion formed the two cover sand sheets (comp. chapter 4.3).

On account of the subarctic summer conditions only the top meter of the permaforst soils thawed. The meltwater was able to cut channels into the sandy moraines, which dried out afterwards.

During the terminal phases of the glaciation, also the outwash plains of the Urstromtal became dry and wind sediments were deposited. Mainly in the today Spandau and Tegel Forests, deflation hollows (later bogs) and dune stretches developed. On the moraine plains, wind action also formed a second cover sand and by solifluction masses, terrain basins were partly refilled.

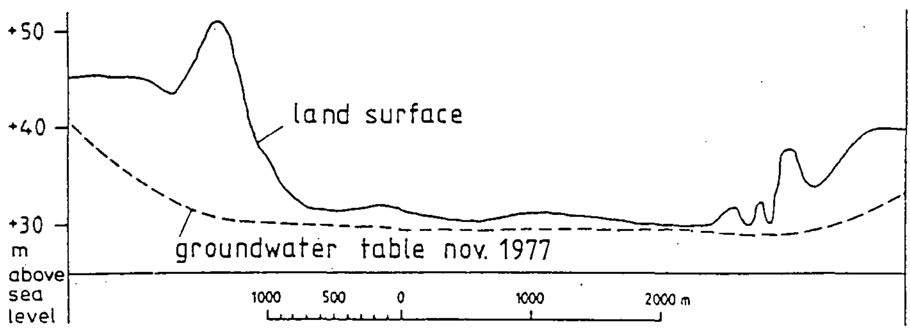
From the late glacial period to the holocene, inland waters caused multiple changes. In the broad sandflats of the Urstromtal the Spree River found favourable conditions to form several meanders with narrow river banks. The lakes were partly filled by windblown sands and alluvial sediments. They became partly silted by hydrated lime and through the accumulation of organic muds (PACHUR & HABERLAND 1977).

2.3 Hydrology

The utilizable groundwater body in Berlin reaches from about +30 m a.s.l. to 110 m b.s.l. which is right down to the old tertiary Rupel clays. This body is partly intersected by layers of marls and clays. The natural water table beyond the moraine plains lies between 34 and 37 m a.s.l. which is up to 10 m below the surface. In the depressions and along the small streamlets, the groundwater reaches the surface. The groundwater fluctuates about 0.4 to 0.8 m every year. The high water mark is reached in spring (March-April) the low in autumn (September-October).

On the moraines, the infiltration and drainage are slow. Therefore, local basins and the kettle holes have periods of stagnant water above the surface or above one of the moraine layers. This feature is well documented in the temporary rain water pools (Himmelsteiche). On the other hand, the groundwater below a till layer may be under a certain pressure.

Fig. 6 Land surface and groundwater table form measurements 1977
(from BLUME et al. 1981)



In the floodplains, considerable groundwater fluctuations occur. The high floods occured especially in spring, when backwater from the floods of the Elbe River entered into the Havel and Spree. The amplitude here was between 29 m a.s.l. and more than 32 m a.s.l. The watertable in the original Spree river valley lay between 0.2 to 4 m below the undisturbed surface of the Urstromtal. Below the dunes and the sandy moraines it naturally lay deeper.

Tab. 3 Water-levels at different water gauges in Berlin
(Senator für Stadtentwicklung und Umweltschutz 1984)

Locality	Sophienwerder - Spree close to entrance into Havel	Schulzendorfer Straße - Spree, Charlottenburg	Tiefwerder Havel - Lower Havel near Pfaueninsel	"Am Bahndamm" Tegeler Fließ, Tegel	Grunewaldsee	Lichterfelde, Teltowkanal	near Lolopfuhl, Rudow	Großer Stern, Grunewald	Teufelsbruch, Spandau	Lützow-Platz, Tiergarten
HHW	30.83	36.40	30.73	33.20	-	32.62	-	-	-	-
HW	30.58	34.39	30.48	33.10	32.30	32.41	-	-	-	-
MW	29.59	33.05	29.59	32.65	32.07	32.06	-	-	-	-
NW	29.22	32.78	29.22	32.52	31.68	32.18	-	-	-	-
NNW	28.96	32.77	28.97	32.41	-	32.03	-	-	-	-
GW	-	-	-	-	29.70	-	36.70	28.30	30.50	30.80

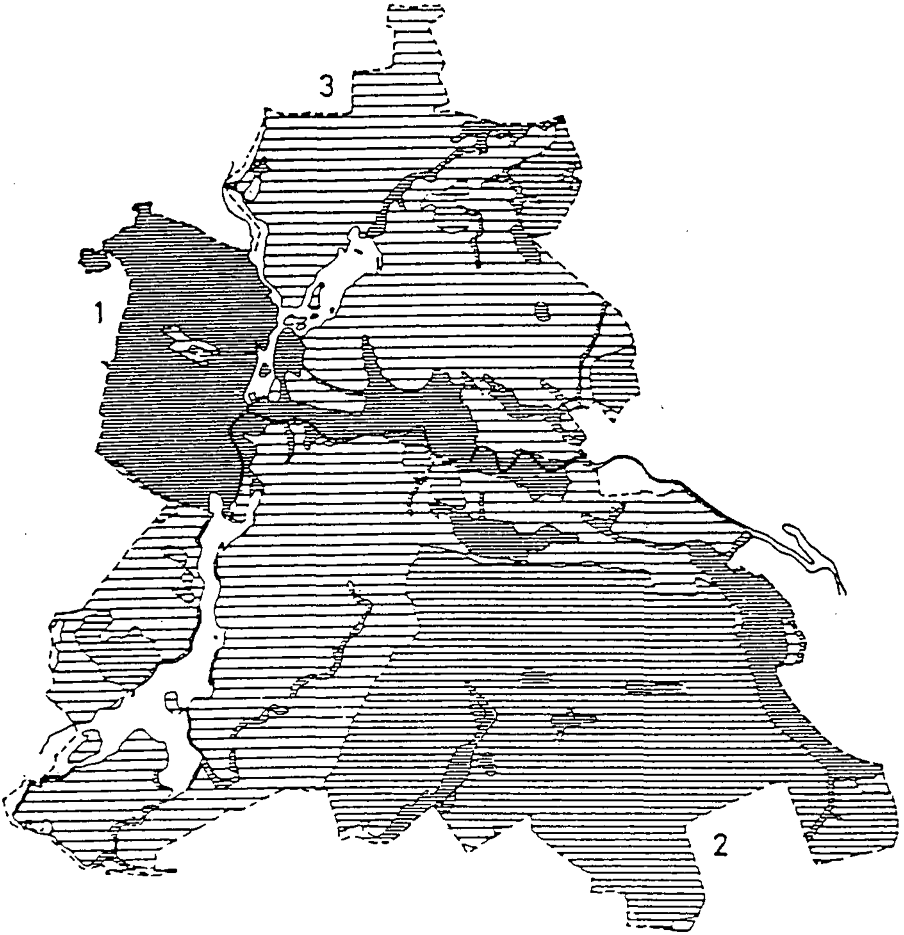
HHW highest recorded water table 1959-1982
HW highest water table 1982
MW average water table 1961-1980
NH lowest water table 1982
NNW lowest recorded water table 1959-1982
GW average groundwater table 1982

2.4 Vegetation

The original natural vegetation of Berlin (West) has been reconstructed by means of pollen analysis, soil conditions, historical reports and logical conclusions (SUKOPP & BRANDE 1980, 1981). The map in Fig. 7 shows three major landscapes.

1) Area of Oak-Hornbeam-Forests influenced by ground water. From this moist vegetation complex very little has been preserved, changes are due to lowering of ground water level, agricultural use (meadows, recreational use and geomorphological changes caused by industrial settlements. Originally, this area comprised stands of Stellario-Carpinetum, other bottomland-forests, different types of

Fig. 7: Original natural vegetation of Berlin (West) according to HUECK 1961 from SUKOPP & BRANDE 1980



1 Oak-hornbeam-forests with groundwater influence (forests of floodplains)

2 Oak-hornbeam-forests without groundwater influence

3 Pine-forests on different sandy terrain

riverbank and aquatic vegetation (for vegetation types see TREPL & KRAUSS 1984).

2) Area of Oak-Hornbeam Forests not influenced by ground water. No complete exemples of this vegetation complex on a loamy soil have been preserved, a number of relict stands can be found in several parks. Changes are due to agriculture, rural, urban and industrial settlements including gardens, traffic lines a.s.o. Originally, it mainly comprised stands of Tilio-Carpinetum, including a large number of ponds and a small number of streams.

3) Area of Oak-Pine-Forests. A large part of this area is still covered by forest as a consequence of lacking soil fertility and protection for hunting purposes. Bound to mainly sandy soils, there is a great variety from dry to moist habitats, where the beech (Fagus sylvatica) may occur under certain conditions (stands of Fago-Quercetum). Originally, this area comprised stands of Pino-Quercetum, Cladonion-Pinetum, Vaccinio-myrtilli - Pinetum on dunes and probably local grassland on loose sand. Changes are due to farming, urban settlements and roads a.s.o.

4) A fourth area can be discerned, that is not shown in Fig. 7, because it is very locally distributed, but nevertheless very different from the other ones: bogs. A number of stands have been preserved in different stages of desiccation. Changes are due to lowering of the ground water level, removing the peat and creating lakes or small parks. Originally, it comprised stands of Ledo-phagnetum medii, Eriophoro-Betuletum pubescentis and a number of dependent cummunities.

The predominant type of oak-lime-hornbeam woodland not influenced by the ground water regime is domestic to the ground moraine plateau areas.
Since Berlin is geographically not connected with the closed beech areal, the isolated occurence of deciduous woodland with a larger share of beech is restricted to edaphically and microclimatically favoured sites (SUKOPP & SCHNEIDER 1971). At the margins of the plateaus and near the rivers, fens with alder dominated. At the Unterhavel only little space of hard-wood riverine stands is present due to the steepness of the banks.

Caused by intensive landuse since 1850, the former landscape changed totally, only some oak and pine forest as well as peat areas remained. Today, the vegetation of the city consists of several different elements, such as trees in the streets and settled areas, gardens, parks, city-waste-lands, industrial fallow, roadside and traffic verges.

2.5 Waters and organic soils

In Berlin (West) more than 7% of the area are covered by lakes, rivers, brooks, ponds, mires and artificial canals, ditches and holes (KLOOS 1978). The natural formation of depressions originates from the Weichselian glacial, partly preformed during earlier glaciations. Since the late glacial the Havel river and lake system was filled with more or less calcareous muds of local thickness up to 25 m or more. The actual water depth is locally more than 10 m. In the Spree meandring river system, recent lakes are less frequent. The Spree drains an area of 10 000 km^2, and the Havel (up to Berlin) 3250 km^2. The Spree transports an average water amount of 40 m^3/sec., the Havel 16 m^3/sec. The highest Havel water level is in spring, the lowest in autumn. The Spandau lock causes a yearly range of the upper Havel level of 45 cm (1951-1960) and in the lower Havel south of the Spree mouth of 95 cm. The sandy Havel valley has a foreland between the reed bank and the slope, which partly is covered with fen peat of Subatlantic age.

Some of the shallower lakes and ponds in the Urstromtal, kames and ground moraine areas already disappeared in the late glacial by overgrowing peat formation, others in subsequent periods. Another type of holes originated as ponds or reappeared as lakes in the Subatlantic period, due to natural and man-caused increase of runoff water of Havel level rise. Artificial ponds were created since medieval times on the moraine plateaus for livestock water supply or as till and marl pits, in other parts as gravel, sand, clay and peat pits. Moreover, in modern times, lakes of various sizes were formed by industrial sand excavation in the Urstromtal, others constructed within recreational park areas. Many canals and ditches for shipping and water runoff were built in the last 250 years.

Today, the waters in Berlin are generally heavily polluted, due to waste water and ship traffic. Even after the passage of irrigation fields or waste treatment plants the water carries a heavy material load. Rapid and strong lake eutrophication is the consequence (SUKOPP & BRANDE 1985), and sapropel is formed on the muds. Therefore, in many lakes and ponds the sludge, but also the naturally formed unpolluted sediments are more or less periodically removed since some decades. Recently, aeration and phosphate elimination stations were built in order to weaken the eutrophication effects (see Tab. 6 , chapter 3.4)

Mires are almost the only remnant of natural vegetation in Berlin. The value of some mires as nature reserves is more than a regional one. Peat formation began on lake sediments locally already in the late glacial and continued in different ways due to water and nutrient supply in the growth landscape units of Berlin

(BRANDE 1985). The final stage of oligotrophic mires in the sandy soil areas is a pine woodland bog rich in peat moss, as the annual precipitation of 550 to 580 mm prevents the formation of woodless raised bogs. The other extreme is the formation of alder carr and eutrophic peat in some parts of the Urstromtal and the brook valleys. Intermediate, i.e. mesotrophic mires have not only a mixture of biotic elements, but are characterised by some special plant communities (Caricetum lasiocarpae e.g.). The climatic conditions of some lowland mires are rather cold and continental, and numerous boreo-subarctic plants and animals occur there. All mires in Berlin are, at least in parts, changed by man, especially by lowering of the water table in the last 100 years. Mineralization of the uppermost peat layers and woodland development has followed. Today, peat formation only occurs rapidly in former mire lakes.

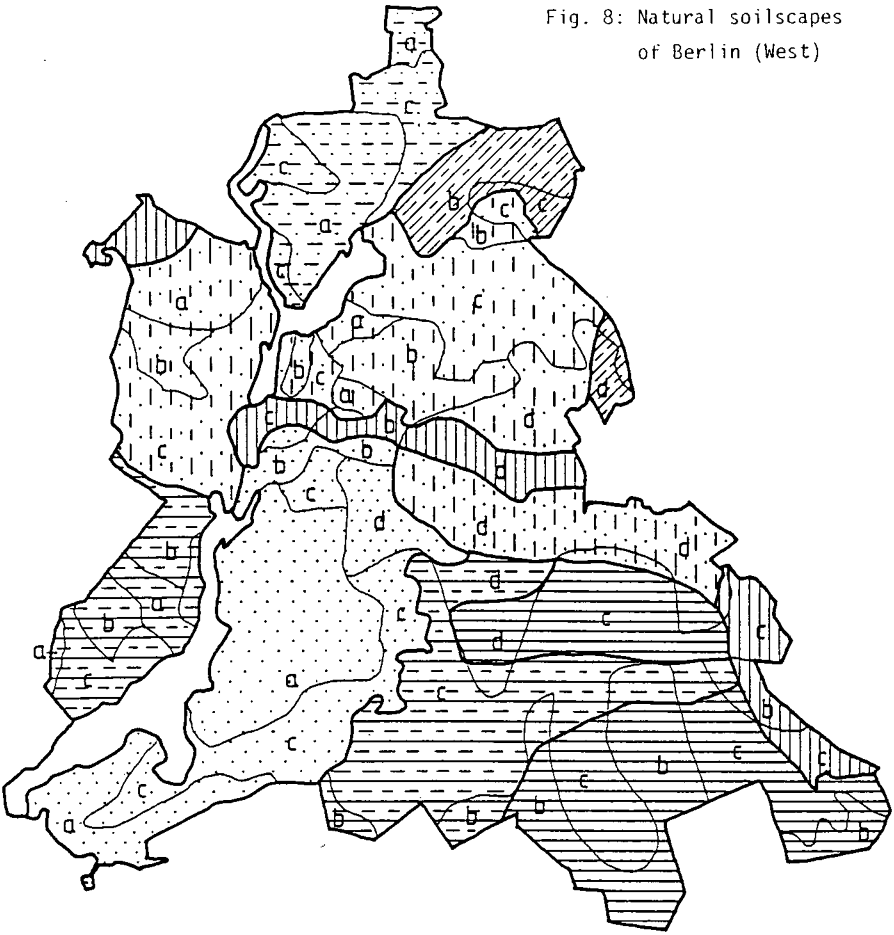
2.6 Soilscapes

The development and spreading of the Berlin soils has been naturally influenced mainly by the occurence of the parent material, the relative height of water tables and the relief. All soils were formed in the late pleistocene and holocene (younger than 20 000 years) and influenced during the 12 to 18th century mainly by deforestation and following agricultural measures. Recently, the soilscapes have been intensely altered by various influences from the growing city (BLUME & RUNGE 1978) (Fig. 8).

The Orthic Luvisols were formed from cover sand above glacial till during the holocene period. Generally, they are now decalcified to about 1 m depth and the topsoil is lessivated too. A morphological speciality is the occurence of a network of periglacial sand-wedges. The net has a width of 3 to 8 m and a depth of 1 to 3 m. The sandy parts show illuviated clay in the form of bands. Because of the regular drainage pattern of those soils the ecological qualities of these soils vary mosaic-like. The deeper the cover sand or the more the till changes into moraine sands, the more clay illuviation is only found in deeper parts of the profile in the banded form while the upper part grades into a Arenosol.

The Arenosols are more dominant in landscapes 2 and 3 whereas the Luvisols occupy landscape 1 (HOFFMANN 1976; GÖTZ 1968).
Under forest the Luvisols show sometimes a well developed albic E horizon and a glossic interfingering of E- and B-horizon. There, they grade into Podzolluvisols (Fahlerde). In depressions and in places where drainage is impeded the Luvisols have hydromorphic properties even in the E-horizon. The Gleyic Luvisols are also associated with the small streamlets and the small pool hollows. In theses places

Fig. 8: Natural soilscapes of Berlin (West)



- Orthic and gleyic Luvisols on level moraine landscape of Teltow
- Luvisol - Arenosol - Gleysol on cover sand moraine landscapes
- Luvisol - Arenosol - Eutric Histosol on pleisto-holocene landscapes
- Cambic Arenosol - Dystric Histosol on elevated sandy terrain (fluvio-glacial landscapes)
- Cambic Arenosol - Gleysol - Histosol on pleisto-holocene dune sand landsc.
- Cambic and gleyic Arenosols, humic Gleysols on glacial outwash sands
- Gleysol - Histosol - Lowlands
- Fluvisol - Gleysol - Eutric Histosol on holocene lake/river landscapes

Different anthropogenic changes to soilscapes

- **a** Low influence, partly drained, acidified, no anthropogenic soils
- **b** Moderate influence, ploughed and fertilized, drained, partly sealed, some anthropogenic soils (Hortisols)
- **c** Strong influence, medium sealed, frequent anthropogenic rocks and soils
- **d** Soilscape dominated by human influence, stronly drained, many different anthropogenic deposits, strongly sealed, mainly anthropogenic soils (Rendzinas, Regosols from concrete and mortar)

a regular but small scale pattern of different hydromorphic soils with groundwater and surface water gleying is observed (comp. chap. 4.2).

As dominant as the Luvisols in the cover sand till plateaus are the Cambic Arenosols within the sandy landscapes 4-6. Under forest vegetation these soils have developed a more or raw humus horizon of about 10 cm thickness and a bright brown (rosty) cambic B-horizon. The A-horizons are shallow and have frequent bleached sand grains and sometimes even patches of a Podzol E-horizon. The dry soil conditions during the vegetation period hinder a further Podzol development. On dune sands or in other places where poor sands are the parent material these soils are acid (pH 3-4). All these soils are decalcified deeper than 2 m or may have been free of lime primarily.

They have either thin clay pans at a depth of 12-15 dm of mostly relictic hydromorphic properties at the same depth or both. The soil is strongly altered down to the lower B-horizon in case it is agriculturally used. These soils have a deep root zone, are dry to very dry stands, well aerated but extremely oligothrophic sites (FRIEDRICH 1979; SCHWIEBERT 1980).
In the sandy landscapes, no important surface water gleying is observed. Hydromorphism is observed in connection with high groundwater table where fromer lakes have been filled by organogenic sediments and graded into raised bogs (Dystric Histosols). The transition between the Cambisols and the Histosols is frequently occupied by Humic Gleyic Podzols with pronounced bleached horizons (Fig. 9 Pechsee, landscape 4).
On more eutrophic sites (landscape 5) the transition between the Cambic Arenosols and the Dystric Histosols is through Eutric and even mollic Gleysols and Eutric Histosols (comp. Fig. 10 Teufelsbruch).

In the flat and depressed part of the Berlin valley and the Havel, we do have a dominance of Gleysols and Histosols (landscape 7 and 8). The parent material is mainly poor, fine sand but locally interlayered by loamy and silty, lime-rich materials. Because of differences in parent materials, the differences in depth and fluctuations of groundwater and the different sources of the water, the Gleysols are very variable in their morphology and ecology. Therefore, all subdivisions of Gleysols except the Plinthic and Gelic may be found in Berlin. However there are four major types of Gleysols.

Related to calcareous tills of to lake chalk deposits Calcaric Gleysols do occur in small patches. Widespread is the acid form of Dystric Gleysols with an iron
2 enriched Bg-horizon. The iron enrichment forms bright brown spots and sometime

Fig. 9: Landscape transect at Pechsee, Grunewald (BLUME et al. 1977)

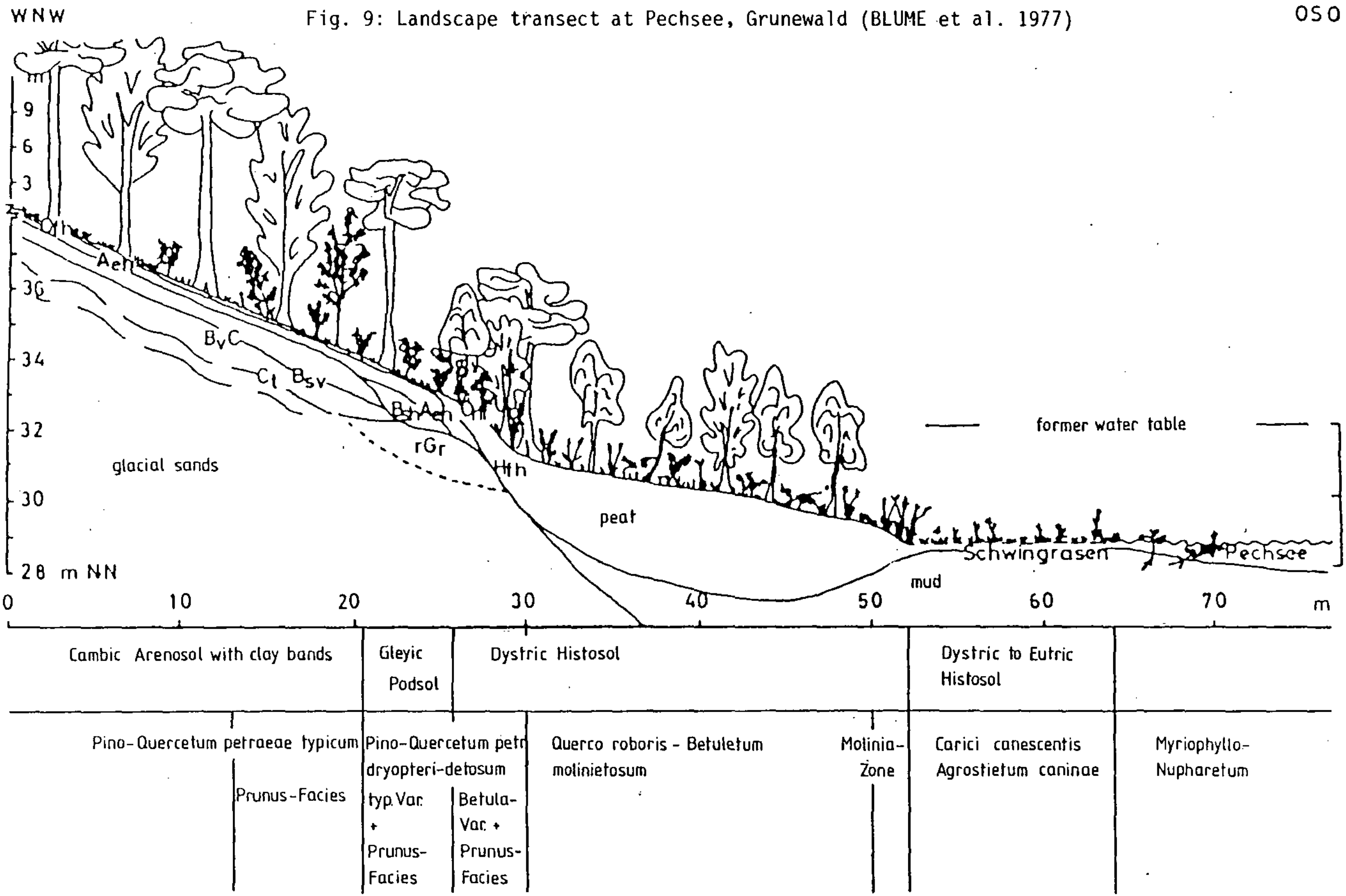
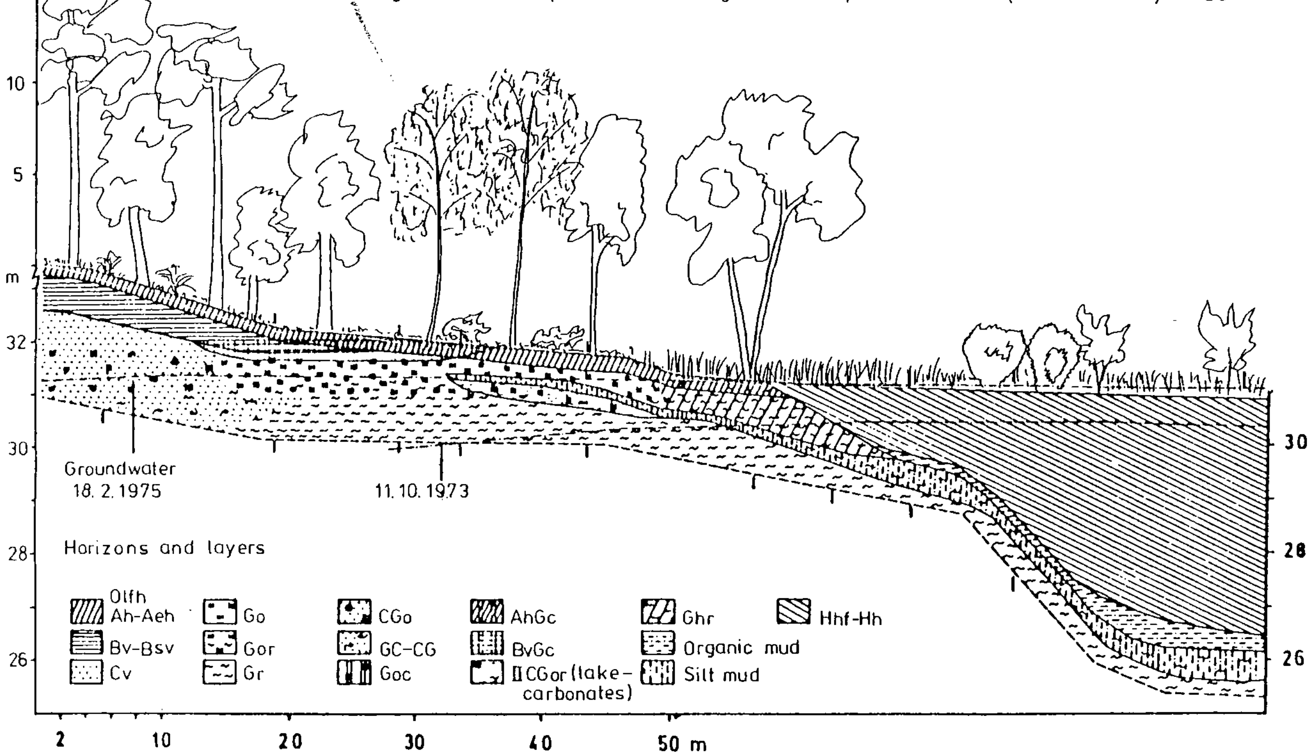


Fig. 10: Soilscape of a dune-bog area at Spandau forest (Teufelsbruch)



<table>
<tr><td>Cambic Arenosol</td><td>Cambic Gleysol</td><td>Calcaric Gleysol</td><td>Eutric Gleysol</td><td colspan="2">Eutric to Dystric Histosol</td></tr>
<tr><td colspan="2">Pino-Quercetum</td><td>Querco-Betuletum</td><td colspan="2">Carici elongatae-Alnetum</td><td>former Caricetum lasiocarpae
actual Frangulo-Salicetum auritae</td></tr>
</table>

concretions in the depth of fluctuating groundwater, which there is 5-12 dm below ground. Another type has higher groundwater with less fluctuations. In this case no enrichment except organic matter is found and the reduced zone is directly adjacent below the organic horizon. The last type are the strong humus enriched Gleysols (Humic or Mollic) which have an extremely high groundwater table and impeded organic turnover because of oxygen deficiency. These soils grade into the bog areas which are mainly groundwater Eutric (Dystric) Histosols.

In the valleys of the Havel and its lakes there are small River banks formed from calcareous fluvial sands. On these Embankments Eutric Gleysols and Calcaric Fluvisols have developed whereas behind the banks Eutric Histosols dominate the lowlands.

These natural soil landscapes have been strongly influenced and altered by different human impacts. Of these influences, the strongest are the permanent use for specific purposes (horticulture) or the complete destruction by digging out or fossilization of soils and covering the surface with new anthropogenous parent materials.

2.7 Settlement density and city development

During the late Weichselian and Holocene landscape and woodland development, late paleolithic and mesolithic dwelling sites were restricted on lake and brook shores (BRANDE 1980). The first traces of neolithic farming, as shown by archaeology and palynology, date to no earlier than the Atlantic/Subboreal transition, about 3000 BC. A relatively dense occupation took place in the late bronce age (MÜLLER von 1977), forming several local settlements aggregations (SCHULZ 1984), while hemerophilous pollen reach a first maximum. It is locally exceeded only in early medieval times after the Slavonian occupation, when the earliest town in the West-Berlin area developed at Spandau (MÜLLER von & MÜLLER-MUCI von 1983). But the human impact on the forested landscape was restricted more or less to the nearby surroundings. The definite change into a rural landscape with widespread rye cultivation is found not before the late medieval colonisation phase with foundation of many villages and the sister towns Berlin and Cölln about 1230 A.D.

Berlin first developed as a trade centre. During the Thirty Years' War it completely collapsed economically. Lateran MERIAN (about 1653) depicts the town with a fortified castle and a system of ditches and ramparts. In front, the village common areas are utilized as pasture and arable land in a system of crop rotation. Numerous vineyards are shown.

Up to the 19th century, Berlin, Charlottenburg and Spandau had a population of over 50 inhabitants/hectare. Since 1850 a rapid population growth occurred, accompanied by devasting effects on the living conditions of the growing immigrant working class. By the end of the century several canals and 75 harbours and quays were in use. The construction of a railway network since 1838 is important as well. The land use of building ground is intensified continuously, which results in absolute overcrowding of the working class boroughs. Only after repeated outbreaks of epidemics (cholera, smallpox, tuberculosis) the construction of a sewer system began in 1874. Large areas for the installation of sewage farms outside the city were obtained. To somewhat compensate for the living conditions, the demand for public parks arises, an idea realized 1846 at Friedrichshain for the first time.

The general transport system of overhead- and underground railway joins the suburbs where new communities spring up. After 1870, the city's population increases to over one million and in 1910 to 3.7 millions. Outside the Wilhelmian city belt with its backyard industry, storage places and small scale business chiefly three storage buildings serving both for accomodation and business come into existence. By the turn of the century the large industrial plants shift their production units increasingly outside the city core, preferentially connected to railway or waterway lines.

In 1920, the conglomerate of 7 towns, 59 rural communities and 27 manor estates are incorporated into the municipality of Great-Berlin with 20 districts and a central government. Some years later public building societies began constructing large residental housing areas in all parts of the city. After 1933 the gigantic building plans for the reorganization of Berlin are not realized beyond the initial stages.

In May 1945 the city centre was almost completely destroyed ("the dead eye of Berlin"). The Wilhelmian city belt was partly razed to the ground and gave way for newly constructed housing estates. An estimated 80 million cubic metres of rubble had to be removed. The systematic redevelopment started about 1950. Today, the city has again established a reputation as an important industrialized area. New business and trade regions have to be aquired mainly in the outskirts. The area used for this purpose in Berlin (West) is nearly twice as large as in 1938. The traffic system planned on the lines of an Autobahn-like network and the underground railway expand further as a means of public transport.

The housing plan is based on the following recommendations: less housing density in the urban belt, sanitation measures for the old buildings, construction of new housing areas in the outskirts. Some of the largest residential areas developed since 1960 are Gropiusstadt, Falkenhagener Feld and Märkisches Viertel, each for 30 000 to 50 000 inhabitants. Green landscaping is included in the post-war years, especially on the 9 rubble mounds located in various parts of the city area. The green landscape system as planned originally is not realized because of the high costs of land in the central districts which are lacking in green areas.

Because of population density, increasing time for leisure and the individual mobility by motorcars, several environmental consequences result, particularly in the lake and river areas attractive for local recreation. The economic problem of the city has severe consequences on the human ecology, as only a limited area is available to meet the demands of water supply, domestic sewage disposal, energy and waste disposal and the construction of housing-, trade- and recreation areas. In this respect, Berlin (West) may be used as an example in assessing wether or not our economic system and society will be able to meet future demands in restricted highly populated and industrialized areas.

3. ECOLOGICAL CHARACTERISTICS OF THE HIGH DENSITY AREA

3.1 City climate

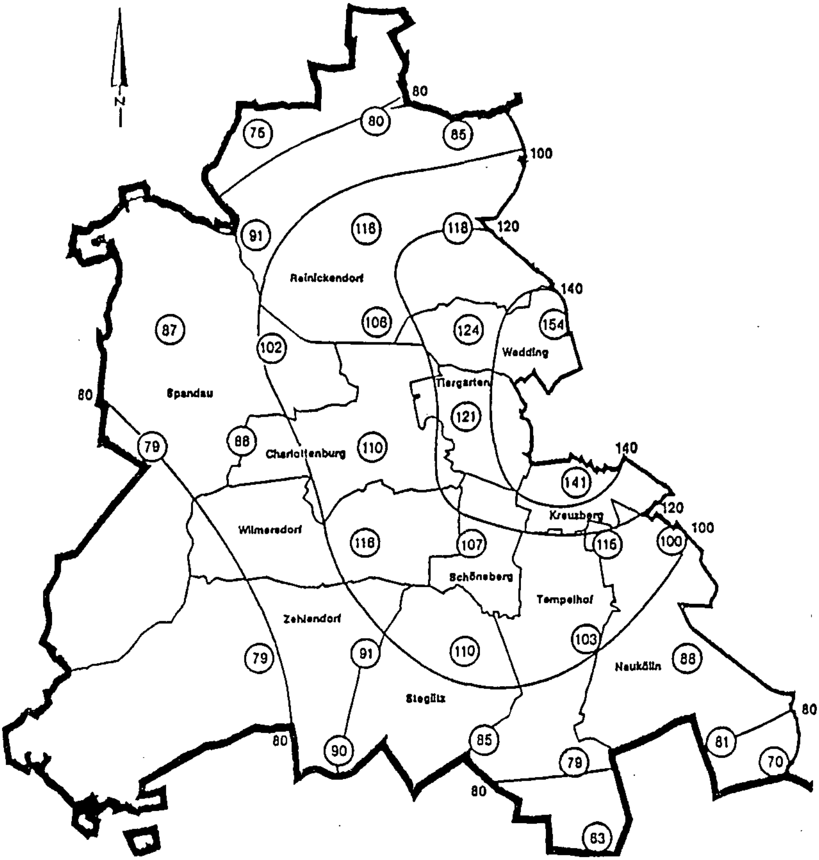
The profound fluctuations in local thermal balance constitute the essential factor determining the nature of climate in densely populated areas. The marginal conditions affecting the energy balance are fundamentally altered by modifications in the surface structure or features, but also by concentrations of various substances in the atmosphere as well as evaporation on the earth's surface.

The current levels of air pollution, which are reflected in the increase in condensation nucleii as well as higher concentrations of trace gases, are proving to be a particularly worrisome problem. In Berlin (West), for example, SO_2 emmissions are caused mainly by heaters and power stations, although some emenate from surrounding areas as well. Atmospheric concentrations are especially heavy during the winter months.
Fig. 11 shows the average yearly values for SO_2 in the Berlin (West) area at levels of equal concentration, together with the values measured at the 31 air quality control stations. In several inner city districts the threshold value for SO_2 of 140 $\mu g/m^3$ was markedly exceeded. However, a general reduction of SO_2 emissions was observed during the most recent years when measurements were made, 1981-1983.

Air pollution is accompanied by the formation of a haze layer. In densely populated areas, this has secondary effects on urban climate. While the poorer light diffusion through the haze layer may be negligible, a reduction of direct solar radiation of 20-25% can be assumed. At the same time, near ultraviolet radiation decreases in summer by 5% and in winter by about 30%. The decreased warming caused by absorption is more than offset by the decreased outgoing radiation in the long-wave region.
This so-called 'greenhouse' effect, coupled with the increased heat absorbing capacity of the buildings and the soils, produces an increase in the mean air temperature. The increase and modification of the air temperature maximum at midday is especially characteristic; likewise the considerable degree of cooling on clear nights. These values are, of course, dependent on the size of the green spaces within the city, but are also subject to a considerable degree to air turbulance between the city center and the outlying areas.

The readings obtained from tours made by a mobile measuring unit along a transect from southeast to northwest through the city are entered in Fig. 12 as a

Fig. 11 Yearly average levels of SO_2-concentrations for the period 1976 - 1980 in $\mu g/m^3$ (Senator für Stadtentwicklung und Umweltschutz Berlin 1984)



profile in relation to area use, and are meant to serve as an example of possible changes in climate in Berlin. Respective temperature and vapor pressure data obtained here, have been projected around a single common time.

At the meterological station in Berlin-Dahlem, early in the evening with clear skies, a northerly wind of 2 m/s was recorded on August 12, 1981, on September 4 of the same year the wind was calm, and on September 15, a south-easterly wind with a velocity of 1 m/s was registered. The temperature profile reveals the strong similarity between the various situations, as well as the strong dependency on respective use. The heavily built up inner city areas are especially warm, while small gardens, parks and wooded areas display more or less pronounced minima. Thus, in the 212 hectar public park Tiergarten, for example, temperatures can be as much as 7°C cooler than in the adjacent heavily built up inner city.

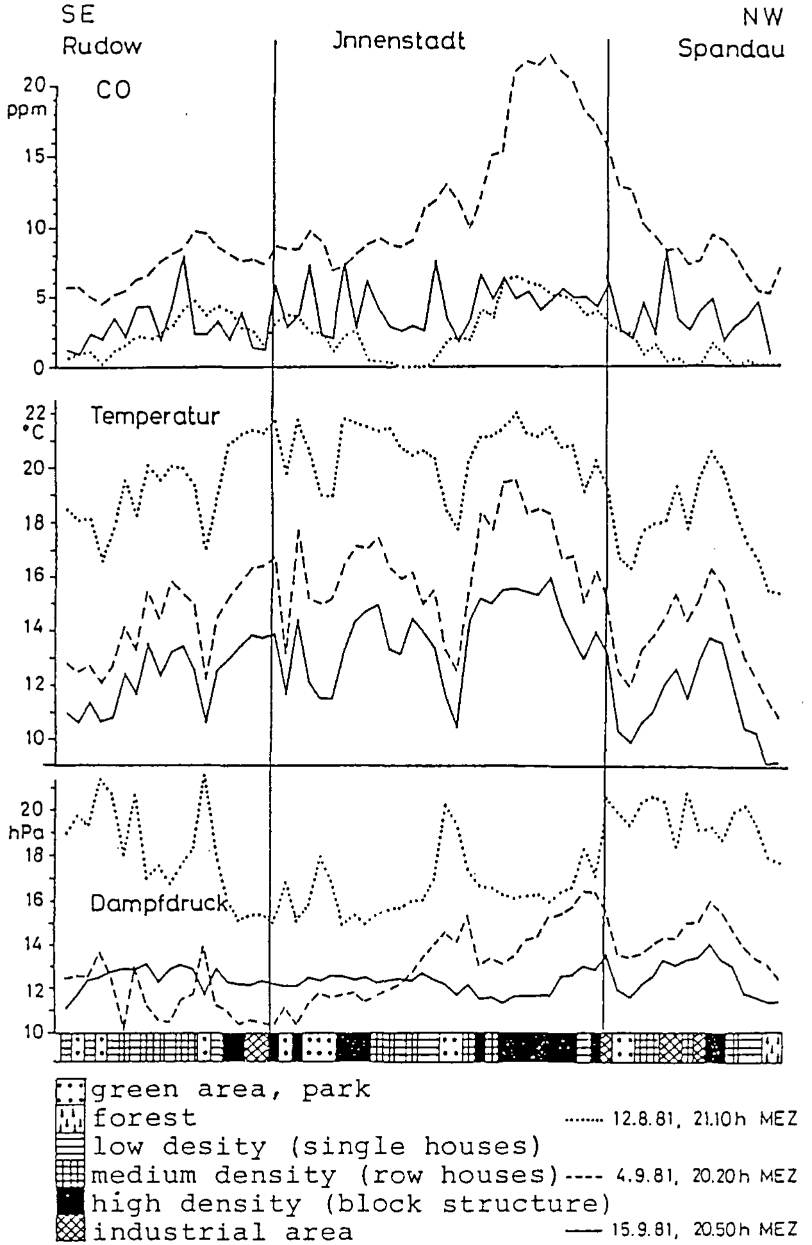


Fig. 12: Profile of carbon monoxide concentration, air temperature and vapor pressure at a height of 2 m on a southeast-northwest transection through Berlin

Due to its definition, relative humidity, which has not been represented here, reveals a high correlation to temperature. The high temperatures in the inner city cause a lower relative humidity, while in the outlying areas humidity almost reaches saturation levels. Vapor pressure conditions are more complicated. The situation on August 12, 1981, which is characterized by elevated values in the green spaces and lower values in the built up areas, corresponds to conditions which are expected to result from the vegetation deficit common to built up zones. However, this tendency was less pronounced on the route taken on September 4, 1981. Here, for example, the public park Jungfernheide had low readings, while those taken at the Spandau city centerwere elevated. The route taken on September 15, 1981 even reveals the opposite tendency, even though the horizontal gradients were greatly reduced. Some parks even had somewhat lower vapor pressure readings than their surrounding built up areas. Especially in the last-mentioned situation,other factors appear to be of importance, such as nightly dew in the cooler parks, or the anthropogenic influx of vapor pressure in built up areas (traffic, industrial plants and power stations).
The momentary readings made of CO concentrations generally reveal a high correlation to over-warming. This is because it is just in the heavily built up and over-warmed areas where the volume of traffic produces the highest concentrations of motor vehicle emissions.

Climate charts of Berlin were needed which would show the qualitative, and where possible, the quantitative effects of urban climate (BÜCKER et al. 1985; SENATOR FÜR STADTENTWICKLUNG UND UMWELTSCHUTZ 1985). On the basis of the many individual studies referred to above, a method was developed which enabled the preparation of such charts using a combination of stationary and mobile measurements even over longer periods of time (HORBERT & KIRCHGEORG & v. STÜLPNAGEL 1984).
In Berlin, the results of 21 climate stations and 100 measuring points with a total of as many as 1000 measured values were available for use. Thus, for certain weather conditions, the distribution of air temperature, relative humidity, vapor pressure and equivalent temperature as a measure for the tendency to sultriness could be produced. With regard to temperature, this method could be expanded to include representation of the average for 1982 and for the years from 1961 to 1980.

Temperature differences are greatest between the inner city and the outlying areas, as was already shown by the network of fixed stations. Thus, the average temperature span over a period of many years is more than 2^{o}C.
With regard to humidity, there is a highly varied distribution of sources and sinks, depending on time of day and weather conditions. While the green spaces inside and outside the city produce more vapor by transpiration, during the night

these cooled down surfaces produce considerably low levels of humidity due to formation of dew. Diverse anthropogenic sources of water vapor, some extending over large surfaces, overlie this mechanism. Nevertheless, there are generally relatively small differences in vapor pressure around 4.5 h Pa, so that the resulting distribution of relative humidity is determined by temperature. In isolated cases, the span between measured equivalent temperatures was approximately 7 K. In general, values for more densely built-up areas and most industrial surfaces were relatively high, those for larger open surfaces average to low. The values for large wooded areas were low.

Through an analysis of area use - combined with wind measurements made at the many stations - wind velocity for the entire Berlin area could be charted. Heavily built up and largely sealed areas experience relatively high wind velocities night and day. On the other hand, dispersed arrangements of buildings with relatively large areas of vegetation produced medium or low values by day and night. Low velocity winds occur day and night in wooded green areas and in hollows. In contrast, the more open green areas have medium to very high readings during the day, at night however wind velocity is low to medium.

Various studies have shown that more pronounced convection and stemming effects can be expected to lead to increased cloud formations and rainfall in the city. In accordance with SCHLAAK (1977), figure 3 (chap. 2.1) depicts the adjusted distribution of precipitation for the Berlin area over many years. The results are based on a combination of measurements taken from 1891-1930, 1901-1950 and a ten year measurement period form 1960 to 1969, the latest being reinforced by a greatly expanded network fo measuring stations. The highest readings for precipitation for the western city sector were made in the Tegel, Spandau and Grunewald forests. The wide, nonforested strips of land between these areas displayed considerably lower levels of precipitation. Markedly reduced readings were made in zones adjoining the Grunewald forest leeward of the main wind direction (WSW). Considerably higher levels of precipitation, corresponding more or less to those measured on the eastern margins of the wooded areas can also be found in the eastern parts of the city. This is due to the increased friction or stemming effects usually arising from a heavily built up urban landscape. Although the altitude of the terrain increases, a corresponding compensation effect can be found along the eastern border of the Berlin urban area.

3.2 City soils

The soils have been markedly changed in their important characteristics depending on utilization as Tab. 4 shows for a Cambic Arenosol and an Orthic Luvisol.

Tab. 4 Anthropic influence and its impact on soil characteristics

Use	Ah or Ap										Ah(p) ppm		pH $CaCl_2$		S-value eq./m^2	
	d_B g/cm^3	depth cm	org. sub. %	C/N	P_{1a} ppm	CEC in % Ca	Mg	K	Na	V %	Pb_t	Cd_t	0-10 cm	90-100 cm	0.3m	1.0m
Cambic Arenosol (sand)																
Forest	1.1	7	5.1	26	10	2	<1	<1	<1	3	32	<0.2	3.4	4.6	1.0	1.4
Forest 25 m from highway	1.1	18	7.0	22	37	17	2	2	<1	23	60	0.5	3.7	4.2	6.5	9.0
Forest 5 m from highway	1.1	30	10.2	16	13	44	4	1	1	50	350	0.7	5.0	4.2	19.0	23.0
Field	1.3	30	1.8	12	-	3	<1	1	-	18	308	0.2	4.0	-	-	-
Park	1.1	45	5.4	24	100	43	8	8	<1	59	78	0.5	6.1	4.4	13.0	26.0
Garden	1.2	40	4.2	13	205	82	5	2	1	90	-	-	6.8	6.6	-	-
Waste water field	1.2	37	6.3	9	117	90	3	1	1	36	1100	75.0	5.2	5.9	27.0	44.0
Cemetery	1.1	15	2.2	11	130	-	-	-	-	-	50	1.5	6.4	6.2	-	-
Orthic Luvisol (till)																
Forest	1.0	9	7.5	21	31	7	<1	1	<1	9	32	0.4	3.4	7.5	2.5	70.0
Field	1.7	32	1.0	11	-	24	2	5	<1	33	22	0.8	4.4	7.6	8.5	75.0
Garden	1.3	45	2.1	13	107	-	-	-	-	-	-	-	6.3	6.7	-	-
Waste water field	1.2	28	2.9	10	-	23	7	3	3	36	100	0.4	5.3	7.5	9.0	48.0
Cemetery	1.6	38	6.2	71	-	-	-	-	-	-	-	-	7.2	7.4	-	-

Tab. 5 Characteristics of typical Berlin soils with different land use

Use	Parent material	Soil type	Ah(p) d_B g/cm^3	Ah(p) depth cm	Ah(p) C/N	Ah(p) K_{1a} ppm	Ah(p) P_{1a} ppm	Ah(p) V %	pH 0-10 cm	pH 10-100 cm	S-value eq./m^2 0,3 m	S-value eq./m^2 1,5 m	org. sub. kg/m^2	K_v g/cm^3	P_v g/cm^3	Mg_v g/cm^3	nFK $1/m^2$ 1,5m
Forest	Moraine sand	Cambic Arenosol	1.1	7	26	35	10	3	3.4	4.6	1	2	20	340	150	300	150
Fen/Forest	Peat	Oligotrophic fen	0.3	34	26	55	40	6	2.9	3.7	10	22	>200	30	70	90	480
Field	Sand/till	Orthic Luvisol	1.7	32	11	-	-	33	4.4	7.6	9	134	5	2940	560	2700	270
Fallow	Peat/fluvial sand	Humic Gleysol	0.2	28	10	147	140	-	5.7	7.2	-	-	18	160	130	230	300
Park	Outwash sand	gleyic Cambic Arenosol	1.1	45	24	350	100	59	6.1	4.4	13	30	16	610	330	530	160
Garden	Marl	Hortisol-Arenosol	1.3	70	13	98	250	(100)	7.1	6.6	-	-	24	1270	1250	960	200-300
Waste water fields	Boulder sand	Dystric Regosol	1.2	37	9	111	117	36	5.2	5.9	27	51	23	250	1050	530	250
Ruderal site	Rubble debris	Calcaric Regosol	1.3	10	20	480	100	98	6.8	7.5	25	106	18	840	320	1400	80-250
Disposal unit	mixed deposits/garbage	CH_4-Regosol	1.0	10	26	120	60	66	6.3	7.3	37	173	37	1070	810	1750	60
Industrial site	cinders/sand	Calcaric Regosol	2.4	11	350	80	15	-	11.	6.6	-	-	7	620	550	3100	140

Their distribution is shown on the soil association map of Berlin. New soils have developed after deep mixing, down pulling and pouring of material, which did not exist under natural conditions in this area. In the city center, almost the whole natural soil cover has been altered.
The new soils differ clearly by their characteristics from the original soil as Tab. 5 shows, presenting dominant soils.

The comparison of Cambic Arenosol and Orthic Luvisol under forest with soils of other areas or with soils near disposal units and streets shows differences in bulk densities of topsoils, horizon thickness, C/N-ratios and nutrient conditions, as well as content of heavy metals.
Differences in soil characteristics are especially obvious if a comparison of different soil depths is made, which reflect the shallow and deep rooting zone. In detail, it could be ascertained, that soils outside of forests have higher bulk densities, with highest values in agricultural fields. The thickness of topsoils is bigger and has its maximum in garden soils (Hortisols). The percentage of organic matter in gardens, agricultural fields and partly in waste water fields compared with forests is smaller, particulary farmland has low values of 1-2%. This also shows up in total organic matter amounts, which are at a minimum of 5-7 kg/m^2 in farmfields.

Gardens which have been partly transformed from farmers fields on loamy ground moraine have higher amounts of organic matter with 13-24 kg/m^2.
The C/N-ratio, in pine forests often more than 20, is much better in agricultural fields, gardens, cemeteries, and especially in waste water fields with values around 10.

The intensive utilization of soils particulary changed the nutrient status. The contents of lactate soluble P are <50 ppm in the Ah-horizons of Cambic Arenosols under forest without groundwater influence. The contents of P and K, are higher in gardens, parks, fields, cemeteries and waste water fields because of fertilization and values of more than 300 ppm are possible.
Ah-horizons under pine forest contain around 3 meq/kg exchangeable Ca at pH-values between 3.0 and 3.5. Ca-containing dusts have produced considerably higher amounts near streets and disposal units. Also, covering the topsoil with rubble brought higer values. Areas of other utilization have up to 30 times more exchangeable Ca than Cambic Arenosols under forest. Manganese is represented in the Ah-horizons of forests by 0.5 meq/kg. Under other utilization it reaches up to 20 times more.
The Ah-horizon of Cambic Arenosols under forest contains < 0.9 meq/kg exchangeable K. Soils under other utilization have up to 10 times of this value.

Exchangeable Na reaches values of < 0.6 meq/kg in the Ah-horizon of Cambic Arenosols. It is significantly higher along the "Avus"-highway and other streets because of the use of thawing salts, as well as on waste water fields, where Na reaches 4% of the CEC or 8% of the S-value (base saturation in meq/kg). In subsoils of waste water fields higher Na-saturations are investigated.
The base saturation (V-value) is as low as ≤ 10% in forest-Ah-horizons at pH-values ≤ 3.5. It is higher near streets and disposal units as well as under other utilization. Highest values are displayed by Arenosols and Luvisols in gardens and soils developed out of Luvisols in cemeteries. The base saturation for gardens and cemeteries is estimated between 80 and 100%.
The pH-values are lower in the subsoils of Arenosols under all utilizations as compared to Luvisols, except where calcareous subsoils in Arenosols are present. According to the nutrient status, presented as exchangeable cationic nutrients (S-value), it is shown, that outside of forests, sandy soils offer more nutrients for shallow and deep rooting plants and loamy soils more for shallow rooting plants. In the root zone of 1.0 m, the difference is not apparent for Luvisols (see Tab. 4). The reason for this is, that differences in clay content of subsoils have a greater effect on the nutrient status than the anthropogenic changes of topsoils. Luvisols have higher nutrient supply than Arenosols under the same use and organic matter content. Nutrient reserves are also higher in Luvisols than in Arenosols. Especially gardens and waste water disposal units show higher amounts of phospherous than forests.

Until now, there exist only a few published data of heavy metal contents of our soils. The common air pollution can be observed from depth functions of forest soils (Fig. 13). Furthermore, there is a tendency, that other topsoils, particulary waste water disposal units, are loaded more severely by specific inputs.

Tab. 5 shows, that anthropogeneous soils like garden soils (Hortisols) and rubble soils (Pararendzinas) have higher amounts of available nutrients than sandy soils under forest. Anthropogeneous soils may also have higher contents of heavy metals.
The available watercapacities for 1.5 m depth are higher in garden and rubble soils, when loamy and poor in stones, as well as in waste water disposal soils than in Arenosols under forest. Furthermore, additional irrigation leads to a higher supply of water for plants in parks, gardens and areas of waste water disposals. The drainage of peat, riverbanks and fluvioglacial sands results in a change of the water, air and nutrient regime as well as in the development of the soils. The mineralization of organic matter is accelerated and affects particulary peats, which get higher bulk densities (Tab. 5). Another effect is a better air supply in soils. Air deficiences are produced by gas evolving from

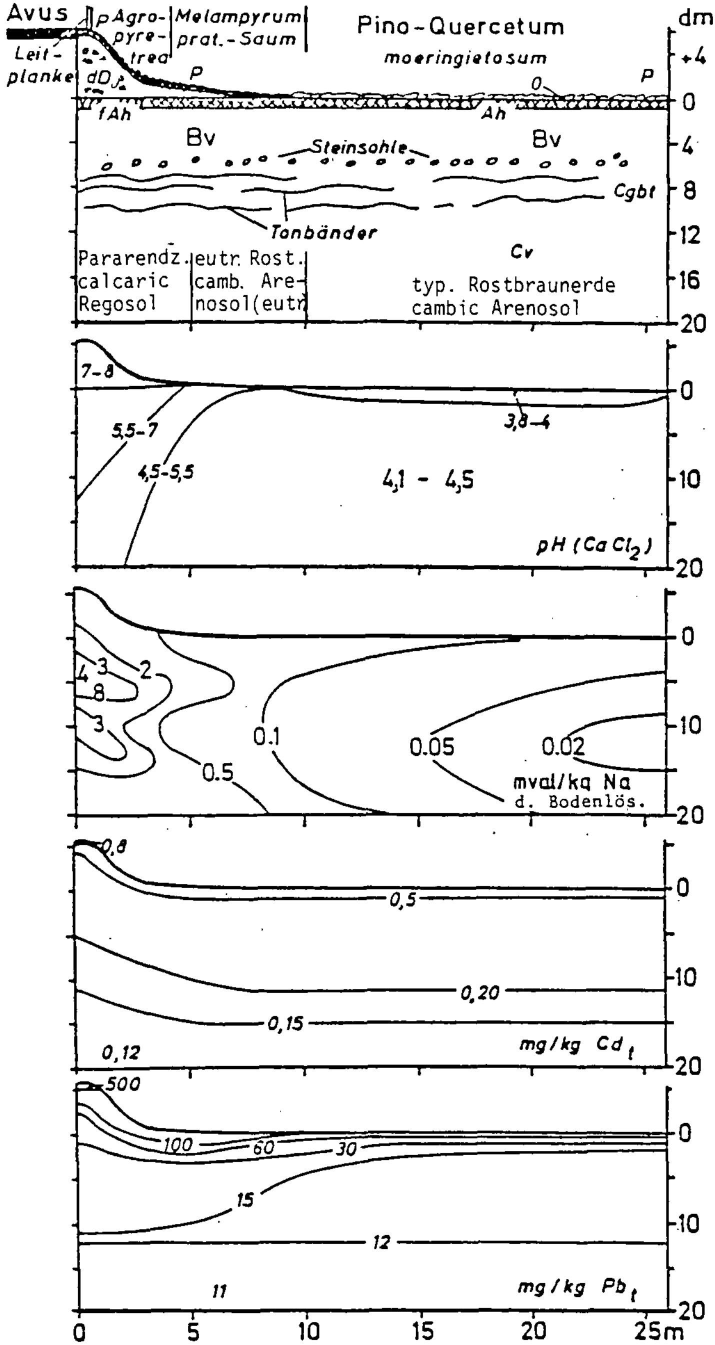


Fig.13 : Soil section next to the AVUS motorway in the Grunewald (according to analyses from CHINNOW and HELLRIEGEL)

disposal units or by compaction of soils.

3.3 Water regime

Human impact on the water regime: Man's activities have influenced the soil- and groundwater regimes of West-Berlin to a great extent. The most important changes are:

- decrease in evapotranspiration as a result of transformation of areas with natural vegetation into industrial, residential, traffic and other zones,
- rise in groundwater recharge owing to the diminuition of transpiration due to groundwater extraction and water level management for constructions
- increase in surface runoff and decrease of groundwater recharge due to sealing up and soil compaction and
- increase in surface-near groundwater flow because of altering drainage systems (e.g. sewer system, underground traffic, construction sites).

Until now, building and sealing up has had the greatest influence on groundwater recharge. All areas covered by buildings, streets and squares that are connected to the sewer system no longer contribute to seepage (BRECHTEL & v. HOYNINGEN-HUENE 1979). However, recent studies show that appropriate construction, especially of squares and pavements, can induce a total or partial drainage by decreasing runoff (BERLINER WASSERWERKE & TU BERLIN, FB 21, 1984). The present study will report on the evapotranspiration and groundwater recharge of some representative soils in Berlin in relation to land-use and groundwater depth.

Evapotranspiration and groundwater recharge: A calibrated digital simulation model was used to calculate longterm annual groundwater recharge and actual evapotranspiration as a function of crop patterns, soil properties and groundwater depth. This model is applicable to sites without external heat convection and without direct plant water uptake by roots from the groundwater.

The two-layer simulation model requires the following input parameters (see RENGER & STREBEL 1982; WESSOLEK 1983):

1. Climate data (daily):
   - precipitation
   - wind velocity
   - air temperature
   - air humidity

   (wind velocity, air temperature, air humidity: 2 m height)
   - net radiation of sunshine duration

3

2. Soil characteristics:
   - relationship between soil moisture content and suction as well as hydraulic conductivity
   - initial soil moisture content

3. Vegetation data: (daily)
   - degree of soil cover
   - growth height
   - root depth
   - geometric factor of the root system
   - plant resistance to water transport

4. Groundwater depth (daily)

The calculation of actual evapotranspiration according to RIJTEMA (1965) and net groundwater recharge (drainage minus capillary rise) was done on a daily basis for the period from 1968 to 1982. The simulation model was calibrated using values of actual evapotranspiration (E_{act}) obtained in field measurements. The measured E_{act}-values were based on determinations of soil moisture content and suction as function of time and depth (RENGER et al. 1970). The calibrations were carried out for coniferous forest, grassland and eight different agricultural crops.

<u>Function of meteorological factors:</u> The most important meteorological factors that influence evapotranspiration processes and groundwater recharge are listed above (1).

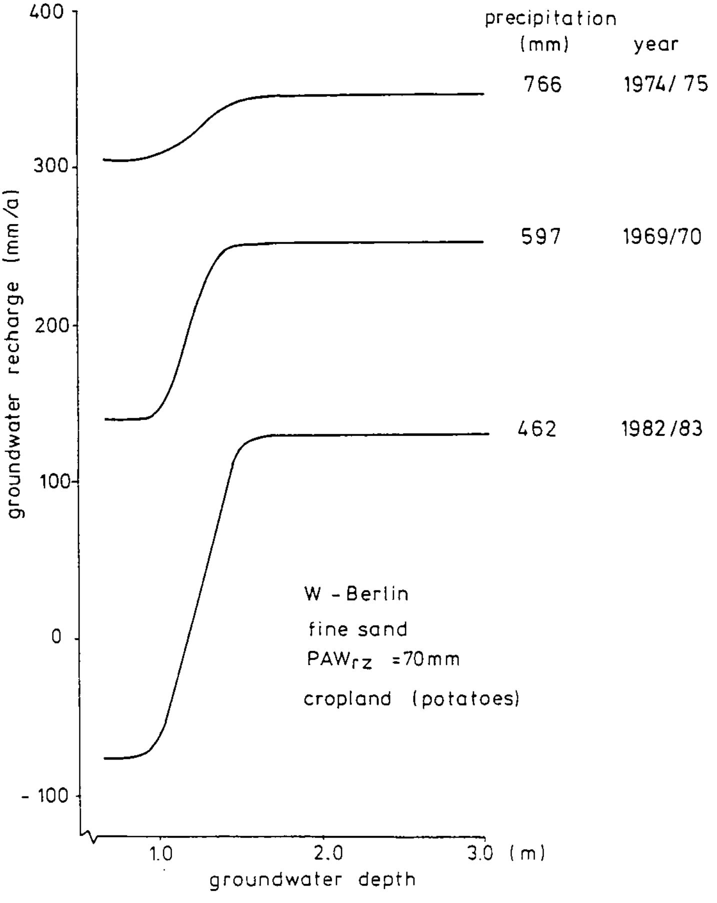
The effect of precipitation on the variation of groundwater recharge is exemplified in Fig. 14 for cropland (potatoes) on sandy soil (plant available water in the effective root zone PAW_{rz} = 70 mm) for different groundwater depths.

In sites with a high groundwater table, an increase in rainfall leads to a nearly equivalent rise in groundwater recharge.

Sites with a deep groundwater level (> 1.5 m for sandy soil) show that the increase in groundwater recharge is less than the corresponding rise in rainfall. The difference remains in the root zone and is available for evapotranspiration.

It can be demonstrated that the relation between groundwater recharge and groundwater depth depends on the annual precipitation. In years with high precipitation (1974/75) - groundwater depth has only little influence on groundwater recharge. In periods with low precipitation (1982/83) plant water supply is closely related to capillary rise, which corresponds to groundwater level during the vegetation period.

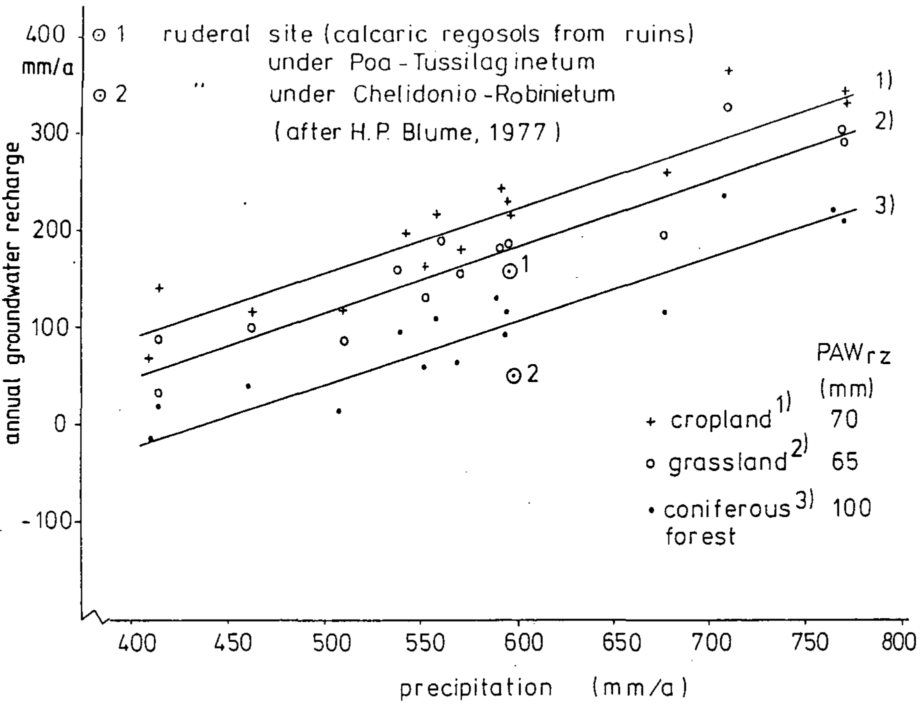
Fig. 14 Annual groundwater recharge as a function of groundwater depth for 3 years with different precipitation.



Function of crop patterns: Differences in vegetation often lead to different degrees and duration of soil cover as well as different growth heights. Increases in soil cover and growth height usually cause a rise in actual evapotranspiration (E_{act}) and a decrease in groundwater recharge (WESSOLEK 1983).

Net groundwater recharge decreases in the sequence cropland-grassland-coniferous forest. In addition, results of two ruderal sites (BLUME 1977) are pointed out. One of the ruderal sites is grown with herb vegetation and its groundwater recharge is a bit lower than corresponding groundwater recharge under grassland.

Fig. 15 Comparison of groundwater recharge values as a function of annual precipitation for different land use systems.



The second ruderal site under Chelidonio-Robinetum vegetation shows less groundwater recharge than coniferous forest. It can be assumed that under comparable ruderal sites long-term groundwater recharge is less than 100 mm/a.

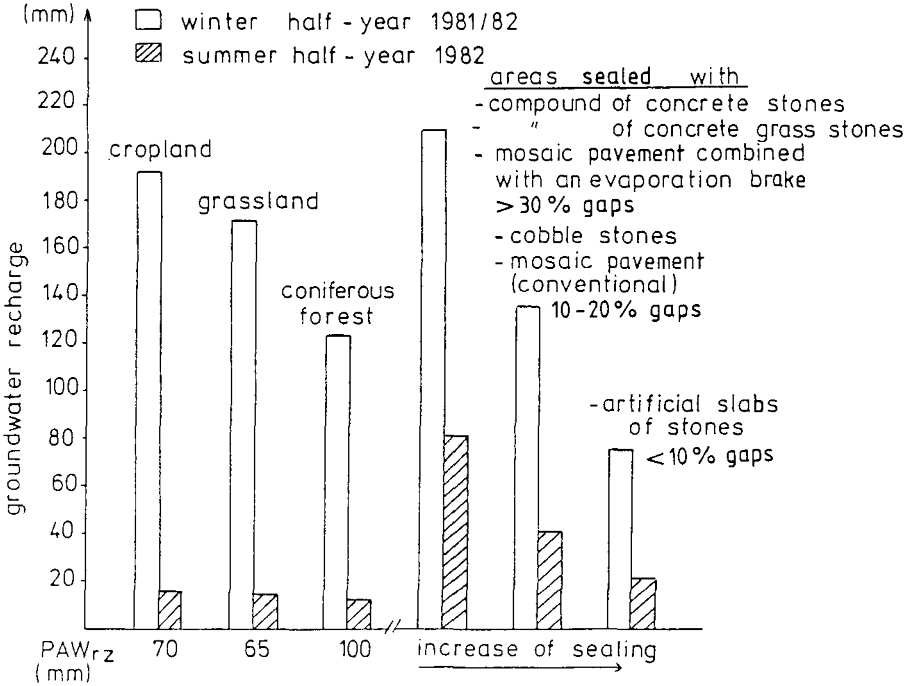
Large areas of West-Berlin are more or less sealed by roads, buildings and pavements.

Fig. 16 presents a comparison of groundwater recharge for some of these areas with those of cropland, grassland and coniferous forest. Results of the sealed areas are taken from the report of the Berliner Wasserwerke (1984). It can be shown, that under sites with a high percentage of gaps and for sites with a evaporation break (gravel layer in the ground) groundwater recharge is higher than under cropland. Furthermore, groundwater recharge can be expected even in summer. Taking these results into account, the following sequence of land use systems in respect to groundwater recharge can be drawn up:

Decrease of groundwater recharge ↓

- fallow areas (without vegetation)
- areas with a low degree of sealing
- cropland with intermediary crops
- grassland
- ruderal sites with herb vegetation
- orchards with intercropping = deciduous forest
- mixed forest
- areas with a medium degree of sealing
- coniferous forest
- ruderal sites with tree vegetation
- areas with a high degree of sealing

Fig. 16 Groundwater recharge during winter and summer for different land use and sealing percentages.



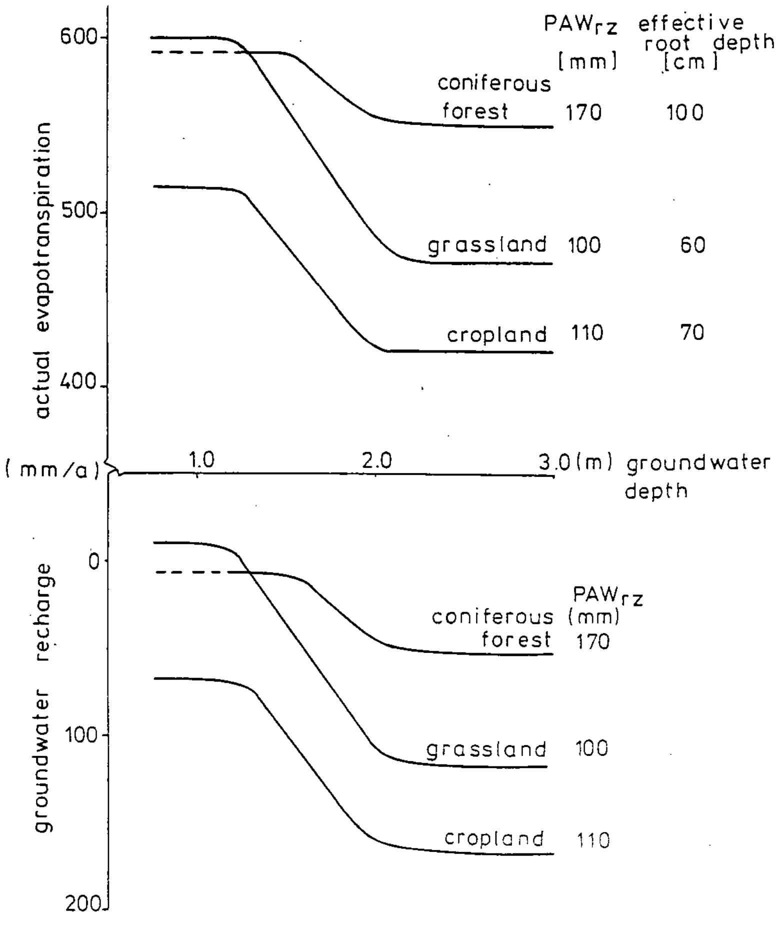
Function of soil factors: For the same climatic conditions evapotranspiration and groundwater recharge depend essentially on the two basical soil-physical relationships between:

- soil moisture content and suction and

- hydraulic conductivity and suction.

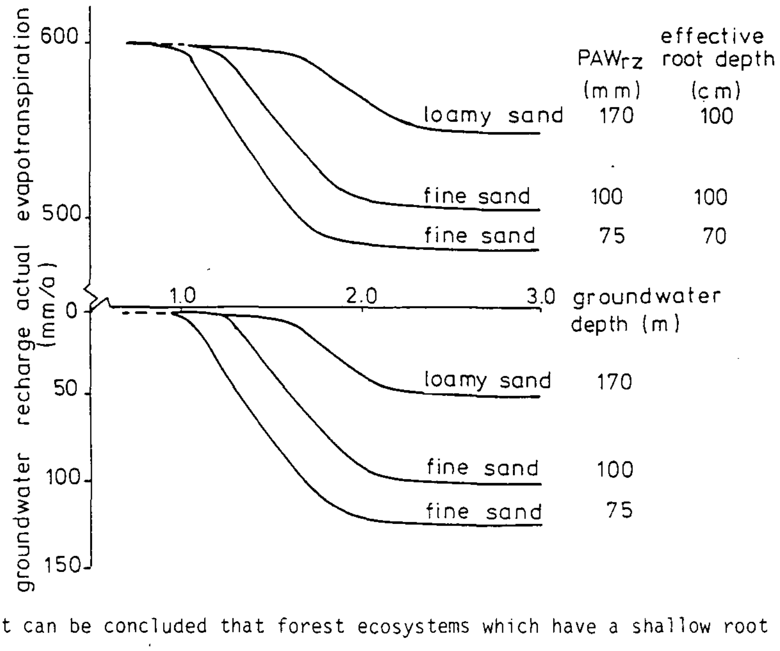
Actual evapotranspiration and groundwater recharge were calculated for a period of 15 years, for two representative soils of West-Berlin, a fine sandy and a loamy sandy soil, derived from pleistocene sands.
An effect of the soil factors is given especially at sites with deep groundwater levels. For corresponding groundwater depth, E_{act} increases as much as the available field capacity (PAW_{rz}).

Fig. 17 Actual evapotranspiration and groundwater recharge as a function of mean groundwater level during the vegetation period for different land use on a loamy sand.



On the other hand, groundwater recharge decreases with increasing PAW_{rz}. It can be gathered from Fig. 17 that groundwater recharge under grassland for groundwater-distant sites decreases by 55 mm/a when, for example, PAW_{rz} rises from 65 to 100 mm.
The influence of different soil conditions in relation to different rooting depth was calculated for three coniferous forest ecosystems. The results, presented in Fig. 18 demonstrate, that for the same soil conditions (for example fine sand) coniferous forests with deep root systems or high amounts of plant available water (i.e. loamy sands) are less dependent on groundwater depth than shallow rooted sites.

Fig. 18 Actual evapotranspiration and groundwater recharge as a function of mean groundwater depth during the vegetation period and amount of plant available water (PAW_{rz}) as well as effective root zone.



It can be concluded that forest ecosystems which have a shallow root system will show an increase in groundwater recharge and a decrease in evapotranspiration.

As climatical conditions vary from year to year, long-term calculations of water budget are necessary for interpreting results of single years. With a probability analysis of normally distributed groundwater recharges it is possible to estimate various probability levels of exceedance.

Fig. 19 Probability analysis of annual (1.4. - 31.3.) groundwater recharge as a function of mean groundwater depth during the vegetation period for coniferous forest on fine sand

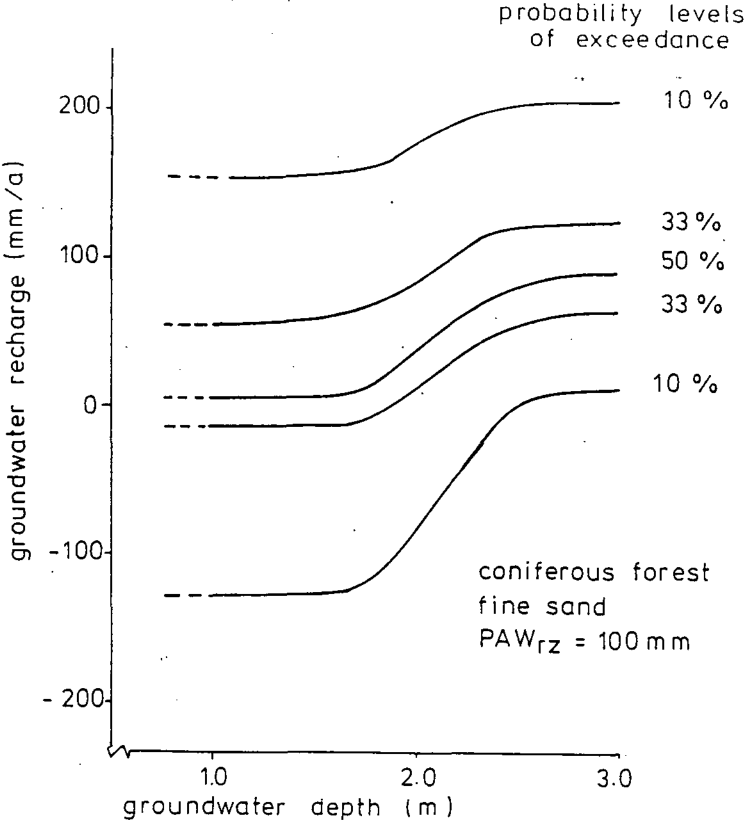
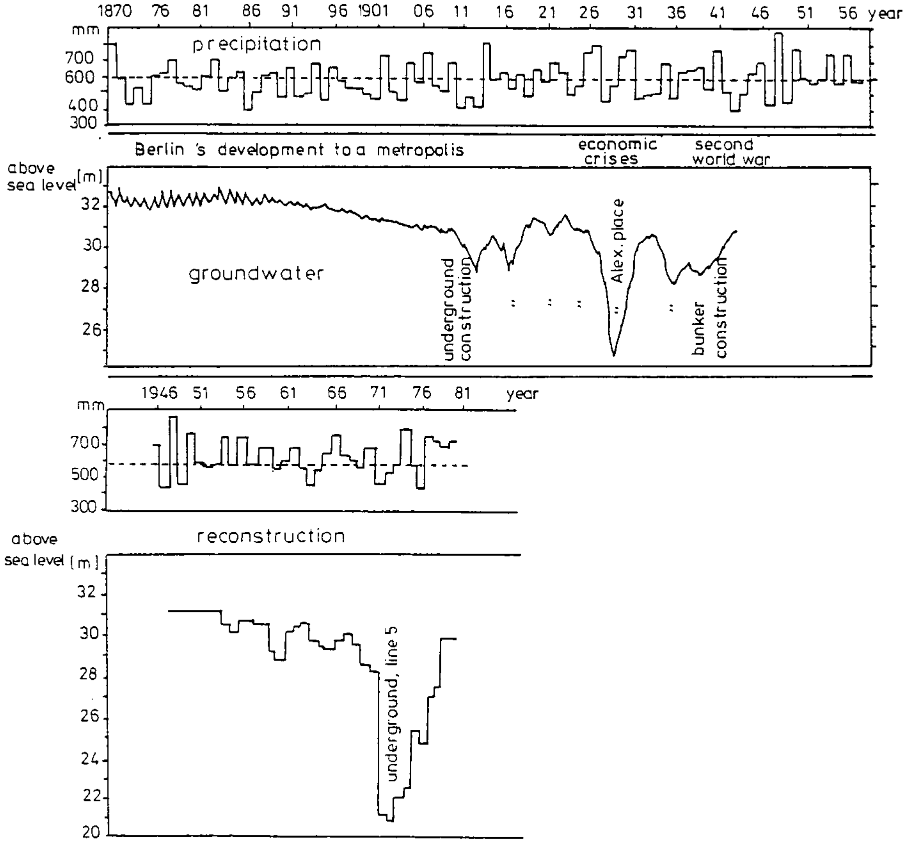


Fig. 19 demonstrates results of a probability analysis of groundwater recharge under coniferous forest for different groundwater conditions. The results based on a calculation period of 35 years show, that the mean groundwater recharge varies from < 10 mm (groundwater level < 1.80 m) to 90 mm/a (groundwater distant sites). When, for instance, the groundwater level during the vegetation period is at 2.50 depth, groundwater recharge is less than zero but once in ten years more than 200 mm/a. In this way it is possible to estimate ranges of groundwater recharge for any desired probability level.

<u>Changes in groundwater depth:</u> The withdrawal of groundwater for use as drinking water as well as construction activities have lead to greater variations of groundwater depth, especially in the urban areas. Such variations can be followed back up to 1870, as is shown in Fig. 20.

Fig. 20 Groundwater level variations in the central part of Berlin (from 1870 till 1946 piezometer No 27 in East Berlin (DENNER 1947); from 1946 till 1981 piezometer No 604 in West-Berlin, Senator Bau-Wohnen 1982).



Until 1885, the groundwater level was about 1-1.5 m deep, due to the low water consumption by the population. Later, the increase in industrialization caused a fall in groundwater levels, whereby temporary building activities led to further decreases in groundwater depth (e.g. underground station Alexander Platz induced a drop of about 10 m; DENNER 1947). Economic crisis and wartime as well as the time after the war until 1950 led to a replenishment of groundwater to a level of about 31 m above sea-level. With the beginning of Berlin's reconstruction, a steadily growing demand together with diminishing drainage area due to building was responsible for a renewed drop of the groundwater level.
During 1954-1978, the drop amounted to 1.20 m or 5 cm per year (KLOOS 1977). The negative groundwater budget can be explained by taking the hydrological year 1975 as an example, where a total uptake of 277.4 km^3 with the Berlin water

works (186.5 km^3), private installations (44.2 km^3) and construction activities (46.7 km^3) was opposed to a maximum groundwater recharge of 241.2 km^3 (Gewässerkundlicher Jahresber. 1975, 1977).

Higher rainfall amounts in the period 1977 to 1980 ($\bar{x}$ = 661 mm) in comparison to the period 1951-1976 ($\bar{x}$ = 584 mm) as well as the complete feeding back of groundwater pumped up during construction activities, as specified by the Nature Conservation Act of 30.1.1979, have led to a rise of the groundwater table, although water consumption has increased.

Groundwater quality: Although groundwater quality can generally be classified as quite good with respect to drinking water supply and in relation to the threshold values valid at present, significant regional differences can be found within West-Berlin. Thus, for instance increased nitrate contents can be found in groundwater near to the surface in the urban area of Spandau, in the sewage farms, in the area Lübars-Hermsdorf and in areas without sewers in Heiligensee (SENATOR FÜR STADTENTWICKLUNG UND UMWELTSCHUTZ 1985).

Increased sulfate contents can be encountered particularly in areas with ruin debris containing gypsum. Relatively high concentrations of chloride can be found in the industrial zone of West Spandau and in the eastern part of Kreuzberg as well as along the railway-line to Lichterfelde-Süd. Causes for this are the storage and transportation of thawing salts, that reach the subsoil by infiltrating rainfall.

The lead contents of the groundwater in Berlin are relatively low and generally only reach about half the value allowed for drinking water of 0.04 mg/l (TVO 1975). However, in comparison to other studies, the values found in Berlin seem to be slightly higher. Thus, the mean load content measured in 329 water samples from West Germany in only 0.009 mg/l. The reasons for the lead contamination are emissions caused by traffic, which reach the groundwater by way of rainfall (Umweltatlas Berlin 1985, Senator für Stadtentwicklung und Umweltschutz). Values for ammonium are high, in practically the whole urban area and surpass the threshold levels (EC - Guidelines for drinking water) of 0.39 mg/l NH_4-nitrogen.

Reasons for these relatively high ammonium concentrations are firstly the partial drainage of waste water into the groundwater from sewage farms and secondly, seepage of sewage water in areas without sewers.

3.4 Freshwater areas

Berlin (west) has many different freshwater bodies. The Spree and the Havel along with the canals form commercial waterways with a cumulative length of 125 km. There are approximately 150 brooks and ditches with a cumulative length of 150 km. There are over 100 natural lakes, ponds and pools as well as earth, gravel, sand and clay ditches. The large lakes - Tegel Lake, Wannsee, Griebnitzsee and Heiligensee are connected with the Havel.
The Spree drains an area of 10.000 square kilometers and the Havel (down to Berlin) 3250 square kilometers. The Spree conveys an average of 40 m^3, the Havel at Spandau 16 m^3 water per second (KLOOS 1978).

The highest yearly water level of the Havel is in spring, the lowest in fall. The average annual amplitude of the lower Havel is 1 m. The Spandau locks cause a relatively small range for the upper Havel of 45 cm. Lakes of various sizes have also been constructed, for example during the establishment of parks (Neuer See in the Tiergarten). A great number of canals now used for shipping and run-off-water have been artificially constructed in the last 250 years (NATZSCHKA 1971). The original sediments of the lakes were partly lime-rich muds; in smaller forest lakes (Pechsee) Dy is also formed.

The waters of Berlin (Tab. 6) are generally heavily polluted today, due to waste waters and ship traffic. Private and industrial waste waters have not been directly drained into the rivers and lakes since 100 years.

However, even after the passage through sewage irrigation fields or treatment plants, the water carries a heavy waste load. The heavy strain on the waters has caused a strong eutrophication. Therefore, sludge is sedimented and sapropel forms on the lake bottoms. For these reasons, the sludge of many lakes has been periodically removed since the beginning of the century. Recently, artificial aeration and phosphate extraction plants have been installed in order to prevent eutrophication. Metal as well as heavy metal concentrations are increased in some of the Berlin waters as examplified for water Tegel lake (Tab. 7).

As an example for a freshwater ecosystems, quoted as an severely eutrophicated lake affected by anthropogenic disturbances, the Heiligensee was intensively studied (SZYMANSKI-BUCAREY in SUKOPP et al. 1980).

The water temperature stratification of the lake is stable from May to mid-September. The always well circulated layer of the epilimnion rises from 4.5 -

Tab. 6 Ion concentrations (mg/l = ppm) of Berlin waters (mean values of water (W) and of pore water (S) from BLUME et al. 1979.

1975/76 average	locality	sample type	Cl	P	N	B	HCO_3	Na	Ca
strong pollution (canals and streamlets)	Nord-graben	W	124	3.4	18	0.6	449	115	163
	Tegeler Fließ	W	97	2.1	7.4	0.6	335	88	167
strong pollution (lakes)	Nord-hafen	W	96	2.7	11	0.5	347	85	131
		S	104	46	196	0.7	1094	105	297
	Tegeler See (NO)	W	69	1.5	5.8	0.3	263	57	119
		S	100	20	34	0.7	616	96	164
	Tegeler See (center)	W	71	2.2	6.3	0.4	277	56	126
		S	72	7.6	51	0.4	898	60	198
low pollution	Tegeler See (SW)	W	49	0.7	2.3	0.2	211	38	100
		S	60	3.4	8.4	0.3	339	46	99
	Ober-Havel	W	37	0.1	0.8	0.1	177	27	83
		S	35	0.4	32	0.1	563	29	124
	Heili-gensee	W	37	0.2	1.4	0.1	156	26	73
		S	34	2.3	35	0.1	520	25	116
almost not polluted	Pechsee	W	17	0.2	<0.1	0.1	7	3	3
		S	17	0.3	1.3	0.1	83	2	2.3

Tab. 7 Metal concentration in the Tegel Lake.
Values of hypolimnion water (W) and sediment pore water (S), data from 1974/75 according to STAUDACHER (1977). For comparison values of the middle Rhine valley (1972 acc. to FÖRSTNER & MÜLLER 1974).

Locality		depth m	mg/l K	mg/l Mg	µg/l Cd	µg/l Pb	µg/l Cu	µg/l Fe	µg/l Mn	µg/l Sr
A3	W	7.4	9.4	9.5	0.3		3.8	80		310
	S		18	15	2.2	18	6.7	500	550	480
C3	W	14	9.8	8.4	0.3			160		390
	S		11	9.1	2.8	8.2	4.4	560	1100	350
F2	W	4.9	11	12		9.3		140		530
	S		18	10	2.4	19	57	280	1700	570
H2	W	4.1	6.3	8.8	0.7	6.2	5.4	80		480
	S		5.5	7.3	2.1	4.1	5.1	310	440	440
Rhine	W				5	3	30	500	300	500

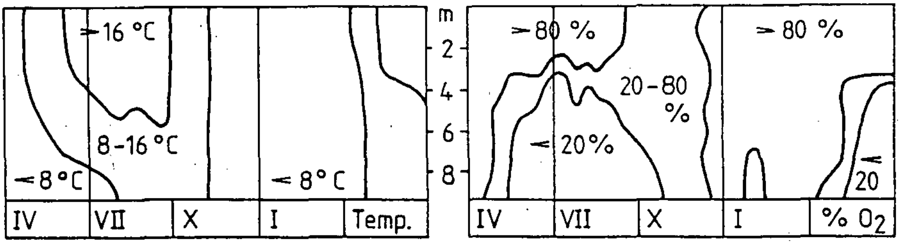
Tab. 8 Physico-chemical properties of the water body (deepest point) of the Heiligensee according to SZYMANSKI-BUCAREY & SIEBOLD (1978).

parameter	max.	min.	comments
epilimnion temperature	24°C	0.2°C	summer layering: from mid/late May to mid-September. Winter layering: in January-February 1979. Spring and fall circulation
hypolimnion temperature	12°C	2°C	
sight depth	4 m	0.6 m	maximum June, minimum September 1977
O_2-sat.	280%	0%	mid-May until approx. late September 1977/78; no O_2 below approx. 6 m
pH	10.2	6.9	
H_2S-S	18.6 mg/l	0	only from approx. 6 m to the bottom
NO_3-N	0.8 mg/l	0.03 mg/l	minimal value in epilimnion during the summer
NH_4-N	8 mg/l	0.1 mg/l	for most of the year predominating form of anorganic nitrogen
NO_2-N	0.02 mg/l	< 0.001 mg/l	maximal value after circulation (nitrification of NH_4)
PO_4-P	2 mg/l	0.001 mg/l	maximal value in August 78 and 8.4 m depth, minimal value between June and September 1978
Chlorophyll a	237 mg/m^3	2 mg/m^3	max. value after fall circulation 1977, minimal value in Nov., Jan.

6.0 meters during the summer. The warming commences during full circulation resulting in high temperatures at depth (8°C) increasing to 12°C during the summer. From the end of September to the beginning of November full autumn circulation occurs. The lake is periodically frozen from late December to mid-March. The sight distance varies (spring/autumn) between 0.6 - 4.0 meters. According to the stratification of the lake, oxygen depletion occurs in the hypolimnion. Severely reduced conditions in the hypolimnion have lead to considerable acid gas (H_2S) concentrations (see Fig. 21).

The phosphate concentrations are highly dependent on primary production and thermal stratification. The concentrations at the surface vary between 0.0013 and 0.2 mg/l PO_4-P respectively. The epilimnetic concentrations decrease rapidly owing to photosynthesis after maximal thermal expansion. The concentrations in-

Fig. 21 Temperature and oxygen saturation of the Heiligensee lake (according to SZYMANSKY-BUCAREY & SIEBOLD 1978)



crease to 0.2 - 2.0 mg/l PO_4-P in the hypolimnion. Since the concentration increases markedly towards the lake's bottom, a large amount is believed to be released from the reduced sediment layer. The minerals of the sinking detritus are also believed to be considerable. The high sulphide concentrations lead to increased iron diffusion which causes the black colour of the sediment. This is assumed to be significant for phosphorus circulation since the low iron concentrations restrict the chemical precipitation of the iron phosphorus complex under aerobic conditions.

The epilimnetic ammonium - and in particular, the nitrate concentrations decrease during the summer through uptake by organisms.

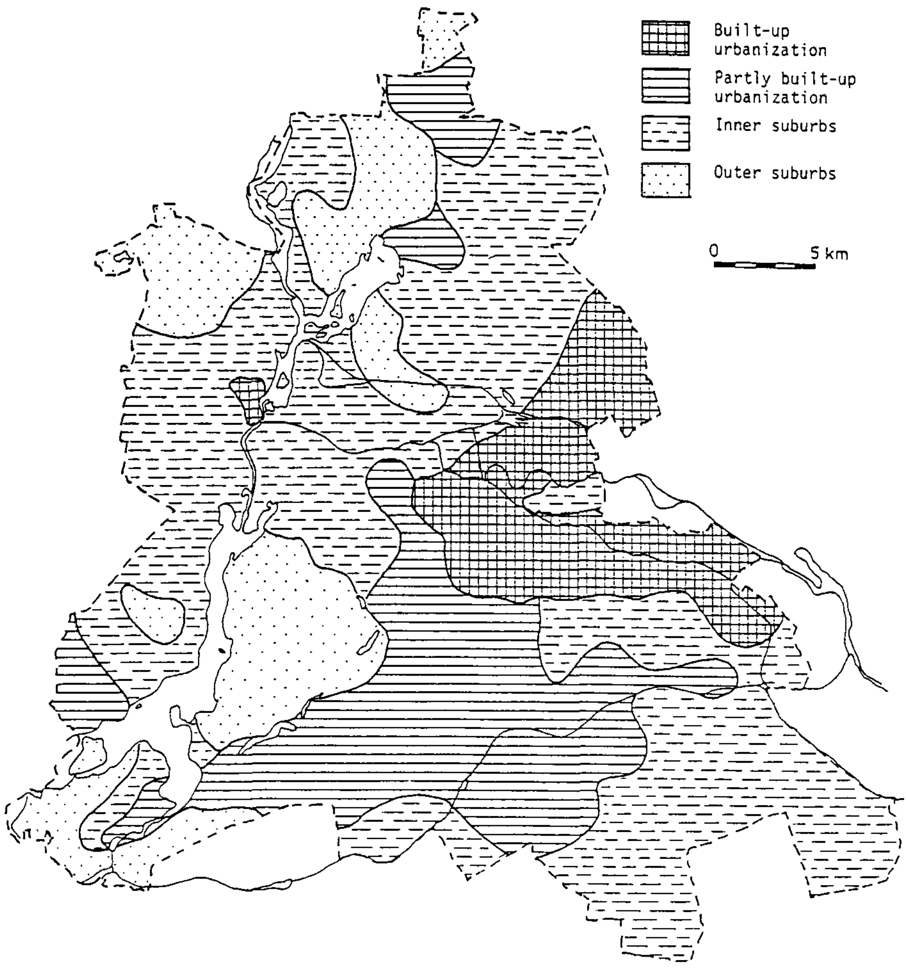
As the trophogenic zone of the Heiligensee lake is quite similar to the well-mixed epilimnion, chlorophyll a can be used as a rough measure for the phytoplankton biomass (1 mg chl. a is the equivalent of about 17 mg carbon and 170 mg fresh weight).

There is a phytoplankton bloom in spring. The low biomass levels during May and June are apparently caused by intensive zooplankton grazing (in clear water). During the late summer and autumn a second massive phytoplankton growth develops. This is assumed to be related to increased nutrient input in the tropholytic zone in response to thermal decomposition.
The primary production was measured by means of the oxygen determination principle in light/dark bottles. During the investigation period in spring 1978 and in spring 1979 the maximum production levels were found close to the surface (compensation level chiefly about 1.5 - 2.0 meters). The highest primary production levels occured during April 1979 simultaneously with the absolutely highest oxygen concentration levels. From this evidence of regular high oxygen concentrations in early spring during the years 1975-79, it is concluded that the highest productivity occurs at that time of the year.

3.5 Flora and fauna

The natural structure of our area has been modified by a new structure set forth by the historical development of the city. This has been shown clearly by KUNICK (1974). KUNICK discerned four zones: Urbanization: 1) built up, 2) partly built up; Suburbs: 3) inner, 4) outer (see also Fig. 22 and Tab. 9).
The ecological factors determining the type of vegetation are caused by the different types of land use in these zones. Consequently, KUNICK (1974) used 16 tpyes of land use for characterizing his zones. Recently, TREPL & KRAUSS (1984) described 54 types as "Biotoptypen", which again can be grouped into 12

Tab. 22 Zoning of Berlin (West) by floristic similar areas, after KUNICK (1974)



more complex types for planning and developmental purposes ("Biotopentwicklungsräume" DRESCHER & MOHRMANN 1984). TREPL & KRAUSS (1984) used two different kinds of criteria: 39 types mainly occuring in the urbanization and inner suburbs zones, are defined by their mode of land use. 15 types, mainly occuring in the outer zone, are defined by their vegetation character. This is in accordance with the fact that for the distribution of plant species in the inner zones of Berlin (West), the urbanization factors are dominant, whereas in the outermost zone, natural factors gain in importance (KÖSTLER 1985).

During the last centuries, the flora of Berlin (West) underwent great changes as a consequence of the growth of the city. The total number of Phanerogames and Pteridophytes according to AUHAGEN & SUKOPP (1982) amounts to 1243. This rather large number can not be compared easily with data from other areas, because only 1006 of them are indigenous species and archeophytes, whereas 237 are neophytes, which usually are not included in floristic lists on non-city areas.

In table 9 it can be seen that the percentage of non-hemerobic (indigenous) plants decreases from 72% in the outermost zone to 50% in the innermost zone. Moreover, 39% of the indigenous species (69% of the indigenous ferns) (BENNERT 1982) are threatened, but only 5% resp. 4% of the archeophytes resp. neophytes. Similar considerations are made on other plant groups (see different authors in SUKOPP & ELVERS 1982).

Tab. 9 Floristic characteristic of zones in different stages of development in Berlin (after KUNICK & SUKOPP from SUKOPP & WERNER 1983).

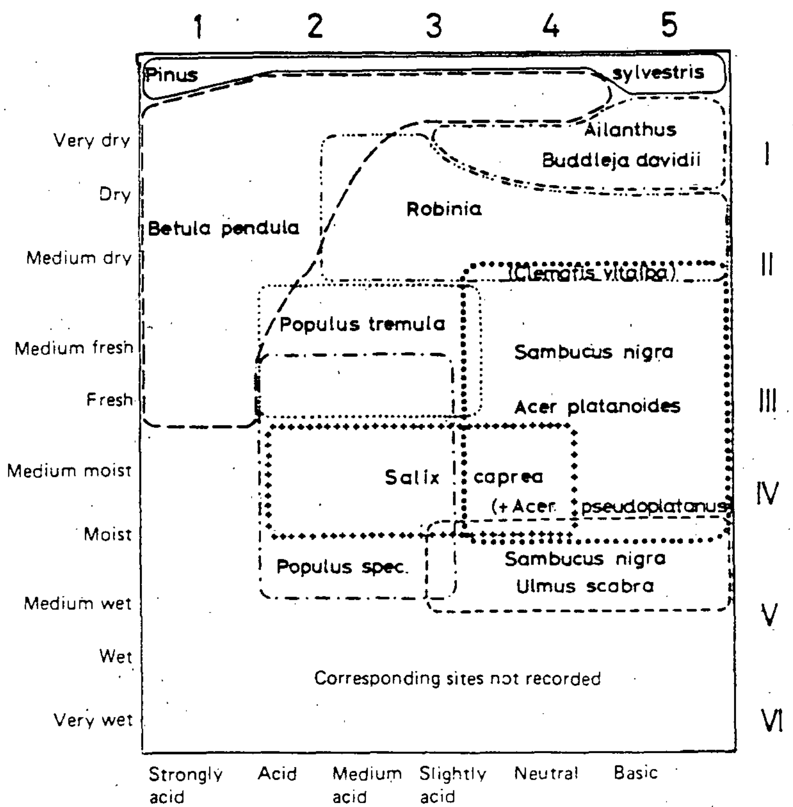
	Urbanization		Suburbs	
Zone	Built up 1	Partly built up 2	Inner 3	Outer 4
Vegetation covered area (percent)	32	55	75	95
Number of species vascular plants per km²	380	424	415	357
Percentage of hemerobic plants	49.8	46.9	43.4	28.5
Percentage of Archaeophytes	15.2	14.1	14.5	10.2
Percentage of Neophytes	23.7	23.0	21.5	15.6
Percentage of Therophytes	33.6	30.0	33.4	18.9
Number of rare species per km²	17	23	35	58

The general change from the outer part to the inner part of the city can be described as increase in hemeroby. In the outer zone, mesohemerobic and euhemerobic ecosystems occur, whereas in the center polyhemerobic and metahemerobic ecosystems prevail (BLUME & SUKOPP 1976).
At the poly- and metahemerobic stages great quantitative and qualitative changes occur, several large groups of organisms (like ferns and reptiles) are nearly extinct, whereas others are relatively overrepresented, as certain groups of mammals (BORNKAMM 1980).

The total number of trees in the city can be assumed to be much higher than the population here (1.8 million); more than 234 000 (FÖRSTER 1985) trees grow at roadsides, tenfold is the number in parks and gardens.
Two types of tree stands in settlements can be distinguished, i.e. in forest settlements (Waldsiedlungen) and park-settlements (Parksiedlungen). Forest settlements are mainly characterized by the appearance of Scotch pine and birch. Park-settlements contain valuable old stands of deciduous trees. Among the characteristic species are beech, elder, maple, sycamore, horse chestnut and oak. The woody plant stands of many gardens will vanish in the future of more intensive build up areas. On the other hand, the owners avoid today the replanting of large-crowned deciduous trees. Instead, coniferous trees are favoured, although these suffer more from the urban pollution.
The design and use of parks is of significance for plant and animal life. KUNICK (1978) studied the dependence of flora and vegetation on size, function, care and use intensity, as well as age and history of establishment, for 22 parks in Berlin. In these parks, which differ in size and location in the city, the inventory of spontaneous occuring plants was determined, i.e. of those that most probably were not intentionally cultivated on a particular site. It became evident that the absolute species number of large extensively used parks was, on the average, twice as high as that of intensively used smaller city parks. Some species groups occur almost only in large parks. These include, in particular, forest species and also species typical for water and shore vegetation and of damp meadows and swamps. If they emerged from former hunting grounds of palace or estate parks or the like, these large innercity parks also contain relicts of relatively natural forest vegetation. They are often refuges for plant and animal species which have become rare in the rest of the city and which are in danger of becoming extinct. They can also function as dispersal centers for species which are just becoming established, as has been demonstrated for grass and seed arrivals.

Waste lands are colonized by new types of plant communities, which signify a new environment created by man (see chap. 4.4, Fig. 42). Rubble sites took up great areas of land after the destruction during the last war. Most soils of inner-city waste lands are thus composed of rubble layers which can reach several meters in depth. Today, habitats with special features and special vegetation and fauna have developed on this anthropogenic material. On the carbonate-containing and dry ruderal sites, which predominate in the inner-city, colonizers such as black locust, tree of Heaven, traveller's joy and butterfly bush are to be found (Fig. 23). On fresh-to-moist rubble sites, in contrast, indigenous woody plants such as poplar, maple, wych elm and elder dominate the scene. The species diversity of inner-city vacant land is surprisingly high, e.g. a block of land (0.8 ha) on Lützowplatz (Berlin-Tiergarten) contains more than 170 flowering plants and at least more than 250 arthropod species.

Fig.23 Woody plants in Berlin City. Range of tolerance of soil moisture and acidity for the most important trees and shrubs.



Whereas the area taken by transportation routes is usually extremely unfavourable for vegetation, hard-to-reach-remnant open areas after the construction of streets, railroads and canals remain. For endangered species these remnant plots represent important retreat and dispersal centres. In Berlin, approximately 400 species (40% of the ferns and flowering plants of the city) grow on roadside verges.

The enormous changes of the vegetation is reflected closely by the change of fauna. Here, too, we have a great number of both dying out and invading animals. This has been discussed by a great number of authors in SUKOPP & ELVERS (1982) and KRAUSS & TREPL (1984). Changes are evident even when regarding the most recent data with not very old ones (WENDLAND 1971; BRUCH et al. 1978). The greatest reduction in species number and the highest percentage of endangered species can be found with the reptiles (100%), amphibians (83%) and fish (71%), but other groups also show figures of > 50% (SUKOPP et al. 1982).

3.6 Emissions and immissions in West Berlin

Types of contamination of the biosphere: Berlin is the largest city agglomeration in Germany and consequently one of the European regions most heavily exposed to immissions (SENAT VON BERLIN 1976; SENATOR FÜR STADTENTWICKLUNG UND UMWELTSCHUTZ 1981). The increase in energy consumption since World War II led to roughly the same increase in air pollution. The main pollutants discharged into the air during combustion are: sulfur dioxide, nitrogen oxides, carbon monoxide and dusts containing heavy metals like lead and cadmium. These pollutants have various negative effects on the natural environments. As far as soils are concerned, this means, an additional deposition of pollutants and acidification, caused by a mobilisation and release of heavy metals of built-up or partly sealed-up areas.

Development and present state of contamination with pollutants: Between 1950 and 1970 the emissions of sulfur dioxide in West Berlin have more than tripled; they increased from 25.000 tons of sulfur dioxide in 1950 to 80.000 tons in 1970. Most of the sulfur dioxide was discharged by power stations, industrial plants and private households (in this order) (SENATOR FÜR STADTENTWICKLUNG UND UMWELTSCHUTZ 1984b).Since then, the emitted quantity remained on the high level of 70.000 tons of sulfur dioxide (Fig.24). In the last years, it was possible to decrease it to the level of the early sixties.

In the closer surroundings of West Berlin another 200.000 tons/year of sulfur dioxide have been emitted. These emissions, along with airborne emissions from

sources further away, lead to a high average annual strain and to a pollution which reaches its peak during the winter months on the so-called "smog days". The average annual immissions registered between 1976 and 1980 ranged from 65 $\mu g/m^3$ on the outskirts of West Berlin to > 140 $\mu g/m^3$ in the city centre (comp. Fig. 9, chap. 3.1). Between 1981 and 1983, on the other hand, the quantities ranged from 50 $\mu g/m^3$ to 125 $\mu g/m^3$. In contrast to this, the heavily contaminated region of North Eastern Bavaria averages 70 $\mu g/m^3$ per year.
Between 1976 and 1983 there was an average of 40 $\mu g/m^3$ during summer months and 200 $\mu g/m^3$ during winter months - the average being the median of all West Berlin measuring points.

Fig. 24 Development of total SO_2 emission in W-Berlin from 1951 to 1979 (tons/year)

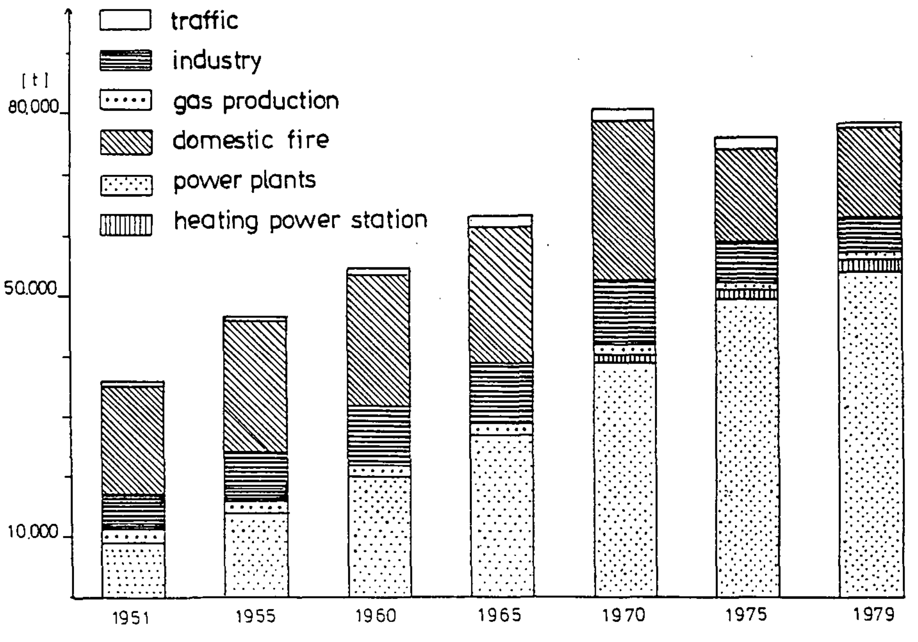
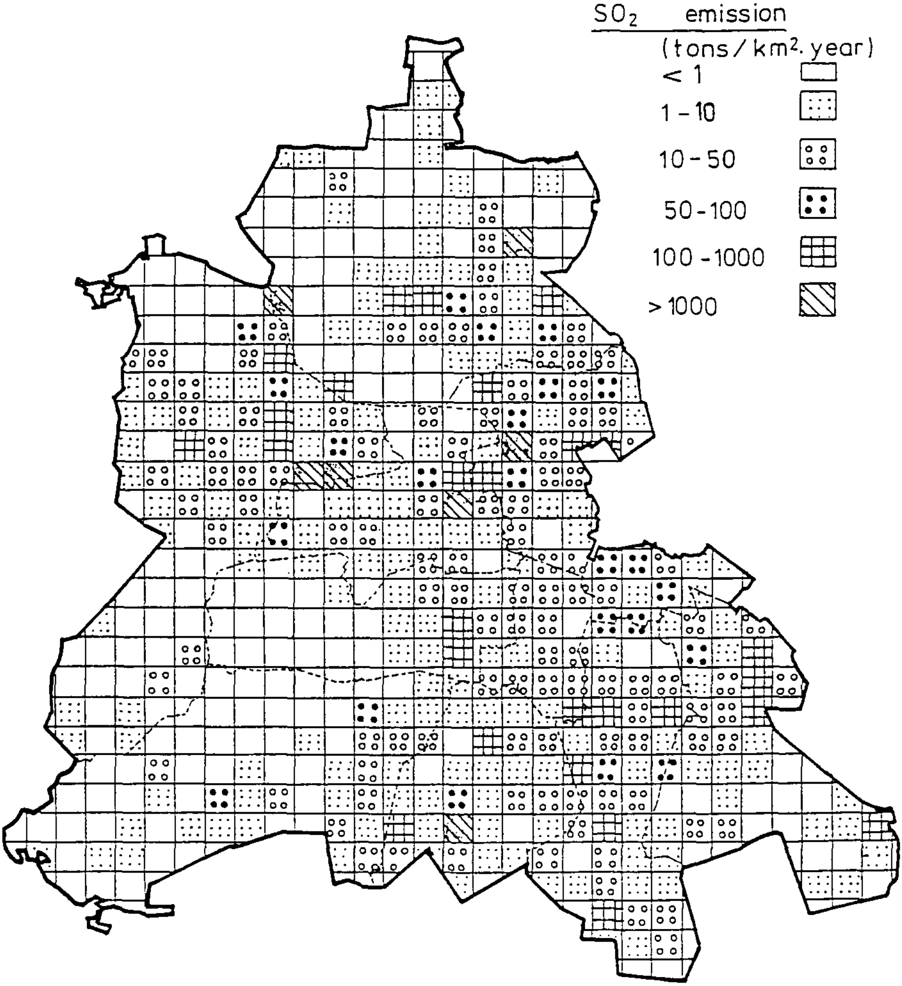


Fig. 25 shows, how the annual SO_2 emissions vary according to the various West Berlin districts; the quantities range from < 1 ton/km^2 per year to > 1.000 tons/km^2. During smog days (on the 19th of January, for example) the sulfur dioxide concentration reached more than 800 $\mu g/m^3$ in the Wedding district (Fig. 26) (days with smog 1983).
In contrast to this, the air measuring points of the Federal Ministry for Environment registered a average daily maximum of sulfur dioxide concentration ranging from 170 $\mu g/m^3$ to 360 $\mu g/m^3$ in the "unpolluted" areas of Lower Saxony and Schleswig-Holstein during the same month (i.e. January 1982).

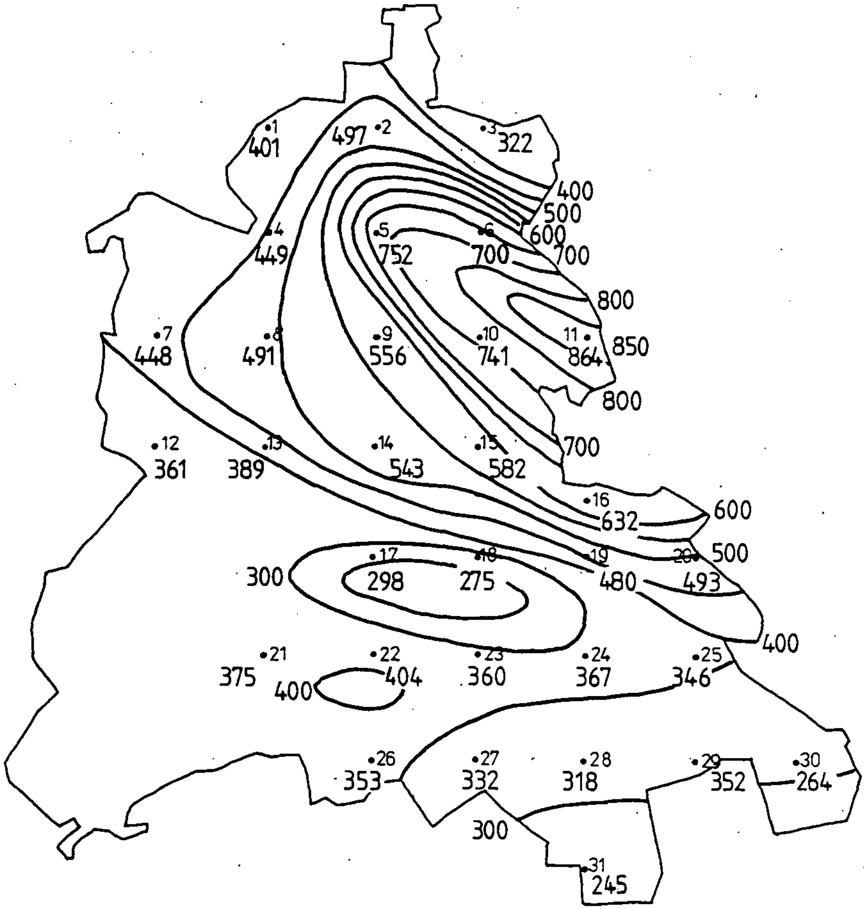
Fig. 25 Local distribution of SO_2 emission in West-Berlin (tons/km^2.year).



The maximum half hour concentration reached 2.300 $\mu g/m^3$ in Berlin (1981), 1.100 $\mu g/m^3$ in the region of Ingolstadt, 800 $\mu g/m^3$ in the region of Nürnberg, 500 $\mu g/m^3$ in the region of Munich and 1.400 $\mu g/m^3$ in the region of North Eastern Bavaria.

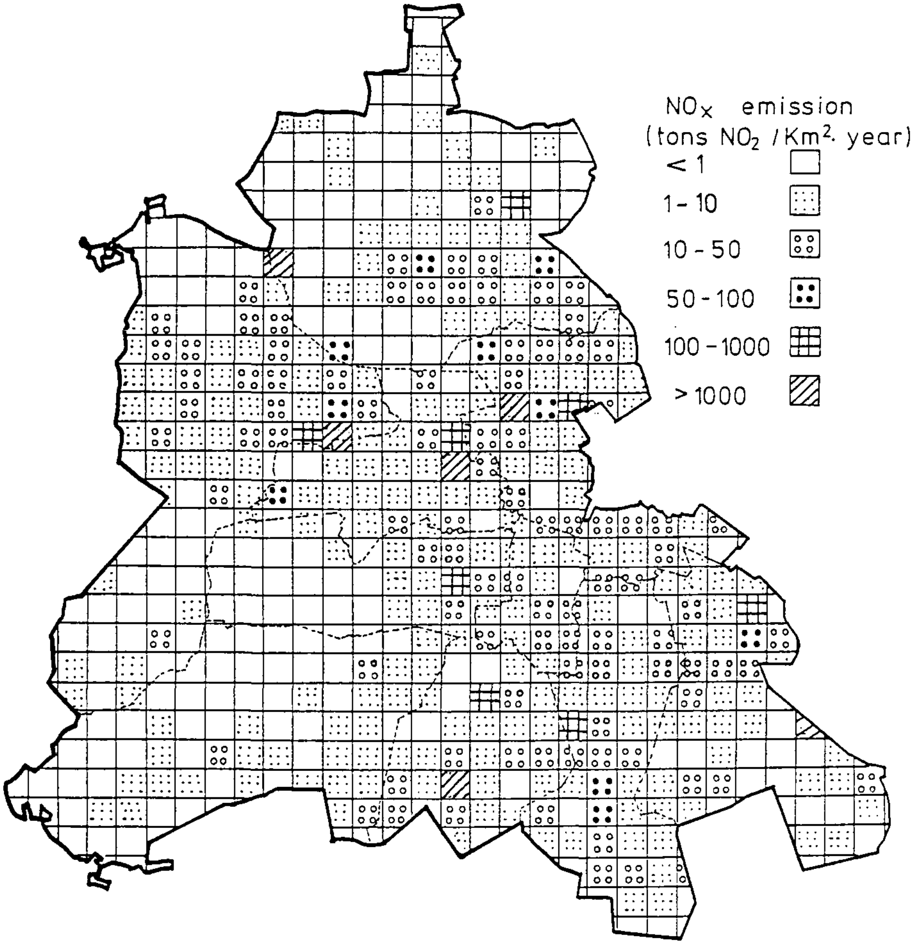
The precipitation of sulfur on open areas - analysed according to the concentration of SO_4^{--} in precipitation - is about 30 kg/ha and year. This is only 4% of the quantity which on the average has been emitted per hectare.

Fig. 26 Mean values of SO_2-concentrations of January, 19th 1982, isolines of concentrations at West-Berlin ($\mu g/m^3$)



The contamination of urban areas with <u>nitrogen oxides</u> has increased considerably over the last two decades. Thus, the concentration of nitrogen oxides in 1976 was seven times that of 1952, and has remained on approximately the same level since 1976. In West Germany, the emissions of nitrogen oxides have increased by 55% between 1966 and 1978 and have also remained on this level (data available till 1982). While in West Germany 55% of the annual emission on nitrogen oxides are due to automobile exhaust and 28% due to power stations, the ratio is inverse in

Fig. 27 Local distribution of NO_x emission in West-Berlin (calculated as NO_2) (tons/km^2.year).



West-Berlin. Thus, from 1955 to 1980 the quantity of automobiles has increased sevenfold and is at present at about 700.000 (SENATOR FÜR STADTENTWICKLUNG UND UMWELTSCHUTZ 1984 c; BRAUER 1983). Nevertheless, the quantity of nitrogen oxides from transportation vehicles has become even more important.

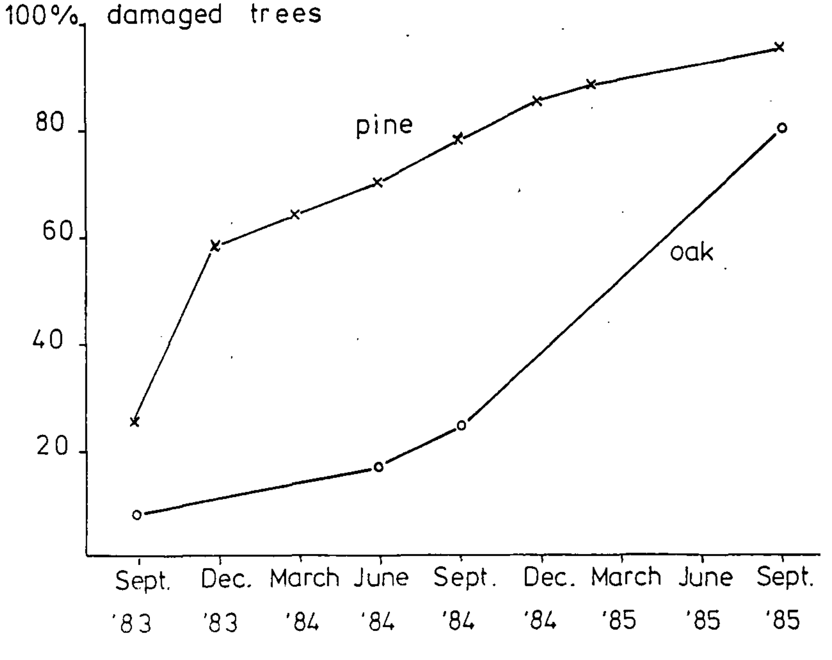
Fig. 27 shows the distribution of West Berlin's annual nitrogen oxides emissions. The precipitation of nitrogen - analysed according to NH_4^+ and NO_3^- in precipitation solution - is about 25 kg N per year. This is about 9% of the mean nitrogen load discharged in urban areas.

The quantity of carbon monoxide emissions is 200.000 tons/year, vehicle exhaust and central heating accounting for 99% of it. In 1981 the mean annual immissions of carbon monoxide registered at the Berlin measuring points were between 0.8 mg/m^3 and 6.0 mg/m^3. The immission have rarely exceeded the threshold of 30 mg/m^3 enacting special smog regulations.

The emission of dusts (dry depositions) in West Germany has been reduced considerably during the last twenty years. In West Berlin, they amounted to 11.400 tons in 1982, that is a mean annual concentration of 240 kg/ha. In the forests of West Berlin, on the other hand, the dust fall is three times that figure. 90 tons of lead emissions have been registered per year. This is a mean concentration of 1.88 kg/ha, whereas the mean input of lead into the forests and the Tiergarten (park area) is 0.17 kg/ha, which is only 9% of emissions.

Consequences of the contamination: The consequences of the SO_2^- and of the NO_x contamination is an increased acidification and seepage of nutrients from the soils. At the same time it has led to an accumulation of heavy metals in the organic surface and the upper horizons.
In accordance with the dose-effect-relationships, plant damages by contamination, particularly among conifers (pines), have been observed in the West Berlin area (see Fig. 28) (SENATOR FÜR STADTENTWICKLUNG UND UMWELTSCHUTZ 1984a; LANDESFORSTAMT 1984).

Fig. 28 Increase of damaged trees (% total number) in forests of Berlin (West)



Investigations showed that during the winter months the high concentrations of pollutants in the air (> 300 $\mu g/m^3$ SO_2) had a negative impact on the state of health, which was particularly felt among the so-called "groups at risk", which include infants and elderly people (BORGERS & PRESCHER 1978; STEIGER & BROCKHAUS 1971). An influence on the mortality of the population is likely and may already be proved for passed smog events (Tab. 10) (Senator für Stadtentwicklung und Umweltschutz 1983).

Tab. 10 Smog periods in the past with increasing mortality

Location	Date	Air pollution (g/m^3)		Increase of mortality
		SO_2	Dust	%
Maas-valley (Belgium)	Dec. 1930	25 000	12 500	950
Donara, PA	Oct. 1948	1 600	4 500	800
London	Dec. 1952	3 830	4 460	72
	Jan. 1955	1 200	1 750	12
	Jan. 1956	1 500	3 250	
	Dec. 1956	1 100	1 200	25
	Dec. 1957	1 600	2 300	27
	Jan. 1959	800	1 200	10
	Dec. 1962	3 300	2 000	21
New York	Nov. 1953	2 200	1 000	9
	Nov. 1962	1 800	800	8
	Jan. 1963	1 300	800	19
	Feb. 1963	1 260	900	23
	Mar. 1964	1 730	520	5
Pittsburgh	Nov. 1975	200	900	8
Ruhrdistrict (W-Germany)	Dec. 1962	5 000	2 400	10

3.7 Nature conservation in the city

Today less than ever before, nature conservation can no longer be understood purely as the protection of undisturbed open areas; on the one hand, because of fundamental alterations of the environment, and on the other hand, because nowadays problems cannot be resolved by merely thinking in terms of black and white.

The idea of nature (and environmental) conservation today is rather the consideration of all those measures which protect the natural resources from the holocaustthrough civilization.
With this statement, civilization isn't being questioned, but it is based upon the possibility of coexistence, presuming that if one keeps as much nature functioning as possible then nature can maintain itself and civilization.

At that, however, it depends upon supporting enough natural space in order to regenerate as well as intersperse and arm the built-up landscape with sufficient natural elements.

Urbanization changes habitat conditions as mentioned above (e.g. increased temperature, lowered groundwater, imported soils, levelled relief, eutrophication, pollution). For the purposes of vital and efficient biotic communities, it should be understood, therefore, that the urban flora and fauna, at least it's composition, isn't comparable to that of the open land around the city.

Accordingly, the task of the city in nature conservation is to look for other organisms and biotic communities in the built up area different from those in the surrounding areas. In principle, however, it is always the same question of intergrating a well-adapted fauna and flora into the respective land uses and of optimizing their conditions.

In practice, this means for the city centre:

- avoidance of the sealing of soil with continous hard surfacing; preference for pavements with many gaps
- measures to protect the roots of street trees from foot and car traffic as well as from sealing and excavation
- development of green areas with roof gardens, courtyards and wall plants
- prohibition of herbicides, pesticides and de-icing compounds
- maintenance and promotion of the spontaneous vegetation on sidewalks, roadsides, shrub borders, left-over open spaces within built-up areas, extensively used industrial areas, landfill sites, railway embankments, etc.
- reduced intensity in the management of gardens and urban green spaces.

Furtheron, the historical task of nature conservation to "conserve" areas and objects must not be forgotten. It is accepted as being a fundamental aspect of research and protection of species.

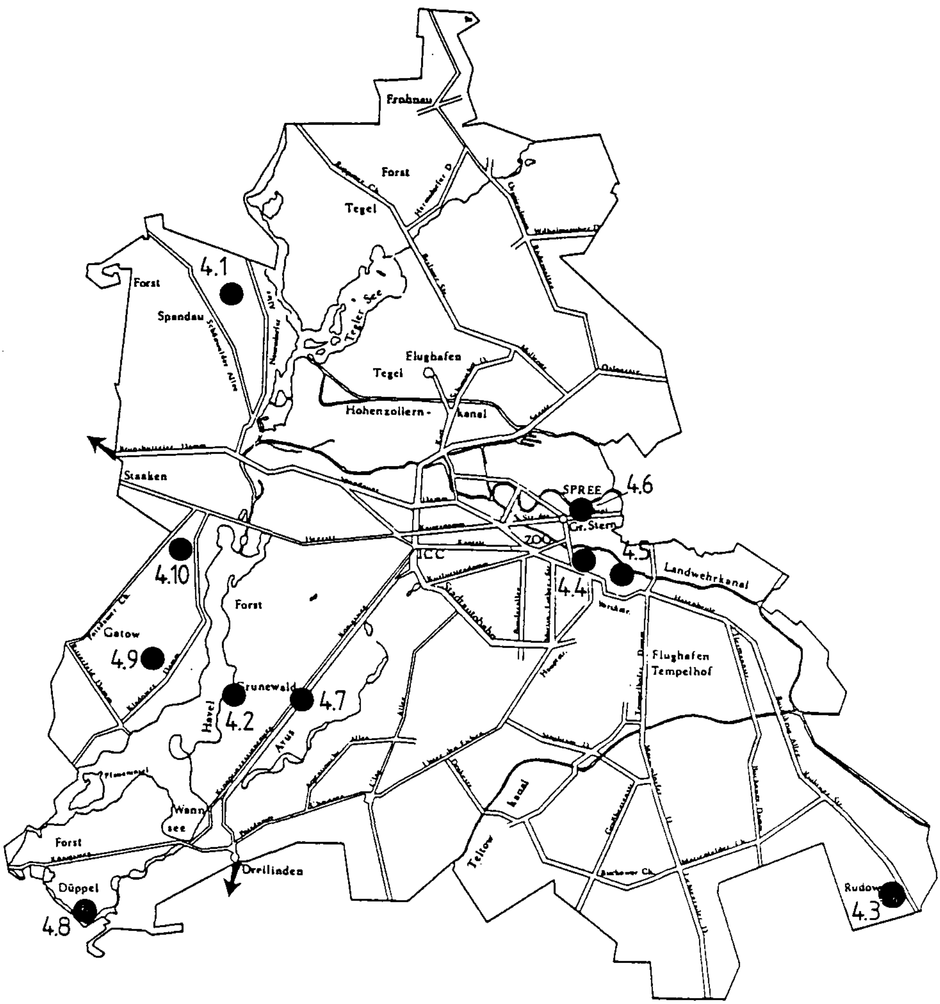
The realistic attitude of urban ecologists has enriched the stock of areas and objects worthy of protection as follows:

- urban parklands, cemeteries, and sewage fields
- extensively used areas of industry, traffic, harbours, etc.
- inner-urban waste sites (Especially those once derived from bricks and rubbles bear typical Berlin problems and chances!).

Moreover, it is necessary to maintain natural elements, maybe for the purposes of ecology, like the protection of wetlands, or for the purposes of scientific research, such as the (suggested) protection of a field of sand wedges (at Berlin-Frohnau).

4. Excursion sights

Fig. 29 Generalized map of excursion sights



4.1 A dune sand-bog landscape - the Teufelsbruch at Spandau (BLUME et al. 1981)

The Spandau Forest has a surface of 1.000 ha and represents one of the important recreation areas for the citizens of Spandau. The eastern part of the forest functions also as a filter for polluted air. The southern part is a protected area for groundwater used by the water supply company of Spandau. The bog areas of the Rohrpfuhl and the Teufelsbruch are wild-life reserves.

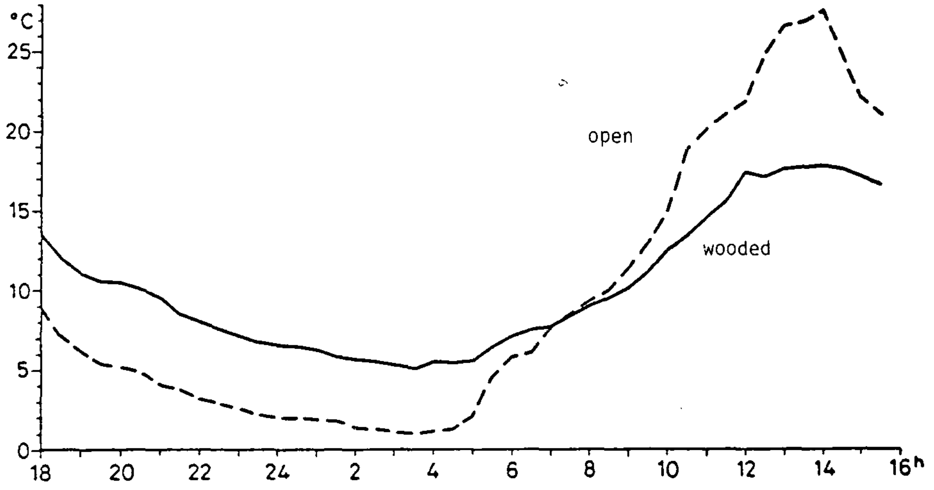
The Spandau Forest is situated on the sandy glacial outwash plain of the Warschau-Berlin-"Urstromtal". The area is nearly flat, with differences in altitude from 32 to 35 m a.s.l. A meltwater channel directed from SE to NW was found. After the melting down of the glaciers, small lakes formed in this channel, in which sediments of various phases accumulated (calcaric muds, chalk and peat). Due to the high groundwater level, bogs finally developed (Teufelsbruch, Großer and Kleiner Rohrpfuhl). In small depressions, formed by deflation of isolated remnant iceblocks, peat also has built up. In such small depressions no calcaric sediments were accumulated.

In the northern and western part of Spandau Forest, dunes with SE-, NW- or EW-orientations occur. They have altitudes of up to 39 m a.s.l. and are well recognized by their steep slopes. These dunes were formed during vegetation-free periods of the late glaciation until holocene. Later, in the bronze age, eolian sand sheets sedimented after forest clearing.

According to the special relief, soil and vegetation, the Teufelsbruch shows some special climatic conditions in comparison to the surrounding area. These special climatic conditions occur in the open area of the northwest part, due to the high groundwater level combined with a low temperature conductivity of the soil, that can not compensate radiation losses at night time. The formation of a cold air mass, gathered from the surrounding area, decreases temperature strongly on the soil surface. Fig. 30 shows air temperatures at 15 cm above the soil surface during day time.

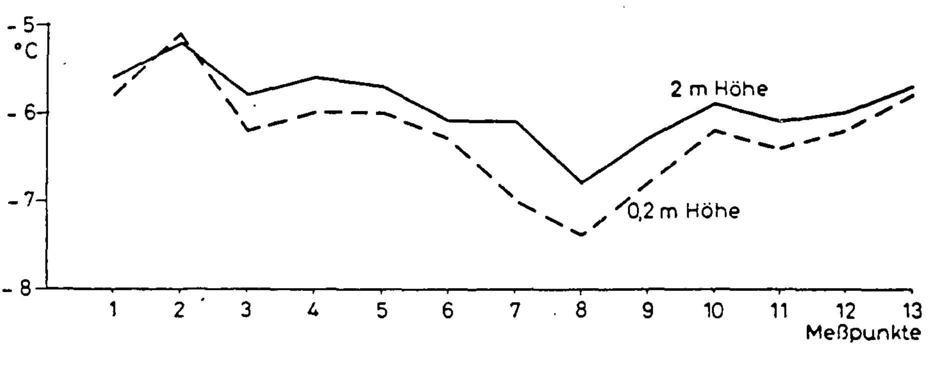
The measurements were carried out during 2 days with low radiation exchange (11. and 12.10.1979) as well in the open area as the forest area in the depression of the Teufelsbruch. The results indicate that in the open area the temperature at midday is very high and in the evening as well as at night the temperature is very low, because of radiation losses. Under the same relief and soil conditions the wooded part of the Teufelsbruch can compensate for the daily temperature fluctuation.

Fig. 30 Temperature curves measured in 15 m height on a (sunny) day with low air exchange in an open and wooded part of the Teufelsbruch



The accumulation of cold air in the open area of Teufelsbruch is illustrated in Fig. 31.

Fig. 31 Temperature distribution in 0.2 and 2 m height along a SW-NE transect through the Teufelsbruch (4.12.1978, 16.40; after HÖRBERT)



Measurements were carried out on Dec. 4, 1978 at 16.40. On this day, the radiation exchange was very small. The air temperature was measured in 13 positions on a line and at 0.2 m and 2 m hight. The border of the wooded area (position 1, 2, 12 and 13) shows higher temperature than the open area. According to these conditions, the Teufelsbruch favors late and early frosts. In some years, only July was free of frost.

Cambic Arenosol - Dystric Gleysol - Histosol - Catena

Location:	Spandau Forest, division 25
Situation:	Pine forest, NE-slope and depression (Fig. 31 and 32)

Spandau Forest I

Location:	35.5 m a.s.l. convex hill top, groundwater 4-5 m below the soil surface
Parent material:	dune sand
Vegetation:	pine-chestnut-oak-forest with Quercus petr., Pinus silv., Sorbus aucup., Avenella flex., Vaccinium myrt., Pteridium aquil., Polygonatum odoratum a.s.o.
Soil type:	Rostbraunerde (Cambic Arenosol)
Humustype:	"moder" (bad moder, transition to rohhumus)
Site qualities:	very deep rooting zone, easy root penetration, dry, well aerated, poor in nutrients

Profile description: (Horizon, FAO)

L (O)	3-2.6 cm	soil surface is covered with: oak leaves, that are sticked together and partially bleached having small holes; pine leaves that are sticked together with fungi; peaces of wood and bark, gradual transition
Of (O)	2.6-1.5 cm	remainders and skeletons of leaves that are sticked together as well as remainders of wood and bark; partially humified
Oh (O)	1.5- 0 cm	brownish-dark, humified and few unhumified remainders of plants, granular loose, some bleached sand grains, many fine roots, abrupt transition
Ah (Ah)	0- 4 cm	very dark brown (7.5 YR 2/1), loose, granular, fS, many fine roots, gradual transition
Bv (Bw)	- 7 cm	dark brown (7.5 YR 3/2), few rusty mottles, slightly loose, singular, fS, medium fine roots, abrupt transition
fOh (Ob)	- 8 cm	black-very dark brown (7.5 YR 2/1), granular-platy, slightly loose, fS, many fine roots, gradual transition
Aeh (E)	- 14 cm	very dark grey (7.5 YR 3/1), dark brownish mottles, bleached sand grains, granular to singular, slightly loose, fS, many fine roots, gradual transition
Bsv (Bw)	- 26 cm	brown (7.5 YR 4/2), dark greyish patches, slightly loose, singular, fS, medium roots, gradual transition
Bv (Bw)	- 40 cm	dark yellowish brown (10 YR 4/4), some grey patches, singular, slightly loose, fS, few roots, wavy boundary
BvC (C)	- 60 cm	yellowish brown (10 YR 5/4), few rust mottles, singular, slightly dense, fS, scarce roots, gradual transition
Cgv (Cg)	-140 cm	light yellowish brown (10 YR 6/4), weakly mottled, singular, slightly loose, fS
Ctgv (Ctg)	-180 cm	light yellowish brown (10 YR 6/4), weakly mottled, loose, singular, fS, brownish clay pans (1-3 mm thick)

No	hor.	depth cm	sto. %	texture in % of humus-/carb. free fine soil: sand c	sand m	sand f	sand Σ	silt c	silt m	silt f	silt Σ	clay	kf cm/d
1	Ah	0- 4	0	0.1	10,8	82,4	93,3	-	-	-	4.5	2.2	370
2	Bv	- 7	0	0	12.8	84.7	97.5	-	-	-	0.5	1.9	
3	fOh	- 8	0	0	9.9	79.7	89.6	-	-	-	8.2	2.1	
4	Aeh	- 14	0	0	9.8	85.0	94.8	-	-	-	1.0	4.1	200
5	Bsv	- 26	0	0	10.1	85.6	95.7	-	-	-	1.2	3.0	360
6	Bv	- 40	0	0	9.7	88.0	97.7	-	-	-	0.3	1.9	510
7	BvC	- 60	0	0	7.2	91.2	98.2	-	-	-	0	1.9	390
8	Cgv	-100	0	0	13.3	85.0	98.3	-	-	-	0	1.8	300

No	hor.	bulk dens. g/cm^3	GPV %	water content in % at pF 0.6	1.8	2.5	4.2	pH $CaCl_2$	Fe_d mg/g	Fe_o mg/g	Fe_p mg/g	Fe_o/Fe_d	Mn_o mg/kg	P_a mg/kg
1	Ah	0.80	65	63	39	29	9	3.4	2.1	1.6	1.10	0.76	420	48
2	Bv							3.3	1.1	0.6	0.50	0.54	4	25
3	fOh							3.2						
4	Aeh	1.29	48	44	28	8	7	3.3	1.3	1.0	0.84	0.77	20	32
5	Bsv	1.41	44	43	24	10	4	3.8	1.5	1.3	0.67	0.87	170	82
6	Bv	1.45	44	39	19	6	2	4.2	1.3	1.0	0.43	0.77	30	67
7	BvC	1.50	42	42	19	6	2	4.4	0.7	0.3	0.09	0.43	50	24
8	Cgv	1.55	40	39	24	8	1	4.4	0.6	0.2	0.03	0.33	50	16

No	hor.	$C_{org.}$ mg/g	N_t mg/g	C/N	carbonate mg/g	CEC_p meq/kg	exchang. cations in meq/kg: Ca	K	Mg	Na	H	Al	V %
1	Ah	64	3.20	20	0	192	16.0	0.81	2.80	0.56	160	11.0	10
2	Bv	17	0.42	41	0	67	2.5	0.35	0.41	0.53	54	9.2	6
3	fOh	250	6.90	36	0	500	21.0	2.20	3.30	2.60	439	32.0	6
4	Aeh	21	0.52	40	0	91	2.6	0.29	0.56	0.15	80	7.9	4
5	Bsv	9	0.27	35	0	60	1.3	0.14	0.21	0.13	51	6.7	3
6	Bv	5			0	34	1.1	0.04	0.21	0.20	32	5.3	5
7	BvC	1			0	18	0.9	0.08	0.08	0.03	14	3.2	6
8	Cgv	0			0	13	0.2	0.28	0.08	0.03	12	3.0	5

Spandau Forest II

Location:	32.8 m a.s.l., foot slope, groundwater 1.3-2.3 m below the soil surface
Parent material:	eolian sand over glacial outwash sand
Vegetation:	pine-oak-forest with Pinus silv., Quercus petr. (planted), Tilia cord., Larix spec. and Pinus strob., Calamagrostis can., Vaccinium mart. a.s.o.
Soil type:	Rostbraunerde-Gley (Dystric Gleysol)
Humustype:	moder, mull-like
Site qualities:	very deep root zone, easy root penetrable, dry to moist, poor in nutrients

Profile description:

L (O)	0.6-0.4 cm	brownish oak leaves with many holes and rents covering intact pine leaves and peaces of branches, loose, gradual transition
Ohf (O)	- 0 cm	small peaces of leaves and needles besides 10-30% fine humic substance, loose, gradual transition
Ah (Ah)	- 4 cm	very dark greyish brown (10 YR 3/2), granular, loose, fS, many fine roots, gradual transition
AhC (Ah)	- 10 cm	dark yellowish brown (10 YR 4/3-4), humic patches, loose, granular-singular, fS, many fine roots, abrupt transition
rAeh (Eb)	- 17 cm	dark brown (7.5 YR 4/2), humic patches, bleached sand grains, singular-granular, slightly loose, fS, many fine roots, gradual transition
Bv (Bw)	- 28 cm	dark yellowish brown (10 YR 4/4), humic patches, singular, loose, fS, many fine roots, gradual transition
Go (Bg)	- 39 cm	dark yellowish brown (10 YR 4/6), rust mottles, singular, slightly loose, fS, some roots, wavy boundary
fAhGo (AbB)	- 51 cm	dark yellowish brown (10 YR 4/4), few rust mottles, singular-granular, slightly loose, fS, some roots, gradual transition
Go (Bg)	- 80 cm	yellowish red (5 YR 5/6), some patches are reddish brown (Go1) (10 YR 5/4) and reddish yellow (Go2) (10 YR 7/5), singular, slightly loose, fS, few roots, gradual transition
Gor (Bg)	-165 cm	pale yellow (2.5 Y 7/5), rust mottles, slightly loose, singular, fS, few roots, abrupt transition
fFGor (-)	-170 cm	light live brown (2.5 Y 5/4), some rust mottles, slightly dense, singular, coherent, fS, few roots, abrupt transition
Gr (Br)	-200 cm	light grey (5 Y 7/2), slightly loose, singular, fS

No	hor.	depth cm	sto. %	texture in % of humus-/carb. free fine soil: sand c	sand m	sand f	sand Σ	silt c	silt m	silt f	silt Σ	clay	kf cm/d
1	Ah	0- 4	0	0.1	12.4	82.4	94.9	0.7	0.6	0.3	1.6	3.4	
2	AhC	- 10	0	0.1	12.5	83.2	95.8	0.7	0.4	0.2	1.3	2.8	
3	rAeh	- 17	0	0	12.3	83.7	95.9	0.7	0.4	0.3	1.4	2.5	780
4	Bv	- 28	0	0.1	11.4	85.3	96.8	0.3	0.1	0.1	0.5	2.7	
5	Go	- 39	0	0.2	9.9	87.1	97.2	0.2	0.1	0.1	0.4	2.4	1360
6	fAhGo	- 51	0	0	11.5	85.8	97.3	0.5	0.2	0.2	0.9	1.8	1040
7	Go1	- 80	0	0	11.7	86.3	98.0	0.1	0.1	0.1	0.3	1.6	780
8	Go2	- 80	0	0	9.1	88.8	97.9	0.1	0.1	0.1	0.3	1.7	
9	Gor	-110	0	0.1	13.4	84.6	98.1	0.1	0.1	0.1	0.3	1.6	350

No	hor.	bulk dens. g/cm^3	GPV %	water content in % at pF 0.6	1.8	2.5	4.2	pH $CaCl_2$	Fe_d mg/g	Fe_o mg/g	Fe_p mg/g	Fe_o/Fe_d	Mn_o mg/kg	P_a mg/kg
1	Ah							3.8	1.7	1.1	0.82	0.65	80	79
2	AhC							3.7	1.4	1.0	0.67	0.71	20	77
3	rAeh	1.39	47		23	7	5	3.5	1.3	1.0	0.70	0.77	30	38
4	Bv							3.9	1.6	1.3	0.93	0.81	10	100
5	Go	1.35	48		23	7	5	4.2	3.9	3.6	2.10	0.92	5	26
6	fAhGo	1.32	49		17	6	5	4.2	2.0	1.7	1.10	0.85	4	24
7	Go1	1.47	44		19	7	4	4.3	3.9	3.4	1.10	0.87	3	10
8	Go2							4.4	0.8	0.6	0.43	0.75	2	13
9	Gor	1.48	43		17	9	6	4.3	0.7	0.3	0.29	0.43	2	18

No	hor.	$C_{org.}$ mg/g	N_t mg/g	C/N	carbonate mg/g	CEC_p meq/kg	exchang. cations in meq/kg: Ca	K	Mg	Na	H	Al	V %
1	Ah	47	2.20	21	0	139	17.0	2.90	9.70	0.31	107	2.5	21
2	AhC	16	0.65	25	0	87	1.8	0.59	5.20	0.12	73	6.7	9
3	rAeh	14	0.36	39	0	83	1.1	0.36	0.35	0.09	72	9.0	2
4	Bv	6	0.20	33	0	57	0.3	0.20	0.10	0.06	56	7.0	1
5	Go	6	0.23	28	0	53	0.3	0.18	0.08	0.05	47	5.8	1
6	fAhGo	6			0	48	0.2	0.16	0.07	0.05	43	5.0	1
7	Go1	3			0	36	0.2	0.12	0.05	0.04	32	3.6	1
8	Go2	3			0	37	0.1	0.13	0.05	0.04	30	3.3	1
9	Gor	2			0	34	0.1	0.13	0.05	0.04	30	3.9	1

Spandau Forest III

Location:	32.0 m a.s.l., foot slope, groundwater 0.5-1.5 m below the soil surface, originally approx. 1 m higher
Parent material:	eolian sand over glacial outwash sand
Vegetation:	birch-oak-forest, with Pinus silv., Quercus petr., Picea abies and Prunus serot., besides Alnus glut., Molinia coerul., Lysimachia thyrsifl., Vaccinium myrt. a.s.o.
Soil type:	Podsol-Gley called "wet-Podzol" (Humic Gleysol)
Humustype:	peat
Site qualities:	deep root zone, groundwater supply, the upper part well aerated, the lower part sometimes lacking air, poor in nutrients

Profile description:

L (O)	22- 21 cm	brownish leaves with many holes, lying in layers with 1/4 intact brown needle leaves and branches
Hf (H)	- 17 cm	small pieces of leaves and branches, sticked together, 10-↓30% fine humic substance, loose, many fine roots
Hh (H)	- 0 cm	strongly humified peat, that is compact and mixed with sand, breakable in sharp edged pieces, some roots, abrupt transition
AeGr (E)	- 24 cm	dark grey (7.5 YR 4/1), singular, slightly loose, fS, some roots, gradual transition
AhGr (Br)	- 79 cm	dark brown (7.5 YR 3/3), humic coated grains, slightly loose, fS, medium rooted, gradual transition
fAhGr (Br)	-114 cm	dark brown (7.5 YR 4/3), humic coated grains, singular, slightly loose, fS, some roots, gradual transition
Ghr (Br)	-149 cm	dark brown - brown (7.5 YR 5-4/3), weakly mottled, singular, slightly loose, fS, few roots

No	hor.	depth cm	sto. %	texture in % of humus-/carb. free fine soil: sand c	sand m	sand f	sand Σ	silt c	silt m	silt f	silt Σ	clay	kf cm/d
1	Hf	21- 17	0										60
2	Hh	17- 0	0	2.1	13.2	77.7	93.0	1.7	1.7	0.8	4.2	2.8	
3	AeGr	0- 24	0	0.1	10.5	86.5	97.1	0.9	0.3	0.2	1.4	1.5	326
4	BhGr	- 34	0	0	10.7	86.7	97.4	0.3	0.2	0.2	0.7	1.9	121
5		- 79	0	0	10.5	86.3	96.8	0.3	0.2	0.2	0.7	2.5	
6	fAhGr	-114	0	0.1	9.1	87.0	96.2	0.3	0.3	0.2	0.8	3.1	118
7	Gr	-149	0	0.1	6.7	90.5	97.3	0.2	0.1	1.0	0.4	2.4	

No	hor.	bulk dens. g/cm^3	GPV %	water content in % at pF 0.6	1.8	2.5	4.2	pH $CaCl_2$	Fe_d (mg/g)	Fe_o (mg/g)	Fe_p (mg/g)	Fe_o/Fe_d	Mn_o (mg/kg)	P_a (mg/kg)
1	Hf	0.25						3.5	2.20	1.40	0.97	0.64	260	130
2	Hh							2.8	1.30	0.91	0.75	0.70	80	38
3	AeGr	1.41	45		21	8	7	3.0	0.07	0.07	0.05	1.00	5	5.9
4	BhGr	1.28	49		21	12	11	3.1	0.11	0.06	0.10	0.54	6	61
5								3.5	0.09	0.05	0.09	0.55	2	180
6	fAhGr	1.31	49		33	19	12	3.8	0.09	0.02	0.09	0.22	5	170
7	Gr							4.2	0.04	0.02	0.04	0.50	2	38

No	hor.	$C_{org.}$ (mg/g)	N_t (mg/g)	C/N	carbonate mg/g	CEC_p meq/kg	exchang. cations in meq/kg: Ca	K	Mg	Na	H	Al	V %
1	Hf	230	3.80	60	0	725	77.0	13.00	14.00	1.20	613	6.7	14
2	Hh	200	5.10	39	0	875	41.0	1.50	1.90	0.52	815	15.0	5
3	AeGr	15	0.37	41	0	78	2.6	0.19	0.27	0.83	70	4.1	5
4	AhGr	25	0.79	32	0	113	2.8	0.16	0.47	1.00	97	12.0	4
5		18	0.47	38	0	139	1.0	0.13	0.25	0.90	123	14.0	2
6	fAhGr	18	0.40	45	0	161	2.3	0.13	0.35	3.10	143	12.0	4
7	Gr	7	0.22	31	0	44	5.5	0.19	1.20	3.00	28	5.6	16

Spandau Forest IV

Location:	31.8 m a.s.l., depression, groundwater 0-1 m below the soil surface
Parent material:	eolian sand over muddy lake sediment
Vegetation:	birch rich alder moor; today planted with pine trees, besides Betula pendula, Betula pubes., Alnus glut., Sorbus aucup., Frangula aln., Lysimachia thyrsifl., Rubus fruct., Molinia caer., Avenella flex. a.s.o.
Soil type:	Hochmoor-oligotrophic forest bog (Dystric Histosol/ Humic Gleysol)
Humustype:	peat (forest peat)
Site qualities:	shallow root zone, wet, poorly aerated, poor in nutrients

Profile description:

L/Hf (O/H)	35- 34 cm	leaves with many holes over grass litter and wood pieces over strongly choped and mated litter with 10-↓30% fine humic substance, abundant fine roots
Hfh (H)	- 0 cm	black-very dark brown, medium humified peat (H 5-7), some wood- and root remainders, many roots, sharp transition
HGr (HBr)	- 2 cm	very dark grey (7.5 YR 3/1), loose, singular, fS, few roots, gradual transition
Grh (Br)	- 62 cm	black (7.5 YR 1/1), slightly loose, singular-humus coated grains, fS, some fine roots, gradual transition
Ghr (Br)	-106 cm	very dark brown (7.5 YR 2/2), few rust mottles, slightly loose, singular-humus coated grains, fS, few roots
fF (-)	-126 cm	dark brown (7.5 YR 3/2), sL, few rust mottles, slightly dense, singular-coherent

No	hor.	depth cm	sto. %	texture in % of humus-/carb. free fine soil: sand c	sand m	sand f	sand Σ	silt c	silt m	silt f	silt Σ	clay	kf cm/d
1	Hfh	34- 0	0										58
2	HGr	0- 2	0	3.9	11.5	82.2	97.6	0.6	0.4	0.2	1.2	1.3	
3	Grh	- 36	0	0.1	11.2	84.6	95.9	0.7	0.8	0.8	2.3	1.8	33
4		- 62	0	0.5	9.9	85.6	96.0	1.0	0.7	0.4	2.1	1.9	
5	Ghr	- 73	0	0.1	8.8	87.9	96.7	0.5	0.2	0.2	0.9	2.3	23
6		-106	0										
7	fF	-126	0	0	16.7	37.3	54.0	14.5	7.6	4.1	26.2	19.7	

No	hor.	bulk dens. g/cm³	GPV %	water content in % at pF 0.6	1.8	2.5	4.2	pH $CaCl_2$	Fe_d mg/g	Fe_o mg/g	Fe_p mg/g	Fe_o/Fe_d	Mn_o mg/kg	P_a mg/kg
1	Hfh	0.25	83		66	56	51	2.9	1.40	1.40	1.16	1.00	7	40.0
2	HGr							2.9	0.40	0.33	0.22	0.82	8	7.1
3	Grh	1.08	56		50	38	17	3.3	0.10	0.09	0.10	0.90	3	5.9
4								3.5	0.09	0.06	0.09	0.67	4	17.0
5	Ghr	1.43	45		38	19	11	3.6	0.07	0.05	0.07	0.71	2	41.0
6								3.7	0.07	0.05	0.07	0.71	4	63.0
7	fF								0.21	0.24	0.16	1.14	23	

No	hor.	$C_{org.}$ mg/g	N_t mg/g	C/N	carbonate mg/g	CEC_p meq/kg	exchang. cations in meq/kg: Ca	K	Mg	Na	H	Al	V %
1	Hfh	370	14.00	26	0	2330	97.0	11.00	12.0	7.30	2200	24.0	6
2	HGr	100	2.00	50	0	150	2.4	0.24	2.0	0.42	138	6.7	3
3	Grh	49	0.84	58	0	273	2.0	0.13	1.5	0.47	263	6.3	2
4		60	1.30	46	0	176	2.1	0.08	3.6	0.47	160	9.7	3
5	Ghr	21	0.36	58	0	104	5.9	0.13	2.5	0.19	88	7.4	8
6		20			0	157	4.9	0.14	2.3	0.19	140	9.5	5
7	fF	31			0		37.0	0.49	19.0	1.80		69.0	

Explanation of the catena in the Spandau Forest

Landscape history: During the late Weichselian sedimentation of fluvioglacial outwash sands, formation of depressions as part of the Teufelssee-melting water channel or the relictic ice formed; during the latest period of glaciation, dunes were formed; afterwards, the depressions were silted up with a fine sandy mud and accumulation of sediments of Laacher sea-pyroclastics dating to the Alleröd time. With ascending groundwater during the holocene, bogs formed in the lakes and the edges were covered several times with eroded sand: Since the middle age, management of forest and strong disturbance of the top soils; planting of pine trees in 19./20. century; since the beginning of the 20. century, groundwater level decreased by 0.5-1 m by use through Water Company of Spandau, resulting in a drop of the bog surface by 0.5 m.

Soil association (Fig. 32 and 33): From the top of the dune to the depression Rostbraunerde, gleyed and Gley-Rostbraunerde, Rostbraunerde-Gley, Podsol-Gley and Moor are found. All soils have low pH-values and have developed from fine sandy parent materials or peat.

Soil development: In the dune area quick acidification and leaching of bases as well as browning of the upper 40-60 cm and translocation of clay into thin clay pans in the subsoil occur; the podzolisation began during subatlanticum period (probably because of pine trees or heath influences). In the present time, acid rains might have an influence on the podzolisation of the soil as well. Under these soil forming processes, only Rostbraunerde was developed, rarely Podsol-Braunerde. In the Rostbraunerde, mainly Al and Mn are translocated whereas Fe is scarcely leached. According to NEUMANN (1976), the Bh-horizon of the Podsol-Gley is relictic. It was formed at a time where the groundwater was deeper than in the present time. In the middle ages, due to the construction of dams and locks in the Havel, the groundwater rose again, forming the Go-horizon of the Rostbraunerde-Gley. It is also possible that the Go- and Gr-horizons were formed syngeneticaly. Due to the high groundwater level in spring time, the Go-horizon could be formed in the capillary range of groundwater and the Grh-horizon of the Podsol-Gley might be due to translocation of humic substance with the groundwater from the peat. The Fe of the Go-horizon might originate from the bog (that today is very poor in Fe) and to a smaller amount from the Rostbraunerde on the dune.

Site qualities: Dune sand and glacial outwash sands are poor in medium pores (0.2-10 μm Ø), therefore, they have a small available water capacity. But the high amount of pores with a diameter of 10-60 μm which drain slowly after rainfalls, increasing the plant water supply. The vegetation of soils on the lower part of the catena are able to reach groundwater. The groundwater can rise with

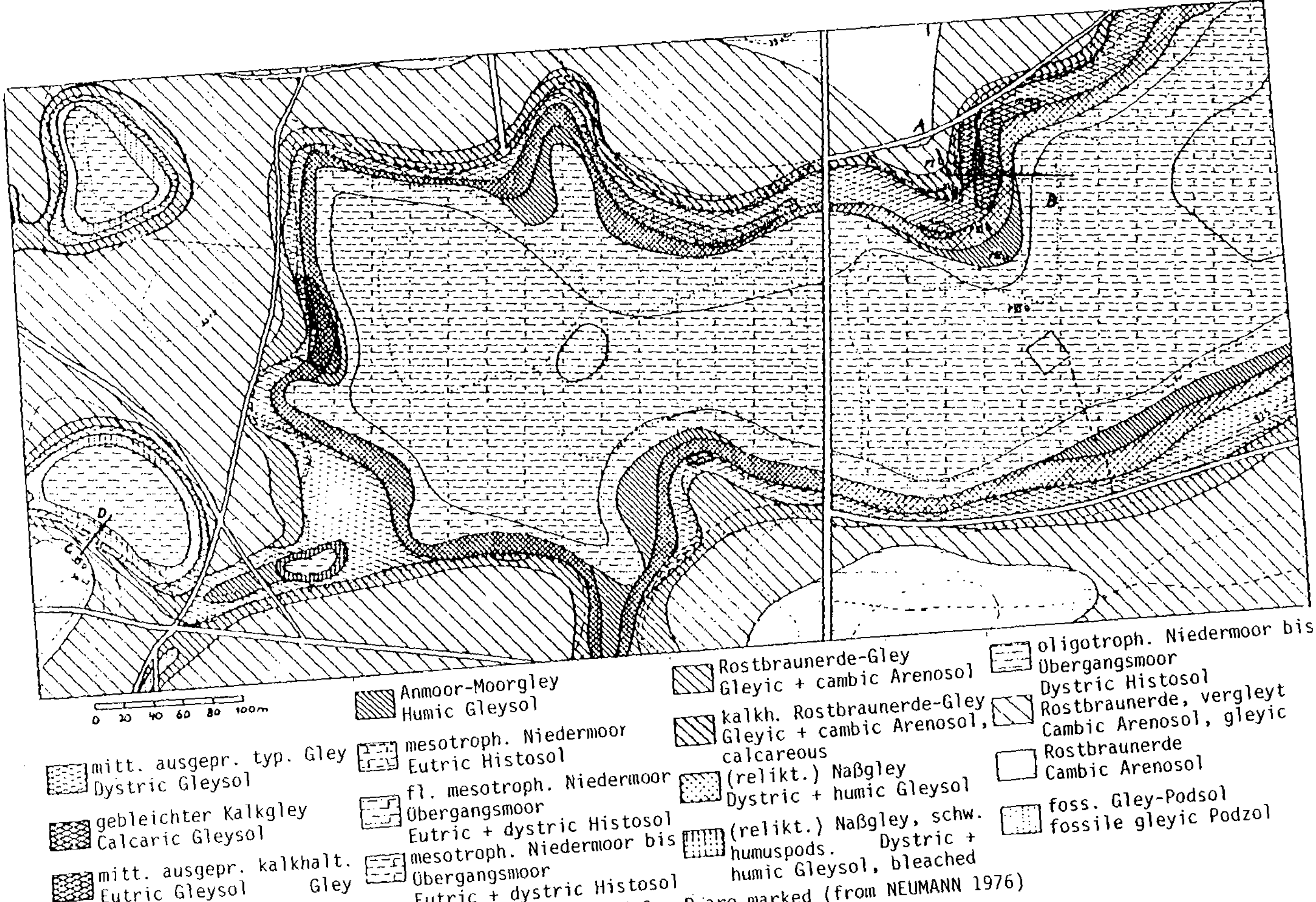


Fig.32 : Soil map of Teufelsbruch, transects A - B and C - D are marked (from NEUMANN 1976)

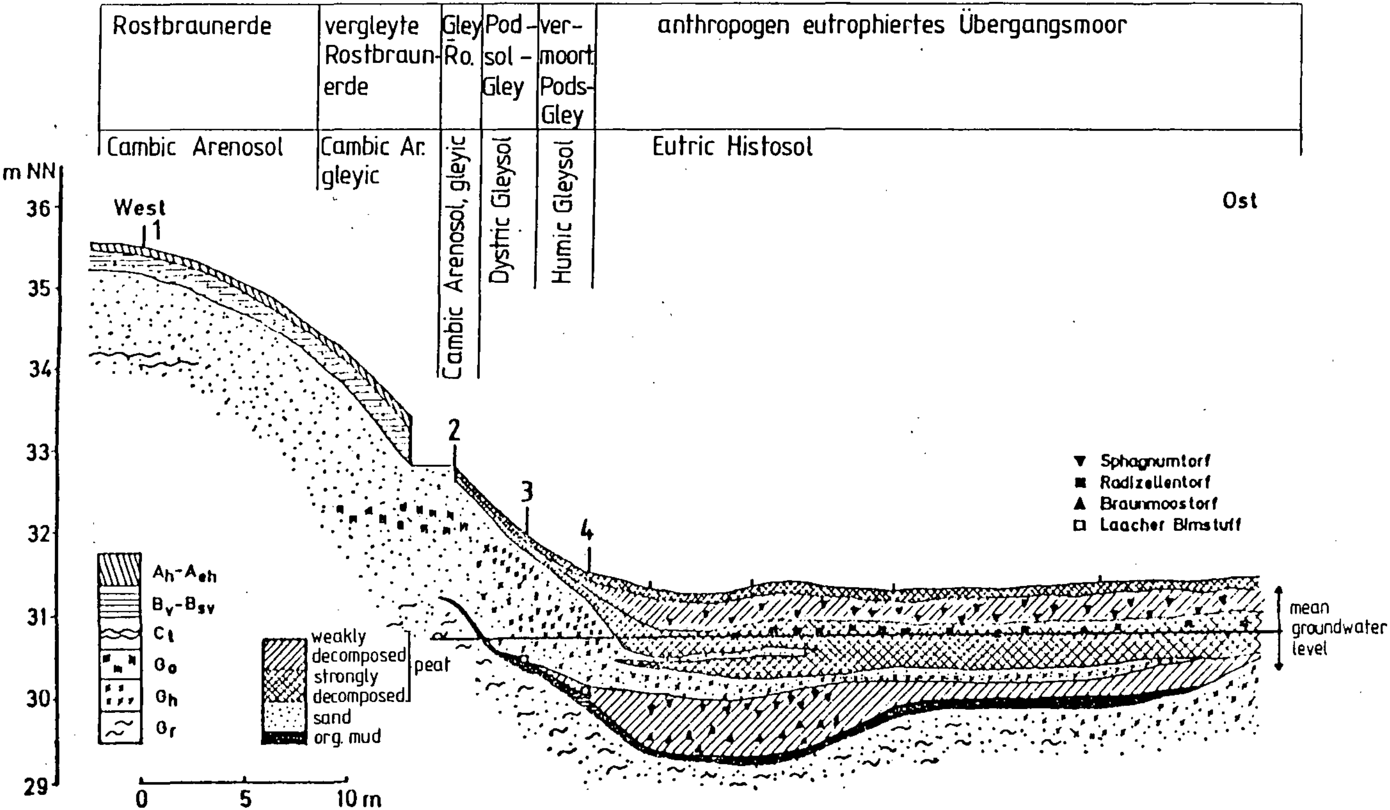


Fig. 33 Cross section through the soilscape of Spandau forest (location is marked in the map). (from ALAILY, BRANDE & NEUMANN 1980)

a rate of 0.5 mm/day for 100-130 cm in the capillar pores (at a water tension gradient of 600 mbar). This is almost enough to cover the water demands of certain plants. In the last decades the groundwater level decreased by about 0.5-1 m due to the pumping of the Water Company of Spandau. Only in the depressions, the groundwater level is high and the soil there is poorly aerated.

The eolian and fluvialglacial sands (Flug- und Talsand) are poor in plant nutrients. Through soil development the content of P has decreased. The available amounts of nutrients are generally low. The relative low C/N ratios of the top soil might be due to nitrogen input from the atmosphere.

4.2 The Havel mires derived from alluvial river sediments - The Kleine Steinlanke

Between Spandau and Potsdam, the Havel passes through a channel formed by melting water, which stretches in a north-south direction between the Nauener and Teltower moraine plateaus (Fig. 5, chapt. 2.2). Within the excursion area, this channel extends to the Wannsee with the Pfaueninsel and other small islands.

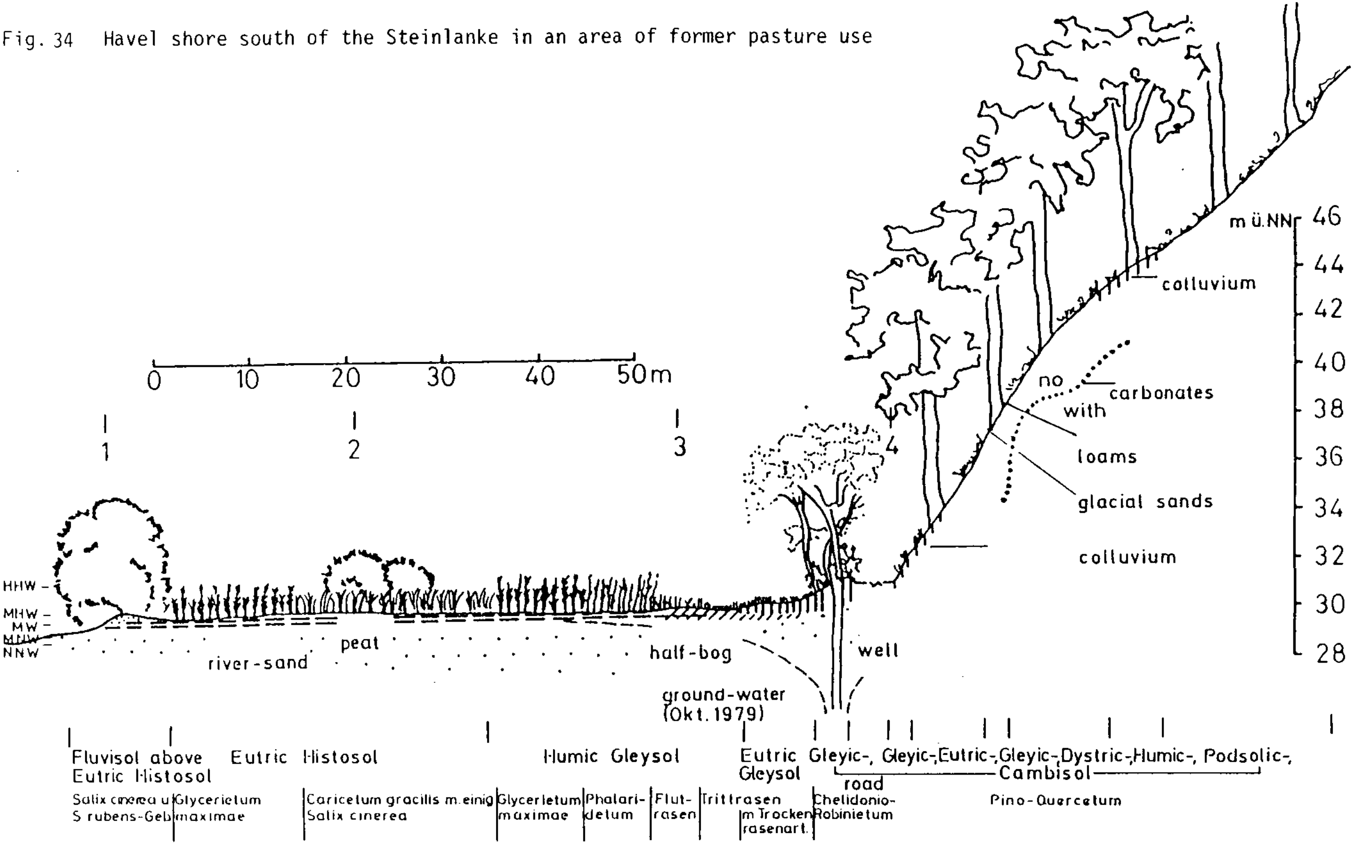
The Havel valley comprises of two levels: the late glacial valley sands and the holocene valley bottom. The latter is primarily built up of sandy sediments partially non-calcareous (e.g. Steinlanke), partially calcareous (e.g. parts of the Pfaueninsel). The small degree of slope and the enlargement to a riverlake result in a low flow velocity of the Havel (4-5 cm/sec. at high water, 0.3 cm/sec. at low water). The yearly variations of the water level are 1 m (with exceptions of 2 m), with peak levels in spring and lowest levels in autumn.

The Havel as a waterway is an important connection to West Germany. It is intensively used for swimming and aquatic sports, but also as a drain for waste water coming from sewage treatment plants and uncontrolled inflow of sewage water, such that the river is strongly eutrophicated. To a large extent, the shores of the Havel are part of water and landscape conservation areas, because well for drinking water are located there. Some islands, e.g. the Pfaueninsel, have been declared nature preserves in order to protect the unique landscapes.

Gleysol-soil association of the "Kleine Steinlanke": The association is located along the eastern shore of the Havel (here widened to a lake), near the Kleine Steinlanke, i.e. to the south of Lindwerder and below the Grunewald-escarpment (see Fig.29). Fig. 34 shows the landscape, which has been greatly altered by human influence. Typical components of this association are shown, as well as changes on account of the winning of drinking water and erosion due to the overuse for leisure purposes.

<u>The vegetation of the Havel shores:</u> An outline of the lake alluvial forest in the Grunewald is shown in Fig. 34. A thin strip of yellow water lilies (Nuphar luteum) grows in front of the reed bank. The reed bank, which formerly extended out to a water depth of 110-120 cm, is composed of pure stands of reed grass (Phragmites communis) on sandy soil. The reed banks nearest to shore, where organic deposits darken the soil (gyttja), are much richer in species than the stands in deeper water. The most frequent reed-accompanying plants are great water dock (Rumex hydrolapathum) and marsh woundwort (Stachys palustris). On the small earth bank with a paternia (Fluvisol), which is characterized by a constant

Fig. 34 Havel shore south of the Steinlanke in an area of former pasture use



change of soil formation and sedimentation, woody vegetation with shrub willows begins, dominated by common oiser, almond willow and common shallow (Salix viminalis, S. triandra, and S. cinerea) as well as tree willows (in particular Salix rubens). On the water side the willows are frequently covered by a thick veil of great bindweed (Convolvulus sepium). Under the protection of the sandy embankment, shallow low moors formed, favoured by mill dams from the Middle Ages (profile II in Fig. 34). The natural vegetation of this zone is composed of an alder marsh within the flood zone and the soil is covered by a great deal of drift material. A loose herbaceous layer grows beneath the dominant common alders (Alnus glutinosa), while shrubs and moss are almost totally absent. On the landside, sandy moors (profile III in Fig. 34) and gleys are followed by an alluvial forest composed of small-leaved elm (Ulmus laevis), common alder (Alnurs glutinosa) and black cherry (Prunus padus). The lower slope of the Grunewald moraines is comprised of acidic, colluvial, gley-brown earth (profile IV in Fig. 34).

These shores have been subject to multiple changes. At first, forest stands were felled in order to gain pastures. After clearing, reed glyceria (Glyceria maxima), green reedgrass (Phalaris arundinacea) and slender tufted sedge (Carex gracilis) grew on the foreland. Reed glyceria and green reedgrass produce high yields. In general, the use as pastureland has been abandoned as a result of bathing activity and frequent pedestrain traffic. At heavily used bathing sites, flood grass and trample grass as well as cockleburr-riverbank-vegetation has replaced the pasture societies (Fig. 34; SUKOPP & KUNICK 1969).

Under natural conditions, the Berlin Havel shores were fringed by a 10-100 m wide reed bank of Scirpo-Phragmitetum, composed mainly of reed grass (Phragmites australis) and lesser reed-mace (Typha angustifolia). The bulrush (Scirpus lacustris), great reed-mace (Typha latifolia), sweet sedge (Acorus calamus) cover only small areas.

Of 93 km of shoreline studied in 1962, 37.4 km of 40% were still reed stands. In 1982, reed vegetation was only observed on 12.9% of the Havel shoreline. This corresponds to a reduction in the longitudinal of reed vegetation of 68% in 20 years or a yearly reduction of 1280 m. The greatest reduction was from 1967 to 1972, after which the rate of reduction decreased somewhat.

The reduction of vegetation is the result of a combination of diverse factors. For the most part, however, mechanical strain and changes in the water and sediment quality are responsible. The effects of uncontrolled bathing activity in the early years after the war were probably responsible for the greatest destruction of shore vegetation in connection with mechanical strain. In 1977 there were three public beaches, 13 protected bathing areas, and numerous so called wild bathing areas. The use-rate of the wild bathing areas is in part higher than that of the public beaches, i.e. more than 10 bathers per meter of shoreline. If reed stalks are bent by bathers or boats, their air tissue can fill up with water. This limits the oxygen supply to the underground parts of the plant. Submerged and bent stalks can no longer assimilate and begin to decay.

Among the factors that were of increasing importance during the observation period, ship and boat traffic are of major significance. Damage is caused by driving to the shore and by wave movement due to motor-driven boats. The number of sport and motorboats was estimated to be 40 000 in 1978, of which 20 000 were motorboats. Accordingly, each boat on the Havel has 23 x 23 m of water surface at its disposal (KLOOS 1978). Of particular importance are ships which displace large amounts of water, such as the numerous freight and passenger ships travelling on the Havel (1978 approx. 13 000 freighters and 50 passenger ships). Until 1976, there was the additional influence of ammunition recovery ships. The construction of sheet piles, pitched slopes, landing stages and the like along large segments of the Havel shore intensifies the destructive effects of waves on the shore vegetation by causing whirlpool formation. Other factors that should be mentioned are the depositing of drift material and feeding damage due to water birds, water vole and, in particular, muskrat (Ondrata zibethica).

A further factor in the reduction of reed vegetation is the increasing concentration of nutrients in the Havel. The increased abundance of trichothallic algae (for the most part Cladophora species) shows distinct parallels to the nutrient content of the water. Especially in the Phragmites stands in Tegel Lake, algae flats which extent to the bottom can be observed. Reed stalks on the fringe and smaller stalks are bent and sometimes dragged into the water by the weight of the algae.

Besides this mechanical destruction, direct effects of eutrophication on the reed plants can be determined: Studies of the sclerenchyma ring thickness of various Phragmites stands and numerous biometric analyses of Typha angustipholia on the Havel have indicated a dependence on nutrient content. Cross-sections from the middle of the third internode of reed stalks from the northern Upper Havel, Lower Havel and Tegel lake were prepared and used to determine the thickness of the outer sclerenchyma ring (the other supporting tissue is, in comparison, less significant; SUKOPP et al. 1975). There was a distinction between Tegel Lake and the rest of the Havel. The average sclerenchyma ring thickness for Tegel Lake was 66.6 m, for the rest of the Havel 94.2 m, i.e. the values for the Lower Havel and northern Upper Havel were 41.5% higher than those of Tegel Lake (=100%).

Steinlanke I

Location:	30 m above sea level, sand barrier, groundwater level 0 - 100 cm under soil surface
Parent material:	Fluviatile sand
Vegetation:	Salix cineria and Salix rubens, the willows are frequently covered by a thick veil of great bind weed (Convolvulus sepinum)
Soil type:	Gley Rambla über Niedermoor (Fluvisol over partly eroded Eutric Histosol)
Site valuation:	wet, temporarily poorly aerated, rich in nutrients due to the influence of eutrophic river water and groundwater

Profile description:

L (O)	0.3- 0 cm	drift material (reed, wood)
A(h) (A)	- 4 cm	light brownish grey (10 YR 6/2) moderately loose, singular, medium sand, shell couches, strongly rooted
CG (C)	- 16 cm	light brownish grey (10 YR 6/2) rust mottles, moderately loose, singular, medium sand, shell couches, Eh = + 215 mV, strongly rooted
fHh (H)	- 22 cm	black (;0 YR 2/1), loose, strongly humificated, weakly calcareous, moderately rooted
HGr (Cr)	- 43 cm	dark brown (10 YR 4/3), loose, medium-fine sand, weakly calcareous, singular, weakly rooted
Gr (Cr)	- 80 cm	greyic brown (10 YR 5/2), moderately compacted, singular, medium fine sand, weakly rooted, Eh = + 135 mV

No	hor.	depth cm	sto. %	texture in % of humus-/carb. free fine soil: sand c	sand m	sand f	sand Σ	silt c	silt m	silt f	silt Σ	clay	kf cm/d
1	A(h)	0- 4	0	1	81	16	98	-	-	-	1	1	
2	CG	-16	0	1	91	6	98	-	-	-	1	1	1500
3	fHh	-22	0	-	-	-	-	-	-	-	-	-	28
4	fHh	-35	0	-	-	-	-	-	-	-	-	-	
5	HGr	-43	1.1	2	44	51	97	-	-	-	1	2	530
6	Gr1	-61	0	2	44	51	97	-	-	-	1	2	1000
7	Gr2	-80	0	2	44	51	97	-	-	-	1	2	

No	hor.	bulk dens. g/cm^3	GPV %	water content in % at pF 0.6	1.8	2.5	4.2	pH $CaCl_2$	pH H_2O	Fe_d mg/g	Fe_o mg/g	Fe_o/Fe_d	Mn_o mg/kg	P_a mg/kg
1	A(h)	-	39		9	5	2	6.7	7.0	0.143	0.15	1.05	35	60
2	CG	1.62	38		9	5	2	7.0	7.7	0.167	0.13	0.78	7	32
3	fHh	0.37	84		77	50	35	6.5	6.3	1.37	0.97	0.71	110	28
4	fHh							5.9	5.7	1.86	2.20	1.18	240	88
5	HGr	1.46	45		15	9	3	6.5	6.7	0.333	0.25	0.75	25	140
6	Gr1	1.59	40		10	6	2	6.7	6.6	0.119	0.09	0.76	8	36
7	Gr2							6.9	6.5	0.143	0.05	0.35	4	60

No	hor.	$C_{org.}$ mg/g	N_t mg/g	C/N	carbonate mg/g	CEC_p meq/kg	exchang. cations in meq/kg: Ca	K	Mg	Na	H	Al	V %
1	A(h)	6.3	0.48	13	1.6	29.9	21.8	0.70	0.72	0.65	6	-	79.9
2	CG	3.6	0.28	13	3.3	41.4	40.1	0.17	0.57	0.58	0	-	100
3	fHh	45.0	3.00	15	13.0	264.4	206.7	0.76	6.83	3.13	47	-	82.2
4	fHh	110.0	12.00	9	65.0	306.1	209.2	0.95	7.62	3.37	85	-	72.2
5	HGr	17.0	1.00	17	2.6	80.8	64.1	0.24	1.55	0.94	14	-	82.7
6	Gr1	5.7	0.46	13	0.5	25.9	16.2	0.22	0.77	0.71	8	-	69.1
7	Gr2	1.1	0.08	14	1.2	28.0	19.1	0.14	0.84	0.43	7.5	-	73.2

Steinlanke II

Location:	29.7 m above sea level, small depression, groundwater level 30 cm above and 70 cm under soil surface
Parent material:	Fluviatile sand
Vegetation:	Caricetum gracilis with Salix cineria
Soil type:	Niedermoor (Eutric Histosol)
Humusform:	Carex peat
Site valuation:	wet, poorly aerated, rich in nutrients due to the influence of eutrophic river water (particularily P, N, Ca) and groundwater

Profile description:

L (O)	30- 28 cm	brown leaves, wood
Hf (H)	- 28 cm	brown leaves, black, greasy fine humus in loose foliation
Hfh (H)	- 12 cm	brownish black (7.5 YR 2/1) 70-90% humate besides rudimentary litter, H 5-7, medium rooted, Eh = + 520 mV, charcoal, gradual transition
Hhf (H)	- 0 cm	black-brown (7.5 YR 2/2), fine humus besides roots, loose
Grh (Cr)	- 21 cm	grey (10 YR 5/1), moderately loose, singular, fine-medium sand, some pieces of bricks, intensively rooted, gradual transition
Gr (Cr)	- 42 cm	grey (10 YR 5/1), moderately compact, singular, fine medium sand, strongly rooted

No	hor.	depth cm	sto. %	texture in % of humus-/carb. free fine soil									kf cm/d
				sand				silt				clay	
				c	m	f	Σ	c	m	f	Σ		
1	Hfh	28-12	0	-	-	-	-	-	-	-	-	-	70
2	Hhf	12- 0	0	-	-	-	-	-	-	-	-	-	-
3	Grh	0-21	0	1	57	40	98	-	-	-	1	1	400
4	Gr	21-42	0	1	67	30	98	-	-	-	1	1	590

No	hor.	bulk dens. g/cm^3	GPV %	water content in % at pF				pH		Fe_d	Fe_o	Fe_o/Fe_d	Mn_o	P_a
				0.6	1.8	2.5	4.2	$CaCl_2$	H_2O	mg/g			mg/kg	
1	Hfh	0.17	90		73	58	33	5.7	5.2	5.16	5.3	1.03	560	140
2	Hhf	-	90		73	58	33	5.6	5.4	8.29	7.6	0.92	517	88
3	Grh	0.84	80		42	35	5	6.4	6.3	0.202	0.11	0.54	< 2	24
4	Gr	1.47	43		26	12	2	7.2	8.0	0.143	0.10	0.70	< 2	36

No	hor.	$C_{org.}$	N_t	C/N	carbonate mg/g	CEC_p meq/kg	exchang. cations in meq/kg						V %
		mg/g					Ca	K	Mg	Na	H	Al	
1	Hfh	160	16	10	0	431.7	280.8	2.8	19.9	6.15	122	-	71.7
2	Hhf	220	20	11	0	630.0	438.8	2.37	29.0	9.80	150	-	76.2
3	Grh	10	0.65	15	0.7	27.9	19.6	0.14	1.37	0.80	6	-	28.5
4	Gr	1.3	0.04	32	5.0	49.4	47.9	0.09	1.01	0.40	0	-	100

Steinlanke III

Location:	30 m above sea level, groundwater level 0-100 cm under soil surface, the groundwater level sunk by 50-100 cm due to the pumping activities of the water company
Parent material:	Fluvial sand (Flußsand)
Vegetation:	Agropyrum junceum, Rumicion and Phalaridetum
Soil type:	Anmoor-Gley (Humic Gleysol)
Humusform:	peat (Anmoor)
Site valuation:	Due to pumping activities temporarily fresh to dry (without pumping = wet). Top soil moderately aerated, poor aeration in greater depths, without influence of groundwater and river water poor in nutrients.

Profile description:

L (0)	2- 0 cm	grass-sod, sharp transition
HA (Ah)	- 10 cm	dark greyish brown (7.5 YR 3/1), some rust mottles, cloddy, loose, fine medium sand (some pieces of bricks), gradual transition
Ah (Ah)	- 20 cm	dark greyish brown (7.5 YR 6/2), rust mottles, fine medium sand, intensively rooted, gradual transition
G(o)r (Cr)	- 50 cm	pinkgrey (7.5 YR 7/3), rust mottles in root canals (7.5 YR 5/8), moderately loose, singular, x coarse sand/fine medium sand, moderately rooted, Eh = + 520 mV
Gr (Cr)	- 62 cm	pinkgrey (7.5 YR 7/3), some rust mottles, singular, moderately compact, moderately rooted

No	hor.	depth cm	sto. %	texture in % of humus-/carb. free fine soil: sand c	sand m	sand f	sand Σ	silt c	silt m	silt f	silt Σ	clay	kf cm/d
1	HA	0- 10	2.2	6	56	36	98	-	-	-	1	1	1600
2	Ah	- 20	2.8	6	56	36	98	-	-	-	1	1	540
3	G(o)r	- 50	3.6	7	55	36	98	-	-	-	1	1	-
4	Gr	- 62	6.0	7	61	29	97	-	-	-	2	1	-
5	IIGr	- 80	0.2	< 1	80	16	96	-	-	-	2	2	720
6	IIIGr	-100	0.1	1	20	75	96	-	-	-	2	2	-

No	hor.	bulk dens. g/cm^3	GPV %	water content in % at pF 0.6	1.8	2.5	4.2	pH $CaCl_2$	pH H_2O	Fe_d mg/g	Fe_o mg/g	Fe_o/Fe_d	Mn_o mg/kg	P_a mg/kg
1	HA	0.63	72		44	40	33	5.5	5.5	2.57	3.6	1.4	212	28
2	Ah	1.58	40		12	7	4	5.6	5.8	1.72	1.5	0.87	136	12
3	G(o)r	-	40		12	7	4	5.9	6.2	0.242	0.1	0.41	5	28
4	Gr	-	-		-	-	-	6.4	7.3	0.231	0.01	0.04	3	52
5	IIGr	1.61	39		7	5	4	6.4	6.7	0.198	0.07	0.35	< 2	60
6	IIIGr	1.64	38		20	9	4	6.5	7.3	0.220	0.10	0.45	< 2	64

No	hor.	$C_{org.}$ mg/g	N_t mg/g	C/N	carbonate mg/g	CEC_p meq/kg	exchang. cations in meq/kg: Ca	K	Mg	Na	H	Al	V %
1	HA	91	7.9	12	0	198.9	181.6	1.91	13.5	1.85	-	-	100
2	Ah	89	7.3	12	0	146.4	134.2	1.06	9.56	1.60	-	-	100
3	G(o)r	2.1	0.13	16	0	9.6	8.5	0.09	0.73	0.29	-	-	100
4	Gr	0.1	-	-	0	9.5	8.5	0.12	0.64	0.18	-	-	100
5	IIGr	0.2	-	-	0	4.1	3.3	0.09	0.45	0.29	-	-	100
6	IIIGr	0.4	-	-	0	12.1	10.8	0.17	0.79	0.36	-	-	100

Steinlanke IV

Location:	31 m above sea level, lower section of a steep west slope, groundwater 1-2 m under soil surfac-
Parent material:	Colluvium above kames sand
Vegetation:	Elm-, pine- and oak-wood
Soil type:	Rostbraunerde over Gley (Dystric Cambisol derived from colluvium above fossile Eutric Gleysol)
Humustype:	Mull
Site evaluation:	deeply rooted, fresh-dry, top soil well aerated, poorly aerated in greater depths, poor moderate in nutrients

Profile description:

L (O)	0.5- 0 cm	brown leaves, wooded material
Ah (Ah)	- 2 cm	dark greyish brown (7.5 YR 4/1), cloddy, bleached sand grains, medium fine sand, loose, intensively rooted, gradual transition
Avh (AB)	- 12 cm	greyish brown (7.5 YR 5-4/1), singular, loose, medium fine sand, loose, intensively rooted, gradual transition
Bv (Bw)	- 36 cm	light brown (7.5 YR 6/4), some rust mottles, singular, medium fine sand, moderately loose and rooted, gradual transition
fAoh (Ahb)	- 55 cm	dark greyish brown (7.5 YR 3/1), small rust mottles, loose, weak loamy sand, moderately rooted
CGo (Bg)	- 83 cm	pinkwhite (7.5 YR 8/2), rust mottles, medium sand, moderately compact, singular, gradual transition
Gol (Bg)	-100 cm	pinkwhite (7.5 YR 8/3), strong rust mottles, coarse medium sand, moderately compact, singular, gradual transition

No	hor.	depth cm	sto. %	texture in % of humus-/carb. free fine soil: sand c	sand m	sand f	sand Σ	silt c	silt m	silt f	silt Σ	clay	kf cm/d
1	Ah	0- 2	1.9	5	44	43	92	-	-	-	5	3	40
2	Avh	- 12											
3	Bv	- 36	2.0	5	44	43	92	-	-	-	5	3	440
4	fAoh	- 55	1.0	8	39	35	82	-	-	-	13	5	530
5	CGo	- 83	4.4	25	61	11	97	-	-	-	2	1	2900
6	Go	-100	35.0	41	43	13	97	-	-	-	2	1	-
7	IIGo	-104	0.2	2	10	86	98	-	-	-	1	1	-
8	Gr	-120	0	1	10	86	97	-	-	-	2	1	500

No	hor.	bulk dens. g/cm^3	GPV %	water content in % at pF 0.6	1.8	2.5	4.2	pH $CaCl_2$	pH H_2O	Fe_d mg/g	Fe_o mg/g	Fe_o/Fe_d	Mn_o mg/kg	P_a mg/kg
1	Ah	1.24	52		30	7	4	4.2	4.7	2.62	1.0	0.38	45	64
2	Avh							3.7	4.2	2.43	1.2	0.49	14	32
3	Bv	1.47	44		11	6	4	4.3	5.1	1.37	0.63	0.46	21	16
4	fAoh	1.32	48		20	11	6	5.7	6.0	1.32	1.30	0.98	3	24
5	CGo	1.60	39		6	3	2	6.2	6.6	0.241	0.06	0.25	< 2	44
6	Go	-	-		-	-	-	6.7	6.9	1.49	0.79	0.53	10	44
7	IIGo	-	-		-	-	-	6.5	-	-	0.95	-	12	88
8	Gr	1.59	40		8	5	2	6.4	6.5	0.242	0.04	0.17	11	80

No	hor.	$C_{org.}$ mg/g	N_t mg/g	C/N	carbonate mg/g	CEC_p meq/kg	exchang. cations in meq/kg: Ca	K	Mg	Na	H	Al	V %
1	Ah	51	4.1	12	0	131.8	47.6	2.51	5.31	0.36	76	2.8	42.3
2	Avh	27	1.7	16	0	58.7	17.7	0.56	2.15	0.29	33	4.78	38.5
3	Bv	4.3	0.27	16	0	44.3	12.9	0.2	1.12	0.07	30	0.95	32.3
4	fAoh	2.2	1.4	16	0	164.6	116.6	0.15	5.45	0.43	42	0.18	74.5
5	CGo	0.8	0.04	20	0	12.2	9.4	0.06	0.78	0	2.0	0.41	83.6
6	Go	0.6	-	-	0	15.0	13.3	0.09	0.49	0.14	< 1.0	-	93.3
7	IIGo	0.3	-	-	0	-	-	-	-	-	-	-	-
8	Gr	0.1	-	-	0	6.8	5.8	0.17	0.57	0.22	0	-	100

Explanations concerning the catena

Landscape history (see Fig. 34 and profile Steinlanke I): Formation of the Havel channel at the boundary between two ice streams of the Weichsel era; formation of the Grunewald hills as arising kames sands; development of an escarpment by fluvial erosion of the edge of the compressed moraines; during the Holocene deposition mainly of medium to coarse fluvial sands with the formation of an embankment towards the river side; especially during the Subatlanticum rise of the Havel's water-level, increased by mill dams and the building of locks during the middle ages, resulting in peat development on the plain protected by the embankment (bricks from the middle ages were found on the bottom of the peat); at the same time erosion through heavy rainfall; construction of a road bank for the Havel road; clearing of the river plains for pastures (horse fodder for the Spandau and Potsdam garnisons); during the 20th century drilling of wells with 30-40 m depth along the Havel road for the gathering of drinking water; after 1950 destruction of the reed belt, caused by munition salvage boats, waves from passenger boats and speed boats, swimmers, furthermore by the chemical and biological effects of the hypertrophicated river water (for instance stalk instability and breaking under the weight of mass-reproducing algae (RAGHI-ATRI 1976); maybe also by musk-rats and aquatic birds), resulting in the rearrangement of the embankment onto the partially eroded bogs; further southwards erosion of the bog up to the bank of the Havel road, followed in 1979 by (temporary!) shore stabilization by deposition of glacial sands (pit material from the construction of the underground) and increasing use for leisure purposes by swimmers.

Water regime: The mean high water level during spring time comes up to 30 m above sea level; that means up to the surface of profile I, II and III. The maximum water levels reach 1 m above that surface. During summer the water level decreases in normal years to 29 m above sea level (1 m below soil surface). Today, the groundwater of the soil profiles III and IV is under the influence of deep wells used to obtain water, resulting in a drop of the groundwater level by 0.5 to 1 m.

Soil association: From sand barrier to the slope derived from kames sand: Calcaric Fluvisol - Eutric Histosol - Humic Gleysol - Cambisol above Gleysol.

Soil development: The low flow velocity of the river water and the groundwater influence led to the formation of Gleysols and Histosols, even though the sediments of the river plain are coarsely grained and have a high permeability. Only on the embankments on the river side sandy Paternias can be found.

The soils have been eutrophicated by nutrient-rich Havel water which has lead, in particular, to an increase in P-, N- and Ca-content in the top soil. The landward soils (profile III and IV)today are under the influence of deep wells. The lowered water table has accelerated the loss of humus and in certain cases led to Gleys with the dynamics of Regosols.
A strong lowering of the pH value has been found only for the Cambisol derived from colluvium (profile IV). As the soil surface is higher than the highest water level of the Havel there is no flooding with nutrient-rich Havel water.

Site characteristics: Soils derived from fluvial sand have small nutrient reserves, but the available amount of nutrients (particularly P, N, Ca) is high due the influence of eutrophic river water and groundwater.

Fluvial sands are poor in medium pores, therefore the soils have a small available water capacity. But the plants are partly able to reach groundwater by capillary rise (profile I and II). The soil profiles III and IV today are under the influence of deep wells used to obtain water. The lowered water table has decreased the capillary rise and accelerated the loss of humus.

The aeration depends on the groundwater level. The soil profiles I and II are mainly poorly aerated. The top soils of the profiles III and IV show a good aeration.

Data have been partly taken from an unpublished manuscript of HOFMANN, I., Kiel.

4.3 Soilscape of the coversand/till plain of Teltow - The Lolopfuhl, a kettle hole at Berlin-Rudow

Development of the coversand/till plains in the late glacial period of Weichselian: The general idea of the development of our landscape during the pleistocene period was already given in chapter 2.2. There are some special features related to the till and coversand areas which should be mentioned here.

The glacial till is mostly covered by cover sand containing periglacial boulders. Within this layer the A- and E-horizons of our holocene soils have developed. The coversand is generally divided into two layers which are separated by a wind-polished stone pavement (KOPP 1969; HOFFMANN 1976).

The youngest boulder clay (marly till) overlies 2-2.5 m thick the older Weichselian fluvioglacial deposits. It is compacted with high bulk densities of more than 1.8 kg/dm^3 and has a laminar structure through compaction and ice lenses. In distances of 5 x 5 m, the boulder clay is intersected by sand wedges, which go down to 1.6 occasionally also 2.0 to 2.5 m from the surface (NEUMANN 1969; GÖTZ 1970). The sand wedges and the contact to the till are completely decalcified. The thin lower end of the wedges is frequently altered by hydromorphism. The sand wedges form a polygonal network of 3 to 8 meters in diameter (Fig. 35).

As a rule, the decalcification is deep in the center of the polygons and decreased towards the wedges. At the wedge the decalcification follows the structure in a distance of two to five decimeters. From the deep decalcification beyond and the shallow beside the wedge it is concluded that seepage is favoured within the wedges (BLUME & HOFFMANN & PACHUR 1979).

The sand wedges have been compared with periglacial ice wedges. The phenomenon is now interpreted mainly as shrinkage cracks in a dry arctic climate according to the observations of BERG & BLACK (1966). This is believed because the cracks have been filled by a well sorted stone free sand. The sand closely related to the dune sands but a bit coarser (diameter about 250 μm). Therefore, it could be transported by saltation and fall into the open cracks. A down melting of ice wedges would have produced a mixing with the till. Structures like this can be observed sometimes but only in the upper part of the sand wedges (Fig. 36).

These features together with the occurence of cryoturbation structures at the top of the hill and in the lower cover sand show us that after the high arctic climatic phase there was a more wet climate. Through the cryoturbation, the eolian sands and the till have been partly mixed, forming the cover sand with

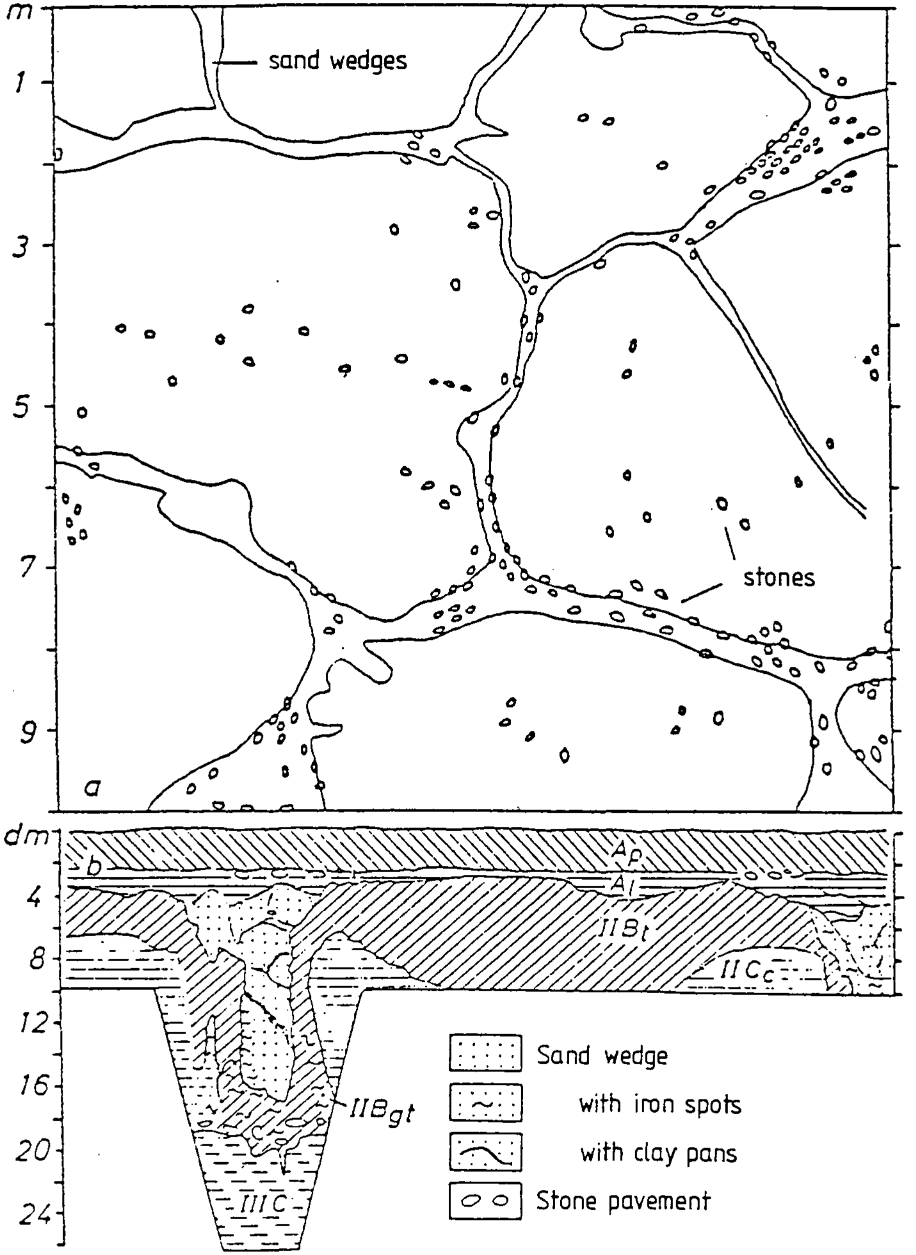
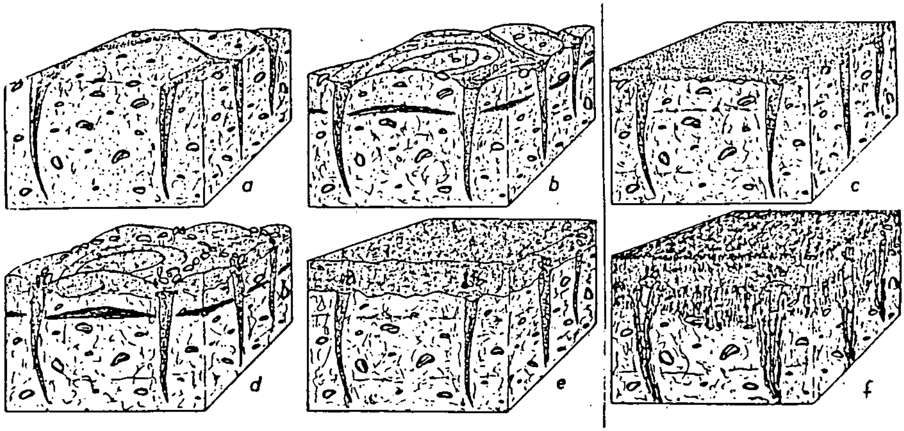


Fig. 35 Map and cross section of sand-wedge polygons on the Teltow plain at Mariendorf. The map was constructed after removing 30 cm of the plough layer (according to BLUME, HOFFMANN & PACHUR 1979)

Fig. 36 Possible periglacial and Holocene drift topography of the Berlin moraines (after BLUME, HOFFMANN & PACHUR 1979)

- (a) Cracking; infill of frost cracks with sands
- (b) Perched ice formation, sealing of the sand wedge network
- (c) Sand sedimentation by wind
- (d) Cryoturbation, stone polygons or circles
- (e) Sedimentation by wind, cryo- and/or bioturbation
- (f) Decalcification, clay migration



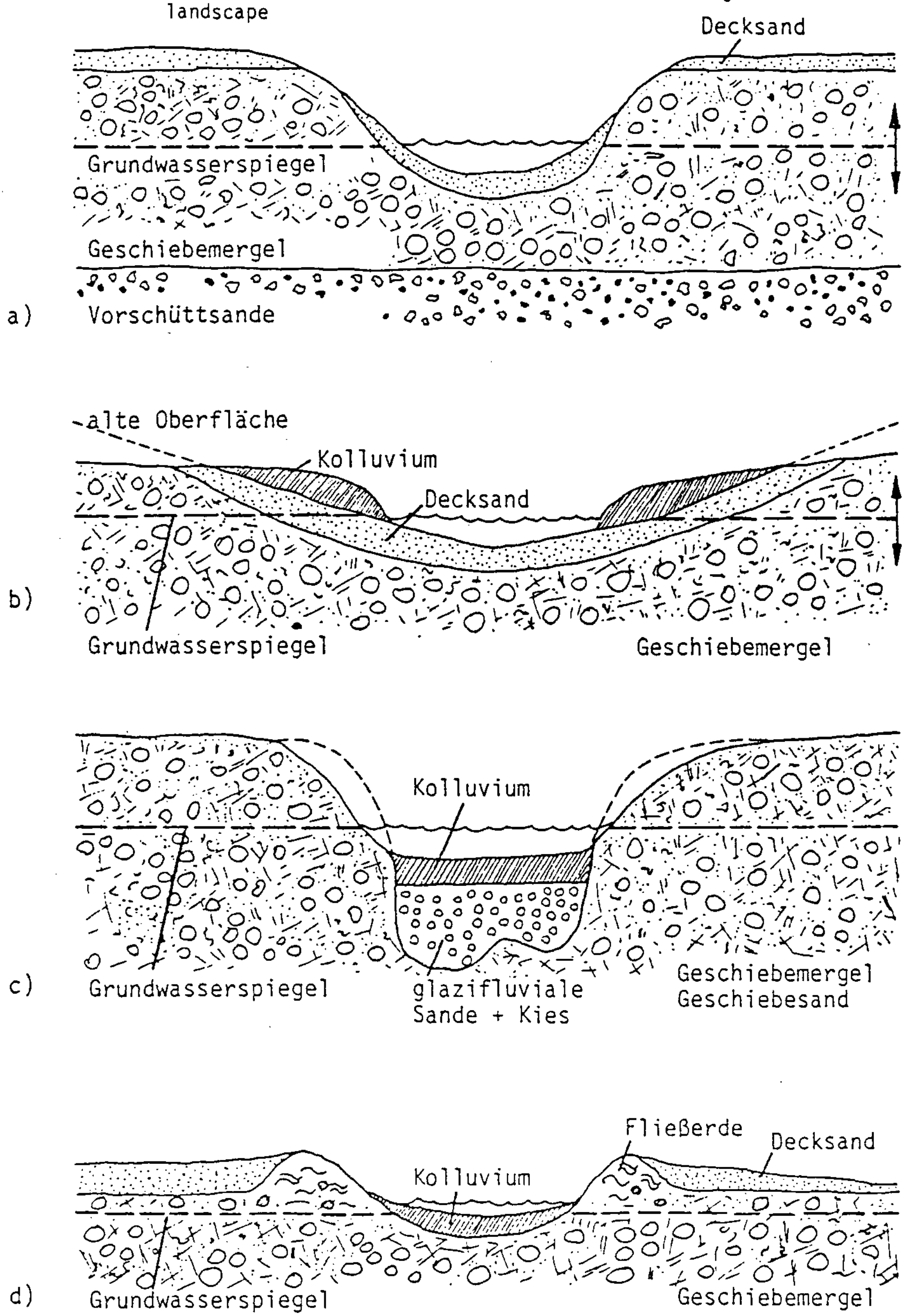
stone heaving and the formation of stone circles above the sand wedge polygons.

The network of stone circles was again overlain by eolian sands which during their formation have produced a wind polished varnish on the surface of the stones. This upper layer was again altered by frost action but later on more by activities of agriculturists.

<u>The kettle holes of Berlin (Pfuhle):</u> Within the moraine plains and also in the glacial valleys a great number of isolated depressions of different size occur (ASSMANN 1957). In the West-Berlin area up to 300 of these kettle holes have been counted. Most of these hollows are only temporarily filled with water ("heaven pools") (FRANZ et al. 1970). After the decrease of the groundwater table in the 19 and 20th century some of the hollows stay dry. The development of the kettle holes is commonly explained by the melting of ice residues during the periglacial period. In reality there are more possibilities for the explanation of their appearance (Fig. 37).

Hollows which are typical ice residue pools are, according to KLAFS & JESCHKE & SCHMIDT (1973), so called "genuine Pfuhle" (a). They are characterized by a

Fig. 37 Generalized sections of kettle holes in a former glaciated landscape landscape



irregular occurence of a lower surface and a smaller thickness of moraine material within the "Pfuhl". The genuine pools may be under groundwater influence or show water logging in their center.

Similar landforms may occur if the land surface of a basal moraine undulates and the farmers have not cultivated the depressions. By accumulation of colluvial material around the depressions a "pseudo-Pfuhl" is developed (b).

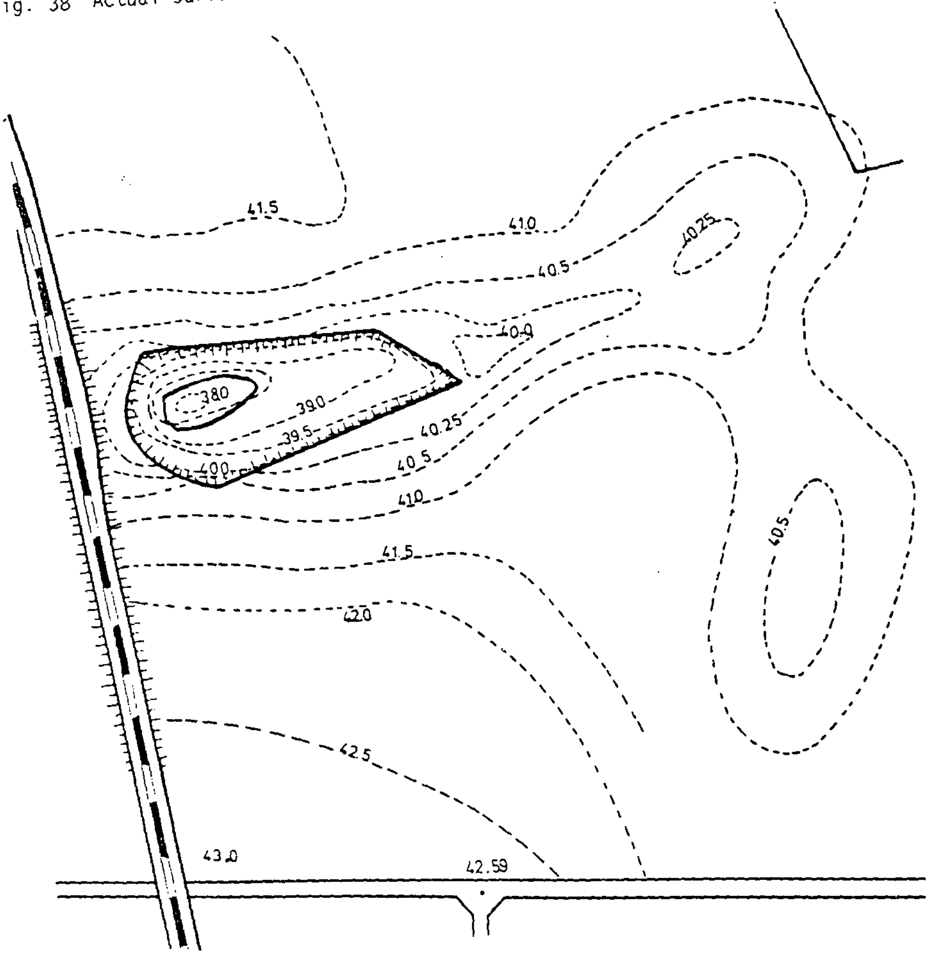
Subglacial meltwater may also erode the sediments below the glacier without the result of a general declination of the surface. Those hollows (c) in general are filled later by a chain of lakes, where at least some fluvioglacial deposits may be found. Those hollows are seldom rounded but more often elongated.
After the melting of the ice sheet, there may form big growing lenses of ice (Pingos or Palsen) at intersections of ice wedges.
The sediment slip down the pingo forming a wall around it (d). A later melting of the pingo results in a hollow.

Lolopfuhl at Berlin-Rudow: Not all the known pools fit within one of the simple concepts shown in the figure. This is due to the several climatic phases of the late glacial period. The Lolopfuhl, in particular, is a hollow which was existent already before the last glacial cover. The formation may be due to meltwater erosion. Both is deducted from intepretation of a few drilled profiles within and beside the Lolopfuhl (STAHR et al. 1983). The form of the hollow is inherited and then preserved through the last glaciated phase by filling with an ice lense. The melting of this ice residue may have happened at the end of the periglacial period (Brandenburg stadial). After that, the periglacial period is characterized by forming of sand wedges, filling partly with eolian sand and formation of a few tongues of gelisolifluction material. Later on, the hollow was subsequently filled with colluvial materials under different influences of man.

The Lolopfuhl with a surface area of 2300 m^2 is a medium sized kettle hole. It is beside its status as a nature reserve subjected to various uses and pollutions. The pressure of use and pollution before 1930 was less while the Lolopfuhl was in the middle of an open landscape and since 1200 was dominantly used as pasture land.
In the past it may have been used differently (MÜLLER 1968; WILLE 1974). At least there was a small well dug in the middle of the Lolopfuhl during the bronce age by prehistoric hunters.

The actual surface is shown by Fig. 38. The edge of the Pfuhl hollow originally was 20 to 30 m further out and 1-1.5 m higher than now. The relative height difference is now 5 m. It was at the end of the Weichselian more than 7 m.

Fig. 38 Actual surface of the Lolopfuhl



The development of the pool may be explained by figure 39.

More detailed information about actual vegetation and plant microfossils was given by BRANDE and LAUNHARDT (STAHR et al. 1983).
The actual soil association of the Lolopfuhl and its surroundings is shown by Fig. 40.

On the plain, there is a Catena of soils from Pararendzina, eroded Parabraun-

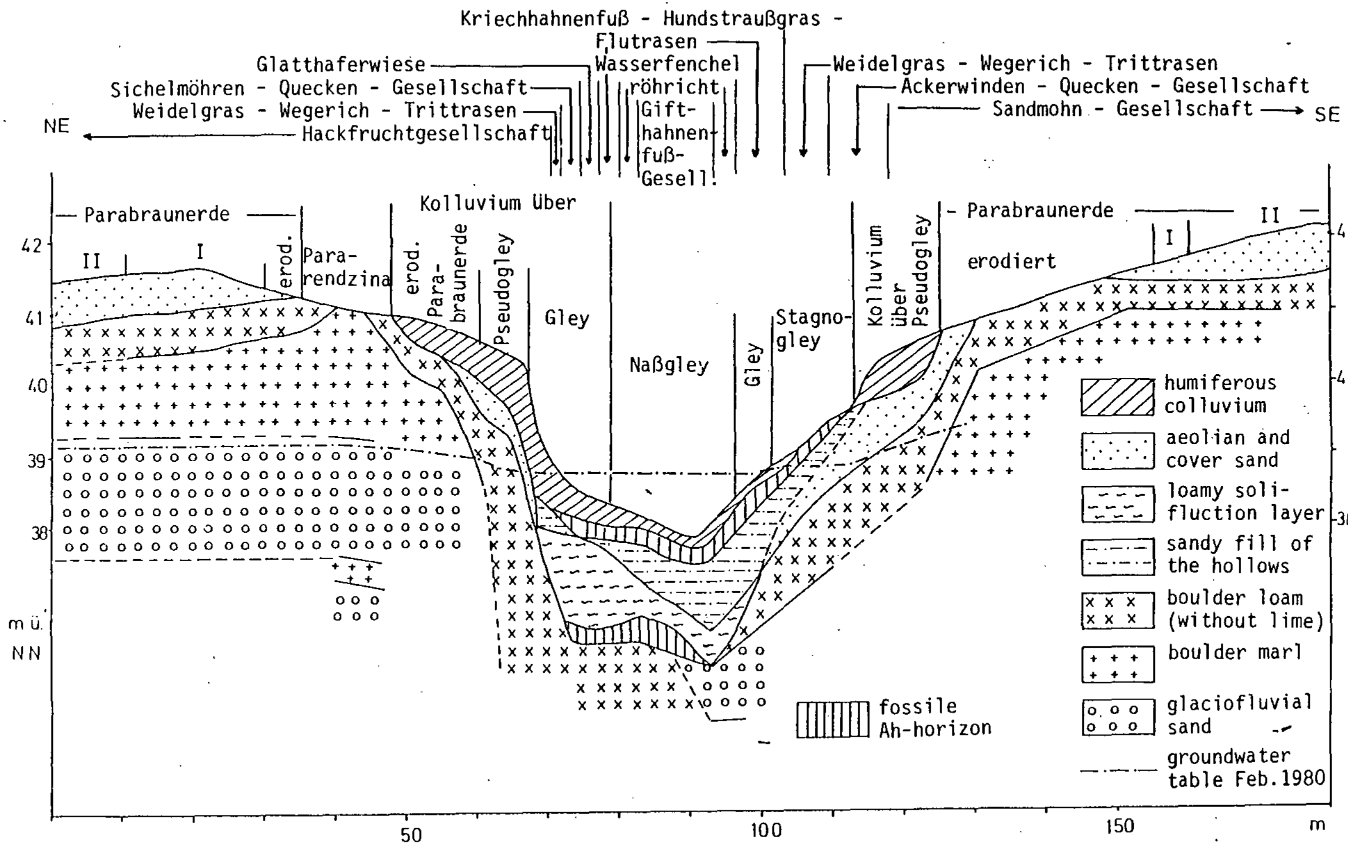


Fig. 39 Cross section of the Lolopfuhl, sediments, soils and vegetation

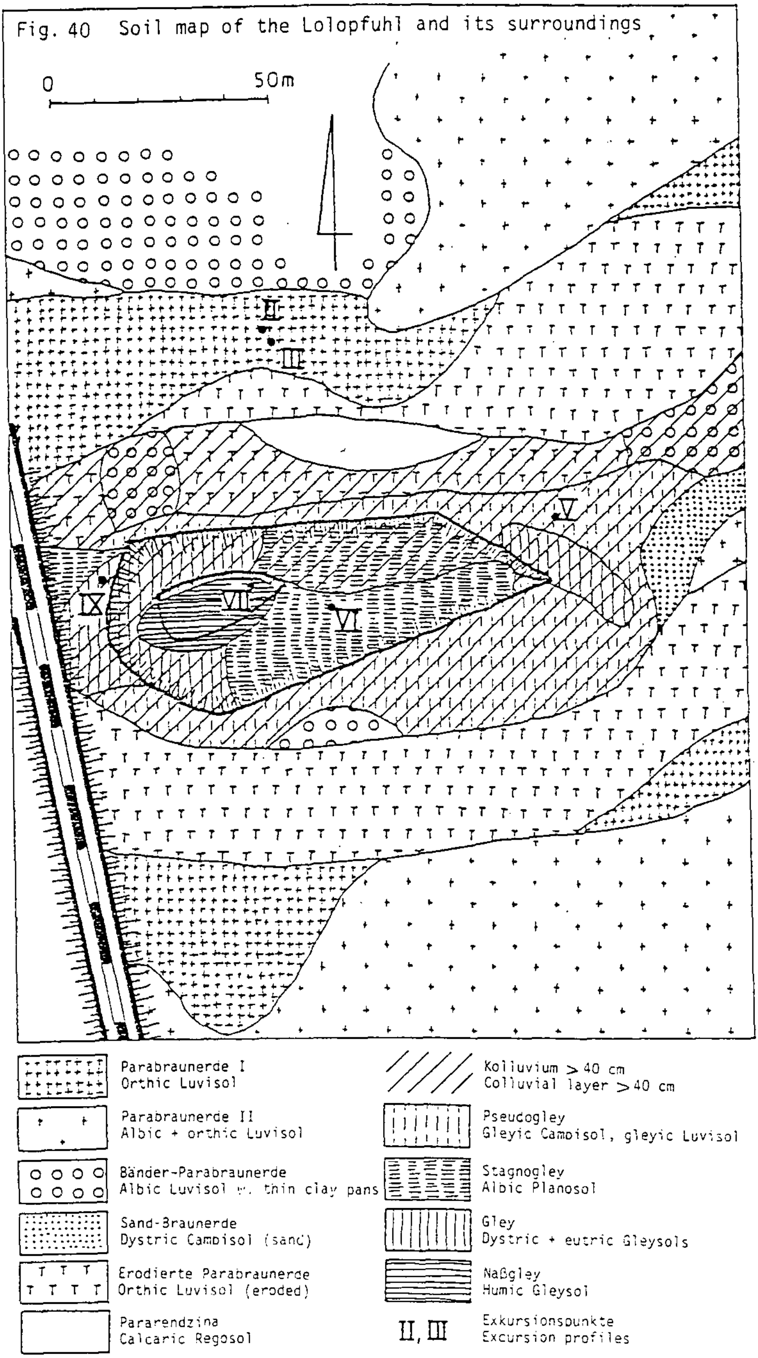


Fig. 40 Soil map of the Lolopfuhl and its surroundings

erde, Parabraunerde I and II, to the Bänderparabraunerde. The first two units result from the erosion of 1 m for the Pararendzina and of about 0.3 to 0.4 m for the Parabraunerde. The two different Parabraunerde have been separated on the variety level because of different depth of the A and E horizon (or the coversand). In some parts of the plain, the sandy cover increases to over 1 m. Then dunesand and coversand can be separated. In profiles like this there occurs an argillic banded horizon in the sandy coversediments and then a second compact one in the till. These profiles are called "Bänder-Parabraunerde". Especially, if the dune sand is deeper than 2 m no argillic horizon is developed, possibly due to a quick drop of pH during the development or due to the lack of clay. The soils are then sandy brown earth. All the terrestrial soils have a network of sand wedges, which partly dominates their properties.
From the edge of the plain down to the hollow, there occurs an increasing colluvial layer. It was mapped, where it was more than 0.4 m thick. The border between eroded and colluviated soils has varied with time. This has produced soils like the eroded and later colluviated Parabraunerde.
It is obvious that the southern part of the hollow is less colluviated. The reason may be the different vegetation at the edge which filtered all the material at the border of the ploughed field. The other hollows SE of the Lolopfuhl are filled with thick colluvium because of a uniform land use. Also, in these hollows, the colluvial layer lies upon hydromorphic soils like Pseudogleys, Stagnogleys and Gleys (see Fig. 40). The colluvial material itself is generally transformed into a Braunerde-Soil, whereas in the hollow it is transformed through hydromorphic processes into the soils mapped there.

The borders between the soil types Pseudogley, Stagnogley and Gley have been drawn according the morphological criteria. Occurence of concretion of Fe and Mn and mottled horizons are estimated to belong to Pseudogley. Pale wet horizons with high value and low chroma are counted to be wet bleached and therefore belonging to Stagnogleys. Horizons with rusty spots and coatings as well as greyish green reduced horizons are taken as groundwater gleyed.

All auger holes deeper than 2 m showed Go, Gr-horizons in the hollow. In the top soil we frequently find the morphology of stagnant water (Sw and Sew). The units Stagnogley and Gley are fairly homogenous in their morphology whereas the Pseudogleys vary strongly in their horizontation and grade of hydromorphism. Especially it has to be mentioned that the soils with perched water do not have C-horizons but influence of groundwater (G-horizon). The Naßgley soil (wet Gleysol) is particularly not in accordance with the general dynamic of such soils. In spring and summer it falls dry and becomes aerated down to about 40 cm. Therefore, it may be taken as a lake-bottom soil in the moist period and as a ordinary Gleysoil in the dry period. Because of the special water dynamics, it was generally difficult to place the hydromporphic soils into the German system.

Explanations for profiles Lolopfuhl II and III

Soil association: The Luvisols (profile II) on the moraine/coversand plain are intersected by a network of sand wedges (profile III). The soil association of different Luvisols and Cambisols on the plains with a variable coversand layer was described above. On the exposure itself we do have a Luvisol (Parabraunerde I) which may have an eroded topsoil of 1-2 dm. From the pit downslope, the erosion increases significantly. There we find an argillic horizon on the surface and even that is eroded exposing the calcaric moraine (Calcaric Regosol). In this case, more than 1 m of soil material was eroded. It is proven that the sand wedges also cover the slope and go right down to the bottom of the hollow. However, they decrease in width and depth and are often transformated by solifluction there.

Parent material: The coversand on the moraine material (boulder clay) are poorly graded and very inhomogenous sediments, whereas the eolian sand in the wedges is much better graded and also more homogenous. This is shown by the coefficient of grain size homogenity/layering ($\bar{Q}_K$) (STAHR, 1975).

Lolopfuhl II	Hor.	Ap		A1		Bt1		Bt2		Bvt		Cv1		Cv2
	So	2.08		2.38		3.16		4.16		3.65		2.37		2.35
	$\bar{Q}_K$		1.16		1.18		1.18		1.13		1.31		1.08	
					1.38									

Lolopfuhl III (sandwedge)	Hor.	Ap		Alv		BCt		Btb1		C		Btb2		C
	So	2.20		1.97		1.81		1.56		1.58		1.56		2.10
	$\bar{Q}_K$		1.20		1.48		1.46		1.11		1.06		2.26	
						2.28								

The transition from coversand to boulder clay is more graded than abrupt. A distinct layer boundary is only found by comparing Ah and Bt2.
There is also a layer discontinuity within the moraine, which is just at the actual limit of decalcification.
Within the analysed sand wedge, the sharp gradient from coversand to the eolian wedge sand is obvious. The different theories of genesis of the two sands have been developed by BLUME, HOFFMANN and PACHUR (1979) and were mentioned above.

Lolopfuhl II

Locality:	Berlin-Rudow, corn field north of Lolopfuhl between Schönefelder Straße and Waßmannsdorfer Chaussee Top. map: 3546 Berlin (south), R: 46 01 935, H: 58 09 180
Elevation:	41.6 m a.s.l.
Landscape:	Teltow plain (cover sand- boulder clay plain)
Relief:	almost levelled 0.5% N
Land use:	farm field (corn, rye, potatoes)
Parent material:	cover sand upon boulder clay
Soil type:	(two layer)-Parabraunerde (Orthic Luvisol)
Site qualities:	deep root zone, rooting impeded, water supply moderately moist, well aerated, moderate N and P and good supply of bases

Profile description:

Horizon (FAO), depth, parent material, colour, carbonate content, structure, structure specialities, actual root density, boundary.

Ap (Ap)	- 32 cm	cover sand, 10 YR 4/2, no lime, singular-coherent, corn straw in patches, few roots, abrupt transition
Al (E)	- 48 cm	cover sand, 10 YR 4/3, no lime, singular-coherent, org. matter in patches, almost no roots, interfingering transition
Bt1 (Bt)	- 68 cm	boulder loam, 10 YR 5/4, no lime, subangular blocky, pale spots and tongues, clay skins, almost no roots, gradual transition
Bt2 (Bt)	- 84 cm	boulder loam, 10 YR 5/6, no lime, subangular blocky, clay coatings, no roots, gradual transition
Bvt (Bwt)	- 94 cm	boulder loam, 10 YR 5/5, no lime, subangular blocky - coherent, no roots, abrupt wavy boundary
Cv1 (C)	-120 cm	boulder marl, 10 YR 5/3, lime, coherent to parallel textured, lime in concretions and pseudomycel, no roots, gradual transition
Cv2 (C)	140 cm	boulder marl, 2.5 Y 5/4, lime, coherent, no roots
	deeper 230 cm	gleyed features within boulder marl, sand content increasing
	about 390 cm	lower boundary boulder marl, gleyed fine sands, free groundwater table about 4-5 m below surface

No	hor.	depth cm	sto. %	texture in % of humus-/carb. free fine soil: sand c	sand m	sand f	sand Σ	silt c	silt m	silt f	silt Σ	clay	kf cm/d
1	Ap	0- 32	3	4	32	38	74	12	6	3	21	5	-
2	Al	- 48	4	4	29	37	70	13	7	3	23	7	3.5
3	Bt1	- 68	2	5	25	35	65	11	7	6	24	11	-
4	Bt2	- 84	3	4	24	32	60	11	6	5	22	18	-
5	Bvt	- 94	3	5	25	32	62	12	6	5	23	15	23
6	Cv1	-120	3	5	32	35	72	12	6	4	22	6	-
7	Cv2	-140	4	6	36	33	75	12	6	3	21	4	26

No	hor.	bulk dens. g/cm^3	GPV %	water content in % at pF 0.6	1.8	2.5	4.2	pH $CaCl_2$	pH H_2O	Fe_d mg/g	Fe_o mg/g	Fe_o/Fe_d	Mn_o mg/kg	P_v mg/kg
1	Ap	1.70	35	33	27	18	11	5.0	4.4	2.3	0.92	0.40	270	360
2	Al	1.84	30	29	19	13	7	6.4	5.7	2.5	0.58	0.23	250	200
3	Bt1	1.79	32	29	24	22	19	6.3	5.7	5.5	1.00	0.18	280	290
4	Bt2	1.71	35	30	25	24	21	6.6	6.0	6.8	1.11	0.16	240	380
5	Bvt	1.76	33	30	26	25	18	7.3	6.9	5.5	0.88	0.16	200	380
6	Cv1	1.80	32	28	22	15	9	8.5	7.6	2.8	0.45	0.16	80	280
7	Cv2	1.81	31	31	23	19	12	8.5	7.7	2.8	0.40	0.14	90	240

No	hor.	$C_{org.}$ mg/g	N_t mg/g	C/N	carbonate mg/g	CEC_p meq/kg	exchang. cations in meq/kg: Ca	K	Mg	Na	H	Al	V %
1	Ap	5.8	0.54	11	0	52	12.5	2.5	1.0	0.1	35	2.5	33
2	Al	1.4	0.15	9	0	42	19.5	1.7	1.0	0.2	18	0.6	57
3	Bt1	1.3	0.18	7	0	62	38.0	3.0	6.0	0.3	15	0	76
4	Bt2	1.4	0.20	7	0	98	65.0	1.8	12.0	0.5	19	0	81
5	Bvt	1.4	0.19	7	0	114	67.0	1.1	15.0	0.4	30	0	74
6	Cv1	0.3	0.07	-	77	66	62.0	0.9	3.5	0.2	0	0	100
7	Cv2	0	0.07	-	64	55	51.0	0.9	3.5	0.2	0	0	100

Lolopfuhl III

Locality:	Berlin-Rudow, like profile Lolopfuhl II
Elevation:	41.6 m
Landscape:	Teltow plain
Relief:	almost levelled 0.5% N
Land use:	farm field (corn, rye, potatoes)
Parent material:	sand wedge (cover sand upon eolian sand within and upon boulder clay)
Soil type:	(sand wedge) Bänder-Parabraunerde (Orthic Luvisol/Luvic Arenosol)
Site qualities:	very deep root zone, moderate root spreading, moderately moist to dry, moderate N- and P-supply, good supply of bases

Profile description:

Horizon (FAO), depth, parent material, colour, carbonate content, structure, structure specialities, actual rooting, boundary.

Ap (Ap)	0- 33 cm	cover sand, 10 YR 4/2, no lime, singular to granular, corn straw in patches, few roots, abrupt transition
AlBw (EB)	- 50 cm	cover sand, 10 YR 6/5, no lime, subangular blocky to coherent, few roots, gradual transition
BCt (BC)	- 95 cm	cover sand, 10 YR 7/3, coherent to singular, thin clay pans (7.5 YR 5/4) and spots, almost no roots, abrupt boundary
Btb1 (Bt)	-110 cm	eolian sand, 7.5 YR 5/4, no lime, coherent, almost no roots, abrupt transition
C (C)	-135 cm	eolian sand, 10 YR 6/4, no lime, coherent to singular, no roots, abrupt transition
Btb2 (Bt)	-160 cm	eolian sand, 7.5 YR 5/4, no lime, coherent, no roots, abrupt transition
Cg (Bw)	-180 cm	boulder loam, 10 YR 5/5/4, no lime, coherent, partly reduced, some Mn- and Fe-oxide spots, no roots
	from 350 cm	lime content
		at the edge the sand wedge is followed (coated) by a 10-15 cm thick Bt (Bt)-horizon, which is surrounded by a 20 cm thick decalcified BvC (BC). Between 1 m and 1.6 m there occur hydromorphic properties within these horizon, especially Mn- and Fe-oxide spots

No	hor.	depth cm	sto. %	texture in % of humus-/carb. free fine soil: sand c	sand m	sand f	sand Σ	silt c	silt m	silt f	silt Σ	clay	kf cm/d
1	Ap	0- 33	3	5	32	38	75	11	6	3	20	5	-
2	AlBv	- 50	7	5	35	42	82	9	3	2	14	4	47
3	BCt	- 95	1	4	42	45	91	4	1	1	6	3	156
4	Btbl	-110	0	6	51	32	89	2	0	0	2	9	9.5
5	C	-135	0	4	55	35	94	3	0	0	3	3	-
6	Btb2	-160	0	5	51	31	87	3	0	0	3	10	-
7	Cg	-180	2	6	39	33	78	10	6	2	18	4	-

No	hor.	bulk dens. g/cm^3	GPV %	water content in % at pF 0.6	1.8	2.5	4.2	pH $CaCl_2$	pH H_2O	Fe_d mg/g	Fe_o mg/g	Fe_o/Fe_d	Mn_o mg/kg	P_v mg/kg
1	Ap	1.64	37	32	26	17	10	4.4	5.0	2.12	0.85	0.40	240	400
2	AlBv	1.71	35	30	21	13	6	5.1	6.1	1.62	0.48	0.30	130	150
3	BCt	1.65	37	32	17	11	2	5.2	6.1	1.22	0.29	0.24	70	90
4	Btbl	1.80	31	27	16	14	9	5.5	6.3	3.20	0.72	0.22	140	210
5	C	1.66	37	29	12	5	2	5.7	6.7	1.06	0.25	0.24	160	140
6	Btb2	1.85	29	26	19	14	8	5.5	6.2	3.60	0.92	0.26	440	300
7	Cg	1.94	26	22	19	15	5	5.6	6.4	1.81	0.52	0.29	130	230

No	hor.	$C_{org.}$ mg/g	N_t mg/g	C/N	carbonate mg/g	CEC_p meq/kg	exchang. cations in meq/kg: Ca	K	Mg	Na	H	Al	V %
1	Ap	6.8	0.60	11	0	53	14	2.7	1.0	0.1	35	3.5	34
2	AlBv	1.0	0.10	10	0	35	11	1.0	0.5	0.3	22	0	37
3	BCt	0.04	0.05	8	0	25	10	1.0	1.0	0.2	13	0	48
4	Btbl	0.6	0.10	6	0	33	22	2.0	3.0	0.2	6	0	82
5	C	0.2	0.04	-	0	16	10	0.7	2.0	0.2	3	0	81
6	Btb2	0.7	0.11	-	0	48	26	2.7	4.0	0.1	15	0	69
7	Cg	0.3	0.05	-	0	20	14	1.1	2.0	0.1	3	0	85

The sand in the wedge is coarser but much better graded than the fine-sand-rich coversand. There is a stone enrichment above the wedge in the Alv. Some of these stones are polished by wind. The C-horizon below the wedge is in good agreement with the calcareous part of the boulder clay in profile II.

Soil development: If the coversand was non-calcareous and the boulder clay contained 70 mg/g $CaCO_3$, than we do have a loss of 56 kg/m^2 $CaCO_3$ and a secondary enrichment of 3 kg within the C-horizon of profile II. With the existing data, the wedge could not be balanced, but the decalcification is estimated to be the same as long as the boulder clay is not cut through by a wedge. There is a low store of only 8 kg/m^2 organic matter in both profiles, from which 5 kg are already bound to the plough layer. This may be due to the longlasting agricultural use (since 1200 A.D.), especially the land utilization over the last 30 years without organic supply or recycling.

There is clay formation as well as clay migration. Both formation and enrichment have a maximum in the Bt-horizons. Fe_o/Fe_d relation estimates the actual maximum of weathering in the Al or Al_v horizon. Hydromorphic properties have not largely developed along the analysed sand wedge. Only in the bottom, there is a slight mobilization of iron and manganese.
Under natural forest, the profile II may already be a Podzolluvisol (Fahlerde). This is because of the interfingering of A and B-horizon and the silty ped surfaces in this part of the profile.

In both profiles, the clay-minerals kaolinite, illite, smectite, vermiculite and interstratified clay-minerals have been identified. The interstratified minerals almost all have chloritic (mainly Al-chloritic) layers. The amount is 10 to 25% of the clay fraction and increases with the weathering. Kaolinite and illite (mica clay) occur as inherited minerals in cover sand and till, whereas illite is concentrated in sandy sediments. Smectites and also vermiculites primarily occur in the till and are substantially altered by weathering.

Soil dynamics (water and air): The Ap and partly Al horizon have a very small volume of coarse pores due to tilling, low org. matter content and pH. This favours water saturation of the topsoil after rainstormes. Then the aggregate stability is very low and the liquid limit will be passed. The saturated water conductivity is also very low, but over the sand wedge regulary higher than over the moraine. In the B-horizons of the Parabraunerde the conductivity is also low and decreases under unsaturated condition. Measurement of water and air content as well as redox potential have shown that there is no surface water gleying in moist periods and the air.supply is sufficient. The calcaric C-horizons are at field capacity all year round, whereas the topsoils dry out below wilting point in summer. In the sand wedge, the clay illuviation causes increase of bulk density and decrease of water permeability. The measurements in our case do not show a favoured seepage through the sand wedge. This was measured at other places of the moraine plain (BRAUN & HORN 1981). The seepage through the wedge is especially then much higher, when it content was stable at 18% Vol. throughout the year below a depth of 1 m. Above, it was higher in winter (27%) and much lower in late summer (8%). Redox potential shows oxidizing conditions (250-700 mV) all year round.

Site qualities: Roots of the crops may enter the Bt-horizons of the Parabraunerde as well as the Btb of the sand wedge, but will not pass through. Both physical and chemical conditions will hinder deeper rooting (9 to 11 dm). The spreading of the roots within the root zone is impeded by high bulk density and small amount of coarse pores. The avialable water capacity is only moderate (120-140 l/m^2) which causes water deficiency during summer and autumn. There is no air deficiency expected. The nutrient stock of N, P and K is moderate to small and in the sand wedge less. The pH garantuees a fair availability, but should not be allowed to drop down deeper. The workability of the soil is bad during winter and spring, due to unfavourable grain size distribution and aggregate stability.

Explanations for profiles Lolopfuhl V and VI

Soil association: The soils vary within short distances in and around the Lolopfuhl. Especially the horizon morphology and depth is altered from place to place. There are four general types observed. Examples for the two with surface water gleying (Pseudogleying) occur on the slopes around the Lolopfuhl and in the eastern part of the Pfuhl. The center and the western part are taken in by groundwater soils (profile VII and IX).
Around the Lolopfuhl and especially in the smooth rills east and west of it, there is a colluvial layer generally over 6 dm deep. All these soils show the morphology of "Pseudogley" in their buried part. The surface water gleying could not be extreme, otherwise they would have been used as grassland and not as ploughed fields. Although this is obvious, we find the morphology of pseudogleying also partly in the colluvial layer. In the lower part within the Pfuhl, strong surface water gleying and air deficiency has led to the development of Stagnogley, which have never been ploughed. In these places, the colluvial layer is therefore only 2-3 dm deep. The soils in this part are all decalcified more than 2 m deep.

Parent material: According to field observation both profiles have a colluvial layer (V = 8 dm, VI = 3 dm) over cover sand. The border is not shown by the grain

Lolopfuhl V

Locality:	Rudow, farm field, 15 m east of Lolopfuhl between Schönefelder Straße and Waßmannsdorfer Chaussee Top. map: 3546 Berlin (south), R 46 02 035, H: 58 09 100
Elevation:	40.0 m a.s.l.
Landscape:	Teltow plain (boulder clay plain)
Relief:	flat, center of a smooth rill, E-W, 0.1% W
Land use:	farm field (corn, rye, potatoes)
Parent material:	colluvial layer over cover sand over glaciofluviatile or solifluction layers over boulder loam
Soil type:	Pseudogley-Kolluvium upon Pseudogley (Gleyic Cambisol)
Site qualities:	deep root zone, moderate root spreading, moist, drainage impeded, partially air deficiency, fair N-supply, moderate P and good supply of bases

Profile description:

Horizon (FAO), depth, parent material, colour, lime content, structure, structure specialities, actual roots density, boundary.

MAp (Ap)	0- 26 cm	colluvial layer, 10 YR 4/2, no lime, subangular blocky, corn straw in patches, many roots, abrupt boundary
MSw (Bw)	- 80 cm	colluvial layer, 10 YR 4/3, no lime, subangular blocky to coherent, Mn-spots, few Fe-concretion, few roots, sharp boundary
fAhS (bA)	- 95 cm	cover sand, 10 YR 5/2, no lime, coherent, Fe- and Mn-concretions, bleached and oxidized peds, Mn-spots, no roots, gradual boundary
Sw (Bg)	-113 cm	cover sand, 10 YR 5/4, no lime, coherent, Fe-concretions, Mn-spots, no roots, gradual boundary
Swd (Bg)	-130 cm	cover sand, 10 YR 5/4, no lime, coherent, bleached and oxidized peds, Mn-spots, no roots, sharp boundary
Sd (Bg)	-175 cm	glacifluviatile silty sand, 2.5 Y 5/3, no lime, coherent, strong bleached peds, no roots, sharp boundary
Gor (Cg)	-255 cm	glacifluviatile sand, 2.5 Y 6/3, no lime, coherent, reduced with few iron stains, no roots, abrupt boundary
CGr (C)	-310 cm	boulder loam, loamy sand, pale yellow grey, no lime, reduced, no roots, gradual boundary
Gor (C)	-360 cm	boulder loam, loamy sand, greyish green, no lime, reduced, with iron spots, no roots

Depth and morphology of all horizons below Sd (130 cm) are highly variable (cryoturbation and solifluction features).

No	hor.	depth cm	sto. %	texture in % of humus-/carb. free fine soil									kf cm/d
				sand				silt				clay	
				c	m	f	Σ	c	m	f	Σ		
1	MAp	0- 26	2	4	30	40	74	12	6	3	21	5	-
2	MSw1	- 38	2	4	30	39	73	13	6	4	23	4	-
3	MSw2	- 80	3	5	36	37	78	11	5	3	19	3	86
4	fAh	- 95	3	5	39	32	76	10	7	3	20	4	-
5	Sw	-113	7	5	35	33	73	13	7	3	23	4	17
6	Swd	-130	2	4	38	29	71	14	7	3	24	5	2.8
7	Sd	-170	1	1	19	33	53	23	11	6	40	7	0.7
8	Gor	->170	11	5	36	33	74	9	5	2	16	10	7.8

No	hor.	bulk dens. g/cm^3	GPV %	water content in % at pF				pH		Fe_d	Fe_o	Fe_o/Fe_d	Mn_o	P_v
				0.6	1.8	2.5	4.2	$CaCl_2$	H_2O	mg/g			mg/kg	
1	MAp	1.51	42	35	31	14	6	4.2	5.0	2.43	1.08	0.44	240	530
2	MSw1	1.63	38	33	30	11	5	5.7	6.4	1.56	0.85	0.54	180	310
3	MSw2	1.63	38	29	27	9	4	5.4	6.1	1.48	0.64	0.43	150	140
4	fAh	1.65	37	29	26	9	4	5.5	6.3	1.47	0.69	0.47	200	120
5	Sw	1.79	32	25	22	11	5	5.7	6.5	1.72	0.62	0.36	80	100
6	Swd	1.96	26	21	20	13	7	5.9	6.6	1.42	0.61	0.43	20	110
7	Sd	2.06	22	22	20	16	10	5.8	6.6	1.45	0.84	0.58	10	130
8	Gor	1.83	31	27	21	17	10	5.9	6.7	2.40	1.14	0.48	60	240

No	hor.	$C_{org.}$	N_t	C/N	carbonate mg/g	CEC_p meq/kg	exchang. cations in meq/kg						V
		mg/g					Ca	K	Mg	Na	H	Al	%
1	MAp	8.5	0.66	13	0	51	10	3.0	1.2	0.1	36	3	29
2	MSw1	3.0	0.29	10	0	48	13	4.0	1.0	0.2	30	3	38
3	MSw2	1.0	0.11	9	0	28	9	1.5	0.5	0.2	16	1	43
4	fAh	0.8	0.07	10	0	18	10	1.5	0.5	0	6	0	67
5	Sw	0.7	0.06	-	0	13	11	1.5	0.7	0.2	0	0	100
6	Swd	0.7	0.09	-	0	17	13	1.5	1.5	0.2	0	0	100
7	Sd	0.7	0.12	-	0	25	20	1.1	1.1	0.3	0	0	100
8	Gor	0.8	0.12	-	0	46	37	1.1	1.1	0.5	0	0	100

Lolopfuhl VI

Locality:	Berlin-Rudow, Lolopfuhl between Schönefelder Straße and Waßmannsdorfer Chaussee, eastern part of the nature reserve Top. map: Berlin (south) 3536, R: 46 01 975, H: 58 09 095
Elevation:	38.8 m a.s.l.
Landscape:	Teltow plain (boulder clay plain)
Relief:	smooth hollow, 2% N
Land use:	nature reserve (recreation area, waste deposit!)
Parent material:	colluvial layer over cover sand over boulder loam
Soil type:	Stagnogley upon Gley (Humic Planosol)
Site qualities:	moderate root depth, good to excellent root spreading, variable wet, well aerated so long not flooded, moderate nutrient supply

Profile description:

Horizon (FAO), depth, parent material, colour, carbonate content, structure, structure specialities, actual rooting, boundary.

Ah (Ah)	0- 12 cm	colluvial layer, 10 YR 2/2, free of lime, crumbs to subangular blocks, very many roots, sharp boundary
AheSw (Bw)	- 28 cm	colluvial layer, 10 YR 4/1, no lime, singular to coherent, moderate roots, sharp boundary
fAh (bAh)	- 40 cm	cover sand, 10 YR 4/2, no lime, singular-coherent, few rusty spots, sharp transition
Sw (Bg)	- 58 cm	cover sand, 2.5 Y 5/2, no lime, coherent-prismatic, frequent rusty spots, root channels, few roots, gradual transition
AeSw (E)	- 88 cm	cover sand, 2.5 Y 6/2, no lime, coherent-prismatic, some rusty spots, no roots, sharp and interfingering boundary
GoSd (Bg)	-113 cm	boulder loam, 10 YR 5/6, no lime, subangular blocky to prismatic, Mn- and Fe-oxide spots, no roots, bleached and oxidized peds, no roots, gradual boundary
Go2 (Bg)	-135 cm	boulder loam, 2.5 Y 4/4, no lime, subangular blocky prismatic, many Mn- and Fe-spots, no roots, gradual boundary
Go3 (Bg)	-155 cm	boulder loam, 2.5 Y 4/4, no lime, subangular blocky to coherent, big rusty spots, no roots, gradual transition
Gr (Cg)	-200 cm	boulder loam, 2.5 Y 5/2, no lime, coherent, reduced, few rusty spots, no roots

Until 400 cm all horizons are reduced. Between 270 and 350 cm the material is sandy, the lower part is again loamy. The whole profile was free of lime, whereas in the neighbourhood lime occurs from about 300 cm downwards.

No	hor.	depth cm	sto. %	texture in % of humus-/carb. free fine soil: sand c	sand m	sand f	sand ∑	silt c	silt m	silt f	silt ∑	clay	kf cm/d
1	Ah	0- 12	2	4	23	34	61	14	10	5	29	10	-
2	AS	- 28	2	5	33	44	82	9	4	2	15	3	-
3	fAh	- 40	2	3	30	40	73	13	6	4	23	4	-
4	Sw	- 58	3	3	36	37	76	10	10	0	20	4	
5	Sew	- 88	6	4	30	36	70	11	10	2	23	7	21
6	Go1	-113	2	4	28	28	60	10	13	1	24	16	
7	Go2	-135	1	4	27	29	60	11	10	3	24	16	0.3
8	Go3	-155	2	4	29	31	64	11	7	5	23	13	0.9
9	Gr	->200	2	4	28	32	63	10	8	5	23	13	16

No	hor.	bulk dens. g/cm³	GPV %	water content in % at pF 0.6	1.8	2.5	4.2	pH $CaCl_2$	pH H_2O	Fe_d mg/g	Fe_o mg/g	Fe_o/Fe_d	Mn_o mg/kg	P_v mg/kg
1	Ah	0.60	73.8	62.4	45.9	34.3	11.6	4.4	4.8	2.39	1.59	0.83	190	880
2	AS	1.49	42.8	36.0	25.4	11.1	5.4	4.1	4.9	0.34	0.34	1.00	0	210
3	fAh	1.64	37.2	31.4	28.6	13.2	6.3	4.2	4.9	0.49	0.45	0.92	0	290
4	Sw	1.72	34.3	28.0	21.0	11.8	5.3	4.2	4.8	0.30	0.25	0.83	0	280
5	Sew	1.78	32.3	25.7	20.5	11.8	4.2	4.	4.8	0.38	0.27	0.71	20	300
6	Go1	1.78	32.3	30.1	28.1	24.0	17.5	4.3	5.0	8.20	3.50	0.43	40	290
7	Go2	1.79	31.8	30.9	29.8	25.0	22.1	4.5	5.2	8.80	3.90	0.44	170	300
8	Go3	1.80	31.6	28.7	27.1	21.2	16.7	4.5	5.1	7.20	3.90	0.54	150	330
9	Gr	1.80	31.7	29.4	28.5	21.5	13.4	4.4	5.2	1.68	1.01	0.60	40	260

No	hor.	$C_{org.}$ mg/g	N_t mg/g	C/N	carbonate mg/g	CEC_p meq/kg	exchang. cations in meq/kg: Ca	K	Mg	Na	H	Al	V %
1	Ah	75.2	5.30	14	0	275	68	6.0	6.5	1.0	190	7.0	31
2	AS	6.9	0.56	12	0	33	0	0.7	0.4	0	32	4.0	3
3	fAh	4.0	0.23	17	0	33	0	0.6	0.1	0.2	32	4.0	3
4	Sw	2.1	0.16	13	0	32	0.5	0.5	0.2	0.1	30	3.0	6
5	Sew	0.7	0.12	6	0	26	2.5	1.0	1.0	0.1	21	2.0	19
6	Go1	1.1	0.20	5	0	66	24.0	2.0	9.0	0.5	30	0.6	55
7	Go2	0.9	0.21	-	0	82	36.0	5.0	14.0	0.8	26	0.5	68
8	Go3	0.6	0.18	-	0	69	24.0	5.0	12.0	0.6	28	0.6	59
9	Gr	0.8	0.16	-	0	43	19.0	3.0	8.0	0.4	12	16.0	72

size distribution. The data below devide the colluvial layer of VI and do not show any prominent deviation in profile V.

Lolopfuhl V

Hor.	MAp	MSw1	MSw2	fAh	Sw	Swd	Sd	Go1
So	2.16	2.19	2.09	2.22	2.34	2.58	2.74	2.26
$\bar{Q}_K$	1.05	1.14	1.16	1.12	1.14	1.73	2.00	

Lolopfuhl VI

Hor.	Ah	AheSw	fAh	Sw	Sew	Go1	Go2	Go3	Gr
So	3.28	1.92	2.12	2.09	2.45	4.07	4.13	3.54	3.76
$\bar{Q}_K$	1.68	1.20	1.15	1.16	1.39	1.06	1.16	1.04	

The colluvial layer of profile V is almost identical with the cover sand. The colluvium of profile VI is much finer and graded itself. The fluvioglacial layer in profile V and the boulder clay in both profiles can be distinguished easily from the overlying material. The boulder clay is a bit finer in the depression than on the plain.

Soil development: The humus accumulation in both profiles is relatively low. Although the colluvium is deep, profile V does not contain more than 9 kg org. matter/m^2. The other profile contains 9.3 kg/m^2 in the Ah but in total only 14.6 kg/m^2. This is explained by the favourable oxygen and water supply for the mineralisation of the organic matter in the topsoil. Decalcification in the profile V is more than 200 kg/m^2 and more than 360 kg/m^2 in profile VI only by calculating the loss from the boulder clay. The data show a much higher carbonate loss in the depression than on the plains. This is possible because of additional water supply from surface run off and higher partial CO_2 pressure. In both profiles, clay illuviation has been detected, which was added to the uppermost part of the boulder loam (first G-horizon). This has been possible only in dryer periods of the postglacial period (boreal). The amount of transported clay could not be calculated because of the stratification and the superimposed dominant clay formation.

The pseudogley-process in profile V is estimated to be a primary one caused by the stratification, and especially the dense lower layers. According to our knowledge there is not relictic gleying but the Gor-horizon is in balance with actual conditions. With large variations of the groundwater table, there may already be an overlapping of groundwater and surface water in the lower part of this profile (< Sw).

This overlapping of groundwater and surface water influence is very strong developed in profile VI, where the upper part is bleached because of reduced conditions for long periods. This part has lost about 1 kg/m^2 Fe, although there is a precipitation of iron oxides during summer in the upper part every year. The lower part of the profile is subject to groundwater gleying. The oxidized part actually has an enrichment of 6 kg/m^2 Fe. This is in accordance with the annual variations of groundwater table. The capillary rise is hindered by the low conductivity of the denseboulder clay. This horizon, therefore, hinders the upward as well as the downward movement of water which is the reason for the Stagnogley profile upon a Gley. The dynamic under these conditions is more or less seasonal, with a Stagnogley period in summer and a Gley period in winter. The Al_o-values show the weathering maximum in the Ah- and Ap-horizon, but it is more prominent in profile VI. The clay-minerals are dominated by vermiculite and interlayer minerals with illite and kaolinite and traces of chlorite in the sandy parts. The weathering of illite may be stronger than in profiles II and III, otherwise one would not understand the low content. The loamy parts of the profile have additional smectites. In this part the relatively high amount of interlayer minerals shows stronger weathering of this part also. This finding does not fully agree with the findings of other authors under Pseudogley conditions (SCHWEIKLE 1971).

<u>Water and air dynamics:</u> The colluvial layer of profile V is relatively loose and should therefore not impede drainage. The surface water gleying is caused by the dense, all year round water saturated Sd-horizon with its low conductivity. The Swd- and Sw-horizons are water saturated during winter time and dry out to pF 2.5 in autumn. The colluvial layer was never water saturated but there was a free surface water in winter and after rainstorms in summer. This part also dries out not more than to field capacity. The measured redox-potential does not correlate with the water saturation but showed strong interference with oxygen change in water content during summer as far down as -490 mV. The Sw-horizon was 100-200 mV in summer but had oxidizing conditions in winter.

Impeded drainage and capillary rise in profile VI due to the dense boulder loam (Gol) was already mentioned above. Differing from the other profiles, there occur variations of water content throughout the profile. In spring the whole profile is water saturated. The decrease in the upper part starts soon and reaches pF 3.0, whereas the Go (Sd) and Gr-horizon stay saturated until early autumn. Then for a short period they have a water saturations of only pF 1.8. The redox potential is low in the Gr all the year (-100 - -400 mV) only in winter it increases to about $\pm$ 0. In the surface water part and the Go there are oxidizing conditions in autumn (+ 400 mV). These drop down during the winter and reach their minimum of -200 mV in spring.

<u>Site qualities:</u> In spite of surface water gleying the Colluvium has a deep root zone with a better spreading of roots than in the profiles on the plain. The

Stagnogley, in comparison, has a shallow to moderately deep root zone. Only specialists like Populus tremula are able to bring their roots down to 6-8 dm. The spreading of roots in the topsoil here is easy to very easy. The water supply in the Colluvium is generally good, only in spring and early summer there may be oxygen deficiency which may harm sensitive plants. The water supply of the Stagnogley is characterized by the variable moisture. The main root zone is well aerated with exception of about two months in spring. The nutrient supply of Profile V is better than in the earlier profiles especially when P and K are taken into account. In the Stagnogley, the nutrients have to be supplied mainly from the organic horizon, which has a moderate stock of N, P, K and Cu but according to pH, water saturation and good structure a good availability. The uptake from the subsoil is negligible. The workability of the Colluvium is bad and the surface is normally encrusted in summer.

Explanations for profiles Lolopfuhl VII and IX

Soil association: The center of the Lolopfuhl is very wet; therefore the soils have morphology of Gley soils dominated by reduced horizons (VII). This situation continued further west before the medieval clear cut. Due to erosion and sedimentation the western part is now less influenced and the deepest point shows the morphology of a typical Gley (IX). This soil, inspite of its colluvial cover, has the same parent material sequence as profile II. The relief is therefore the striking factor which caused the difference. The deepest part of the hollow is generally flooded form late November till August.

Parent material: According to the field observation, both profiles have a similar sequence of glacial and post glacial sediments. The youngest colluvial layers show bigger differentiation in the hollow (profile VII) than on the western edge. Whereas the colluvial layer on the field is simply the same material as the coversand, in the center the sediments are more diversified through the transport. Furthermore these sediments are finer than all comparable. This profile has some periods without sedimentation, which led to development of A-horizons.

The stratigraphy of profile IX was a very simple one but shows all phases of the development in the latest glacial period. The till has been subject to drying out and formation of cracks, which have been filled by eolian sand. Then the till has been covered by pure eolian sand. A wetter period caused a solifluction tongue of boulder clay from the slope covering the sand. Then a second layer occurs which has been transformed to cover sand. During the holocene a colluvium covered the profile possibly in two phases.

Lolopfuhl VII

Hor.	Ah		Go		fAhGo		Gor1		Gor2		Gr1		fAh2		Grh		Gr2
So	4.02		3.89		4.19		4.35		3.16		2.45		3.43		2.54		2.44
$\bar{Q}_K$		1.28		1.29		2.19		1.60		1.35		1.71		1.76		1.19	

Lolopfuhl IX

Hor.	MAp		MGo		fAhGo		Gor1		Go		Gr		Gr2
So	2.35		2.37		2.27		2.16		2.00		2.02		4.15
$\bar{Q}_K$		1.12		1.12		1.30		1.17		3.62		4.69	
											1.50		

Soil development: The organic matter content in profile IX amounts to 19 kg/m^2 whereas profile VII reaches the maximum of 25 kg/m^2. In both cases 7.9/7.7 kg/m^2 are bound in the first Ap/Ah horizon. The other part is preserved in the respective subsoils under reducing conditions. The fact that there is no higher stock built-up can only be explained with the good condition for mineralization in summer and autumn in both profiles. Otherwise, one would expect a development of peaty material. Decalcification has already brought a loss of 300 to 320 kg/m^2 in both cases. This can only be explained by a generally downward water movement. High CO_2 partial pressure helps to dissolve the lime. The dynamics of Fe and Mn are consistent with a Gley-dynamic. The maximum of the Mn-oxides is in the oxidized zone of the upper A-horizon. The Fe-oxides are generally depleted. In both profiles a loss of about 6 kg Fe/m^2 is calculated. Only the Ah-horizon of the Naßgley is enriched in Fe. The remaining Fe-oxides are very mobile, which can be proven by the high $Fe_o/_d$-Ratio. The fossile A-horizon marks the beginning of the agricultural period at about 1200 A.D. The lower A in the central profile was formed in the early holocene (STAHR et al. 1983).

Water and air dynamics: At the profile IX no measurement in the field took place. This profile is estimated to be continously wet in winter and spring and then moist throughout the vegetation period. The air supply may be good in summer in the whole root zone. This profile, therefore may have better conditions for plant growth than the respective profile V at the eastern end of Lolopfuhl.

The profile VII is completely saturated with water all year with exception of the month's August till November. But during this period with a water table about 0.5 m deep, the topsoil remains in a wet condition. The water permeability has a minimum in the Gr2-horizon. This horizon, therefore, may impeed the drainage. From the fact that beyond the Gr2-horizon the horizons of the next two meters have reduced colours and are water saturated, it can be therefore concluded that the water of the Lolopfuhl lies directly upon the regional groundwater body. Redoxpotential was measured in Gor1 and Gr2-horizon and varies between +50 and

Lolopfuhl VII

Locality:	Berlin-Rudow, Lolopfuhl like no. VI 10 m east of the center beyond willow trees
Elevation:	38.1 m
Landscape:	Teltow plain (boulder clay plain)
Relief:	Hollow
Land use:	Nature reserve (recreation area, waste deposit)
Parent material:	Colluvial layers over glacial and periglacial layers
Soil type:	Gley-Naßgley (Humic Gleysol)
Site properties:	very shallow root zone, excessive root spreading, variably wet, very bad aeration and good nutrient supply

Profile description:

Ah (Ah)	0- 8 cm	colluvial layer, 10 YR 3/1, no lime, when dry crumbs, rusty spots, many roots, sharp boundary
Go (Bg)	- 20 cm	colluvial layer, 10 YR 4/2, no lime, subangular blocky, many rusty spots, few roots, sharp boundary
fAhGo (bAh)	- 40 cm	colluvial layer, 2.5 Y 4/2, no lime, subangular blocky to angular blocky, rusty spots, almost no roots, gradual transition
Gor 1 (Bg)	-100 cm	colluvial layer, 2.5 Y 5/3, no lime, subangular blocky to angular blocky, bleached peds, almost no roots, gradual transition
Gor2 (Bg)	-115 cm	solifluction layer, 2.5 Y 6/3, no lime, coherent, bleached peds, almost no roots, gradual boundary
Gr (C)	-130 cm	solifluction layer, 2.5 Y 5/2, no lime, coherent, reduced, almost no roots, sharp transition
fAh2 (bAh)	-155 cm	cover sand, 2.5 Y 5/2, no lime, coherent, reduced, no roots, sharp transition
Grh (C)	-177 cm	cover sand, 2.5 Y 4/2, no lime, coherent, strong smell of H_2S, no roots, gradual transition
Gr2 (C)	-230 cm	boulder loam, 2.5 Y 5/2, no lime, coherent, reduced, few rusty spots, no roots, gradual transition
Gr3 (C)	-330 cm	boulder loam, 2.5 Y 5/2, no lime, coherent, reduced, no roots

All profiles in the center are decalcified deeper than 4 m.

No	hor.	depth cm	sto. %	texture in % of humus-/carb. free fine soil: sand c	sand m	sand f	sand ∑	silt c	silt m	silt f	silt ∑	clay	kf cm/d
1	Ah	0- 8	6	1	6	13	20	16	23	20	59	21	-
2	Go	- 20	0	0	4	15	19	23	22	17	62	19	-
3	fAhGo	- 40	0	1	7	16	24	18	24	15	57	19	605
4	Gor1	-100	1	2	17	29	48	16	15	8	39	13	199
5	Gor2	-115	2	3	31	28	62	16	9	3	28	10	44
6	Gr1	-130	3	5	35	33	73	11	6	3	20	7	-
7	fAh2	-155	3	3	22	29	54	19	10	5	44	17	-
8	Grh	-177	4	5	39	28	72	11	6	4	21	7	-
9	Gr2	-230	2	5	32	34	71	13	6	4	23	6	0.2

No	hor.	bulk dens. g/cm^3	GPV %	water content in % at pF 0.6	1.8	2.5	4.2	pH $CaCl_2$	pH H_2O	Fe_d mg/g	Fe_o mg/g	Fe_o/Fe_d	Mn_o mg/kg	P_v mg/kg
1	Ah	0.87	62	62	50	45	17	4.5	4.9	3.40	2.81	0.83	150	1300
2	Go	1.01	59	53	43	37	20	4.3	5.0	1.88	1.57	0.84	70	1000
3	fAhGo	1.33	48	39	36	33	12	4.4	5.3	1.48	1.30	0.88	90	630
4	Gor1	1.81	31	30	27	24	12	4.7	5.5	0.48	0.44	0.92	50	220
5	Gor2	1.88	28	27	25	20	7	4.9	5.7	0.24	0.25	1.04	20	240
6	Gr1	1.81	31	28	23	16	7	5.2	6.0	0.11	0.11	1.00	10	230
7	fAh2	1.75	33	31	26	21	7	5.0	5.9	0.30	0.31	1.03	30	510
8	Grh	1.57	40	35	27	20	8	5.2	6.1	0.16	0.18	1.12	10	290
9	Gr2	1.95	26	24	21	16	7	5.2	6.2	0.13	0.13	1.00	10	180

No	hor.	$C_{org.}$ mg/g	N_t mg/g	C/N	carbonate mg/g	CEC_p meq/kg	exchang. cations in meq/kg: Ca	K	Mg	Na	H	Al	V %
1	Ah	64.7	4.90	13	0	230	45	9.0	6.0	0.6	170	5.0	26
2	Go	26.8	2.40	11	0	130	15	4.0	2.0	0.3	105	4.0	19
3	fAhGo	12.1	0.78	15	0	125	15	4.0	2.0	0.2	105	3.5	16
4	Gor1	1.9	0.19	10	0	37	15	3.0	3.5	0.1	15	3.5	59
5	Gor2	1.2	0.14	9	0	34	12	3.0	3.0	0.2	14	1.5	59
6	Gr1	1.3	0.14	9	0	31	10	2.5	2.5	0.3	13	2.0	58
7	fAh2	2.4	0.24	10	0	56	18	3.5	4.0	0.2	30	4.0	46
8	Grh	1.2	0.14	8	0	32	11	2.5	3.0	0.1	15	2.5	53
9	Gr2	0.6	0.08	-	0	27	10	2.5	3.5	-	11	0.7	59

Lolopfuhl IX

Locality:	Berlin-Rudow, corn field at western border of Lolopfuhl, deepest place; Top. map: Berlin (south), R: 46 01 026, H 58 09 100
Altitude:	39.6 m a.s.l.
Landscape:	Teltow plain (boulder clay plain)
Relief:	smooth depression, deepest point, 1 m step downwards to Lolopfuhl east of profile
Land use:	farm field (corn, rye, potatoes)
Parent material:	sandy colluvium over cover sand over boulder loam
Soil type:	Gley-Kolluvium over Naßgley (Eutric Gleysol)
Site qualities:	moderate to deep potential root zone and moderate root spreading, moist, poor aeration, moderate to good N and P and good base supply

Profile description:

Horizon (FAO), depth, parent material, colour, carbonate content, structure, structure specialities, actual rooting, boundary.

MAp (Ah)	0- 30 cm	colluvium, 10 YR 3/3, no lime, weak subangular blocky, many roots, abrupt boundary
MGo (Bgw)	- 69 cm	colluvium, 10 YR 4/2, no lime, coherent to weak subangular blocky, soft rusty spots, few roots, sharp boundary
fAhGo (Ahb)	- 82 cm	cover sand, 2.5 Y 4/2, no lime, subangular blocky, few rusty spots, almost no roots, sharp boundary
Gor 1 (Bg1)	-150 cm	cover sand, 2.5 Y 5/4, no lime, coherent, soft rusty spots, root and earthworm channels coated with org. matter, stone line at about 125 cm, no roots, abrupt boundary
Go (Bg2)	-190 cm	solifluction layer form boulder loam, 2.5 Y 5/4, no lime, subangular blocky, many rusty spots, stone line at lower boundary, no roots, abrupt boundary
Gr (Bgr)	-225 cm	eolian sands, 2.5 Y 6/2, no lime, singular to coherent, pale bleached, no roots, sharp boundary
Gor2 (Brg)	-240 cm	boulder loam, 2.5 Y 4/4, no lime, coherent, few rusty spots, no roots

No	hor.	depth cm	sto. %	texture in % of humus-/carb. free fine soil: sand c	sand m	sand f	sand Σ	silt c	silt m	silt f	silt Σ	clay	kf cm/d
1	Map	0- 30	3	5	32	38	75	12	6	3	20	4	-
2	MGo	- 69	2	1	29	41	71	15	7	4	26	3	-
3	fAhGo	- 82	3	4	31	41	76	12	5	4	21	3	-
4	Gor1	-150	5	6	35	41	82	7	5	3	15	3	-
5	Go	-190	2	4	28	45	77	8	6	3	17	6	-
6	Gr	-225	0	4	44	47	95	1	1	1	3	2	-
7	Gor2	->240	3	5	25	35	65	8	8	5	18	14	-

No	hor.	bulk dens. g/cm³	GPV %	water content in % at pF 0.6	1.8	2.5	4.2	pH $CaCl_2$	pH H_2O	Fe_d mg/g	Fe_o mg/g	Fe_o/Fe_d	Mn_o mg/kg	P_v mg/kg
1	Map	-	-	-	-	-	-	4.6	5.3	1.8	1.2	0.66	250	530
2	MGo	-	-	-	-	-	-	4.6	5.4	1.1	0.7	0.64	100	260
3	fAhGo	-	-	-	-	-	-	5.0	5.7	0.6	0.3	0.50	10	240
4	Gor1	-	-	-	-	-	-	4.9	5.8	0.4	0.2	0.50	10	150
5	Go	-	-	-	-	-	-	5.2	5.8	3.0	2.4	0.80	30	300
6	Gr	-	-	-	-	-	-	5.3	5.9	0.2	0.1	0.50	0	70
7	Gor2	-	-	-	-	-	-	4.7	5.3	4.0	2.4	0.60	70	240

No	hor.	$C_{org.}$ mg/g	N_t mg/g	C/N	carbonate mg/g	CEC_p meq/kg	exchang. cations in meq/kg: Ca	K	Mg	Na	H	Al	V %
1	MAp	8.2	0.52	16	0	96	44	0.2	0.8	2	40	4.6	60
2	MGo	6.0	0.45	13	0	57	26	0.1	0.7	2	28	6.2	51
3	fAhGo	2.6	0.12	22	0	37	19	0.1	0.6	2	15	2.5	59
4	Gor1	0.6	0.05	-	0	23	16	0.1	0.4	2	4	-	83
5	Go	0.5	0.09	-	0	54	45	0.1	1.2	2	5	-	91
6	Gr	0.2	-	-	0	23	20	0.1	1.0	1	2	-	91
7	Gor2	0.6	0.10	-	0	130	105	0.4	4.5	2	18	-	86

-350 mV without an annual rythm. That means reducing conditions all the time.

Site qualities: The profile IX has a moderately deep root zone in the colluvial layer whereas profile VII has an extremely shallow root zone. Water regime of profile IX is moist to wet and profile VII wet to very wet. Oxygen supply in profile IX is moderate to good in the plough layer, whereas it is very bad all over the profile VII. The vegetation period at this site is limited by the oxygen deficiency. Nutrient supply has compared with the air conditions no limitations at this site, because of high org. matter content and a relatively high stock of minerals. The nutrient supply on the farmers field is less but still the best of all sites analysed in the fields. Especially pH and base saturation are higher than in the other profiles.

4.4 Ruderal sites on rubble deposits in the city - Lützowplatz area

Through the events of World War II, sites with rubble deposits gained in importance. Many parts of the ruined and not restored parts of the inner city consist of rubble deposits. These layers of one to several meters thickness have meanwhile developed into soils with specific properties (RUNGE 1975, BLUME & RUNGE 1978). Sites on pure rubble are comparatively rare (SUKOPP et al. 1974). After the War, the restoration of the city started by clearing the ruines, collecting valuables (esp. metals), mixing the rubble with soil material, refilling and levelling the areas. In the following period, an intensive vegetation development on the rubble sites began, proceeding in more or less rapid succession from annual to perennial stages of herbaceaous vegetation to shrubs and finally to forest like stands (comp. Tab. 11 and SUKOPP 1978). Meanwhile the natural succession is generally disrupted by clearing and reconstruction works.
The features of a meanwhile 25 years old rubble site will be illustrated at the intensely studied Lützowplatz.

The Lützowplatz lies in the glacial valley (Urstromtal), that originally consisted of sandy Gleysoils and bog areas with the respective vegetation. The younger history of this area in the inner city district - Tiergarten - was as follows: Agricultural land use up to the turn of the century; construction of the "Landwehrkanal"; mixing of the soil surface and constructing four storeyed houses; after the War, clearing down to the foundation; in 1959 filling with a mixture of rubble and soil, afterwards levelling.
From that time on, recent soil and vegetation development (now 25 years)(Fig. 41). The natural succession of vegetation for this special area was first studied in 1961 (KOHLER & SUKOPP 1964). Seedlings of Robinia and Betula could already be found. Undisturbed vegetation development led to the differentiated types of today. Influences by man, such as parking lot for circus, refuse disposal, dog run, childrens playground etc. can almost be neglected. Until 1978 the Robinia stands had covered the greatest part of the area; only the north-west and eastern part had been areas without woody plants. The highest stage of ruderal succession under Berlin conditions had been reached. In December 1978 big part of the Robinia stands had been thinned to a quarter of its original density. The herbs and shrubs in the southern part had been totally destroyed by caterpillars. In 1980 a part had been reclaimed for flat buildings. The remaining area has an extension of about 6000 m^2. The survey of flora and vegetation yielded a total of 164 species; the number decreased to 150 in 1984. Nearly 60% of the vascular plants can be considered to be native (indigenous) to Berlin. The others have been introduced by influence of men; 20% - the neophytes have been disseminated after 1500, they nowadays belong

Tab.11 Succession stages of ruderal vegetation and soil development on city waste lands of Berlin (West) (altered from SUKOPP et al. 1980)

parent material	sand, poor in nutrients and org. matter	Rubbles and waste deposits	accumulated nutrient rich substrates
succession stages			
- annual plants initial soil formation (Ai-C-soils)	Bromo-Corispermetum (typical Syrosem on unconsolidated acid rock)	Chenopodietum botrys (lime rich Syrosem on unconsolidated rocks)	Chenopdietum stricti (e.g. colluvium over brown earth)
	↓	↓	↓
- biannual plants	Berteroetum incanae	Oenothera stage	Lactuca-Sisymbrium altissimi stage
	↓	↓ ↘ Melilotetum ↙	← Melilotetum ↓
- perennial herbs and grasses mature A-horizons (Ah-C-soils)	Festuca trachyphylla stage (Syrosem-Regosol)	Poa-Tussilaginetum (Syrosem-Pararendzina)	Artemisietum vulgaris
	↓	↓	↓
- pioneer shrub vegetation	Robinia-resp. Lycium shrubs (Typ. Regosol)	Chelidonio-Robinietum (Typ. Pararendzina)	Sambucus nigra association (eutrophicated sites)
	↓	↓	↓
- deciduous forest subsoil development (Ah-BvC-soils)	not observed (Betula-Pinus) ((Braunerde-Regosol))	not observed (Quercus, Tilia, Acer, Budlaja, Ailanthus) ((Parabraunerde-Pararendzina))	Acer platanoides-stage Acer pseudoplatanus-stage (e.g. Eutrophic brown earth)

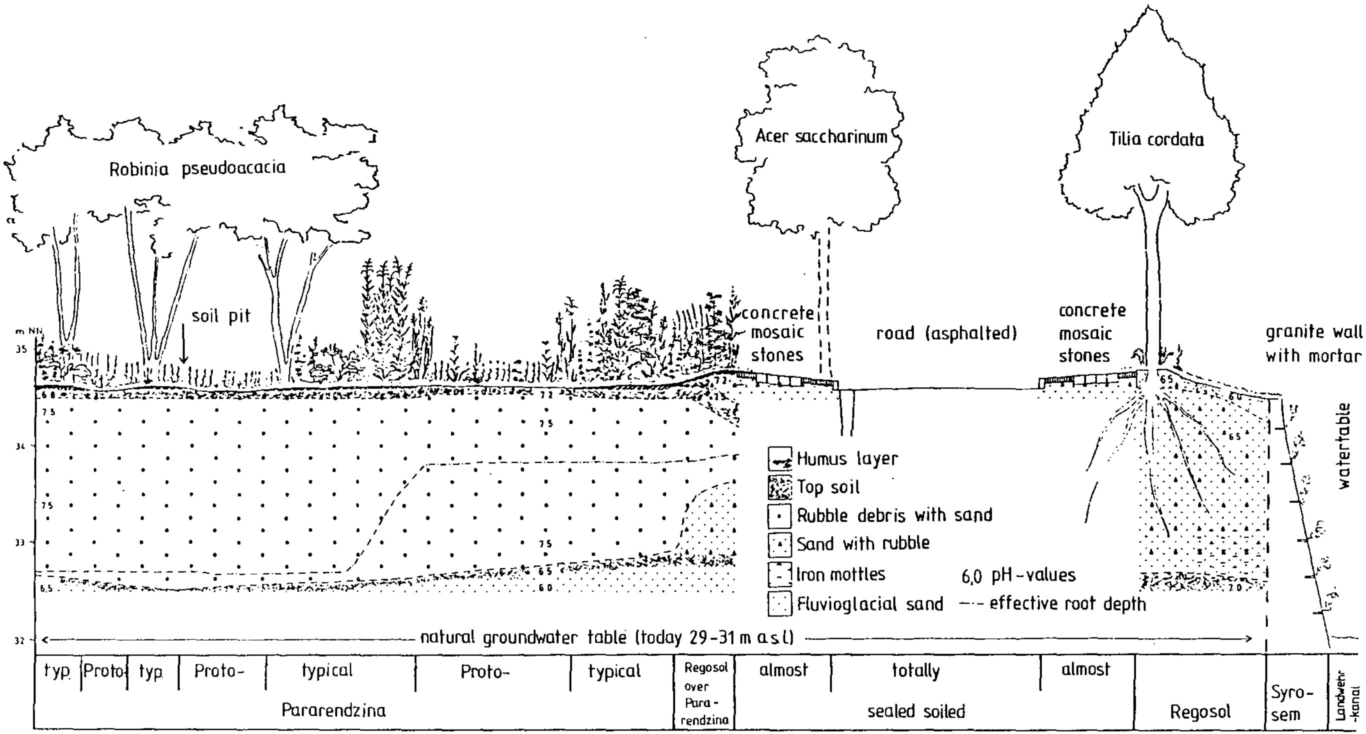


Fig. 41 Soils at Lützowufer (from WEIGMANN et al. 1981)

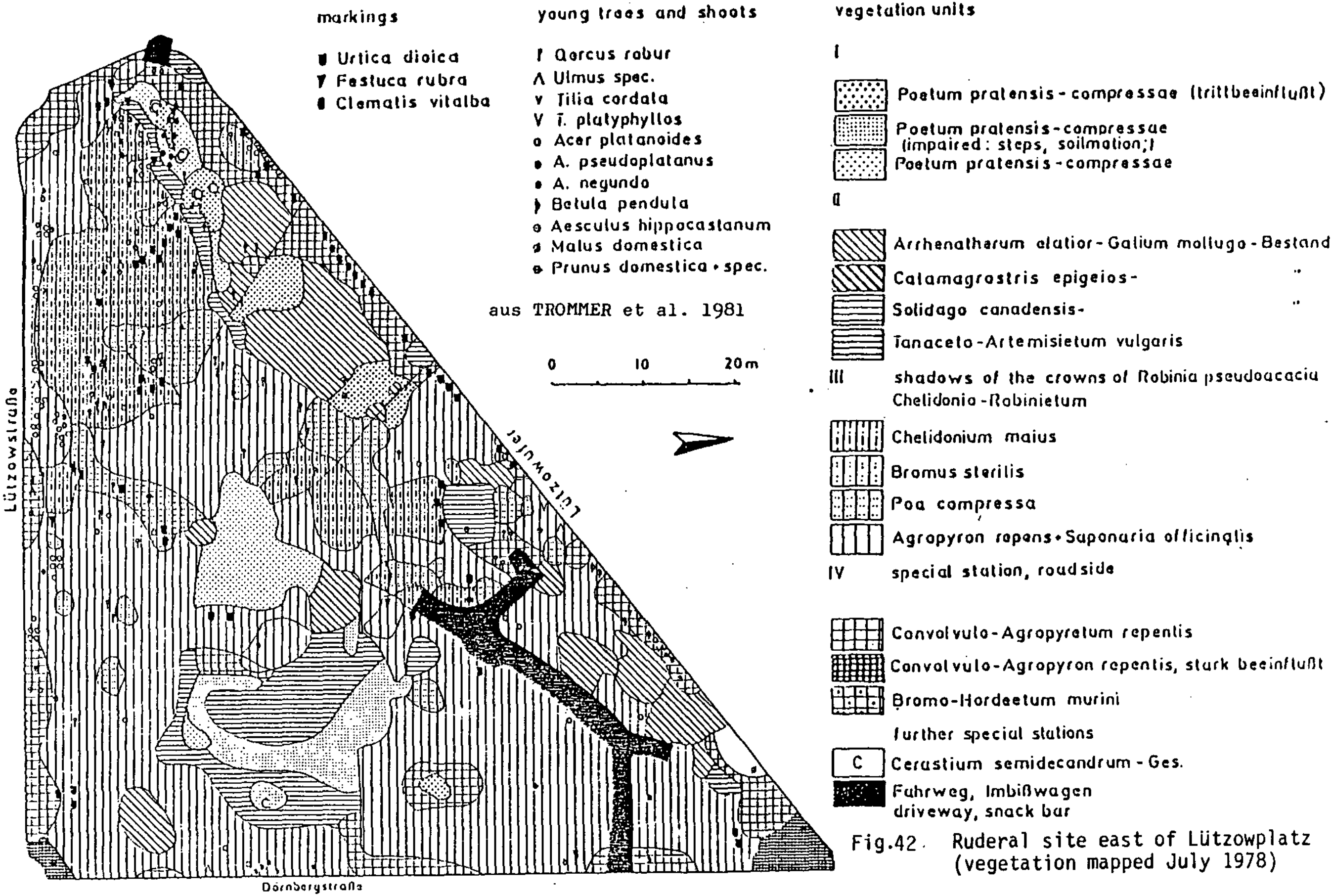
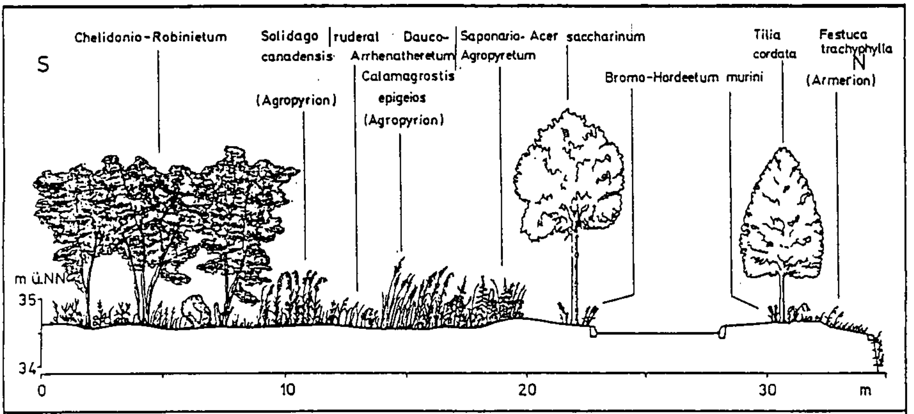


Fig.42 Ruderal site east of Lützowplatz (vegetation mapped July 1978)

to the flora of this region (Fig. 42). The vegetation was mapped (WEIGMANN et al. 1981) by a physiognomic classification: the black-locust (Robinia pseudacacia) stands, the high growing ruderal shrubs and herbs, ruderal "meadows", ruderal dry lawns, and the roadside verges. Annual associations were not found in 1978.
The transect shows the typical vegetation (Fig. 43). The habitat conditions in the Robinia forest are distinctly milder than those of the open ruderal dry lawns. As shown by measurements taken over a period of two years (Fig. 44), the Robinia gathered water from the ground during the summer down to a depth of 2 m, so that almost no water stress was present.

Fig. 43 Ruderal site Lützowplatz - Vegetation and its indicator values



Nr.	1	2	3	4	5	6	7	8	9	10
L	7.1	6.9	7.6	7.4	7.7	7.7	7.3	7.3	7.6	7.6
T	6.2	6.8	6.7	5.9	5.4	6.2	6.5	6.0	6.6	5.5
K	5.1	4.6	5.2	4.6	5.6	4.2	5.2	4.4	3.0	5.5
F	4.6	4.4	4.6	4.5	4.8	4.8	4.9	4.9	4.0	3.7
R	7.7	8.6	8.0	8.0	7.8	7.2	7.0	6.3	7.0	9.0
N	6.4	6.2	6.1	4.9	5.4	5.8	7.1	5.7	5.0	5.2

ELLENBERG (1979) indicator values: L - light, T - temperature, K - climate, F - moisture, R - reaction, N - nitrogen

In contrast, the shallow rooted ruderal dry grasses frequently showed signs of drought damage because the effective root zone was shallower. Also, the leaf litter of the Robinia improved the nitrogen supply. An evaluation of the vege-

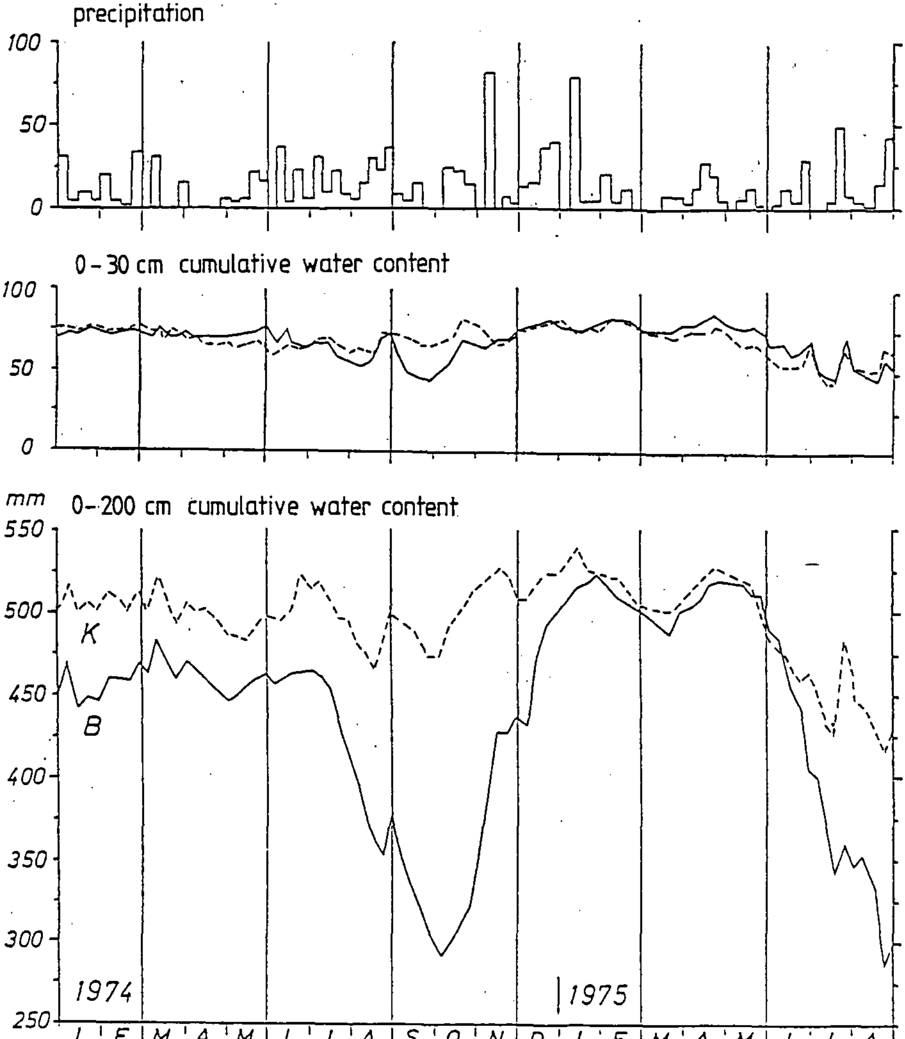


Fig. 44 Precipitation and soil water storage for a Pararendzina (calcaric Regosol) from rubble under Robinia trees (B) and ruderal grassland (K) at Lützowplatz

tation (see Fig. 43) by aid of the ELLENBERG (1979) indicator values yielded nitrogen values of approximately 6.5 under Robinia and 5 for the ruderal lawns. Rapid desication in the lawns led to a lower use of the favourable nitrogen supply.

The accumulation of especially organic material caused at the roadside verges a better water and nitrogen supply. The vegetation is adopted to disturbances like chemical weed control (up to 1981) and trampling. The root pioneers as Field Bindweed (Convolvulus arvensis), Quackgrass (Agropyron repens) are able to resist these impacts.

Further succession tendencies: Within the Robinia stands many seedlings of native and neophytic decidious trees are found, like Maples (Acer negundo, A. platanoides, A. pseudoplatanus), Lime (Tilia cordata), Tree of Heaven (Ailanthus altissima), Oaks (Quercus robur). This indicates that in the future, the Black locust will be replaced mainly by native trees, if the site will remain undisturbed.

While surveying flora and vegetation 1978 and 1979 a total of 164 species of vascular plants, as well as 4 moss and 1 fungus species (Basidiomycetes) were determined. 57% of the vascular plants are considered to be indigenous the others have been disseminated by direct or indirect influence of man.

Vertebrate animals are very scarcely represented in the area. The mammals observed, except dogs, were only rabbits (Oryctolages cuniculus) and long-tailed mouse (Apodemus sylvaticus). The only breeding birds were wood pigeon (Columba palumbus) and icterine warbler (Hippolais icterina) as well as a few other feeding guests.

In contrast, approx. 250 species of arthopods were found (WEIGMANN et al. 1981), which correlates directly with the variety of flowering plant species.

Explanation for profile Lützowplatz - Pararendzina

Parent material: The site has a cover of 2 m rubble-sand mixture over an old Gley soil formed from glacial outwash sands of middle to fine sand texture. The rubble mixture contain about two third of fine earth and one third of various skeleton. The properties are shown in Tab. 12.

One of the striking features of the skeleton is that the stones have the considerable pore volume of about 30% (RUNGE 1975). The skeleton add about 5 l/m^2 x dm to the available moisture content of the soil. The carbonate content of the material is higher than in all natural substitutes around. Furthermore, the gypsum content of the rubble is fairly high.

Profile Lützowplatz

Locality:	Ruderal site east of Lützowplatz, south of Lützowufer at Landwehrkanal
Altitude:	34.6 m a.s.l.
Landscape:	Glacial valley of Warschau-Berlin; Central Berlin city part
Landuse:	non, natural succession after rubble deposition
Parent material:	Mixture of rubble from World War II and sand over fluvioglacial sands. The rubble contains bricks,charcoal, glass, mortar, concrete, gypsum, metals, ceramics, wooden peaces a.s.o.
Soil type:	Typische Pararendzina (Calcaric Regosol)
Humusform:	Mull humus on sand, litter layer discontinous
Site qualities:	very deep root zone, moderate root spreading, moderately dry, extremely well aerated, good to very good nutrient supply

Profile description:

Horizon (FAO), depth, parent material, colour, carbonate content, structure, structure specialities, coarse stones Vol.%, actual rooting, boundary.

Ah1 (Ah)	0- 2 cm	rubble and sand, 10 YR 2/1, 5% carbonates, fine granular and loose, 5% stones, many roots, sharp boundary
Ah2 (Ah)	- 6 cm	rubble with sand, 10 AR 3/1, 5% carbonate, granular and loose, 15% stones, extreme root amount, sharp boundary
AC (AC)	- 18 cm	rubble with sand, 10 YR 4/2, 10% carbonate, subangular blocky, 30% stones, many roots, gradual boundary
C1 (C)	- 70 cm	rubble with sand, 10 YR 4/3, 10% carbonate, subangular blocky, 40% stones, frequent roots, gradual boundary
C2 (C)	-120 cm	rubble with sand, 10 YR 5/3, 10% carbonates, coherent to weak subangular blocky, 35% stones, frequent roots downward decreasing, gradual boundary
C3 (C)	-195 cm	rubble with sand, 10 YR 5/3, 10% carbonate, coherent to weak subangular blocky, 35% stones, few roots, abrupt boundary
fAh (Ahb)	-210 cm	fluvioglacial sand, 10 YR 3/2, traces of carbonate, coherent, no stones, almost no roots, sharp boundary
CGr (BC)	240 cm	fluvioglacial sand, 10 YR 7/3, no lime, coherent, no stones, almost no roots

No	hor.	depth cm	sto. %	texture in % of humus-/carb. free fine soil: sand c	sand m	sand f	sand Σ	silt c	silt m	silt f	silt Σ	clay	kf cm/d
1	Ah1	0- 2	13	4	65	15	84	3	3	2	8	8	3330
2	Ah2	- 6	15	5	60	20	85	3	3	3	9	6	
3	AC	- 18	27	8	65	18	91	2	3	1	6	3	870
4	C1	- 70	33	11	62	20	93	2	2	1	5	2	570
5	C2	-120	32	8	64	19	91	2	2	2	6	3	850
6	C3	-195	37	11	62	17	90	3	2	2	7	3	935
7	fAh	-210	<1	3	61	30	94	2	1	-	3	3	188
8	CGr	>210	<1	9	80	9	98	-	1	-	1	1	1160

No	hor.	bulk dens. g/cm^3	GPV %	water content in % at pF 0.6	1.8	2.5	4.2	pH $CaCl_2$	pH H_2O	Fe_d mg/g	Fe_o mg/g	Fe_o/Fe_d	Mn_o mg/kg	P_a mg/kg
1	Ah1	0.79	67	56	21	18	14	7.0	7.1	2.8	1.68	0.60	62	530
2	Ah2							7.2	7.3	2.6	1.36	0.53	55	510
3	AC	1.37	48	43	22	15	8	7.4	7.7	2.0	0.97	0.48	31	460
4	C1	1.30	50	47	23	17	7	7.6	7.7	1.86	0.88	0.47	46	530
5	C2	1.30	50	45	20	15	7	7.7	7.7	1.53	0.76	0.50	34	480
6	C3	1.29	51	47	21	16	6	7.8	7.8	1.58	0.73	0.53	33	480
7	fAh	1.58	40	36	22	10	4	7.6	7.8	1.21	0.97	0.80	69	960
8	CGr	1.71	36	35	6	3	1	7.8	8.1	0.06	0.05	0.69	<1	90

No	hor.	$C_{org.}$ mg/g	N_t mg/g	C/N	carbonate mg/g	CEC_p meq/kg	exchang. cations in meq/kg: Ca	K	Mg	Na	H	Al	V %
1	Ah1	83.5	4.9	17	51	303	330	8.0	9.7	0.7	4	-	100
2	Ah2	56.9	2.5	24	51	273	330	6.4	7.4	0.4	2	-	100
3	AC	12.8	0.4	34	86	64	350	4.1	2.9	0.4	-	-	100
4	C1	8.1	0.1	-	112	54	460	2.4	2.8	0.8	-	-	100
5	C2	7.2	0.1	-	89	54	390	4.1	3.9	1.3	-	-	100
6	C3	7.6	0.1	-	83	54	370	4.3	3.5	1.2	-	-	100
7	fAh	3.3	0.1	-	4	39	70	3.2	3.3	0.2	-	-	100
8	CGr	0.4	0	-	-	< 1	1	0.4	0.4	<0.1	-	-	100

Tab. 12 Properties of fresh rubble (Berlin) (after BLUME & RUNGE 1978)

	weight	C[3]	$CaCO_3$	B	Cu	Mn	Zn	Pore volume	wilt. point	field cap.
	%			ppm				%		
fine earth < 2 mm Ø	60	0.7	10.3	30	100	160	800	40	5	18
bricks	22.4	0	3.0	20	30	500	200	45	17	38
mortar	12.4	<0.1	15.5	10	30	14o	300	34	3	26
coal	-	62.0	2.3	3	40	120	9000	-	-	-
slag	0.6	6.2	1.7	60	80	1500	300	-	-	-
artificial product[1]	2.7	5.3	11.0	70	2200	900	24000	-	-	-
natural product[2]	1.9	-	n.b.	n.b.	n.b.	n.b.	n.b.	-	-	-

1) metals, ceramics, glass, bitumen

2) leather, slate, marble, limestone fragments

3) carbon, organic for fine earth, in organic (coal-carbon) for skeleton

Soil development: The soils of Lützowplatz have first been analysed by RUNGE (1975) and BLUME & RUNGE (1978) with samples taken 1972-1974. The recent analysis from 1985 makes it possible to show some tendencies of soil formation by comparison. One of the first and most important soil forming processes is humus accumulation. RUNGE in the seventies found 3-6 kg/m^2 org. matter enriched in about 10 cm depth. A comparable profile contained 5.2 kg/m^2 more org. matter than its parent material, and recent data show an enrichment of 7.6 kg/m^2 which was found down to 30 cm. So the average increment for the first 12 years was 0.4 $kg/m^2/a$ and for the second twelve years 0.2 $kg/m^2/a$. The organic nitrogen increase was even more relevant. The profile in 1972 shows a N-increase relative to the parent material of 150 g/m^2, 1985 210 g/m^2. The increment therefore is 12 $g/m^2/a$ and 6 $g/m^2/a$ (which is 120/60 kg/ha/a) for the two twelve year periods. This was only possible through the N-uptake of bacteria in symbiosis with Robinia. It is worthwhile to mention that the C- and N-amounts in the upper horizon (0-2 cm) already were in equilibrium after 12 years. Their amount did not increase any more. There is a lower skeleton content in the upper 10-20 cm. This may be due to the break down under the heavy load of the levelling machines in 1959, due to weathering of mortar e.g., additions of dust and activity of animals especially arthopods.

The topsoil is decalcified continously since 1960. The loss of carbonates is partly redistributed in the subsoil. The calculated losses of 4-5 kg/m^2 seem to be too high and may be due to inhomogenous parent material. The additional loss during the last decade would be up to 40-50 $g/m^2/a$, which is 400-500 kg/ha/a. The acidification has not led to a significant result because there is free calcium carbonate still in all horizons. A clay formation can not yet be proven, but it is obvious that through disintergration of bigger particles and decalcification more clay and silt is present in the upper 6 cm of the profile. The heavy metals Pb and Cd are enriched in the topsoil due to dust accumulation in the upper 4 cm (Pb 400-450, Cd 0.5-0.6 ppm) and also in the depth of 10 cm (Pb 200-250, Cd 0.3-0.35 ppm). In contrast, B, Cu and Zn-contents are stable or depleted through seepage or plant uptake.

Site ecology: The rubble sites generally have a deep to very deep root zone. It may end over remains of foundations. The root action is generally obstructed by the substantial amounts of gravels and stones. The roots are unable to enter the cavities of bricks and other stones. Due to the high total and especially coarse pore volume the soils are extremely well aerated and show a rapid drainage. The total water capacity is relatively high with 500 l/m^2 down to 2 m depth, but only 200-250 l/m^2 are available because of unavailable water in pores of stones and about 150 l/m^2 bound at wilting point. With this data, it can be explained that the Robinia with their deep roots are well supplied with water, whereas plants with shallow roots suffer from drought.

Because of the sand in the deep subsoil and the lowering of the groundwater table, water uptake through capillary rise is not possible for the plants. The low humidity and the higher temperature in the inner city increase evaporation and interception; therefore, even for the plants with deeper root zones water stress may occur occassionally.
The nutrient conditions are generally good. The total and especially available potassium and phosphorus are higher than those in sandy soils in the city. This is even valid after high stone contents are taken into account. The main root zone already shows similar amounts of available nitrogen as agricultural soils in Berlin (BLUME & RUNGE 1978). The favourable nitrification conditions are indicated by a nitrate domination. An additional input of 20-30 kg N/ha/a through pollution has to be taken into account. An even higher eutrophication is visible caused by faeces. Because of the high total contents of trace elements like Cu, Mn and Zn there should be no lack of available trace elements despite of the high pH-values. Toxic reaction to Zn may be expected after a sharp decrease of pH. Other trace elements like Pb and Cd, inspite of their levels, are still not harmful as long as the pH remains high.

4.5 Soils on ruined railway stations - The Anhalter Güterbahnhof

In urban environments large railway sites and stations represent a special ecological situation. Different land utilizations and parent materials produce many different habitates in these areas (Fig. 45 - Location Map).

At the "Anhalter Güterbahnhof" - formerly a very important goods station and freight yard for the railway - World War II has destroyed some parts. In these never reconstructed parts one can find a 40 year old, undisturbed development of soil and vegetation. For comparison, in other parts there still exist railway banks and storage sites in use with initial soil and vegetation structures.

Geology and water regime: For the construction of the Anhalter Güterbahnhof around 1885, the river sediments were covered by about 4 m banking materials consisting of medium to fine sand, debris of brick stones and mortar and partly of industrial cinder, mostly overlayed by gravel. This mixture is highly permeable. The groundwater table is to be found about 6 m below the surface not influencing the water supply of the vegetation. Due to buried foundations and cable ditches, soil water can accumulate in some faces. So the relations between soil and vegetation development and the native ecological conditions are very low and the ecological situation is mainly influenced by the men-made substrate.

Flora and vegetation: Corresponding to the variety of parent materials, character and intensity of human impact, and time available for vegetation development, flora and vegetation are characterized by a high number of species (vascular plants) and high diversity of vegetation structure (Tab. 13). Faunistic investigations confirm the biological richness of derelict railway territories, especially for invertebrates. With 417 species of vascular plants, a third of the Berlin flora is represented on Anhalter Güterbahnhof. Among them, many species are found that are endangered both in the natural and extensively cultivated landscape. These are now colonizing secondary habitats, particularly on more or less undisturbed sites, that are dry and poor in nutrients, e.g. the conspicuously flowering Helichrysum arenarium on sand.

The considerable occurence of aliens, amounting to forty percent of the flora and dominating not only the early succession stages but nearly half of the preforest stands, mainly result from three factors:

1) For more than a hundred years the railway system has supported the immigration of species bound to the transport of goods. In the meantime, most of these,

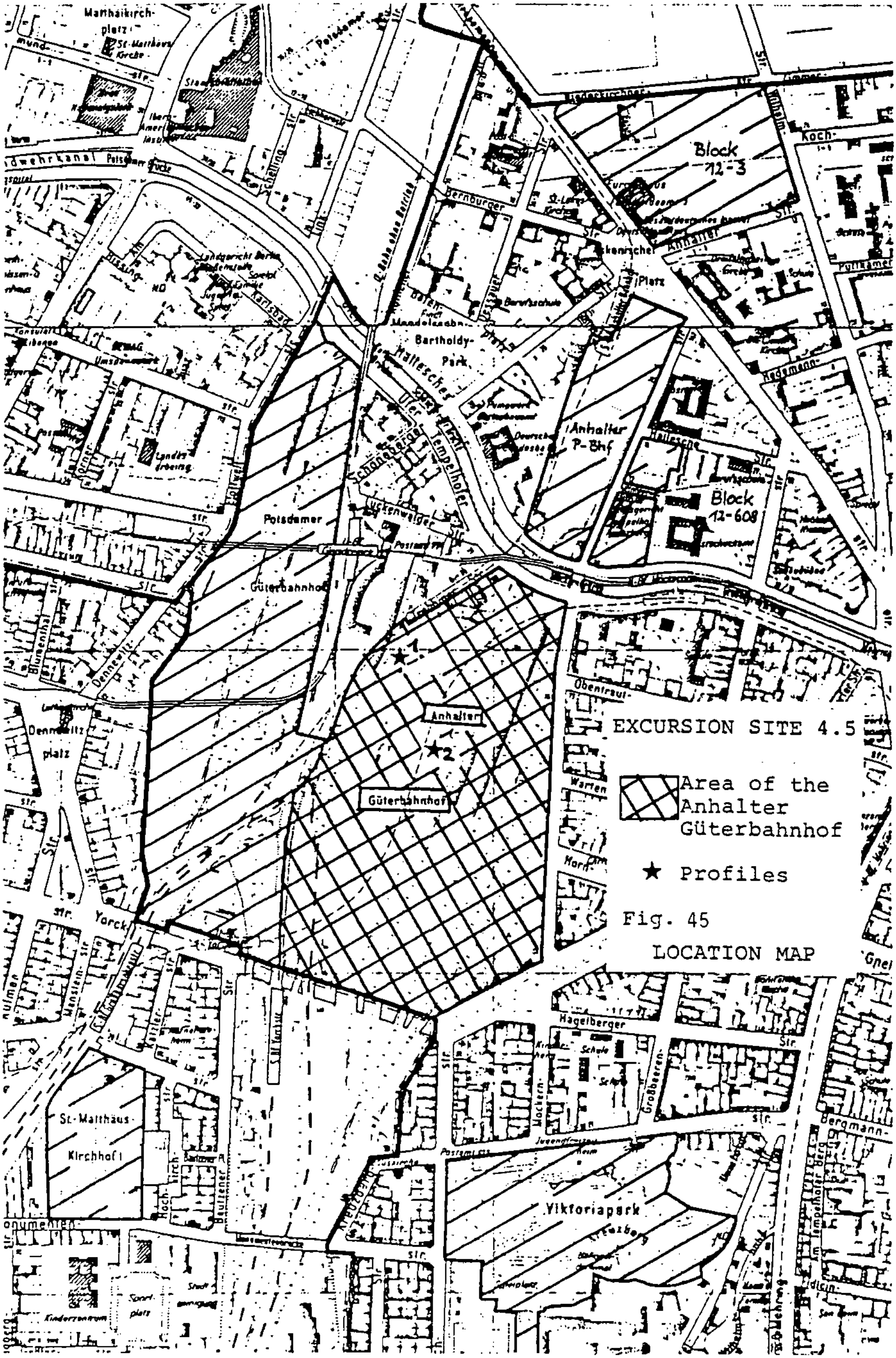


Fig. 45
LOCATION MAP

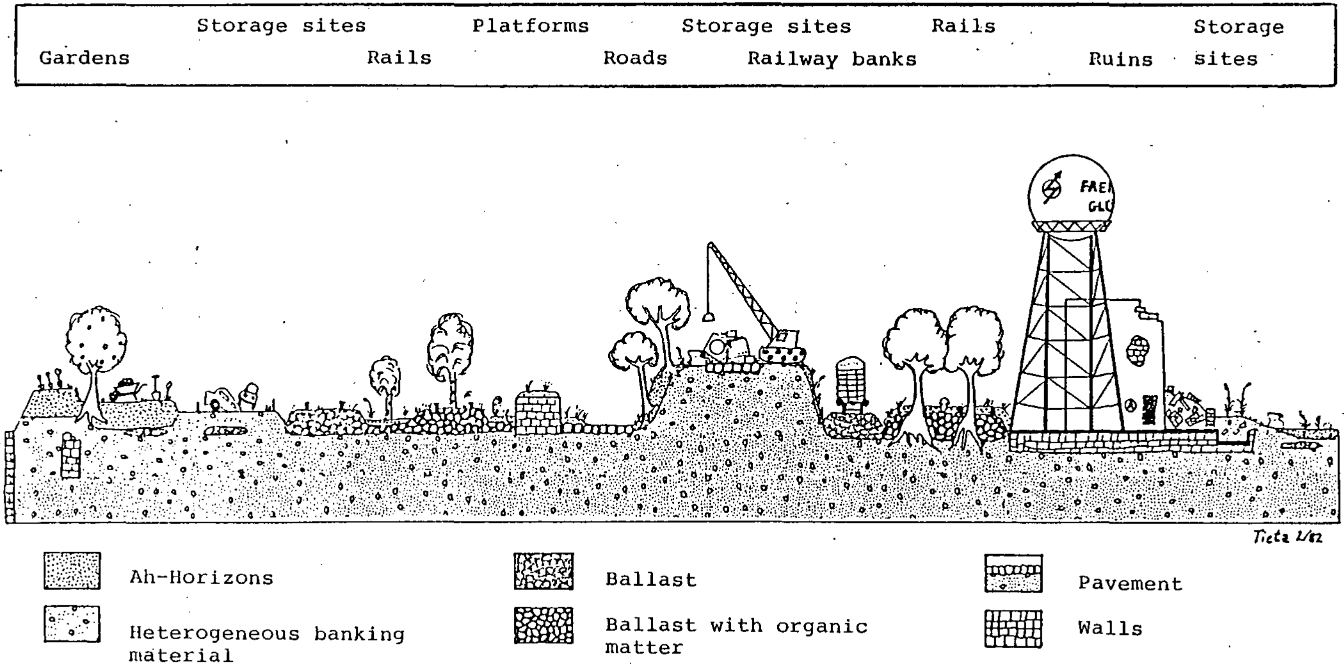


Fig. 46 Catena of the excursion site 4.5 - Area of the Anhalter Güterbahnhof

Tab. 13 Floristic characterization of Anhalter/Potsdamer Güterbahnhof compared with dates from two neighboured railway territories (basic data after ASMUS 1980, 1981, KOWARIK 1982, cited in KOWARIK 1986)

	Anhalter/ Potsdamer Güterbahnhof	Ringbahn Yorckstraße	Südgelände
area (ha)	63	17	73
number of species (vascular plants)	417	332	395
- native species (%)	60	64	66
- alien species (%)	40	36	34
- rare and endangered species (%)	10	8	12
index of similarity (Jaccard)	-	52	58
number of species without occurrence on Anhalter Güterbahnhof	-	73 (22%)	117 (30%)

e.g. Corispermum leptopterum, are frequent on urban-industrial sites, whereas only a few species remain restricted to the railway territory, e.g. Erysimum durum not far from reloading points of Galeopsis angustifolia on gravel. Because of the spatial connections to neighbouring railway areas, each of them characterized by a specific stock of species (see Tab. 13), migration of species is going on.

2) The urban climate with higher temperatures, partly increased by dark colours of gravel, coal-slag, or by the heat capacity of old buildings and ruins, allows the occurence of species native to warmer regions. Under extreme climatic and/or edaphic conditions (e.g. waterstress, application of noxious chemicals), their competive capacity can surpass that of the native species (e.g. Chenopodium botrys, Amaranthus spec. div., Sisymbrium spec. div. of southern and south-eastern origin).

3) The proximity of urban parks and gardens supports the dispersal of naturalized ornamental plants, which have become important components of the local flora and vegetation. Sixty percent (85 species) of the non-indigenous ornamental shrubs and trees, actually naturalized in Berlin, are to be found in the railway territories (Tab. 13). The most frequent is Robinia pseudacacia from the

northern part of America, forming large stands; others are the chinese Ailanthus altissima or the mediterranean Colutea arborescens.

Vegetation dynamics: Proceeding in more or less rapid succession from short-lived and perennial stages of herbaceous vegetation to shrub and forest-like stands, can be summarized in a succession diagram, differentiated according to four important parent substrates (KOWARIK 1986, Fig. 47). In general, the change of vegetation resulting from very specific environmental conditions partially leads to yet unknown units of vegetation.

Due to the low utilization during the last four decades, perennial stages dominate the vegetation on Anhalter Güterbahnhof. Pioneer stages exist on locally disturbed sites, quickly colonized by mainly yellow-flowering annual and biennial plants attached to the alliances Sisymbrion and Dauco-Melilotion (e.g. Sisymbrium loeselii, Oenothera biennis agg.). In the sphere of rails still in operation, herbicide application is responsible for durable pioneer stages forming a specific "herbicide-vegetation". Annuals like Conyza canadensis and Senecio viscosus profit from the periods between the dates of herbicide application, whereas several species with a deep root system like Calamagrostis epigeios, Saponaria officinalis and also the liana Clematis vitalba can survive this special human impact. Thermophilous species belonging to the genus Amaranthus (A. retroflexus and A. albus occurring as a ground runner) are typical for soils covered by black coal-slag.

As to the perennial stages, rough meadows consisting of tall grass communities (Poa-Tussilaginetum) grow on carbonate-containing dry soils. They change into light shrubbery often dominated by Robinia pseudocacia infiltrating the grass communities by suckering. Under the canopy of the black locust pre-forest, seedlings and young growth of nitrophilous species like Sambucus nigra or Chelidonium majus indicate the improvement of the nitrogen supply caused by the leaf litter of the nitrogen-fixing black locust and point to future succession stages: within a few decades, provided that vegetation will remain undisturbed, the Robinia stands will have been displaced by a maple-oak forest (Acer platanoides, A. pseudoplatanus, Quercus robur). On nutrient-rich sites with a better water supply, succession tends in the same direction, proceeding more quickly from tall herb communities with Artemisia vulgaris and Solidago canadensis over a shrub stage with Sambucus nigra to a maple-dominated forest.

On sand and on gravel, the perennial stages are characterized by Arrhenatherum elatior and low grasses, e.g. Festuca trachyphylla and - indirectly promoted

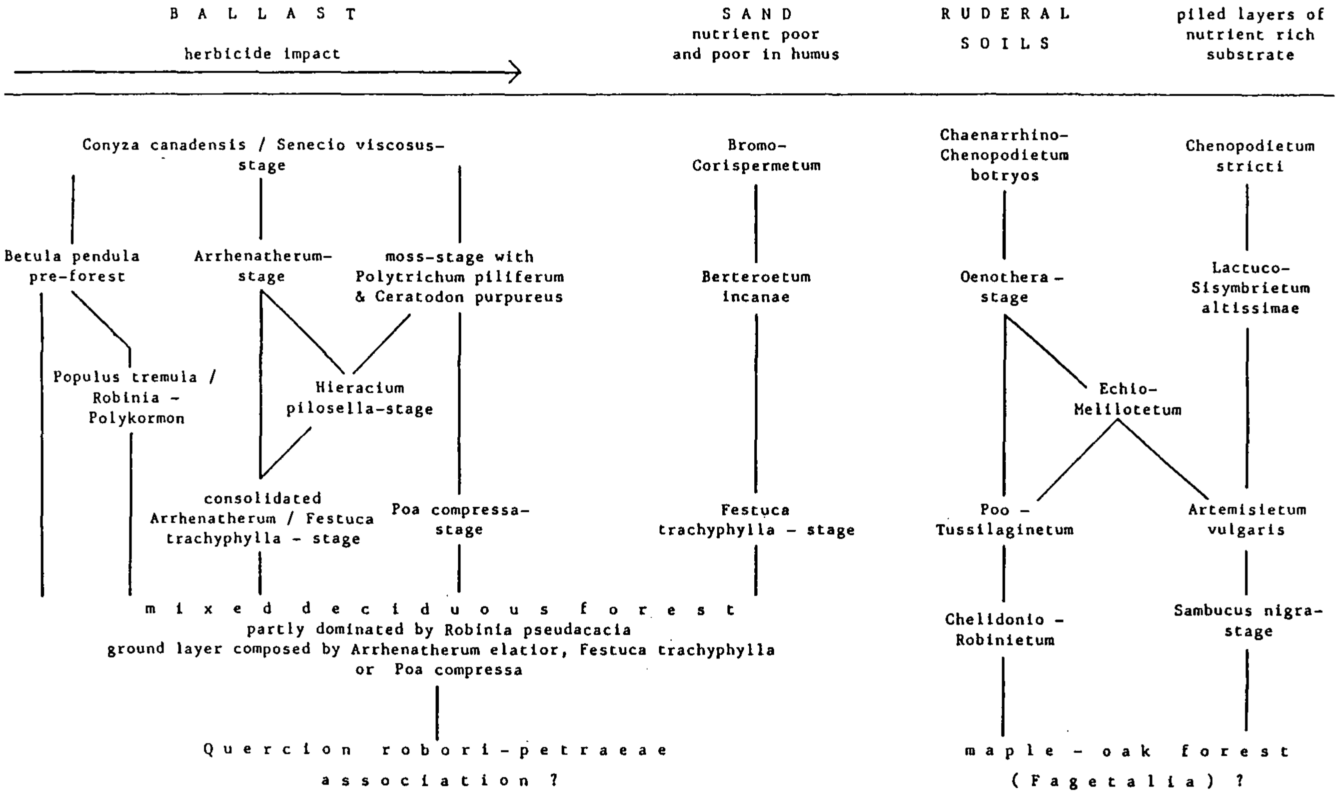


Fig.47 Succession diagram for vegetation dynamics on innerurban vacant lots
(according to SUKOPP, 1973, and KOWARIK, 1982, in KOWARIK 1986)

by herbicides - Poa compressa, also constituting the ground layer of the mixed deciduous pre-forests. Indigenous species like Quercus robur and sporadic young growth of Pinus sylvestris indicate succession tendencies towards a forest community resembling those of the native Quercion-communities on sandy soils. If the gravel is poor in fine earth, succession can start with sand birch (Betula pendula), alter on accompanied by trembling poplar (Populus tremula). One site is extraordinary because of a light pre-forest consisting of Prunus mahaleb, a species, which generally occurs isolated in Berlin. In the herb layer grows already a grass common to natural forests (Deschampsia flexuosa).

Railway banks: The soil development depends on age of the railway banks covered by debris, intensity of use and the moment of traffic shut down. The main factor of soil genesis on railway banks is the accumulation of dusts, ashes, corrosion particles and organic matter between the banking gravels, i.e. the debris, resulting from unloading or train,cleaning works and later biological activity. A horizon with high content of humified organic matter is forming, when the first vegetation establishes. Later, trees can germinate in this horizon, loosening the gravel and reaching the sandy banking material in the ground. That means an important enlarging of the root space. This development will be demonstrated at profile I.

Storage sites: Some former railway banks were levelled and used as storage sites. Here, different conditions prevail dependent on the type of storage materials like coal, timber, bricks, scrap iron and others. After ending the storage, on the rests of these parent materials vegetation and soil develops too. This situation is shown at profile II with a top soil consisting of coal debris.

Interpretation of analytical results including special investigations

Anhalter Bahnhof I - Calcaric Regosol

Organic matter accumulations are due to the rich vegetation. Dusts of carbonates increase pH in the top soil. Medium amounts of available N and K are found in the top soil, but little amounts of P. In all horizons, Pb and Zn are accumulated. Zn in this concentrations can be harmful for Zn-sensible plants. Nevertheless, a high accumulation of fine soil makes a rich vegetation possible.

Anhalter Bahnhof II - Eutric Regosol

High to very high amounts of N, K and Zn are found in the top soil, due to the sedimentation of coal detritus and industrial dusts. There are problems for vegetation settlement, because in the 2C-horizon no fine soil is accumulated. So water for plants is not available in the summer, if roots are not capable of reaching the deeper layers.

Anhalter Bahnhof I

Location:	shut down railway bank, Anhalter Güterbahnhof
Parent material:	banking material derived from basalt overlaying sandy brick debris
Soil type:	Kalkregosol aus Gleisschottern (Calcaric Regosol, stony phase)
Humusform:	Mull
Vegetation:	Prunus-mahaleb-forest

Profile description:

Ah (Ah)	0- 11 cm	60% banking gravels derived from basalt (very gravelly), black, 10 YR 2/1, loamy sand, fine crumb, high abundance of roots, slightly calcareous, pH 7.2, high biological activity (sample no. 4.5.11)
AhC (AC)	- 31 cm	dark yellowish brown, 10 YR 4/6, medium to fine sand, single grain, gravelly, fine roots, partly nodules of mortar, pH 6.5, fine gravels are rusty (sample no. 4.5.12)
2C (C)	- 79 cm	dark grey ,10 YR 4/1, loamy sand, single grain, abundance of roots, very gravelly, calcareous, pH 7.3, debris of brick and mortar, partly basaltic gravels (sample no. 4.5.13)
3C (C)	-120 cm	pale brown, 10 YR 6/3, medium sand, single grain, gravelly, calcareous, pH 7.3, sandy debris of brick and gravels (sample no. 4.5.14)

All boundaries are abrupt.

Analytical results:

notes: 1) available nitrogen 1% KAl $(SO_4)_2$-Extraction

2) NH_4-lactat soluble Potassium

3) 0.05 n AEDTA-Extraction of heavy metals

No	hor.	depth cm	sto. %	texture in % of humus-/carb. free fine soil: sand c	sand m	sand f	sand Σ	silt c	silt m	silt f	silt Σ	clay	kf cm/d
1	Ah	0- 11	58	14	45	23	82	-	-	-	17.7	0.3	not determinable
2	AhC	- 31	45	13	62	20	95	-	-	-	4.7	0.4	
3	2C	- 79	54	21	41	23	85	-	-	-	12.0	2.9	
4	3C	-120	20	8	65	20	93	-	-	-	6.3	0.8	

No	hor.	bulk dens. g/cm^3	GPV %	water content in % at pF 0.6	1.8	2.5	4.2	pH $CaCl_2$	pH H_2O	Fe_d mg/g	Fe_o mg/g	Fe_o/Fe_d	Mn_o mg/kg	P_a mg/kg
1	Ah	1.69	36	-	20.6	15.5	8.9	7.2	7.3	17.3	11.9	0.69	120	30
2	AhC	1.70	35	-	16.3	9.4	2.8	6.5	4.5	15.4	14.2	0.92	60	5.4
3	2C	1.62	39	-	17.6	10.8	3.0	7.3	7.9	3.2	1.8	0.56	290	29
4	3C	1.51	43	-	19.8	13.2	2.4	7.3	8.2	1.4	0.6	0.43	30	83

No	hor.	$C_{org.}$ mg/g	N_t mg/g	C/N	carbonate mg/g	CEC_p meq/kg	exchang. cations in meq/kg: Ca	K	Mg	Na	H	Al	V %
1	Ah	76	2.67	28	7	113.1	71.9	5.98	12.50	0.55	5	0.01	95
2	AhC	8	0.17	40	2	27.0	6.6	0.58	1.17	0.06	38	0.16	18
3	2C	14	0.28	47	150	62.6	43.3	2.32	3.20	0.20	2	0	96
4	3C	3	0.12	-	35	32.4	63.2	3.16	1.38	0.32	0	0	100

No	hor.	mg/kg total soil: NO_3-N 1)	NH_4-N 1)	K_{1a} 2)	mg/kg fine soil 3): Fe_e	Pb_e	Mn_e	Zn_e	Cd_e
1	Ah	6.3	7.7	125	329	74	33	299	1.5
2	AhC	0.7	6.7	15	317	4.4	4.2	17	0.3
3	2C	1.0	18.3	45	111	34	55	320	1.0
4	3C	77.0	19.3	101	66	14	11	36	0.9

Anhalter Bahnhof II

Location:	Old storage site, Anhalter Bahnhof
Parent material:	Detritus of coal overlaying banking gravels and sandy brick debris
Soil type:	Lockersyrosem aus Industrieschutt über planierten Gleisflächen (Eutric Regosol)

Profile description:

(A)C (AC)	0- 15 cm	black, 10 YR 1.7/1, loamy sand, single grain to fine crumb, slightly gravelly, pH 6.6, partly banking gravels, brick debris, mainly detritus of coal (sample no. 4.5.21)
2C (C)	- 39 cm	90% banking gravels, rusty, very dark greyish brown, 10 YR 3/2, loamy sand, single grain, pH 6.8 (sample no. 4.5.22)
3C (C)	- 67 cm	dark greyish brown, 10 YR 4/2, loamy sand, gravelly, single grain, pH 6.9, sandy debris of brick, mortar and organic matter, partly banking gravels (sample no. 4.5.23)
4C (C)	- 82 cm	black, 10 YR 1.7/1, sand, single grain, very gravelly, slightly calcareous, pH 7.1, industrial cinder with gravels (sample no. 4.5.24)
5C (C)	-120 cm	brown, 10 YR 5/3, loamy sand, coherent, 10% yellowish brown, 10 YR 5/6, mottles, partly calcareous, pH 7.3, gravelly, sandy brick debris, partly with garvels (sample no 4.5.25)

All boundaries are abrupt.

No	hor.	depth cm	sto. %	texture in % of humus-/carb. free fine soil: sand c	sand m	sand f	sand Σ	silt c	silt m	silt f	silt Σ	clay	kf cm/d
1	(A)C	0- 15	9	27	38	14	79	-	-	-	20.1	0.8	not determinable
2	2C	- 39	89	20	37	23	80	-	-	-	16.1	3.9	
3	3C	- 67	19	6	37	34	77	-	-	-	16.6	6.4	
4	4C	- 82	50	22	32	26	80	-	-	-	18.0	1.9	
5	5C	-120	38	5	39	31	75	-	-	-	17.6	7.4	

No	hor.	bulk dens. g/cm^3	GPV %	water content in % at pF 0.6	1.8	2.5	4.2	pH $CaCl_2$	pH H_2O	Fe_d mg/g	Fe_o mg/g	Fe_o/Fe_d	Mn_o mg/kg	P_a mg/kg
1	(A)C	0.75	60		27.2	21.8	15.2	6.6	5.4	13.4	5.8	0.43	140	35
2	2C	1.80	32		4.8	3.1	1.6	6.8	5.0	35.9	14.9	0.42	90	1.2
3	3C	1.67	37		22.3	13.9	11.9	6.9	6.1	7.4	4.1	0.55	120	22
4	4C	0.96	61		26.6	17.5	5.0	7.1	7.0	23.1	17.4	0.75	63	46
5	5C	1.84	30		25.5	17.9	13.2	7.3	7.6	3.7	1.7	0.46	42	42

No	hor.	$C_{org.}$ mg/g	N_t mg/g	C/N	carbonate mg/g	CEC_p meq/kg	exchang. cations in meq/kg: Ca	K	Mg	Na	H	Al	V %
1	(A)C	438	0		0	226.2	109.8	2.28	17.40	3.13	98	0	58
2	2C	62	0.46	135	0	119.6	81.6	0.93	8.89	8.89	82	0.03	55
3	3C	12	0.23	52	0	108.7	24.4	1.14	3.72	5.35	27	0	56
4	4C	201	0.11		5	321.4	181.0	11.20	63.50	27.84	3	0	99
5	5C	13	0.25	52	0	85.3	90.7	2.32	2.45	1.23	0	0	100

No	hor.	mg/kg total soil: NO_3-N 1)	NH_4-N 1)	K_{1a} 2)	mg/kg fine soil 3): Fe_e	Pb_e	Mn_e	Zn_e	Cd_e
1	(A)C	4.0	132.9	286	399	71	104	305	1.2
2	2C	0.5	2.5	4.6	386	18	45	55	0.6
3	3C	5.2	11.6	38	219	2.2	9.5	43	0.5
4	4C	7.4	7.1	35	197	44	79	91	2.0
5	5C	3.7	8.3	29	59	5.5	38	15	0.5

4.6 Green and recreation areas of the city - The Tiergarten

The oldest park in Berlin was on the Spree island near the palace of the prussian Kurfürst. It is recorded on the oldest city map from 1652, made by Johann Gregor Memhard. The area of the Great Tiergarten was redeveloped starting in 1697. This park was followed by the baroque park of the Charlottenburger Schloss, established at the beginning of the 18th century. The first small area on the Pfaueninsel was developed 1794-1798. Beginning in 1816, there were attempts to turn the entire island into a park. A total redesigning of the island was carried out by Peter Josef Lenné from 1824-1834. Essential elements of this park design determine the features of the island up to the present day.

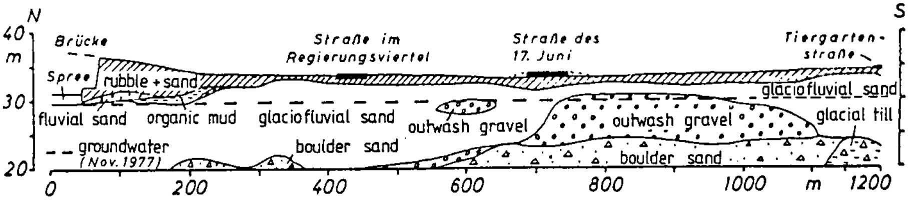
The Pfaueninsel and the Schlosspark Charlottenburg were open to the public several days a week. As early as the 18th century, the Tiergarten was looked upon as a recreation area. The Friedrichshain (1846-48) is noteworthy as the first citizen's park. Its novelty, in comparison to the Park of the Kurfürst, consisted essentially in the opening up of extensive areas for unsupervised, unconstrained play and sport activities. According to these criteria, the Humboldthain (1869-72), Treptower Park (1876-88), and Victoria Park (1888-94), which were established in the late 19th century, may be considered to be predecessors of the Volksparks. Characteristic Volksparks are facilities created at the beginning of this century and into the period of the Weimar Republic (the Schiller-Park 1909-1913, Volkspark Wilmersdorf 1912-1913, Volkspark Jungfernheide 1920-23, Volkspark Mariendorf 1923-27, and Volkspark Rehberge 1926-29). Present-day area use plans show approx. 7% of the area of Berlin (West) as green area.

Soils of green areas which had originated in woodland, and had remained intact during urban development were comparatively little changed: often only the relief was straightened and the topsoil had become compacted through the pressure of feet. The soil humus was changed through plants of varying degrees of litter decomposition and litter removal. The soils were also further contaminated with polluting agents via the air and with waste substances in comparison to soils outside the agglomerations.
More severe soil changes are apparent where multifactoral uses occurred. An example for such a park is the park Glienicke which was established in the first half of the 19th century by the famous garden architect Peter Josef Lenné and traditionally belongs to the palace and parks of Potsdam. This park was used as an orchard, wine yard and agricultural field as well as partly as pine forest. In the course of establishing the park, the morphology of the landscape underwent

profound changes. Lakes, as well as gullies were laid out. The diggings served as material for dikes and as landfill at other places (e.g. pleasure grounds). Consequently, some ground consists of layers of varying substrates while others apart from light surface disturbance show the soil morphology and reaction of natural Dystric Cambisols. In the years 1824 and 1825 25 000 trees, indigenous and alien, were planted. Since that time, soil and vegetation development restarted under the changed conditions.

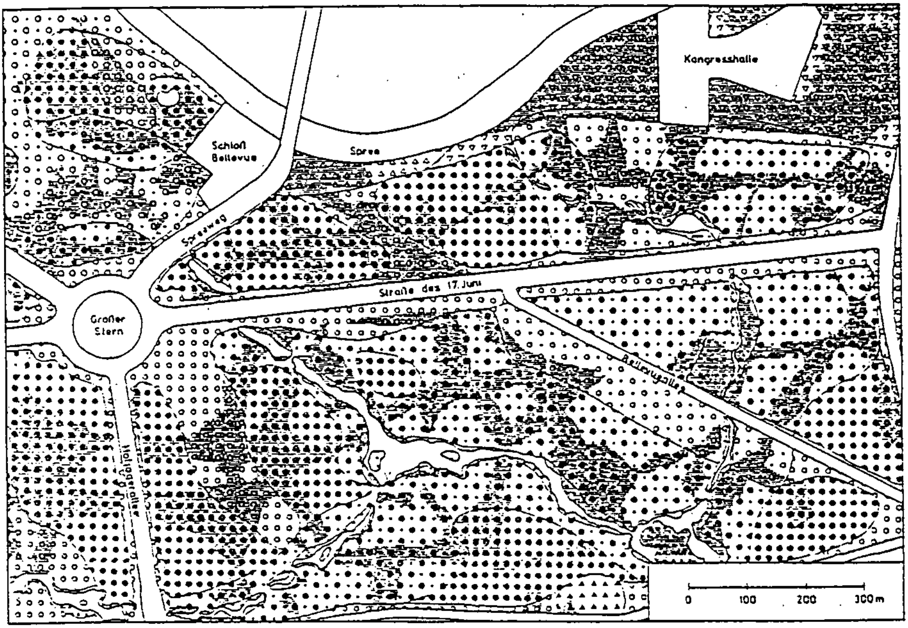
Finally, the Tiergarten in the center of Berlin may be quoted as an example of severe soil change in recent times.

Fig. 48 Geology of the Tiergarten along Entlastungsstraße (from SUKOPP et al. 1979)



The soils were deeply tilled lately, and fertilized with organic matter and chemicals and regularly irrigated. In their ecological properties, they changed to such a degree that they are quite analogous to horticultural soils now. Sites rich in carbon and rocks are predominant in the formerly built-up areas: the rubble is especially thickly layered in the filled up meadows of the old floodplain of the Spree (Fig.49). On the embankment of the (only) partly artificially constructed) lakes, the dynamic forces of a floodplain meadow are missing because the height of the groundwater is lowered and only negligible of the artificially supplied water in the lakes seep into the ground since they are sealed by a thick sludge layer. Generally, the topsoil of the meadows, in relation to the wooded areas, was compacted by foot pressure and after destruction of the peat. Partial microerosion had set in already. Finally, the sites along the paths are eutrophic and along the roads contaminated additionally with road salt, dust, and heavy metals. Alltogether, many variations of site properties are present here.

Park climate: Of the climatological parameters measured in the areas, air temperature was considered to be of special significance, since this variable, in particular, reacts with great sensitivity to anthropogenic influences such as construction density and the degree of surface sealing. Figure 50 shows the local temperature distribution in the form of isotherms, as the result of a measurement tour that was carried out in the late evening fo 30th March, 1978.



Pararendzinas, > 2 m rubble over mf sand,
pH 7,0, groundwater 4 m below surface

Pararendzinas, 0,8 - 2 m rubble over mf sand,
pH 6,1, groundwater 4 m below surface

Pararendzinas, < 0,8 m rubble over mf sand, hydromorphic properties,
pH 7,0, groundwater 2,5 - 4 m below surface

Pararendzinas, 0,3 - 0,8 m rubble over mf sand, hydrom. properties,
pH 6,0, groundwater 2,5 - 4 m below surface

Gley-Pararendzinas, 0,3 - 0,8 m rubble over mf sand,
pH 6,2, groundwater 1 - 2,5 m below surface

Braunerde, humiferous sand/ mf sand, hydromorphic properties,
pH5,3, groundwater 2,5 - 4 m below surface

Gley-Braunerde, humiferous sand/ mf sand,
pH 5,5, groundwater 1 - 2,5 m below surface

Braunerde-Gley/ Pararendzina-Gley/ Anmoore, rubble or humiferous
sand/ mf sand, pH 4,7 - 6,1, groundwater 0,5 - 2 m below surface

Compaction of topsoil by tread

- all units have a mixed topsoil because of deep ploughing (Rigolen)

Fig. 49 Soil map of the Tiergarten

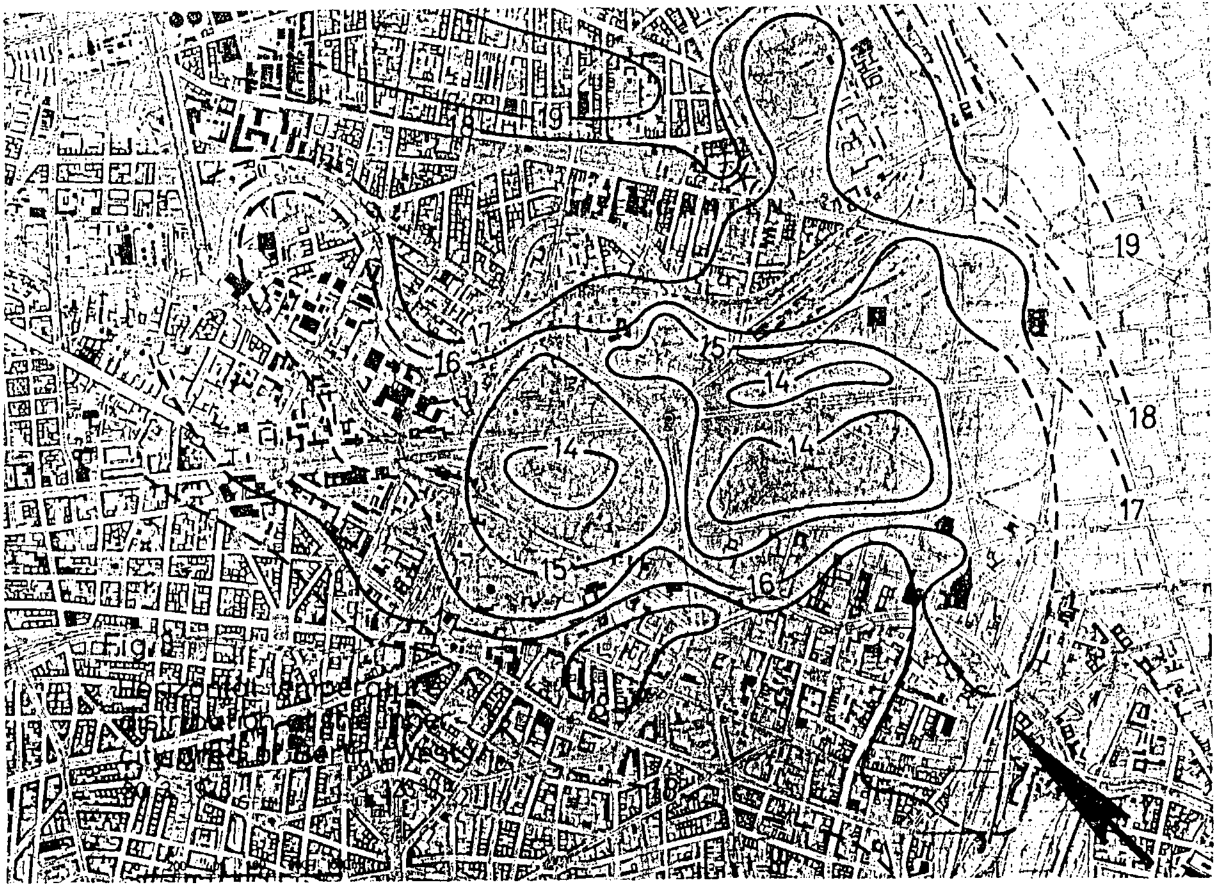


Fig. 50 Horizontal temperature distribution in the inner city area of Berlin (West), 30.3.1978; 23.30 h

The dispersed cloud cover and relatively low wind speed of 1.7 m s^{-1} resulted in a very stable weather situation, i.e. one with poor air circulation.

Heat radiation in the area of the Tiergarten produces a great temperature reduction in comparison to the built-up surroundings, which retain larger heat reserves due to their building mass. Temperatur differences of as much as 7^{o}C were measured between the inner area of the Tiergarten, on the one hand, and the neighbouring urban areas to the southwest and, in particular, Moabit and Wedding to the north, on the other. As shown by separate measurements in the winter months, these values can be exceeded at that time of year. The wide streets within the Tiergarten lead to a subdivision of the cold islands into several smaller areas.

The relatively large temperature decline in inner-city green areas during the night hours is due to the vegetation structure which allows for unimpeded heat radiation. Thus, in the warm summer months, the Tiergarten in its present size is of a bioclimatic significance that should not be underestimated. However, the temperatures of the air layers near the ground, which are quite low in comparison with the surroundings, additionally stabilize the atmosphere near the ground under weather conditions with poor air circulation. The inner area of the Tiergarten is, therefore, particulary subject to emission pollution. High air pollution values are to be expected in the early afternoon, especially in the winter months, due to the high traffic levels that prevail during these hours.

The changes in air temperature, relative humidity, and vapor pressure caused by a city climate can basically be correlated to the construction density, degree of sealing and the proportion of green areas in a particular of the city area can be differentiated in the Tiergarten and its immediate and more distant surroundings:

Type 1, dense, inner city construction (mainly 4-6 storied block structure);

Type 2, dense, inner city construction with a limited amount of green areas (mainly city squares);

Type 3, mainly sealed or compacted areas with occasional construction (freight yards, harbour installations, trade and industrial areas, rubble-filled land without vegetation);

Type 4, open construction type with high proportion of green areas (equal distribution of green areas and built-up areas, 3-4 storied row construction, in part block edge construction with inner gardens);

Type 5, sealed surfaces in green areas (broad streets in parks and on the fringe of parks);

Type 6, green areas, mostly forest-covered (dense to disperse tree and shrub layer);

Type 7, mostly open green areas (large grass of fallow surfaces within parks or on the fringe of parks).

The following diagrams summarize the climatic values recorded with the measuring vehicle in these seven areas, according to surface conditions and building structure. In the representation of air temperature, humidity, and vapor pressure, a qualitative differentiation according to the prevailing degree of air circulation (I - IV) was included.

With regard to air temperature, the diagramm in Fig. 51a may be interpreted as follows. A basic dependence of the temperature on the vegetation (e.g. forest), the degree of surface sealing (e.g. streets), and the particular construction density can be determined. These differences are, as can be expected, relatively low under weather conditions with good air circulation. With increasing stability of the atmosphere near the ground, the specific thermic structure of these areas becomes increasingly evident. Under conditions of poor air circulation, an average temperature increase of 3.3^{o}C in the built-up areas, as compared with the open spaces in the Tiergarten, was registered. As shown by individual studies, overheating can reach much higher values in isolated areas.

In Fig. 51b, relative humidity, corresponding to the temperature, is shown in relation to the type of location. Because of the definition of relative humidity, the dependence on the characteristic surface type which is evident here was to be expected. A high density of construction and high degree of sealing lead to a large decline in humidity. In the case of vapor pressure (Fig. 51c), a clear correlation with the particular surface type or with the prevailing weather conditions cannot be observed. Under moderate air circulation, the water vapor content of the air drops with an increase in the degree of sealing, as is to be expected. Under particularily stable weather conditions, there is even a decrease in water vapor content towards open grass areas, probably caused by dew formation. In general, however, the differences between the individual surface types are very slight.

The air-hygienic situation in the Tiergarten is very problematical. The SO_2-distribution of Berlin demonstrates threshold levels of air pollution not only for the neighbouring districts of Kreuzberg and Wedding, but also for the Tiergarten itself.

When the unfavourable air-circulation conditions in such parks are further

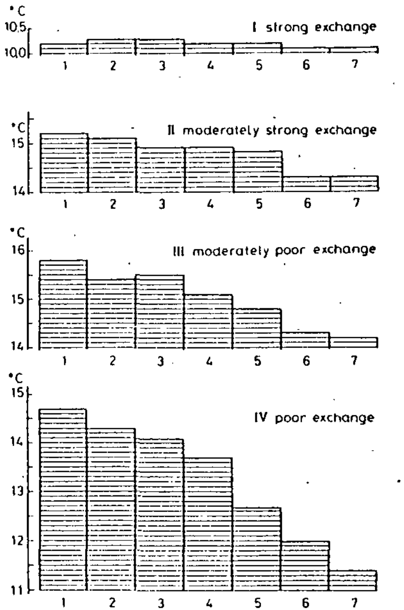
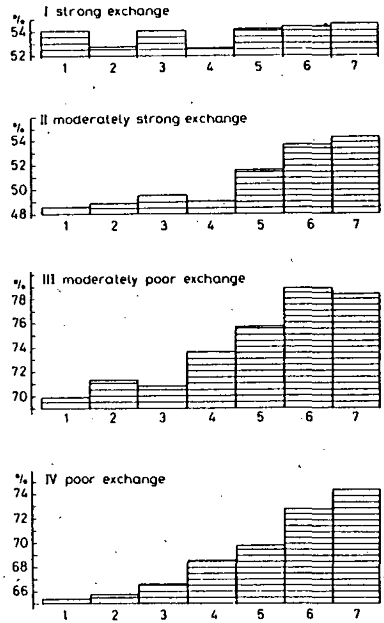
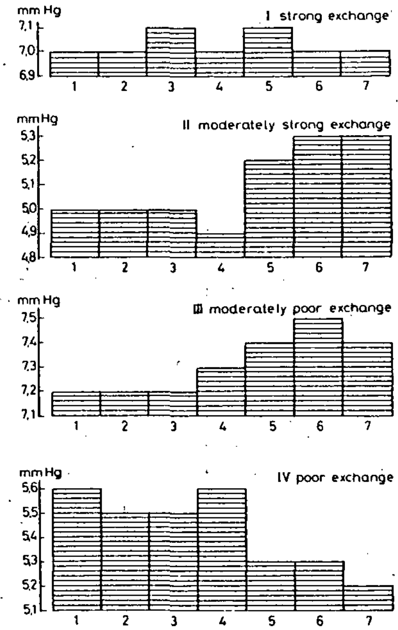


Fig. 51 a Mean air temperature in °C in dependence of the weather situation (I- IV) and the relevant type location (1-7)



b Mean relative humidity in % in dependence of the weather situation (I-IV) and the relevant type of location (1-7)



c Mean vapor pressure (mm Hg) in dependence of the weather situation (I-IV) and the relevant type of location (1-7) affected by near to ground emissions from motor vehicle traffic, a substantial increase in air pollution results. An analysis of the traffic load shows that both the neighbouring residential areas and the Tiergarten itself are transected by streets with a traffic load of 60.000 vehicles per day. This corresponds to a mean daytime frequency of 3.600 vehicles per hour.

In order to present an example of the actual traffic-related stress, the result of 6 recording tours undertaken in the course of the climate studies have been compiled in Table 14. The results of a few recording tours should not, however, be interpreted as mean pollution values.

Tab. 14 Carbon monoxide concentration (mg/m^3) on streets with a heavy or light traffic load or within park grounds

	day	night
Streets with a heavy traffic load (> 7500 vehicles/day)	7.0	6.16
Streets with a light traffic load (< 7500 vehicles/day)	4.28	4.27
Park grounds	2.50	2.34
Total mean	4.91	4.79

The mean CO concentration of streets with varying traffic loads shows the following tendencies in the daytime and at night. Although the daytime recording tours were all carried out under conditions of relatively good air circulation, the CO values measured are higher than those measured at night, in spite of the fact that the nights recorded were poor in air circulation. The streets with heavy traffic loads lave CO concentration values which are almost double those of the streets with a light load. On all recording tours, however, it was observed that the air pollution could reach as far as the inner areas of the park.

The distribution of the pollution by vehicles is greatly dependent on the circulation of the air layers near the ground. Tab. 14 also indicates to what extent the nightly formation of relatively stable air layers can inhibit the dilution of CO pollution. The difference between the CO emission rates at night and in the daytime in streets with a heavy load of traffic amounted to only 12% in this study, although a decrease in CO emissions of 83% has previously been observed. Particularly in streets with light traffic and in parks, the difference between daytime and night pollution becomes minimal under these conditions. In view of these facts, the planned construction of a motor highway (Autobahn) through the Tiergarten (110.000 vehicles per day)must be considered to extremely problematical from an air-hygienic point of view.

Profile Tiergarten

Locality:	Meadow in the Großer Tiergarten 100 m north of Straße des 17. Juni and 100 m west of Entlastungsstraße
Altitude:	33.2 m a.s.l.
Landscape:	Glacial valley of Warschau-Berlin, Central Berlin city part, 500 m south of Spree river
Relief:	levelled plain, natural groundwater table 1 - 1.5 m, presently 4-5 m deep
Land use:	pleasure ground, deposit of organic wastes for recycling purposes
Parent material:	fluvioglacial medium to fine sands of Weichselian age, covered and mixed with humiferous sands
Soil type:	Gley-Hortisol (Haplic Phaeozem or Humic Cambisol)
Site qualities:	deep root zone, spreading of roots not impeded, moderately dry, very well aerated, good nitrogen and base supply, poor phosphorus supply, low nutrient amount in stock

Profile description:

Horizon (FAO), depth, parent material, colour, carbonate content, structure, structure specialities, coarse stones Vol. %, actual rooting, boundary.

RAh1 (Ah)	0- 20 cm	sand humiferous, 10 YR 2/2, no lime, granular, <1% stones, very many roots, gradual boundary
RAh2 (Ah)	- 30 cm	sand humiferous, 10 YR 3/1, no lime, very weak subangular blocky, < 1% stones, some roots, gradual boundary
Ah3 (Ah)	- 40 cm	outwash sand, 10 YR 3/3, no lime, very weak subangular blocky, charcoal pieces, 3% stones, few roots, sharp boundary
AC (AC)	- 65 cm	outwash sand, 10 YR 3/4, no lime, very weak subangular blocky, charcoal, root trays, earthworm holes, <1% stones, few roots, gradual boundary
CG1 (C)	- 95 cm	outwash sand, 10 YR 6/4, no lime, coherent to weak subangular blocky, root trays, earthworm holes, <1% stones, few roots, gradual boundary
GoC2 (Cg)	-130 cm	outwash sand, 10 YR 6/4, no lime, singular to coherent, rusty spots, bleached zones, root channels, almost no roots, gradual boundary
GrC (Cg)	->140 cm	outwash sand, 10 YR 7/3, no lime, singular to coherent, bleached zones, few rusty spots, root channels, almost no roots

No	hor.	depth cm	sto. %	texture in % of humus-/carb. free fine soil: sand c	sand m	sand f	sand Σ	silt c	silt m	silt f	silt Σ	clay	kf cm/d
1	Ah1	0- 20	1.1	2	43	46	91	3	2	1	6	3	1000
2	Ah2	- 30	0.5	2	48	39	89	4	2	1	7	4	510
3	Ah3	- 40	0.3	2	47	44	93	2	1	1	4	3	420
4	AC	- 65	0.5	2	52	40	94	2	0.8	0.5	3	3	780
5	GC1	- 95	0.1	0.4	53	44	98	0.4	0.1	0.4	1	1.4	1020
6	GoC2	-130	0.1	2	72	24	98	0.2	0.2	0.2	1	1.3	700
7	GrC3	- 150	0.3	2	79	18	99	0.4	0.1	0.1	0.5	0.6	1200

No	hor.	bulk dens. g/cm^3	GPV %	water content in % at pF 0.6	1.8	2.5	4.2	pH $CaCl_2$	pH H_2O	Fe_d mg/g	Fe_o mg/g	Fe_o/Fe_d	Mn_o mg/kg	P_a mg/kg
1	Ah1	1.13	56	35	21	12	6	5.5	5.9	4.1	1.31	0.64	76	75
2	Ah2	1.49	43	42	30	13	6	5.4	5.7	4.0	1.62	0.41	75	81
3	Ah3	1.44	45	43	30	13	7	5.2	5.5	2.5	1.08	0.43	85	87
4	AC	1.40	47	43	18	7	4	4.9	5.3	2.4	0.84	0.35	57	88
5	GC1	1.58	40	37	25	5	1	4.9	5.1	0.39	0.25	0.64	68	76
6	GoC2	1.69	36	32	16	4	0.6	4.8	5.2	0.30	0.22	0.73	23	83
7	GrC3	1.72	35	34	7	5	0.7	5.3	5.6	0.15	0.07	0.50	30	46

No	hor.	$C_{org.}$ mg/g	N_t mg/g	C/N	carbonate mg/g	CEC_p meq/kg	exchang. cations in meq/kg: Ca	K	Mg	Na	H	Al	V %
1	Ah1	15.3	0.80	19	-	60	28	0.8	2.7	0.2	20	-	67
2	Ah2	14.7	0.77	19	-	68	32	0.8	3.2	0.4	24	-	65
3	Ah3	9.7	0.48	20	-	49	16	0.5	1.0	0.2	22	0.5	55
4	AC	5.9	0.31	19	-	33	8	0.3	0.6	0.3	18	0.7	45
5	GC1	0.7	0.05	-	-	10	3	0.2	0.2	0.2	9	0.2	13
6	GoC2	0.3	0.02	-	-	6	2	0.2	0.2	0.4	4	-	33
7	GrC3	0.1	0.03	-	-	4	2	0.2	0.4	0.3	1	-	75

Explanation for profile Tiergarten

Landscape development, history of land use and parent material: During late Weichselian sedimentation of fluvioglacial sands in the Warschau-Berlin-valley (Urstromtal) took place. Later, the area belonged to the low lying terrace close to the floodplain of the Spree but was flooded occasionally. Groundwater table was relatively close to the surface. The natural forest was Oak-hornbeam forest. 16.-17. century the area outside Berlin was a hunting reserve of the "Kurfürst". Since 1697 construction of the main roads and since 1742 architecture of a residential "Barockgarten" by Knobelsdorf. 1832-1839 transformation to a park landscape by famous Lenné. 1944/45 complete destruction and fire wood gathering. 1945-1949 restoration of the landscape, landfill with rubble and horticultural use, 1949-1951 start of reconstruction of the park by deep ploughing, fertilization and planting of a "Maple - Oak-City Forest". Since that time, increasing use as a pleasure ground. 1961-1971 the specific site was a field camp of the British army to observe and guard the Russians at their monument across the street. Since that time use as deposit for organic recycling in the park.

Soil association: The natural Braunerde - Gley - Moor (Cambic Arenosol - Dystric Gleysol - Histosol) soilscape has been altered through lowering of the groundwater table, deposition of different natural and artificial products and building and tilling activities. The recent Pararendzina - Hortisol - Braunerde - Gleysol association (Calcaric Regosol - Phaeozem/Humic Cambisol -Gleysol) is illustrated by the map (Fig. 49).

Soil development: First development of a acidic, weathered profile with gleying in the subsoil. The recent soil development is influenced by various anthropogenic influences. At first the lowering of groundwater table in the 19. (Landwehrkanal construction) and 20. (Pumping of groundwater for industrial and private use) century and then the various influences described above.
The accumulated organic matter of more than 16 kg/m^2 = 160 t/ha is very high compared with sites of forests and agricultural fields. Together with the high nitrogen stock of 510 g/m^2 = 5 t/ha these data confirm the cultural influence. Influence of liming is only detectable through the still slightly higher pH of the topsoil and the respective base saturation. The topsoil is relatively loose. Compaction by trambling is not observed at this site. The roots and earthworm holes show favourable conditions for flora and fauna.

Soil conditions: Very deep root zone and no limitations of root spreading. Pleasure grounds in the neighbourhood show severe compaction of the topsoil. Moderately dry site with 175 l/m^2 available water stored. Old trees still reach groundwater. Meadows are frequently irrigated in summer. In moist periods and after irrigation, aeration may be limited through the lack of coarse pores. Nutrient stock is naturally low. For nitrogen, calcium, magnesium and trace elements, this, is substantially ameliorated (eutrophicated). Phosphorus and potassium are still problematic nutrients in the specific site. In other places with more faecal fertilizer inputs, this is significantly different (up to 10 times more K, P). Without the irrigation and fertilization, the site will become dryer and poorer very quick, although there is a buffer capacity in the organic matter.

4.7 Roadside forest soils - The Avus Highway through the Grunewald

On modern roads with complex pavements e.g. deep excavation of soil, filling with gravel that tolerates heavy mechanical stress, compression and sealing with a dense, water and air impermeable surface, no life can exist. However, street edges have been subject to profound changes, which are more intense in the inner-city than in the open areas that surround it.

Whereas the space taken up by traffic is usually extremely adverse to vegetation, hard-to-reach surplus areas often remain after the building of streets. These areas can become important retreat regions or secondary biotopes for plants and animals. The linear course of streets also allows them to become migration lines for species from the area and for species foreign to it.

Approximately 400 species of ferns and flowering plants grow on streetside areas in Berlin (West). Under some conditions, endangered species, even those threatened by extinction grow in such areas, for example, the Botrychium ferns (Botrychium multifidum and B. matricariifolium). The value of such habitats and of their crops can be demonstrated in an example: the interbreeding of a winter-hard form of devilgrass (Cynodon dactylon) from a Berlin roadside area led to a new variety, Tifton 44. This is an economically very valuable cultivated plant, whose cultivation could then be expanded further to the north.

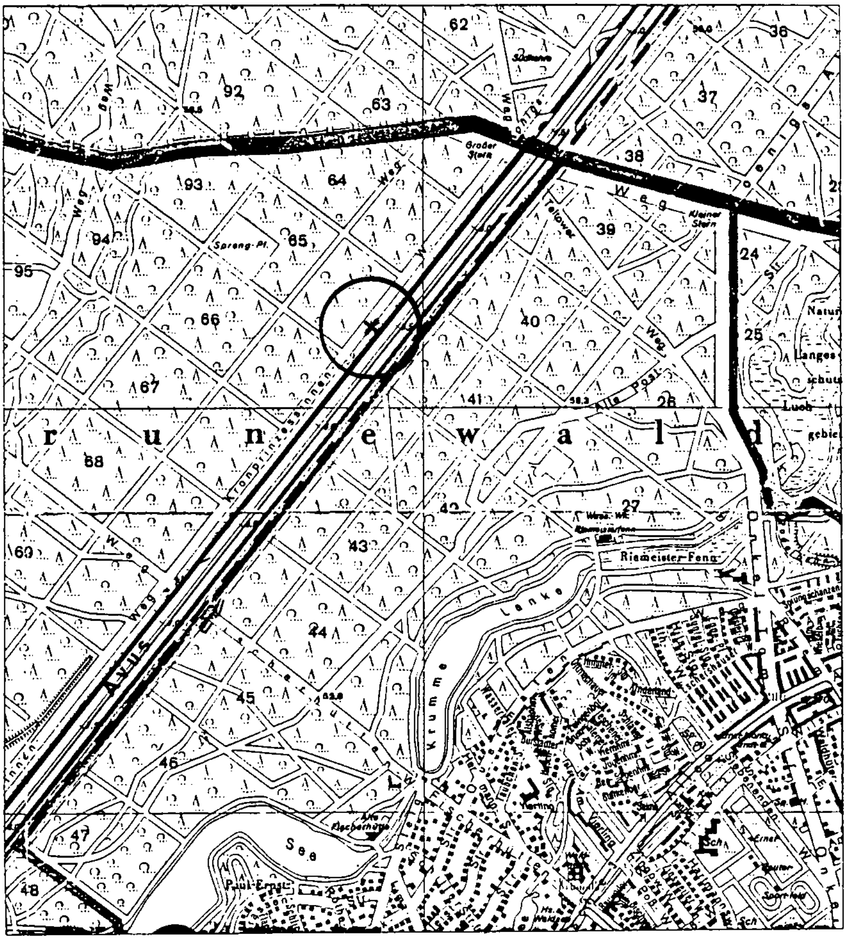
The following example from the Grunewald will show how changes appear along a heavily used highway (Autobahn) (Fig. 52).

The construction of an Automobile, Traffic and Practice Street (AVUS) between Charlottenburg and Nikolassee began 1913. It was completed after the First World War and opened in 1921 as the first "intersection-free" automobile street in Europe. During construction of the AVUS, different methods and surface constructions, such as tar macadame, cement concrete and asphaltic concrete were tested.

The 30 meter wide surface of the AVUS-segment in the area studied was constructed as follows at the time of the study:

3.5 cm poured asphalt
8.5 cm asphalt binding
9 cm bituminous base (2x)
15 cm cement fortification
base- 100% simple Proctor density

Fig. 52 Location of profiles near AVUS-highway



The six-lane expansion of the AVUS between Hüttenweg and the AVUS-interchange was planned in 1969 and begun in 1970, in order to master the ever increasing traffic load. South of Hüttenweg, the load is less high with up to 20 000 automobiles/24 h. Here, only the surface was renewed.

Since the vegetation of these unfavourable sites adjacent to the AVUS is protected by a guardrail from being trampled or, occasionally, driven over, pedestrian-influenced societies are missing directly by the roadside. The only pedestrian influenced species found are Lolium perenne and Trifolium repens.

Between the guardrail and the actual forest edge, a light-loving plant society, dominated by herbs and grasses is observed. This includes an unmistakeable number of nitrophilic species, resulting from the street influence, which can be designated as a Poa angustifolia-stand (Agropyretea). After a transition zone (Melampyrum pratense-edge), there follows Pino-Quercetum moehringietosum as a forest society with a large portion of Prunus serotina, which increases in the direction of Kronprinzessinnenweg. In general, roadside areas outside of built-up communities are characterized by a particularly high percentage of therophytes. The spread of common sea meadow-grass (Puccinellia distans) along the German highways that has been observed in recent years is presumably a result of salt concentration. In certain places in Berlin, the spray zone at the roadside is characterized by the appearance of prickly saltwort (Salsola kali).

In Fig. 53 the corresponding traffic load, the portion of trucks, the average speed of traffic v, and the average wind speed u are submitted. Furthermore, the calculated pollution load (I_1 values) caused by the traffic for seven immission parameters from the edge of the road are presented. In calculating the pollution concentration of NO and NO_2, correction factors were used, since experimental studies have shown that during the dispersal of these substances, the limits set for nitrogen oxide (0.2 mg/m^3) and for lead (0.002 mg/m^3) are exceeded. It must be noted that the corresponding background pollution is not included in these calculations.

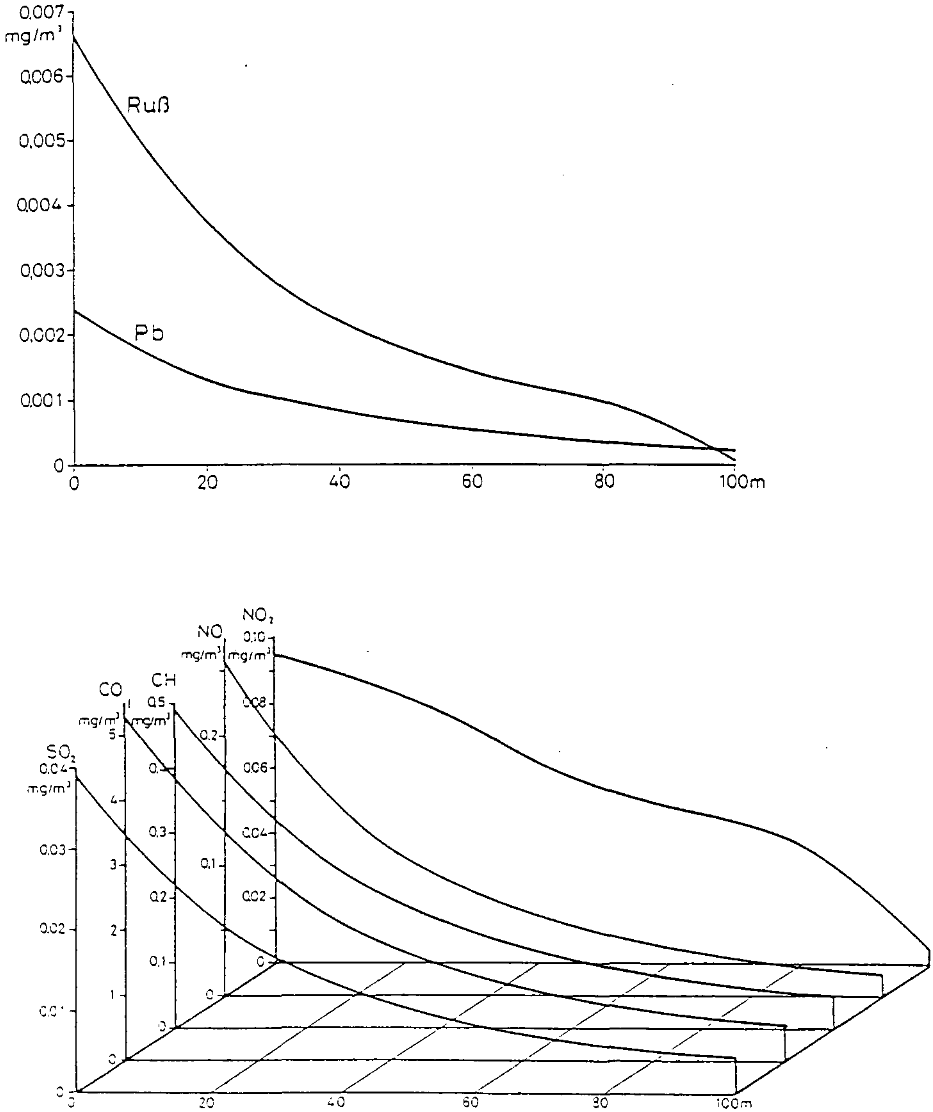


Fig. 53 Pollution through motor vehicle traffic in dependence of distance from the edge of the street (HORBERT from SUKOPP et al. 1980)

Description of profiles Avus I, II and III, Grunewald

Locality:	Grunewald (forest), section no. 65, between Avus (highway) and Kronprinzessinnenweg (road) profiles I = 25 m, II = 5 m and III = 1 m from the highway
Altitude:	50 m a.s.l., groundwater table more than 20 m below ground
Landscape:	Outwash plain (rest of sandy ground moraine above glacio-fluvial sands)
Relief:	Plain for profiles I and II, slight acclivity III
Land use:	Forest

Avus I

Soil type:	Rostbraunerde (Cambic Arenosol) - 25 m from highway
Humustype:	mull to moder humus on sand
Parent material:	glacial sand, u'fmS
Vegetation:	Pino-Quercetum moehringietosum with a lot of Prunus serotina, although Acer plat., Pteridium aquig., Avenella flex., Holcus mol., Viola riviniana and Polygonatum odorat.
Site qualities:	very deep root zone, dry, always good aeration, very low nutrient supply

Profile description:

O (O)	2- 0 cm	partly decomposed litter
Aeh (Ah)	- 18 cm	brownish black, 10 YR 3/1, singular-platy, loose, gravel, fmS, strongly rooted
AhBv (AB)	- 33 cm	brown, 10 YR 4/4, singular, loose, gravel, fmS, strongly rooted
Bv (Bw)	- 68 cm	dull yellow orange, 10 YR 6/4, singular, loose, gravel, fmS, fairly rooted
BvC (BC)	- 95 cm	dull yellow orange, 10 YR 6/5, singular, loose, gravel, fmS, nearly no roots

Avus II

Soil type:	Rostbraunerde (Cambic Arenosol) - 5 m from highway
Humustype:	mull to moder on sand
Parent material:	glacial sands (u'fmS), weekly covered by construction sand
Vegetation:	Melampyrum-pratense-strip, although with Prunus serotina, Poa nemora, Avella flex. and Holcus mol.
Site qualities:	very deep root zone, dry, always good aeration, higher pH in topsoil and better nutrient supply (Ca, Mg) than I

Profile description:

LO (O)	3- 0 cm	partly decomposed litter, mortar fragments, paper-, glas-, brick pieces

YAh (Ah)	- 6 cm	brownish black, 10 YR 3/2, singular-platy, fairly loose, gravel, fmS, medium rooting
Avh (Ah)	- 30 cm	greyish yellow brown, 10 YR 4/2, singular, fairly loose, few gravel, fmS, medium rooting
Bv (Bw)	- 55 cm	dull yellowish brown, 10 YR 5/4, fairly loose, singular, few gravel, fair rooting
	50- 60 cm	stony layer
Cgtv (Bw)	-220 cm	dull yellow orange, 10 YR 7/3, weak rust mottles between 60-100 cm thin clay bands, singular, few gravel, fmS

Avus III

Soil type:	Typische Pararendzina (Calcaric Regosol) about Braunerde (Arenosol) - 1 m from highway
Humustype:	mull humus on rubble and sand
Parent material:	glacial sands covered by material of highway construction
Vegetation:	Nitrophil, lightlovering, Poa-augustifolia-stand (Agropyretea) although with Lolium peren., Trifolium rep., Arrhenatherum elat., Achillea millef. and Lotus corniculat. Salt tolerant plants like Puccinellia dist. or Salsola kali. could not be observed.
Site qualities:	very deep root zone, dry to fresh, always good aeration, alcaline, partly saline, good nutrient (Ca) supply, high Pb-contents in topsoil

Profile description:

L (O)	1- 0 cm	fresh litter, cement and asphalt pieces, glass, paper, metal pieces
Ah (Ah)	- 10 cm	brownish black, 5 YR =/1, fair loose, singular stone content, cement pieces, fmS, strong rooting
Cv (C)	- 55 cm	striped: dull yellowish brown, 10 YR 5/3, 10 YR 5/4, dull yellow orange 10 YR 7/4, singular, few gravel, cement pieces, fmS, fairly dense, weak rooting
IIfAh (Ah) partly absent	- 61 cm	brownish black, 10 YR 4/3, singular-platy, fairly dense, gravel, fmS, medium rooting
Bv (Bw)	- 86 cm	dull yellowish brown, 10 YR 4/3, singular, fairly dense, fmS, charcoal, fairly roots
Bgv (Bw)	-113 cm	dull yellow orange, 10 YR 6/4, weak rust mottles, charcoal, singular, fairly dense, few roots, fmS
	110-120 cm	stone layer
Cgtv (Bw)	-200 cm	dull yellow orange, 10 YR 6/4, weak rust mottles, between 110 and 150 cm clay bands, singular, fairly dense, fmS

hor.	depth	sto.	texture of humus-/carb. free fine soil in %						kf	bulk dens.	PV	water content in % at pF				pH	
			sand				silt	clay									
	cm	%	c	m	f	≤			cm/d	g/m^3	%	0.6	1.8	2.5	4.2	H_2O	$CaCl_2$
25 m from highway																	
Aeh	0- 18	2	7	43	33	83	14	3	250	1.12	50	34	26	13	6	4.3	3.7
AhBv	- 33	2	7	46	33	86	11	3	220	1.49	44	34	23	10	3	4.6	4.1
Bv	- 68	4	7	47	31	85	10	5	270	-	43	33	21	10	3	4.6	4.2
BvC	- 95	2	7	50	31	88	8	4	80	1.65	40	30	19	10	3	4.6	4.2
C	175-200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.8	-
5 m from highway																	
YAh	0- 6	10	9	31	36	76	16	8	-	1.09	57	41	29	20	6	5.2	5.0
Avh	- 30	16	6	46	30	82	14	4	-	1.32	50	36	23	13	5	4.6	4.6
Bv	- 55	5	6	43	34	83	14	3	-	1.43	46	34	21	10	3	4.5	4.1
Cgtv	-100	3	5	46	38	89	9	2	-	1.56	40	34	20	11	3	4.9	4.2
C	175-200	2	7	42	32	81	12	7	-	1.66	37	36	21	12	3	4.4	4.3
1 m from highway																	
Ah	0- 10	7	6	43	40	89	7	4	990	1.06	50	36	26	16	7	7.6	7.1
Cv	- 55	7	4	43	41	88	11	1	260	1.57	41	29	21	10	2	8.0	7.9
fAh	- 61	2	4	43	43	90	9	1	-	1.65	46	39	29	16	5	-	7.0
Bv	- 86	11	6	47	35	88	8	4	34	1.67	39	33	23	11	3	-	-
Bgv	-113	3	6	49	35	90	8	2	-	-	37	31	21	10	3	7.5	6.9
Cgtv	175-200	4	5	46	38	89	9	2	-	1.66	37	31	22	10	3	6.2	5.3

hor.	Fe_d	Fe_o	Fe_p	Fe_o/Fe_d	Mn_p	Al_d	C_{org}	N_t	C/N	carbonate	CEC_p	exchang. cations in meq/kg					S	V	0.1n NH_4Cl meq/kg	
	mg/g			%	‰		mg/g			mg/g	meq/kg	Ca	K	Mg	Na	H	meq/kg	%	Al	H
25 m from highway																				
Aeh	2.50	1.59	0.94	64	0.14	0.83	40.0	1.86	22	0	115	20	2.3	2.5	0.23	88	25	23	7.2	0.58
AhBv	1.99	0.94	0.53	47	0.03	0.83	7.5	0.19	39	0	30	0.67	0.19	0.16	0.13	29	1.15	3	5.1	0.51
Bv	1.58	0.61	0.31	39	<0.01	0.42	3.6	0.11	33	0	18	0.46	0.19	0.13	0.04	17	0.82	6	4.1	0.24
BvC	1.79	0.24	0.17	13	<0.01	-	0.8	0.03	27	0	9	0.33	0.09	0.09	0.03	8.5	0.54	6	9.8	0.37
C	0.71	-	0.04	-	<0.01	-	-	-	-	0	-	-	-	-	-	-	-	-	-	0.04
5 m from highway																				
YAh	3.13	1.40	0.83	45	0.41	1.04	58.0	3.6	16	3	164	72	2.2	6.0	1.5	82	82	50	6.8	-
Avh	2.57	1.25	0.44	49	0.01	1.35	25.0	1.0	25	0	144	40	0.5	2.5	0.9	100	44	31	3.9	0.14
Bv	1.97	1.15	0.65	58	0.03	1.10	3.0	0.1	30	0	18	13	0.4	0.5	0.5	3.2	14	82	4.8	0.33
Cgtv	0.77	0.48	0.15	62	<0.01	0.52	1.5	0.05	30	0	20	0.3	0.3	0.4	0.22	27	1.22	-	2.6	0.16
C	1.15	0.35	0.11	30	<0.01	-	0.5	0.02	25	0	14	1.9	0.25	0.25	0.10	11	2.5	21	8.9	0.52
1 m from highway																				
Ah	6.44	5.07	0.17	79	0.03	-	23.0	1.1	21	0.6	83	52	2.3	2.4	25	1.0	82	99	0	-
Cv	2.03	0.46	0.12	23	0.06	-	2.2	0.07	30	10	16	22	0.46	0.14	3.7	0	26	100	0	-
fAh	-	0.57	-	-	-	-	6.0	0.19	32	1.7	25	15	0.40	0.11	6.4	3.0	37	88	0	-
Bv	1.80	-	0.04	-	0.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bgv	1.29	-	0.19	-	0.01	0.47	3.2	-	-	0	10	8.2	0.60	0.31	4.3	0.9	13	91	0.7	-
Cgtv	1.02	-	0.09	-	<0.01	<0.2	-	-	-	0	9	4.2	0.50	0.20	1.8	2.0	6.7	77	0	-

hor.	K_{la} mg/kg	P_{la}	pH	soluble cations in saturation extract meq/kg April 1974				October 1974				EC mmho/cm		K_v	P_v	Mg_v	Pb_t mg/kg	Pb_e	Cd_t	Cd_e
			H_2O	Ca	Mg	K	Na	Ca	Mg	K	Na	1:2.5	sät.							
25 m from highway																				
Aeh	79	13	4.2	0.48	0.18	0.11	0.09	0.34	0.09	0.21	0.23	0.25	2.02	0.28	0.32	0.70	69	58	0.57	-
AhBv	10	3.4	4.3	0.08	0.05	0.03	0.02	0.18	0.07	0.04	0.04	0.09	0.99	0.26	0.18	0.52	13	2.0	0.21	-
Bv	8	3.5	4.5	0.06	0.04	0.02	0.03	0.13	0.04	0.07	0.03	0.07	0.80							
BvC	5	2.5	4.4	0.03	0.03	0.02	0.02	0.09	0.03	0.07	0.07	0.10	1.38	0.22	0.11	0.38	12	0.2	0.2	-
C	-	-	4.5	0.10	0.03	0.03	0.02	0.09	0.02	0.03	0.02	0.02	-	0.22	0.06	0.31	11	0.3	0.12	-
5 m from highway																				
YAh	203	37	6.5	2.3	0.41	0.21	1.7	4.4	0.31	0.31	0.62	0.44	2.92	0.34	0.47	0.81	430	250	0.71	0.37
Avh	-	-	6.3	1.7	0.23	0.09	1.2	0.13	0.26	0.14	0.49	0.14	1.28	0.26	0.45	0.60	170	72	0.55	0.25
Bv	35	9.6	6.1	1.1	0.14	0.07	0.76	0.83	0.16	0.06	0.88	0.14	1.47	0.21	0.21	0.43	26	5.9	0.29	0.08
Cgtv	12	2.5	6.3	0.36	0.06	0.02	0.28	1.0	0.46	0.06	1.6	0.07	0.80	0.17	0.10	0.35	16	1.1	0.24	0.04
C	9	5.6	5.2	1.0	0.22	0.05	1.4	0.28	0.06	0.02	0.31	0.14	1.61	0.17	0.10	0.32	11	0.3	0.12	0.02
1 m from highway																				
Ah	124	66	8.5	1.1	0.08	0.09	1.9	1.6	0.11	0.21	0.67	0.25	1.84	0.36	0.38	1.6	420	300	0.74	-
Cv	24	28	7.5	0.15	0.01	0.01	1.2	0.04	0.09	0.01	0.09	0.22	2.98	0.50	0.19	1.1	33	19	0.18	-
fAh	19	15	8.0	0.58	0.03	0.02	2.6	0.09	0.05	0.01	0.93	-	-	0.62	0.21	1.3	-	-	-	-
Bv	-	-	7.0	0.57	0.05	0.02	2.9	0.17	0.07	0.01	3.9	0.23	2.91	0.23	0.22	0.48	27	7	0.21	-
Bgv	-	-	6.8	1.6	0.13	0.08	4.9	0.17	0.05	0.01	2.0	0.25	3.35	-	-	-	-	-	-	-
Cgtv	-	-	7.1	1.2	0.12	0.03	0.55	0.05	0.05	0.09	2.4	0.32	4.28	0.23	0.08	0.35	11	0.3	0.12	-

Explanation for profiles Avus I to III

History of the demonstration area: Oak-pine-forests dominated between 1000-1300 A.D. Since the 12. Century, woodcutting and utilization with cattle and bees (fire favours Caluna-heath). In the 18. Century reforestation with woodcutting and 99% pine. Since 1915 sanitation cuttings because of strong damage. After the World War II, deforestation of 60% of the area. Since that time, reforestation with last reforestation of deciduous trees under pine-screen 1940.

Soil development of Berlin forest soils: Since the later glacial period 17 000 years ago, deep decalcification (> 3 m) on these medium sandy soils, weak eluvation of clay which is accumulated in 1 to 2 m depth as clay pans. Decrease of base saturation and strong acidification connected with a decrease of potassium in illites and formation of secundary chlorite. Acidification is a natural process, but is increasing since a few decades due to the acid precipitation (pH 2.7 - 3.5) and to the SO_2 and NO_x increase in the atmosphere.
The slight podzolisation of these soils, despite the semihumid climatic conditions, could be caused by pine litter, since in comparable landscapes of lower Saxony results in an eluviation of Al and Mn out of the Aeh-horizon (see page 159), but generally not of Fe.

Changes in the soil caused by the highway: The most severe changes materialized within 5 m of the road because the construction results in a compaction and covering of the original topsoil layers by a mixture of soil material, building debris, mortar fragments, brick pieces and cinder. This cover substratum, rich in stones and carbon with an already enriched humus content in the topsoil may be classified as a Calcaric Regosol (FAO). Soils with natural horizons are contaminated in the following meters by building material and trash, resulting in an eutrophication of the surface. On an area 5 meters wide running parallel to the road, the pH-values are greatly increased, Even at a distance of 5 to 10 meters, they are still slightly changed due to cement, mortar and carbonate dusts. De-icing salt is mainly responsible for the increase in the salt concentration of the soils (see Na-content of the saturation extract) up to a distance of 10 meters. Sodium in the absorption complex reaches values higher than 15% within the immediate vicinity of the road. The conditions of a Solonetz are dominant here, at least in the spring (electr. conductivity > 4, V_{Na} > 15). Repeated measurements taken over the course of a year have shown that the salt had been transported into subsoil but had not, under the normal atmospheric conditions, reached a depth of 2 meters until two years, so that the salts of 2 or 3 winters were constantly present in the root zone (see Na-maximum at 8 and 1.5 dm in Fig. 13 (chapter 3.2).

The vehicle traffic has resulted in a high contamination of lead in the vicinity of the road up to 15 meters, In contrast to road salt, lead is not displaced to groundwater but is accumulated in the surface soil since it is partly absorbed by the colloidal complex of the soil (about 40% is organically bound). This is favoured by the high pH-values, preventing the plant roots from being damaged by lead. However, surface soils in Berlin generally show a lead accumulation relative to fresh sediments as a result of air pollution.

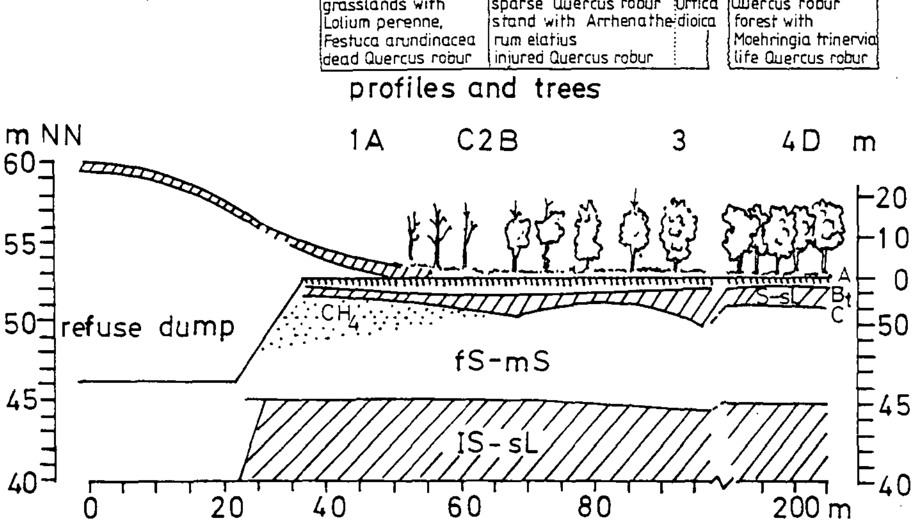
The cadmium content is also enriched within the vicinity of the road absolutely and relatively (in reference to the natural content) but not as strong as lead (Fig. 13, chapter 3.2). The better solubility at low pH-values as compared to lead is responsible for a transport to greater soil depth.

Ecological site characteristics: Possibility of good and deep rooting, always good aeration, very dry location because fair precipitation (500-600 mm/y) and low suitable water capacity. In dry periods water tensions in the subsoil only up to pF 3.2 because extremely low unsaturated flow. In forest soils, low contents of available nutrients and nutrient reserves. The roadside soils become alkaline over a wide-spread area. This changes the nutrient supply to plants and alters the filtering efficiency for many other substances (i.e. heavy metals). Simultaneously, the soils become more rich in nutrients because of the roadside pollution. The salt concentrations are partly toxic and damage plants. Increasing heavy metal contamination results in a decrease of filter capacity. The forest soils are very sensitive to a heavy metal load, because of low pH-values (topsoil: 0-10 cm pH 3.6; subsoil: 90-100 cm pH 4.6), favouring their solubility.

4.8 Soils around and on waste deposits - The Wannsee refuse dump in the Düppel Forest

The Wannsee refuse dump was established after 1945 in a sand quarry in the Düppel Forest in form of a controlled dump. Thereby, household refuse was dumped in 1-1.5 m thick layers, then compacted and covered by building debris or quarry material. Liquid non-poisonous special refuse was deposited in tanks lined with loam placed over about 10 m of refuse with about 30 m diameter and which were covered by another 10 m layer of refuse after filling in. Today the dump has a height of 93 m and contains 11.5 mill. m^3 of household refuse (Fig. 54).
The experimental dump and the older dump were already covered with 2-3 m quarry material and planted from 1968 onwards. The recultivation of the new dump was begun in 1979 and has not yet been terminated. As some parts are not covered, the 30 to 50 cm deep root zone is a mixture of building debris, quarry material and some refuse (see Fig. 55).
A high amount of gas is formed in the dump (mainly methane), which is burnt at a rate of about 200 m^3 per hour. Larger amounts of dump-gas escape through the covering and through the sides of the former quarry. This has led to high losses of the young trees and shrubs planted as well as dying away of neighbouring forest trees at distances of up to 50 m from the dump (Fig. 54). Heavily damaged forest soils can be found where sands were covered by loamy material, so that the gas could escape sidewards (Fig. 56).

Fig. 56 Schematic cross section of the area next to the refuse dump at Berlin-Wannsee (covered 1968, investigations 1976, BLUME et al. 1979)



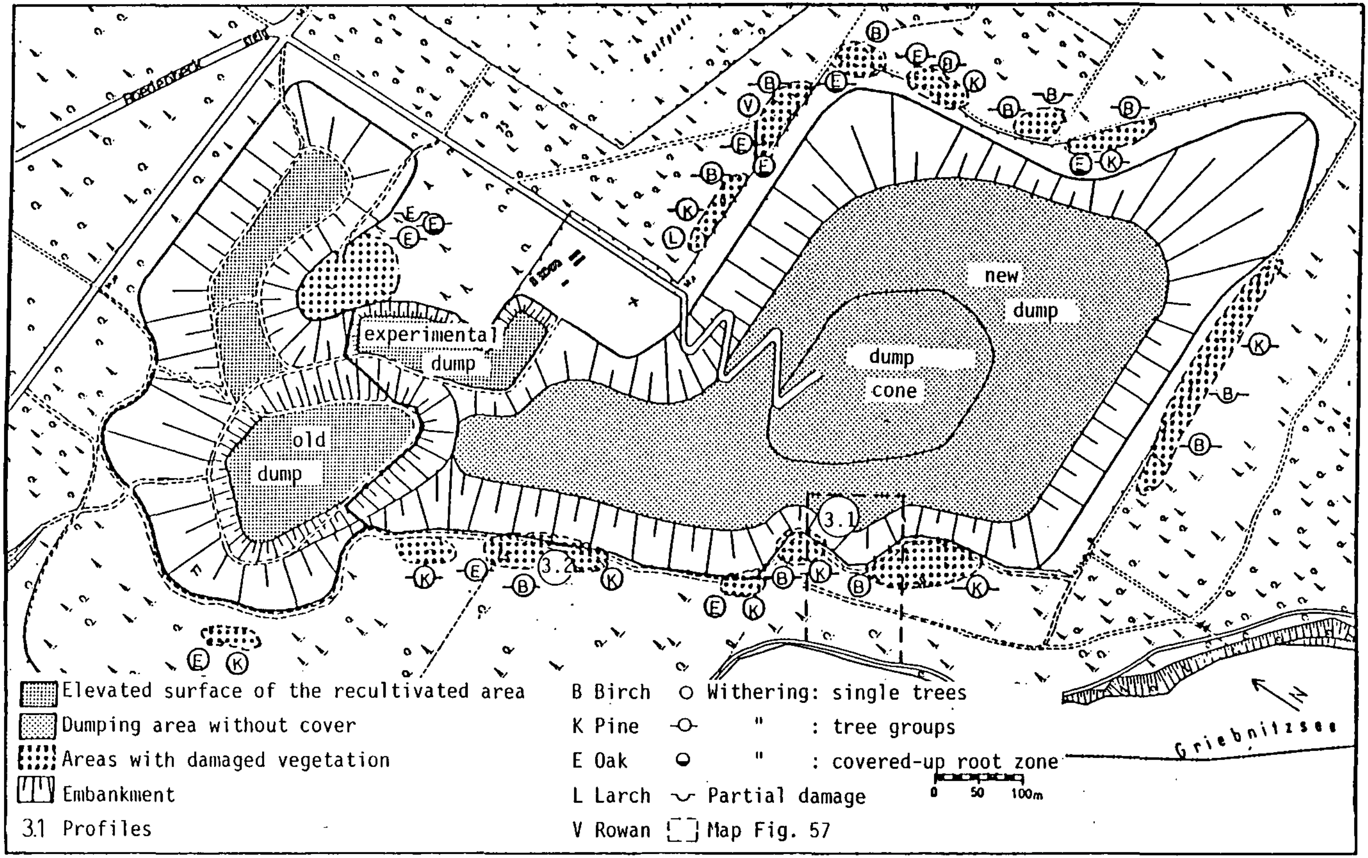


Fig. 54 Wannsee refuse dump with vegetation damages due to dump-gas (mapped July 1978 by B.TIETZ)

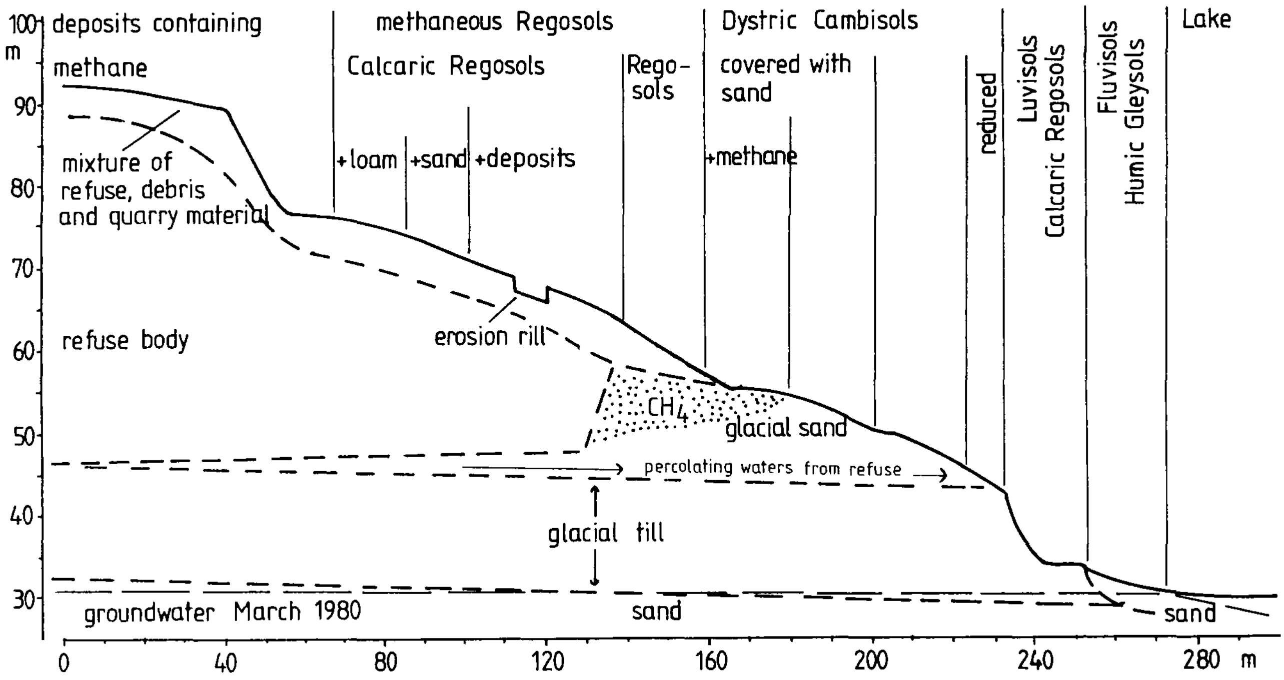


Fig. 55 Soils and sediments on top of and next to the Wannsee refuse dump (position of the cross section marked in fig. 53; after BLUME a.o. 1983)

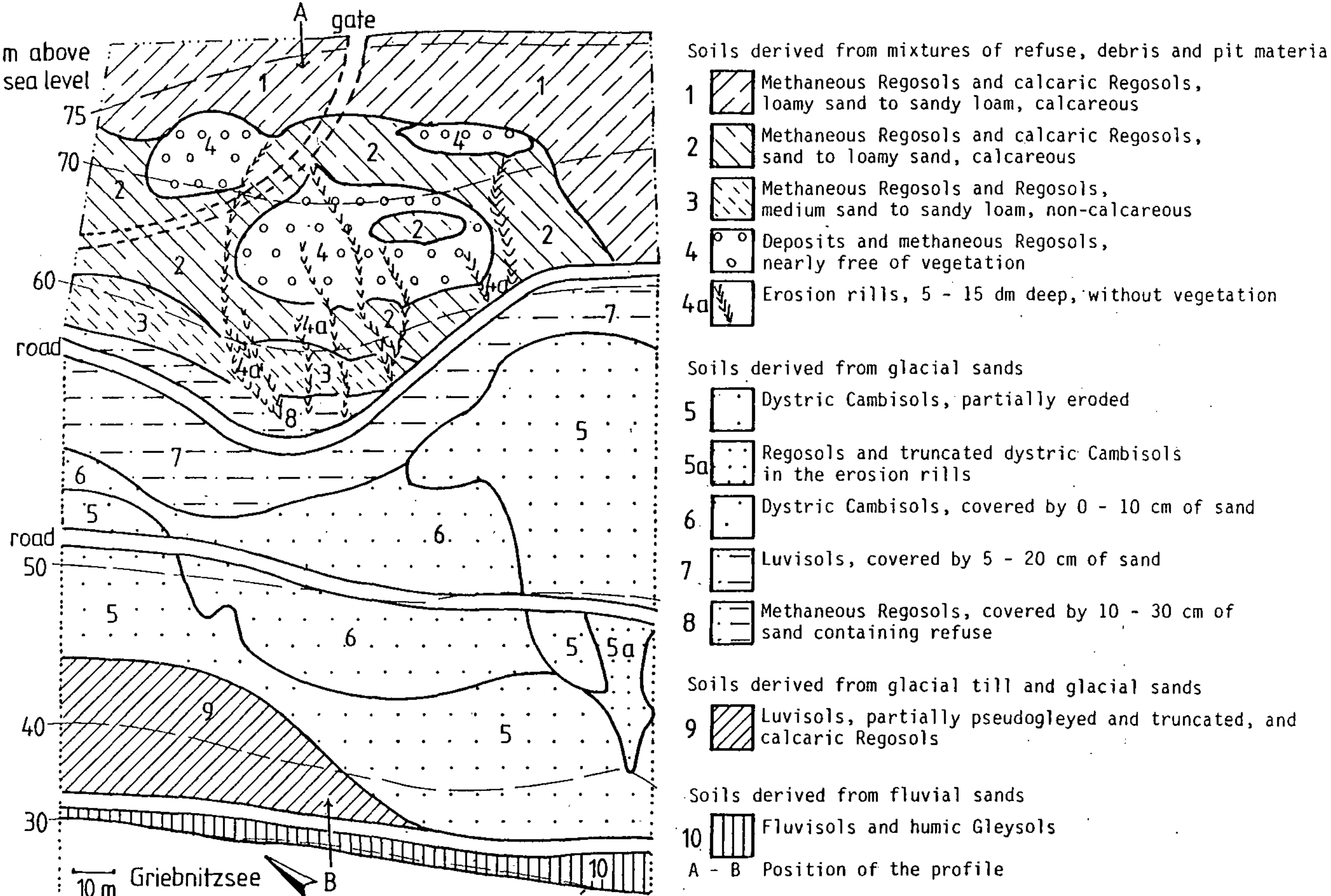


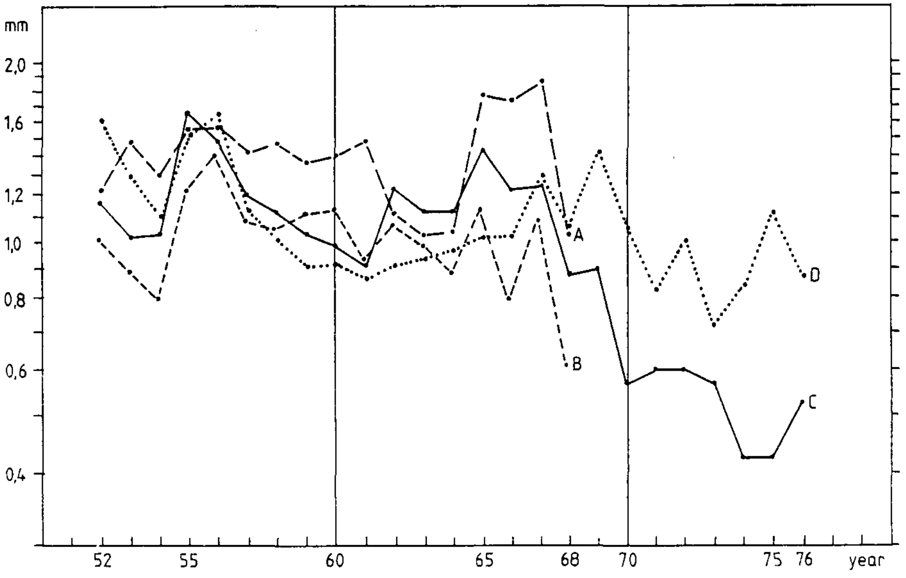
Fig. 57 Soils on the Wannsee refuse dump and in its vicinity (mapped by J. HOFMANN and MOIMOU, May 1981)

Gas also escapes along the slope. Presently, a part of the dump-gas is beeing used to heat the Hahn Meitner Institute, and an extension of the gas utilization is planned (SCHNEIDER, Hahn Meitner Inst., pers. comm. and SCHNEIDER 1985).

The dump's slopes are partially dissected by erosion rills (Fig. 57), whereby the sediment load is washed into adjacent forest for up to 100 m. The neighbouring forest sites have also been contaminated and eutrophied by refuse dust.

Vegetation: Ecotopes adjacent to the refuse dump are contaminated through deposition by paper, dust etc. This accounts for eutrophication in the neighbouring sites and changes the composition of the vegetation cover. Beneath an oak stand, near the refuse dump at Berlin-Wannsee, the pH-values in the topsoil increased. Presumeably, this is due to dust immission. The immediate edge of the sanitary landfill was compacted by bulldozers and was partly overlapped by the loamy cover material of the refuse dump. Extreme changes, which caused the death of many trees, appeared only after completion of depositing and covering. In the case at hand, this was proved by the analysis of the annual ring-growth (Fig. 58).

Fig. 58 Analysis of annual rings of injured trees at the refuse dump at Berlin-Wannsee



The lateral escape of gas, especially methane, resulted in oxygen loss which caused the death of trees immediately bordering the refuse disposal site. It was also responsible for crown drought over a greater distance. The oxygen loss was much more a result of microbial action than escaping gas as TIETZ (1979) suggested on the basis of CO_2-readings.

The vegetation development on household refuse was observed at various garbage dumps in Berlin over a period of several years (KUNICK & SUKOPP 1975). The results are summarized in Tab. 15.

Tab. 15 Plant colonization of household refuse in Berlin (according to KUNICK & SUKOPP 1975, modified)

colonization in:	1st year	3rd year	4th year	10th year	20th year
number of test sites	3	2	2	5	4
vegetation cover (%)	60	60	90	90	100
number of species	35	25	26	10	20
vegetation type:					
useful or ornamental plants	11	4	2	-	1
annual or biennial ruderal vegetation	3	6	6	-	-
agricultural and garden weeds	9	3	3	1	1
therophyte vegetation on wet sites	1	-	-	-	-
pasture vegetation	3	5	4	1	1
perennial settlement weeds on dry sites	2	3	2	2	-
perennial settlement weeds on fresh to moist sites	2	3	5	3	3
nitrogen-influenced bush and fringe veget.	2	1	4	1	8
forests	1	-	-	-	4
mosses	-	-	-	2	2
other	1	-	-	-	-

It was found that even after more than 20 years after recultivation, the garbage dumps studied exhibited vegetation that differed greatly from that of their surroundings, i.e. consisting mostly of common elder bushes (Sambucus nigra). A planting of species from the surrounding area, which has occasionally been tried, usually failed. Re-assimilation, if at all possible is a long-term process. Even succesful "reforestation" produces stands that are similar to the surrounding forests only in structure, not however in their floristic composition.

Another course of action conceivable, namely accentuating the peculiarities of the dump habitats by deliberately planting those plants that appear here spontaneously, was suggested by NEUMANN (1971) and GUTTE (1971), among others. In this manner, garbage dumps could become ecological test fields for long periods of time. There is no reason why this possibility should remain unexplored.

Explanations for profile Wannsee I

Evolution of the site: Until 1978 deposition of refuse, towards the end as a mixture of quarry material, building debris and refuse, 1979 recultivation with different trees, 1980 slope erosion, dying away of the trees.

Soil association (Fig. 57): Dump soils, i.e. Methanous Regosols and Regosols (with an already formed Ah under denser vegetation) of changing texture next to fresh deposits and deep erosion rills. On the slope bottom shallow Regosols from eroded dump material above buried Dystric Cambisols containing methane.

Soil development: Anaerobic decomposition in the refuse with reduction of Fe and Mn-oxides; in the top-soil rusting of aggregate surfaces by Fe-oxidation as well as incipient humus accumulation and structure formation by soil fauna.

Site characteristics: Moderately rootable due to high stone contents; dry because of westerly slope and medium avialable field capacity; accentuated O_2-deficiency on account of methane-decomposing bacteria as well as O_2-displacement by rising methane; rich in nutrients, especially nitrogen, possibly toxic concentrations of heavy metals (e.g. Mn due to low E_h-values); high subsoil temperatures as a result of intensive microbial decomposition (according to NEUMANN (1971) 15-10^{o}C as a yearly average in 30 m depth for refuse two years old, temporarily 45^{o}C and in greater depths up to 88^{o}C).

Explanations for profile Wannsee II

Landscape evolution and use: Push moraines from the Weichsel period (Brandenburg stage) with glacial sands (above frontalapron of a glacier, or above glacial till, forestry.

Soil association (Fig. 57): Cambic Arenosol containing methane on the slope bottom (partially eroded) loamy Luvisols, and sandy loamy Dystric Cambisols.

Wannsee I

Location:	new dump in the Düppel Forest, Block No. 70
Position:	71 m above sea-level, midslope to the west
Parent material:	mixture of quarry material and building debris, with increasing amounts of household and industrial refuse underneath
Soil type:	Methanous Regosol (Calcaric Regosol or Eutric Gleysol)
Vegetation:	practically without vegetation, small planted trees that have died away, surrounded by pioneer plants one to two years old
Site valuation:	deep, moderately rootable, dry, poor aeration, rich in nutrients (and maybe toxic elements)
Sample analysis:	mainly by D. MOIMOU (1983)

Profile description:

A(h) (Ah)	0- 15 cm	dark greyish brown, 2.5 Y 4/1, aggregate surfaces dark reddish brown, 5 YR 3/3, to platy, moderately loose, stony (bricks, concrete, cristalline rock, wood, tin plates, rubber, plastic) sandy loam, single earthworms, sharp transition
Cor (Br)	- 40 cm	grey, 5 Y 6/1, single mottles, coherent, moderately loose, stony (see above) sandy loam, gradual transition
Cr (Cr)	- 80 cm	very dark grey, 7.5 YR 3/1 and 3/0, coherent, moderately compacted, stony sandy loam

No	hor.	depth cm	sto. %	texture in % of humus-/carb. free fine soil: sand c	sand m	sand f	sand Σ	silt c	silt m	silt f	silt Σ	clay	kf cm/d
1	A(h)o	0-15	66	10	38	30	78	-	-	-	17	5	1400
2	Cor	-40	19	11	37	36	84	-	-	-	12	4	1600
3	Cr	-80	39	11	37	34	82	-	-	-	14	4	250

No	hor.	bulk dens. g/cm^3	GPV %	water content in % at pF 0.6	1.8	2.5	4.2	pH $CaCl_2$	pH H_2O	Fe_d mg/g	Fe_o mg/g	Fe_o/Fe_d	Mn_o mg/kg	P_a mg/kg
1	A(h)o	1.87	42	37	29	25	9	6.7	7.5	3.8	2.3	0.61	92	63
2	Cor	1.48	46	43	42	40	13	7.1	7.4	2.1	1.4	0.67	28	41
3	Cr	1.74	32	26	19	14	10	7.1	7.8	2.4	1.8	0.75	53	48

No	hor.	$C_{org.}$ mg/g	N_t mg/g	C/N	carbonate mg/g	CEC_p meq/kg	exchang. cations in meq/kg: Ca	K	Mg	Na	H	Al	V %
1	A(h)o	18.9	1.39	14	19.1	16.7	16.2	0.21	0.28	0.074	-	-	100
2	Cor	13.0	0.78	17	14.9	15.0	14.3	0.20	0.41	0.093	-	-	100
3	Cr	7.6	0.57	13	25.4	16.2	15.2	0.25	0.65	0.160	-	-	100

Wannsee II

Location: Düppel Forest, Block No. 70, 10 m besides the western edge of the Wannsee refuse dump

Position: 50 m above sea-level, flat slope WSW below the refuse mound

Parent material: Glacial sands of the Weichselian period, covered by sand eroded from the refuse mound

Soil type: Methan-Braunerde (Cambic Arenosol, containing methane and covered by sand deposits)

Humustype: moder

Vegetation: Pine-oak forest (Pino-Quercetum typicum and moehringietosum) with plants originating from the refuse dump, which were partly sown and whose seeds were eroded; birch trees, oak trees and pine trees partly dead or partly with damaged crowns

Site valuation: very deep, well rootable, very dry, poor aeration in greater depths, poor in nutrients, but top-soil eutrophicated by eroded material from the dump

Profile description:

(Drawn up in Jan. 1980, with a cover one year old in Dec. 1980)

dD	0- 7 cm	light olive brown, 2.5 Y 5/3, singular, loose, fine medium sand, sharp transition
fOfh (Ob)	- 14 cm	black, 10 YR 2/1.7, moderately to well humified, sandy layers, loose, sharp transition
Aeh (E)	- 21 cm	very dark brown (10 YR 2/2.5) dark greyish brown, 10 YR 4/2, mottled, bleached sand grains, moderately loose, fine medium sand with stones, intensively rooted, ragged transition
Bsv (Bsw)	- 37 cm	light yellowish brown, 10 YR 6/4 brownish yellow, 10 YR 6/6, mottled, with single rusty spots, 7.5 YR 4/6, singular, moderately loose, gravelly, fine medium sand, moderately rooted, gradual transition
Crv (C)	- 67 cm	pale yellow, 2.5 Y 7/4, yellow, 2.5 Y 7/6, mottled, singular, moderately loose, gravelly, fine medium sand, only single blackened dead roots, gradual transition
Cvr (Cr)	- 97 cm	pale yellow, 5 Y 7/4, light grey 5 Y 7/2, reddish yellow 7.5 YR 7/8 and reddisch violet, 7.5 R 4/5 spots, singular, moderately loose, medium sand, at 87 cm thin clay layer, blockened dead roots, gradual transition
C(r)v (C)	-187 cm	light grey, 7.5 Y 7/2, singular, moderately loose, medium sand, few blockened dead roots, at 157 cm thin clay pans

No	hor.	depth cm	sto. %	texture in % of humus-/carb. free fine soil: sand c	sand m	sand f	sand Σ	silt c	silt m	silt f	silt Σ	clay	kf cm/d
1	dD	0- 7	0	7	40	37	84	-	-	-	8	8	1600
2	fOfh	- 14	0	9	63	17	89	-	-	-	7	4	1200
3	Aeh	- 21	0	9	63	17	89	-	-	-	7	4	600
4	Bsv	- 37	0	6	61	26	93	-	-	-	4	3	710
5	Crv	- 67	0	6	56	33	95	-	-	-	4	1	1020
6	Cvr	- 97	0	5	72	21	98	-	-	-	1	1	980
7	C(r)v	-187	0	12	81	5	98	-	-	-	1	1	1090

No	hor.	bulk dens. g/cm³	GPV %	water content in % at pF 0.6	1.8	2.5	4.2	pH $CaCl_2$	pH H_2O	Fe_d mg/g	Fe_o mg/g	Fe_o/Fe_d	Mn_o mg/kg	P_a mg/kg
1	dD	1.42	-	-	-	-	-	7.2	8.1	1.75	-	-	92	48
2	fOfh	1.01	46	43	33	20	3	3.8	5.8	4.40	1.60	0.36	138	35
3	Aeh	1.52	50	39	30	24	6	4.1	5.3	1.54	1.02	0.66	9.0	26
4	Bsv	1.60	49	47	15	10	3	4.1	4.9	1.10	0.51	0.46	4.7	40
5	Crv	1.67	38	35	12	7	2	4.4	5.3	0.68	0.29	0.42	3.1	13
6	Cvr	1.67	37	31	8	4	2	4.8	5.4	0.47	0.15	0.32	3.1	7.6
7	C(r)v	1.63	38	35	10	4	1	4.0	5.5	0.36	0.13	0.36	4.7	7.0

No	hor.	$C_{org.}$ mg/g	N_t mg/g	C/N	carbonate mg/g	CEC_p meq/kg	exchang. cations in meq/kg: Ca	K	Mg	Na	H	Al	V %
1	dD	4.8	0.29	17	23	165.6	161.0	0.95	3.26	0.36	-	-	100
2	fOfh	135.0	6.50	21	0	270.9	167.1	1.74	10.50	0.51	91	1.27	66.8
3	Aeh	31.0	1.30	24	0	103.7	30.8	0.75	2.84	0.29	69	0.90	33.4
4	Bsv	7.6	0.60	13	0	40.8	1.7	0.24	0.79	0.14	38	1.27	5.9
5	Crv	4.2	0.27	16	0	17.3	0.3	0.17	0.14	0.13	16	0.42	7.3
6	Cvr	0.7	-	-	0	12.7	0.4	0.13	0.04	0.07	12	0.32	5.2
7	C(r)v	0.5	-	-	0	10.0	0.8	0.09	<0.05	0.07	9	0.32	10.4

Soil development: Deeply decalcified (original lime content probably below 2%), base depleted and acidified, browned and weakly lessivied (single clay streaks) hindered litter decomposition, beginning podzolisation (only redistribution of Fe in the Aeh, whereas Al is rearranged in the B-horizon, with partial incorporation into intermediate layers of clay); temporary reductive conditions as affected by dump-gases lead to bleaching in the sub-soil, mottling as well as increased oxalate solubility of iron oxides; covering up with calcareous sand deposits from the dump.

Site characteristics: The profound, dry site poor in nutrients has been eutrophicated in the top-soil by covering up with sand; on the other hand in the subsoil dump gases penetrating sidewards have resulted in air deficiency and thus in the dying away of deeply rooting plants; effects of refuse seepage water were not observed at the site Wannsee II (due to the high soil permeability).

4.9 Organic recycling with foliage litter - Agricultural fields at Gatow

Agriculture is not a very important industry in a dense populated area like Berlin. The importance has decreased since 1950 also, because of housing and road buildings and because of recreation activities. There are still about 250 agricultural and horticultural entities in Berlin (West) which cultivate about 1100 ha arable land and about 180 ha pastures. The main crops and their average yields are listed below.

area under cultivation (ha)	crop	average yield 1979 (dt/ha)
697	rye (grains)	27
9	wheat (grains)	38
73	other cereals mainly barley	37
21	potatoes	245
7	fodder beats	459
35	fodder maize	468
5	alfa alfa	64
132	pasture	65
21	cabbage	178
10	salat (other foliage vegetables)	70
17	root vegetables	143
3	beans	70
75	other vegetables	70

Farmers, breading-, fattening- and milk production units feed about 700 cows, 3700 pigs, 300 sheep, 100 goats, 2600 horses, 100 000 hens, geese and ducks and 2800 swarms of bees. Especially the pig fattening units use about 40 000 t of kitchen refuse. The food production from the fields is estimated to be only 1% of the requirements. Its importance seem to increase lately, especially, by increase of horticultural production on a private basis.

The agricultural fields are also used as recreation areas in the metropolitan area. Thereby, losses of yield occur which, however, are refunded by the city. The agricultural fields are mainly on Parabraunerde and Braunerden (Luvisol, Cambisol and Arenosol) in the cover sand - boulder clay plains of Rudow, Gatow and Lübars. Drained sandy Gleys (Gleysols) are also used at Spandau and Heiligensee. Especially the fields with cereals are extensively used with low mineral fertilizer input, no organic recycling and no liming. Fields for vegetable production are in a far better condition. On the poor farm fields and in parks more organic recycling is taken into consideration.

Profiles Gatow "Farmer Ernst"

Locality:	Gatow agricultural fields south of Großglienicker Weg east of Kladower Damm (see Fig. 59)
Landscape:	Glacial cover sand - moraine plateau of Nauen
Relief:	gentle, northfacing slope, groundwater deeper than 5 m below ground
Land use:	farmfields with dominant rye cultivation
Parent material:	cover sand and glacial boulder sand (sandy till) 0.4 - 2 m thick over boulder clay. The thickness of the sandy top layer determines soil types

Gatow Ernst I

Soil type:	Parabraunerde (Orthic Luvisol)
Site qualities:	moderately deep to deep root zone, no limitation to root spreading, moderately dry to dry, well aerated, low nitrogen, moderate phosphorous, low to very low Ca, Mg and K supply, no trace element deficiency and good sulfur supply

Profile description:

Horizon (FAO), depth, parent material, colour, carbonate content, structure, structure specialities, coarse stone (Vol.%), actual rooting, boundary.

Ap (Ap)	0- 24 cm	cover sand, 10 YR 4/2, no lime, weak subangular blocky, 2% stones, many roots, sharp boundary
Al (E)	- 55 cm	cover sand, 10 YR 6/3, no lime, coherent to weak subangular blocky, 2-5% stones, few roots, sharp boundary
Bt (Bt)	-110 cm	boulder loam, 10 YR 5/6, no lime, subangular blocky shiny clay skins, few manganese and iron spots, 2% stones, no roots

Gatow Ernst II

Soil type:	Typische Braunerde (variety sandige Ackerbraunerde) (Cambic Arenosol)
Site qualities:	very deep root zone, no limitations to root spreading, dry to moderately dry, well aerated, nutrient supply like profile I

Profile description:

Ap (Ap)	0- 30 cm	cover sand, 10 YR 6/3, no lime, weakly subangular blocky, 4% stones, many roots, sharp boundary
Bv (Bw)	- 80 cm	boulder sand, 10 YR 5/4, no lime, coherent to weak subangular blocky, 5-7% stones, few roots gradual boundary
C (C)	-100 cm	boulder sand, 10 YR 6/4-7/3, no lime, singular to coherent, 5% stones, almost no roots, few thin clay pans and manganese spots

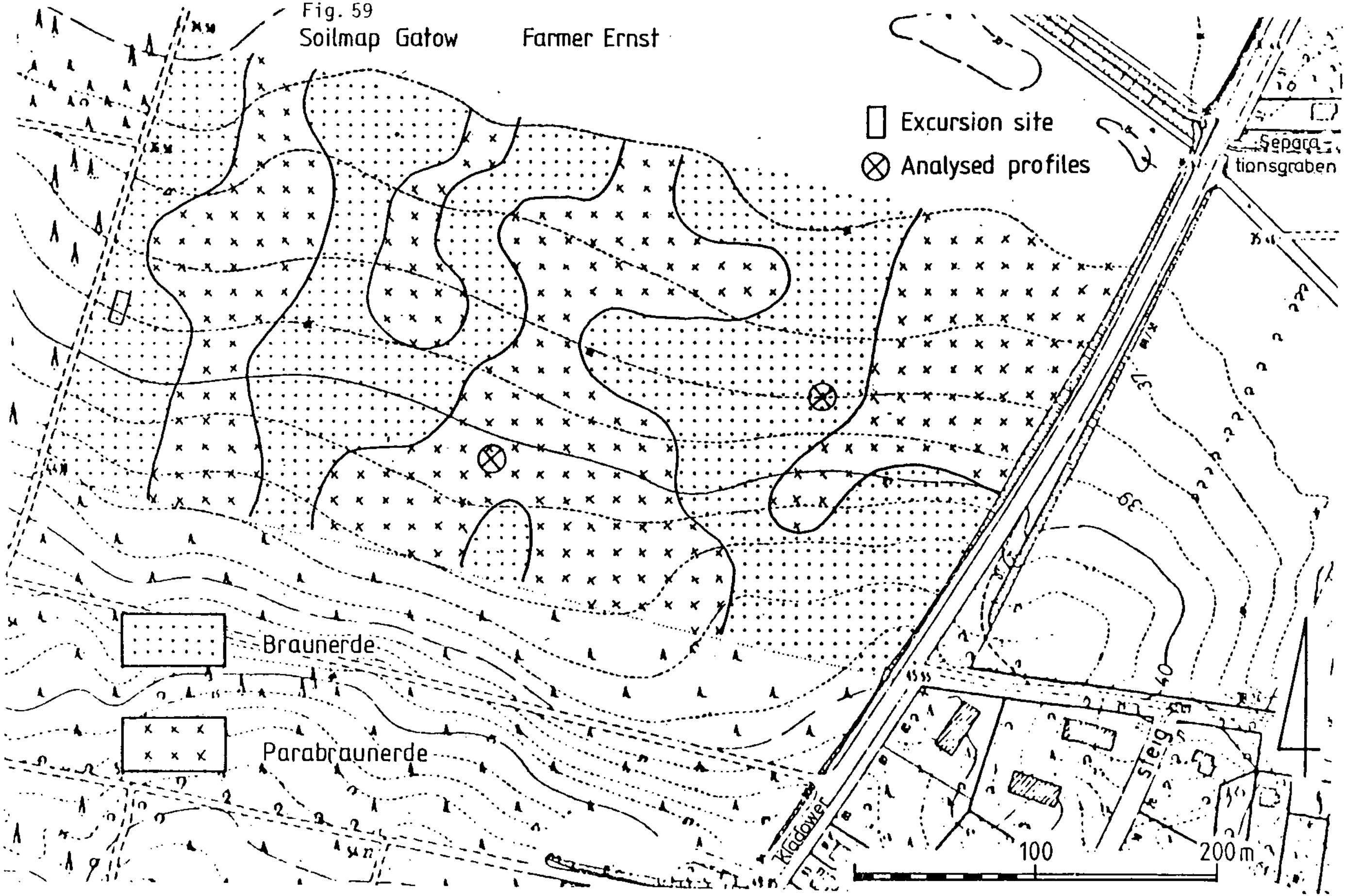
No	hor.	depth cm	sto. %	texture in % of humus-/carb. free fine soil: sand c	sand m	sand f	sand ≰	silt c	silt m	silt f	silt ≰	clay	kf cm/d
E I	Ap	0- 24	2.1	3.8	40.6	32.7	77.2	11.2	4.7	2.0	17.9	4.9	-
	Al	- 55	2.0	4.4	36.2	33.7	74.3	14.2	4.9	2.7	21.7	3.9	-
	Bt	-100	1.8	3.5	30.7	33.7	67.8	10.9	4.9	2.7	18.5	13.7	-
E II	Ap	0- 30	3.6	5.9	37.9	32.2	75.9	11.7	4.0	2.9	18.5	5.6	-
	Bv	- 80	6.5	4.4	36.1	36.3	76.7	11.0	4.9	2.4	18.3	5.0	-
	Cv	-100	2.6	4.8	29.7	35.7	70.2	10.4	7.1	4.0	21.5	8.3	-

No	hor.	bulk dens. g/cm^3	GPV %	water content in % at pF 0.6	1.8	2.5	4.2	pH $CaCl_2$	pH H_2O	Fe_d mg/g	Fe_o mg/g	Fe_o/Fe_d	Mn_o mg/g	P_a mg/g
E I	Ap	1.5	43	35	20	11	5	3.9	4.6	1.87	0.95	0.51	243	99
	Al	1.7	36	32	21	10	4	4.2	4.9	1.40	0.54	0.39	304	17
	Bt	1.7	37	37	25	18	13	5.1	5.9	5.41	0.74	0.14	229	48
EII	Ap	1.6	39	36	21	11	7	3.9	4.5	2.17	1.16	0.53	267	125
	Bv	1.7	37	33	21	10	5	4.1	4.9	1.70	0.73	0.43	355	38
	Cv	1.7	38	32	20	14	7	4.6	5.4	2.63	0.55	0.21	225	18

No	hor.	$C_{org.}$ mg/g	N_t mg/g	C/N	carbonate mg/g	CEC_p meq/kg	exchang. cations in meq/kg: Ca	K	Mg	Na	H	Al	V %
E I	Ap	9.4	0.64	13	0	37	3.2	1.3	0.4	-	32	2.2	18
	Al	1.7	0.14	11	0	18	2.7	1.3	0.5	-	13	1.7	32
	Bt	1.1	0.13	7	0	55	35.0	3.2	4.9	0.4	12	0.5	78
EII	Ap	10.3	0.68	13	0	41	4.5	1.8	0.6	-	34	2.4	21
	Bv	3.5	0.26	12	0	32	3.7	1.6	0.5	0.2	26	2.1	24
	Cv	1.3	0.13	8	0	34	16.1	1.8	2.7	0.2	13	0.7	63

No	hor.	heavy metal concentrations in g/kg atro: Cd_t	Pb_t	Cu_t	Zn_t	Cd_e	Pb_e	Cu_e	Zn_e
E I	Ap	0.04	97.8	23.6	32.7	0.03	36.3	5.7	1.9
	Al	0.02	11.2	17.4	19.7	0.03	4.8	1.5	1.0
	Bt	0.02	19.4	17.6	84.1	0.09	6.1	1.5	(17.4)
EII	Ap	0.10	95.3	26.5	42.0	0.03	56.6	8.6	6.3
	Bv	0.07	20.2	8.1	25.5	0.03	9.1	3.0	2.3
	Cv	0.07	10.2	9.1	51.9	0.10	6.3	3.0	1.8

Fig. 59
Soilmap Gatow Farmer Ernst



Explanations for profiles Gatow

Land use and parent material: Sandy glacial and periglacial deposits from Weichselian, development under natural forests (dry oak-hornbeam forests) since about 1200 in agricultural use. Since 1945 dominant rye production with low inputs.

Soil development: Profound decalcification of the sandy profile took places since late glacial, acidification and base losses are also old processes but are increasing recently. Clay illuviation took place in both profiles at different amounts. The organic matter content of 10 kg/m^2 is low, but the average of the fields is even less (about 8 kg/m^2).

Organic recycling: The agricultural fields around Gatow have a low organic matter content, as well as low amounts of available nutrients and weatherable minerals. The organic recycling possible within a farm is not enough to increase the organic matter content of all fields substantially. Furthermore, the fields are acidified. The A-horizon is rather thick but has a low field capacity and high bulk density and also low aggregate stability. Through additional organic matter, especially if it would be of high nutrient status these problems could be overcome.

From parks, streets and squares in the city, every year high amounts of foliage litter (about 200 000 m^3) are gathered. Until 1980 this litter was mainly deposited at waste deposits. This useless and expensive handling could be overcome if there would exist a possibility of recycling the organic matter after a fermentation. The problem of a technical fermentation could be solved fairly easily but the question remains, if the litter is so heavily polluted that it may harm agricultural production.

Since 1982, some field trials have been carried out in order to test if the leaf litter could be used for amelioration or if it intoxicates the agro-ecosystem. Three cases of intoxication have been tested.

1. salinity (thawing salts)
2. acidity (mineral acids)
3. heavy metals (esp. Pb and Cd)

It was easy to find out that the first and second case are not of significance. In the third case, there is still some doubt. Therefore, some more analytical data have been gathered and more field trials are carried out. The heavy metal content of the analysed soils are shown in Tab. 16. The Cd-content is very low (already depleted), lead is comparatively high especially the EDTA-soluble fraction, Cu and Zn are within the normal range but higher than the parent material.

Tab. 16 A tentative balance of trace elements in a sandy soil under cereals at Berlin-Gatow (Farmer Ernst)

	Lead	Cupper	Zinc	Cadmium
Soil stock (kg/ha)				
Pough layer	600	150	220	0.6
Subsoil	140	90	450	0.8
Input (kg/ha x y)				
dry and wet deposition	1	0.1	0.3	0.01
fertilizer	0.03	0.007	0.005	0.0005
Output (kg/ha x y)				
seepage	0.003	0.01	0.1	0.005
harvest	0.01	-	-	0.001
Translocation (kg/ha x y)				
top soil/subsoil	0.005	0.02	0.3	0.005
Additional Input (kg/ha x y)				
with litter compost 20 t/ha	2.2	0.8	3.3	0.04
80 t/ha	3.2	3.2	13.2	0.16
with horse manure 20 t/ha	0.7	0.3	0.4	0.02

The comparison in Tab. 17 shows that the leaf litter has higher N, Ca, Mg values than horse manure, whereas horse manure contains more K and the same amount of P. The trace elements Pb, Cu and Zn are higher in the leaf litter but not Cd. From the data available from 1982 and 1984 a rough budget of the trace elements in the agro-ecosystem has been made. The result is that the lead addition is not significant because the content will not increase in the plough layer since the addition is overbalanced by the material-import. This is not true for Cd. Therefore, Cd is the element which may have a negative influence and has to be analysed in more detail. It is a bit encouraging that the trace element content in the leaf litter seems to decrease in the last years.

Tab. 17 Analytical data of leaf litter and straw with horse manure which was used on the fields of Gatow

	pH	C_t	N_t	P_t	K_t	Ca_t	Mg_t	Pb_t	Cd_t	Cu_t	Zn_t
leaf litter 1981	6.8	166	6.5	1.55	4.3	18.3	1.9	142	4.4	39	110
leaf litter 1983	6.4	384	17.6	1.14	3.6	22.4	1.7	105	1.0	42	290
horse manure	7.7	486	7.8	1.27	16.4	3.8	0.8	29	1.0	13	17

4.10 Waste water disposal fields - Gatow-Carolinenhöhe sewage farm

The development of the waste water removal in Berlin and its suburbs was started during the middle of the last century, when the increasing amounts of waste water could no longer be removed continuously through gutters and sink pits. According the proposals from CRELLE (1842) and WIEBE (1860), a mixed canalization (domestic and industry waste water as well as rain water in a common pipe system) of Berlin was planned and realized in 1869; above all, according to instructions of famous doctors and politician VIRCHOW and HOBRECHT. Initially planned out-let pipes into streams were neglected on behalf of the waste water disposal in fields. This was also a consequence of protestes from the agricultural sector, encouraged by LIEBIG's saying "the crop fields have to be resupplied with the nutrients, that were removed from the crop fields".
The first attempt of the waste water irrigation was conducted in 1869 on Tempelhof-research-fields, according to the english model. These fields had to show the evidence for the purification effect and also about the agricultural success under given conditions. It was seen, that the knowledge obtained in England for heavy soils were not applicable for sandy soils in Berlin. The stepwise slope irrigation, for the purification by the filtering effect of the surface and by the vegetation, showed to be not applicable to permeable soils. The waste water infiltrated the soil completely, leaving no water at the end of the slope with moderate disposal; the purification was not enough with strong disposals, this resulted in the development of the dam irrigation system. Prepared corresponding areas were flooded with waste water for a short while. The purification takes place during the passage of water through the soil by sorption and biological decomposition. In contrast to slope irrigation, with a maximum waste water load from 60 inhabitant per ha, waste water from up to 1200 inhabitants could purified by flooding on one hectare. The emphasis of this method was on waste water purification, the water or the nutrients in it were of secondary importance.

Up to 1915, the city of Berlin and later the incorporated communities obtained 36 irrigation objects with an area of 22 255 ha, of which 10 708 ha were chosen and prepared for waste water disposal. These areas were partitioned into allotments of 0.25 ha and were levelled. Individual areas with large slopes were prepared for slope irrigation by infiltration. All the lots are surrounded by small dams. 10-20 lots are surrounded by roads, forming a "parcel". Ditches, dams and roads occupy about 15% of the area.
The waste water is pumped from the water-works pump station through pipes to the highest point of an irrigation field. From there the water is carried to the secondary high points through distributing pipes. Before it is pumped on the

fields, the water is mechanically purified in concrete sedimentation tanks. The irrigation fields used for rye grass and vegetables, potatoe and cereals production. The meadows are only moderately flooded, so that the waste water stands on the surface only for a short time. Furrow irrigation is practiced in crop fields with separated beds; which occasionally is followed by flooding shortly after the harvest. The amount of irrigated waste water is dependent on the permeability of the soil, level of the ground water table and the crop. Absence or insufficient mechanical purification in sedimentation tanks leads to a blocking of the soils by sink substances, so that only 30-50 l waste water per m^2 can be used for daily irrigation. Up to 70% of solid substances can be separated in a concrete sedimentation tank, so that the average amount of irrigation water could be increased up to 135 litres per m^2 (the remaining solid substances of organic nature decompose rapidly). Thereby, the additional nitrogen fertilization can be reduced.

In 1927, the total amount of 182 mill. m^3 waste water of greater Berlin were irrigated on 1100 ha irrigation fields, namely at an average of 1650 mm. The yellowish grey waste waters rich in oxygen (4 mg/l) and nitrate leave the houses and turn black after 6-8 hours being rich in ammonium and H_2S (4-5 mg/l). When these water reaches the disposal fields, it is almost free of oxygen and nitrate.

Tab. 18 Composition of waste water in Berlin depending upon the time (average values in mg/l of three pump-station in 1926)

Time	dry	Solid substances		Soluble substances		total amounts			
hours	sludge	mineral	organic	mineral	organic	N	Cl	P	K
3	920	5	85	590	240	42	100	3.4	8.5
10	1680	150	400	760	370	150	250	15	67
15	1450	130	300	740	280	74	200	8.4	32
∅	1550					110		9.0	43

The composition is also highly variable with the day time (see Tab. 18). The sludge of the sedimentation tanks is dried and dumped. Earlier, these were partly used as manure.

Waste water fields (sewage farms) allow optimum recycling for liquid wastes, with a risk for vegetation hazards and groundwater contamination. The excess water is drained through pipes, at a depth of 1-1.5 m into the Havel. The waste water properties and the cleaning rate for some parameters are recorded in Tab. 19. The values are taken from a single sampling and may vary greatly, of course.More informations are given in table 20 and figure.

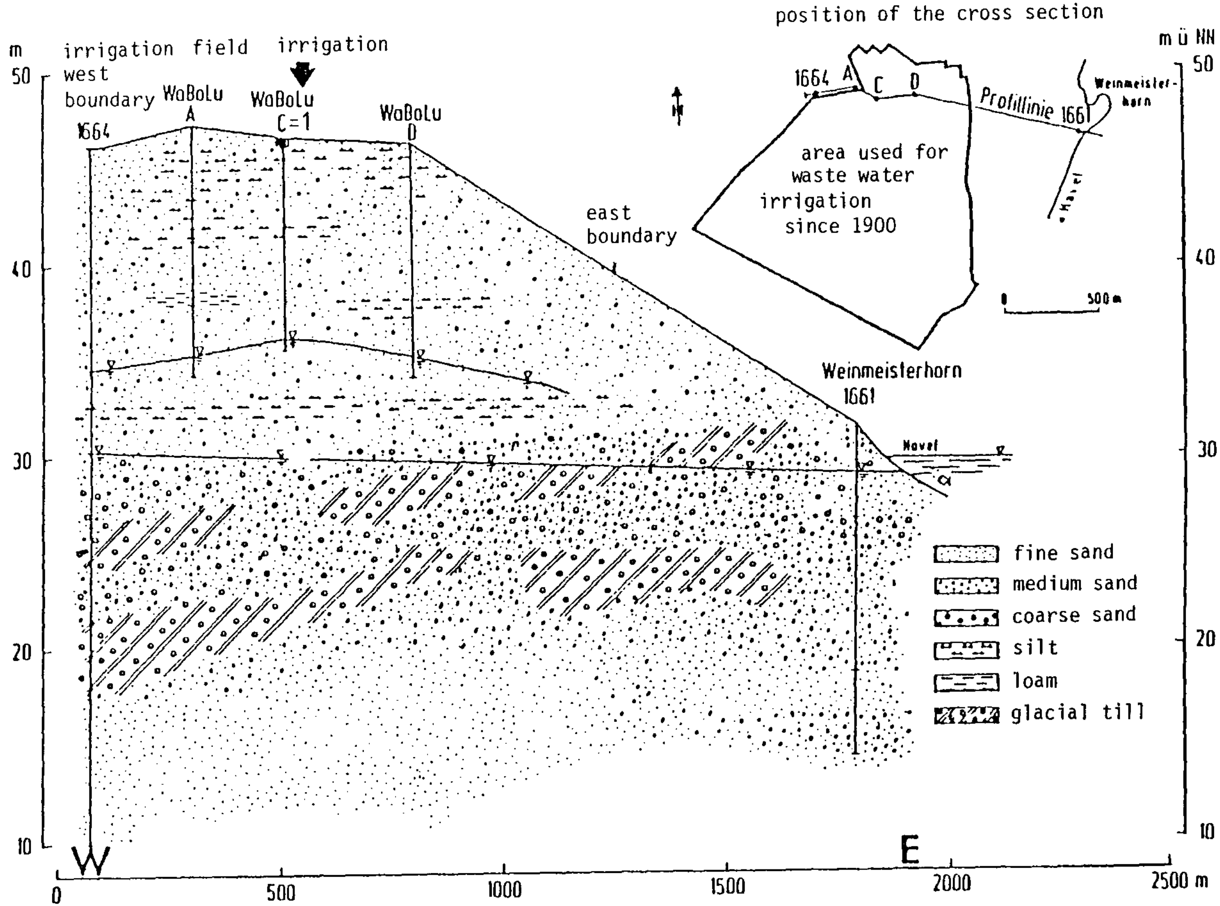


Fig. 60 Groundwater levels at Karolinenhöhe

Tab. 19 Water analysis sample taken from the sewage farm at Berlin-Gatow in spring 1976 (after KAMPF in WEIGMANN et al. 1978)

	untreated sewage (waste water)	irrigated field run off	Havel
NH_4-N (mg/l)	61	3.4	2.9
NO_3-N (mg/l)	0	15.0	1.5
PO_4 (mg/l)	28	4.6	0.7
bacteria count	$10^7 - 10^9$	$10^2 - 10^3$	$10^2 - 10^3$

On waste water fields in Berlin (West), optimal biological purification of sewage is still possible eighty years after operations commenced (cheaper in fact than in a modern sewage treatment plant). However, the increase of chemical residues in the waste water no longer allows a sufficient filtration of inorganic materials, so that the irrigated filed purification should be supplemented with a final purification (as in modern sewage disposal plants).

The visual effects of irrigation on the soil can be ascertained by way of the vegetation. However, there are also differentiations here due to type of cultivations and type of soil (WEIGMANN et al. 1978). In the case of use as pasture land, the following plants dominated: couch grass (Agropyron repens) and Welsh's darnel (Lolium multiflorum); in crop cultivation and vegetable fields: galinsoga (Galinsoga parviflora), white goosefoot (Chenopodium album), chickweed (Stellaria media), shepherd's purse (Capsella bursa-pastoris), red dead nettle (Lamium purpureum); in corn fields, the slightly salt-tolerant species; burr marigold (Bidens frondosus), cockspur grass (Echinochloa crusgalli), spear leaved crache (Atriplex hastata), red goosefoot (Chenopodium rubrum), knotgrass (Polygonum lapathifolium).

Along the paths, pure stands of couch grass (Agropyron repens), stinging nettle (Urtica diolca), brome (Bromus inermis), and catchweed (Galium aparine) can be found.
On the other hand, almost no species of nutrient-poor, dry habitats are present in the irrigation fields.

The variety of species has been greatly reduced on irrigated fields, because of the over-supply of water and nutrient salts. However, in the total system of the sewage farm area, including the plant societies of the path fringes, hedges, and forest patches, the same number of species are represented as in the neighbou-

Tab. 20 Groundwater and waste water qualities for the period from Aug. 1980 - March 1981 (Inst. für Wasser-, Boden- und Lufthygiene 1982)

	sewage water	northern solute loads from the GDR (observation wells 1664, 1665)	lower groundwater under the central part of actual sewage farms (observ. well 1944)	upper groundwater under WaBoLu site C	solute loads from northern sewage farms (observ. wells 1582, 1659, 1660, 1661)	groundwater without influence of waste water (observ. wells 26, 29, 33, 58)	raw water from the Waterworks "Kladow" and "Tiefwerder" (BWW)
LF μS	1270...1680	1340...1410	1290...1480	1110...1250	580...1210 (1580)	530...790 (90)	640...810 400+
pH	9.9...7.4	6.2...6.9	6.3...7.1	5.8...6.2 (6.9)	6.7...7.5	7.5...8.3	7.1...8.0
eH mV	50...393	460...470	460...560	460...560	160...260 (450)	220...550	150...160
NH_4 mg/l	61.2...88.3	<0.2...1.5	<0.2...0.4	<0.2...2.9	<0.2...1.0 (5.0)	< 0.2	0.8...2.2 0.5+
NO_3 mg/l	nd	142...194	276...283	193...305	nd (134)	nd ...18	nd 50+
SO_4 mg/l	50...84	127	136...167	92...110	127...223 (311)	87...120 (nd)	57...105 250+
PO_4 mg/l	0.39...0.46	nd	0.3...23.3	0.40...26.9	nd	nd	nd
Cl mg/l	167...204	154...185	144...168	142...168	107...211 (43)	28...61 (8)	62...100 200+
Ca mg/l	51...52	121...152	136...138	60...145	128...150 (78)	84...129 (9)	94...109
Mg mg/l	8.2...8.3	9.9...14.5	10.5...11.4	9.7...13.3	10.4...16.0	7.9...11.7 (1.5)	7.5...10.6 50+
Na mg/l	129...146	131...200	142...145	127...136	27...98 (151)	18...32 (3)	37...70 175+
K mg/l	21...23	17...20	24...25	18...20	4.9 (21)	2...6	2...6 12+
Mn μg/l	< 400	970...1000	437...507	<100...105	693...1249	<100...388	291...486 50+
Zn μg/l	540...570	222...368	397...474	66...2318	70...1565	305...629 (60)	<60...73 100+
Fe μg/l	4250...4890	<200...941	< 200	<200...596 (4906)	<200...224	<200...1924 (14236)	1355...3253 200+
Ni μg/l	47...65	6...7	7	3...19	5...12 (21)	5...7	9...13 50+
Cu μg/l	72...91	17...36	501...656	1597...3313 (nd)	16...157 (1376)	17...39 (510)	37...70 100+
Cr μg/l	46...49	2	3	2...17	3...11	2...3	3...5 50+
Cd μg/l	19...20	0.8...1.0	1.4...1.5	0.9...4.3	0.9...3.3	0.9...1.6	0.5...0.6 5+
Pb μg/l	262...263	13...17	18...19	11...56	17...38	16...21	26...38 50+
Co μg/l	35...43	5...6	6	2...12	4...16	4...6	7...9

+) permitted maximum concentrations of the EC-guide line from July 15, 1980 concerning the quality of water for human use

(...) strongly over - or below the general trand

nd not detectable

ring Gatow fields.

The variety of the landscape is greatly increased by the presence of hedges, bushes, and old trees. The sewage farms and the Gatow fields are the only areas in Berlin with a significant portion of hedges. Other than hawthorn and elm bushes, there are also plum hedges, in which not only cultivated forms grow, but also wild plums with primitive characteristics appear.

Since the construction of two purification plants, only 60% of the annual total waste water amount of Berlin (173 mill m^3) was used for irrigation, but mainly for the irrigation of the fields in East Berlin. The soil characteristics of a waste water disposal field is demonstrated with two Cambisols.

Explanations for profiles Carolinenhöhe I and II

Landscape history and utilization: According to HAHN & LANGBEIN (1928), sedimentation of the calcareous glacial sand over glacifluvial sands during Weichselian glaciation; (probably) agricultural utilization since 13th century; since 1890-1900 levelled and dyked waste disposal lots (0.25 ha) as part of the waste water disposal area Carolinenhöhe, which represents all together 330 ha; up to 1903, irrigation of not pre-purified waste water up to a maximum of 1000 mm; thereafter, sedimentation of about 75% of the solid substances in pre-shunted concrete discharging tanks, making irrigation with up to 7000 mm a year possible (without blocking of soil pores); as an average about 4500 mm water were irrigated per year between World War I and II mostly domestic waste water and street run-off from Charlottenburg (for example, only 7.3% industrial waste water in 1921, of which a quarter was inorganically polluted by gas-plants and metal processing industries); irrigation established a new groundwater level, that is 5 m above the original level (Fig. 60).

Through this secondary groundwater the neighbouring arable fields were moistened; therefore, introduction of tube drainage with peat mantles in distances between 4-6 m and in depths between 120-180 cm; removal of excess water over 18 m deep outfall ditches into the Havel-river. Presently, approximately 90% of the percolating water in the soil reaches groundwater. The chemical composition of waste water and groundwater is shown in Tab. 21.

Irrigation intensity was dependent on the land use: Utilization as grassland till 1945 (rye-grass), flooded 4-8 times with 300-500 mm water per year (except during the frost period); after that crop fields irrigated with 100-500 mm

Tab. 21 Mean chemical composition of rain- and waste water of 1978/78 in mg/l (from JAYAKODY 1981 and MESHREF 1981)

	pH	NO_3-	NH_4-	NO_3	org.N	C	P	Cu	Fe	Mn	Zn
Rainwater	4.2	.91	2.8	.01			.08	.02	.04	.04	.39
waste water[1)]											
dissolved	8.0	.38	50	.02	4.7	33	7.4	.01	.16	.03	.09
undissolved					12	80	6.8	.05	.95	.03	.25

[1)] Mean values of 16 samples taken immediately before the entrance to the allotments (effluent of the sedimentation tanks)

of waste water, namely as furrow irrigation between beds; for winter cereals once in autumn, for summer cereals and potatoe two times in winter, for beat 4-6 times in winter and summer and for vegetables 4-6 times in spring; from 1965 on (after the construction of sewage treatment plants) again grassland utilization, but with reduced annual irrigation intensity (up to 2000 mm).

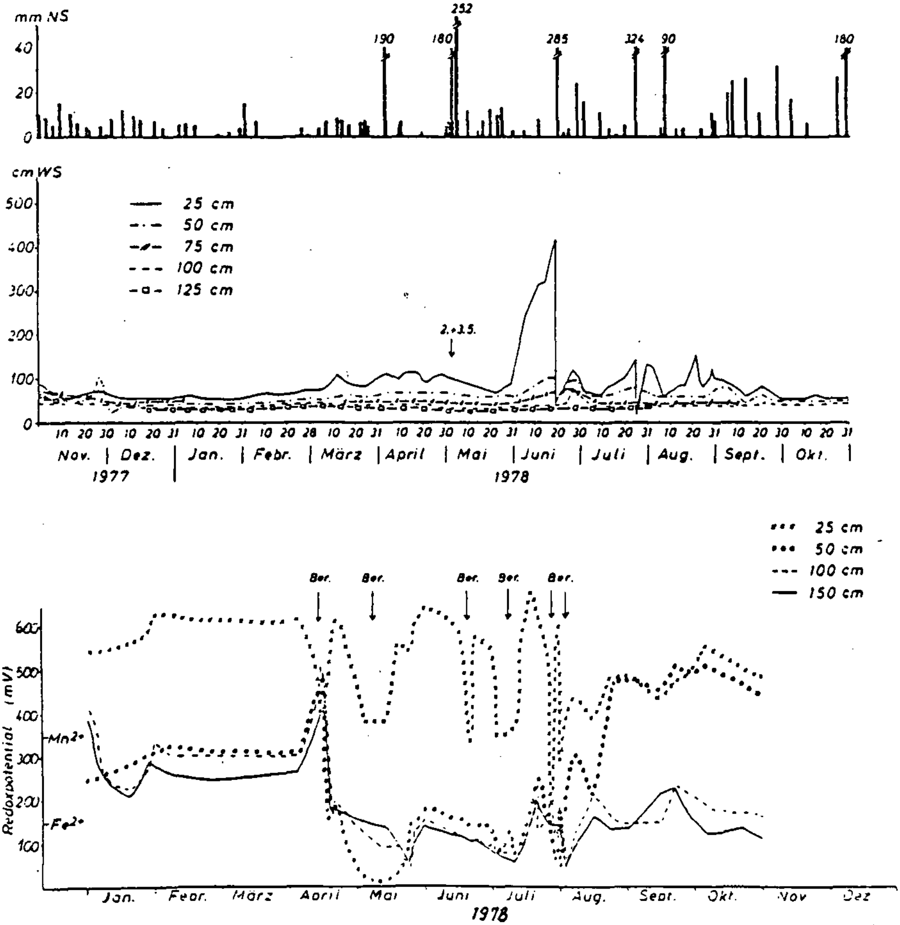
Since 1962, site No. H 2, profile II, was no longer irrigated with waste water. Its borders were levelled and the area was used for vegetables and field crop production alternating with meadow. Since 1977, due to high content of some heavy metals in the soil, cultivation of vegetables and root crops for human support is not permitted. Presently it is not allowed to cultivate cereals for human use either.

Soil association: The Cambisols on glacial sand are associated with Luvisols on sand covered loamy glacial till.

Soil development: Deep decalcification since late glacial period, acidification and loss of bases; weak clay dislocation with formations of thin clay pans; increasing pH values and nitrogen content as well as strong enrichment of P, Cd, Cu, Pb and Zn and impoverishment of nearly all weatherable Fe and Mn are due to waste water irrigation (Tab. 22). In the last 23 years, no significant amount of Fe or Mn has been washed out of profile I but a significant amount of Zn has been enriched. The decrease of pH-value, organic matter- and P-content as well as impoverishment of Zn are the consequences of stopping the waste water irrigations.

Redox and nitrogen dynamics: These soils are moist and wet due to periodical waste water flooding throughout the year (Fig. 61); in the top-soil, quick decrease of the redox-potentials down to negative values as an effect of flooding

Fig. 61 Annual course of water input (precipitation and waste water), water tensions and redox-potentials of a Cambisol used for waste water irrigation



Tab. 22 Preliminary element balance for a coniferous forest and cropland on a Cambisol under actual and former waste water irrigation

		g/m²				kg/m²
		N_t	Mn_t	Cu_t	Zn_t	Org.
Forest (0-110 cm)	initial	1	157	6	36	0
	present	1512	126	7	31	77
	loss or gain	+1512	-31	+1	-5	+77
Actual waste water cropland	initial	1	171	9	47	0
	present	1483	128	29	242	28
	loss or gain	+1483	-43	+20	+195	+28
Former waste water cropland	initial	1	223	7	38	0
	present	1011	179	25	173	26
	loss or gain	+1011	-44	+18	+135	+26

with 200-300 mm waste water; the initial values are again recorded after 2-3 days; the decrease in the sub-soil is small, but these low values last for a longer period. The nitrogen input of the soil with waste water is about 20-30 g per m^2, mainly as ammonium; increase in ammonium concentrations of the soil solution, but a large amount is absorbed; later aeration of the soil results in a strong nitrification; the next flooding leaches the nitrates into the groundwater and produces losses of nitrogen by denitrification (Fig.62).
The redox-potentials in the non-irrigated soil is usually > 200 mV and the in organic nitrogen is found as nitrate.

Summary: Through high waste water irrigation intensity (> 200 mm/a) during the last 80 years, the soil has a high biological activity and is still able to eliminate organic substances. On the other hand, nutrients and heavy metals are filtered incompletely (specially N and Mn). A comparison with former waste water irrigated field shows that a termination of waste water deposition results in an increase of N-, P-, Zn- and a decrease of Fe- and Mn-leakage.

Carolinenhöhe I, present irrigation

Location:	Allotment 7b of the earlier waste water disposal farm Carolinenhöhe in Berlin-Gatow, center of the 0.25 ha big allotment, present irrigation
Situation:	47 m a.s.l., levelled, groundwater 14 m below the surface
Parent material:	glacial sand over glaci-fluviatile sands
Vegetation:	sown rye-grass meadow (Lolium multiflorum); in the spring 1981, almost meadow chervil (Anthriscus silv. with 50% covering), couch-grass (Agropyron rep.), panicle (Poa trivialis) and dandelion (Taxacum offic.)
Soil type:	Acker-Braunerde (Cambisol with hydromporhic properties due to waste water irrigation)
Humustype:	mull
Site qualities:	very deep root zone, easy root penetration, fresh, periodically poor aeration, rich in nutrients
Analysis:	mostly by JAYAKODY (1981), and MESHREF (1981)

Profile description:

Ofh (O)	1- 0 cm	partly humified litter and remanents of harvests
Ap1 (Ap)	- 15 cm	brownish black, 10 YR 3/1, partly bleached sand particles, granular, loose, gravelly, stony (bricks, slacks), loamy sand, abundant roots, sharp transition
Ap2 (Ap)	- 37 cm	blackish brown, 10 YR 3/2-3), brownish yellow patches, granular, gravelly, stony loamy sand, loose, many roots, sharp transition
Bhv (Bw)	- 52 cm	yellowish brown, 10 YR 5/4, structureless, loose, gravelly, stony sand, few roots, gradual transition
Bgv (Bg)	- 70 cm	light yellowish brown, 10 YR 6/4, mottled, structureless, loose, gravelly, stony sand, few roots, gradual transition
C(t)v (C)	-170 cm	very greyish brown, 10 YR 7/3, light yellowish, 2.5 Y 7/3, brown, 7.5 YR 5/8, wavey clay pans with 1-10 mm Ø in 105, 114, 130, 150 and 160 cm depth (lower clay pans are buldged out into pockets and destructed in patches, isolated mottles, 10 YR 6/6, over clay pans, structureless, loose gravelly, stony sand

No	hor.	depth cm	sto. %	texture in % of humus-/carb. free fine soil: sand c	sand m	sand f	sand Σ	silt c	silt m	silt f	silt Σ	clay	kf cm/d
1	Ap1	0- 15	3.0	4.5	39.8	34.4	78.7	7.7	3.0	1.3	12.0	9.2	328
2	Ap2	- 37	2.2	4.9	39.3	35.8	80.0	7.8	2.9	1.2	11.9	8.1	285
3	Bhv	- 52	4.0	4.1	37.2	38.2	79.5	9.2	3.1	1.2	13.5	7.1	86
4	Bgv	- 70	4.0	2.8	33.1	42.3	78.2	10.3	3.3	1.3	14.9	7.0	86
5	Cv1	- 84	5.2	4.0	43.5	36.9	84.4	6.5	1.8	1.3	9.6	5.9	210
6	C(t)v	-110	2.7	3.4	43.7	40.8	87.9	4.9	1.1	0.7	6.7	5.4	69
7	Cv2	-140	0.5	3.7	66.7	23.8	94.2	0.5	0.1	0.2	0.8	5.0	216
8	Cv3	-170	0.5	2.7	79.4	12.9	95.0	0.6	0	0	0.6	4.4	216
6	Tonb.			3.2	44.3	36.4	83.9	3.0	1.3	1.0	5.3	10.9	

No	hor.	bulk dens. g/cm³	GPV %	water content in % at pF 0.6	1.8	2.5	4.2	pH $CaCl_2$	pH H_2O	Fe_d mg/g	Fe_o mg/g	Fe_o/Fe_d	Mn_o mg/kg	P_a mg/kg
1	Ap1	1.20	53	50	27	22	11	5.2	6.2	3.60	2.30	0.63	140	1009
2	Ap2	1.50	42	40	24	16	7	5.3	5.8	2.40	2.00	0.83	90	843
3	Bhv	1.67	35	33	16	8	2	5.5	5.7	1.20	0.56	0.47	10	291
4	Bgv	1.67	36	33	16	8	2	5.6	6.0	0.98	0.45	0.46	10	284
5	Cv1	1.59	39	35	11	4	1	5.6	5.9	0.81	0.17	0.21	+	157
6	C(t)v	1.69	38	33	21	18	9	5.9		0.58	0.16	0.28	+	
7	Cv2	1.60	38	34	11	5	1	5.8		0.60	0.15	0.25	+	
8	Cv3	1.51	38	34	11	5	1	6.1		0.51	0.15	0.29	+	

No	hor.	$C_{org.}$ mg/g	N_t mg/g	C/N	carbonate mg/g	CEC_p meq/kg	CEC_a meq/kg	exchang. cations in meq/kg: Ca	K	Mg	Na	H	NH_4	V %
1	Ap1	36.0	3.9	9.2	0	138	217	129	6.7	10.6	8.0	62	7.6	72
2	Ap2	19.0	1.8	10	0	124	146	85	3.9	7.9	5.6	44	2.2	70
3	Bhv	2.2	0.32	6.9	0	49	41	20	1.2	1.6	2.1	17	1.8	61
4	Bgv	1.2	0.21	5.7	0	37	27	13	0.7	1.2	1.3	11	1.8	62
5	Cv1	0.8	0.13	6.1	0	18	16	8	0.4	1.0	1.0	6		64
6	C(t)v	0.8			0							4	0.7	
7	Cv2	0.4	0.07	5.7	0							4	0.7	
8	Cv3	0.4			0									

No	hor.	pH $CaCl_2$	in F. E. $C_{org.}$ %	in F. E. N ppm	mg/kg: Cu_t	Zn_t	Mn_t	Pb_t	Cd_t
1	Ap1	5.2	3.6	3.9	49	217	222	223	2.1
2	Ap2	5.3	1.9	1.8	36	146	167	252	2.4
3	Bhv	5.5	0.2	0.3	11	63	88	89	1.0
4	Bgv	5.6	0.1	0.2	9	50	83	15	0.9
5	Cv1	5.6	0.8	0.1	6	34	70	12	0.5
6	C(t)v	5.9	0.8		6	35	63	23	0.5
7	Cv2	5.8	0.4	0.1	5	24	52	12	0.5
8	Cv3	6.1	0.4		5	30	66	25	0.5

Carolinenhöhe II, old abundant irrigation

Location:	Middle of allotment No. H 2 previously irrigated with waste water at Carolinenhöhe in Berlin-Gatow
Situation:	47 m a.s.l., nearly level (very gentle slope), groundwater 14 m below the surface
Parent material:	glacial sand over glacio-fluviatile sands
Vegetation:	Till 1962 similar to profile I. At present it is used for field crop production and meadow, alternatively. Because of high level of some heavy metals, potatoes-, salads- as well as cereals-production for human support is not permitted.
Soil type:	Acker-Braunerde (Cambisol with thin clay pans)
Humustype:	mull
Site qualities:	very deep root zone, good root penetration, dry to moderately moist, rarely poor aeration, rich in nutrients

Profile description:

Ap1(Ap)	0- 14 cm	brownish black, 10 YR 3/1, granular to spongy (crumbs), loose, loamy sand, abundant roots
Ap2(Ap)	- 31 cm	blackish brown, 10 YR 3/2, granular to crumbly, loose, loamy sand, many roots, sharp transition
Bv (Bw)	- 52 cm	yellowish brown, 10 YR 5/4, structureless, loose, sand, few roots, gradual transition
BvC (BC)	- 78 cm	yellowish brown, 10 YR 5/3, structureless, loose, sand, some thin (1-2 mm) wavy clay pans, very few roots, very few mottles, gradual transition
C (C)	-110 cm	light yellowish brown, 10 YR 6/4, structureless, loose, sand, very few thin (1-2 mm) and wavy clay pans, very few mottles, no roots

No	hor.	depth cm	sto. %	texture in % of humus-/carb. free fine soil: sand c	sand m	sand f	sand Σ	silt c	silt m	silt f	silt Σ	clay	kf cm/d
1	Ap1	0- 14	1.7	3.8	48.4	30.9	83.1	5.5	3.5	3.5	12.5	4.4	399
2	Ap2	- 31	3.0	4.5	44.2	34.6	83.2	5.7	3.5	1.8	11.0	5.7	300
3	Bv	- 52	1.2	3.1	49.7	36.6	89.4	4.0	2.7	0.3	7.0	3.7	688
4	BvC	- 78	1.2	6.3	51.8	38.8	96.3	1.1	0.7	0.1	1.9	1.2	769
5	C	-110	-	1.2	54.1	42.7	98.0	0.6	0.4	0.2	1.2	0.9	850

No	hor.	bulk dens. g/cm^3	GPV %	water content in % at pF 0.6	1.8	2.5	4.2	pH $CaCl_2$	pH H_2O	Fe_d mg/g	Fe_o mg/g	Fe_o/Fe_d	Mn_o mg/kg	P_a mg/kg
1	Ap1	1.16	55	52	41	27	7	4.2	4.8	2.6	2.3	0.88	77	420
2	Ap2	1.31	50	48	39	16	9	4.3	4.7	2.7	2.2	0.81	82	490
3	Bv	1.59	40	37	14	5	1	5.3	5.8	1.0	0.5	0.50	11	325
4	BvC	1.59	40	37	14	5	1	5.4	5.9	0.6	0.2	0.33	8	205
5	C	1.59	40	38	15	6	1	5.4	6.0	0.5	0.2	0.40	8	165

No	hor.	$C_{org.}$ mg/g	N_t mg/g	C/N	carbonate mg/g	CEC_p meq/kg	CEC_a meq/kg	exchang. cations in meq/kg: Ca	K	Mg	Na	H	NH_4	V %
1	Ap1	28.9	2.70	10	0	97	102	31	3.9	1.8	1.2	64	-	38
2	Ap2	29.6	2.40	12	0	102	113	44	1.2	2.1	1.1	65	-	43
3	Bv	2.9	0.08	36	0	30	33	16	1.4	1.2	1.0	15	-	57
4	BvC	1.2	0.06	20	0	19	18	9	0.7	0.7	1.0	7	-	63
5	C	0.8	0.02	34	0	18	14	7	0.6	0.7	0.9	5	-	64

No	hor.	pH $CaCl_2$	in F. E. $C_{org.}$ %	in F. E. N ppm	Cu_t mg/kg	Zn_t mg/kg	Mn_t mg/kg	Pb_t mg/kg	Cd_t mg/kg
1	Ap1	4.1	2.9	2.7	41	237	169	308	2.4
2	Ap2	4.3	3.0	2.4	38	248	161	281	2.4
3	Bv	5.3	0.3	0.1	7	111	66	56	0.5
4	BvC	5.4	0.1	0.1	7	39	39	48	
5	C	5.4	0.1	0	10	57	57	29	

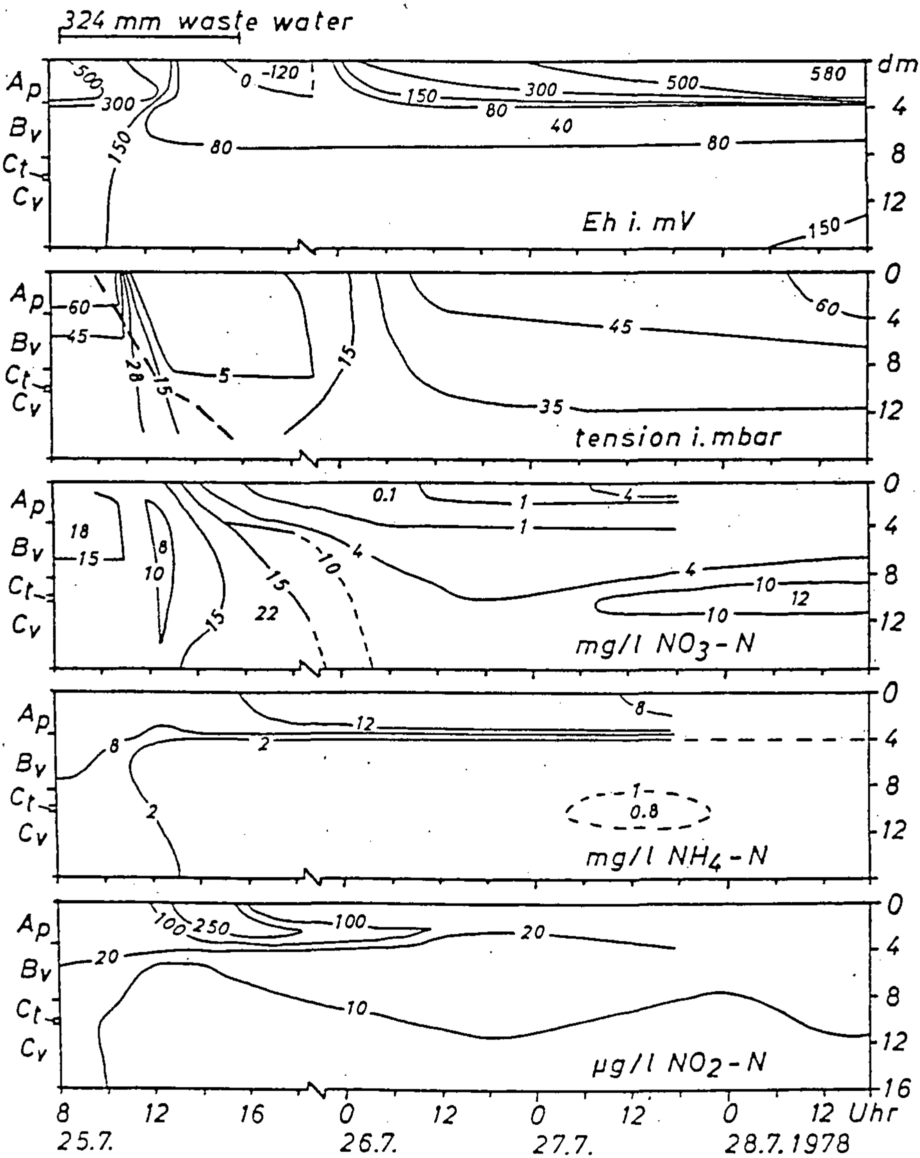


Fig. 62 Changes of redox-potentials, water tensions and contents of soluble nitrogen of a Cambisol during and after flooding with waste water (BLUME et al. 1981)

5. Methods for analytical procedures

The field and laboratory data compiled within this tour guide book have been collected (partly) from different research projects and authors. Therefore it is possible that different analytical procedures are followed. In some cases original publications of data are cited. In these cases please refer to the cited papers. In the following only the generally used procedures of the Dep. of Ecology, Soil units, are explained.

Profile description: The soil horizons are designated according to the new soil system of the Federal Republic of Germany (1985). Other features are described according to MÜLLER (1982). FAO-horizons are put into brackets. Colours are generally determined under moist conditions.

Soil sampling: For chemical analysis, representative samples of 1 kg to 4 kg have been taken from every horizon. For physical analysis have been taken:

6 cores à 100 cm^3 to determine pore size distribution
10 cores à 100 cm^3 to determine saturated water conductivity
3 cores à 250 cm^3 to determine unsaturated water conductivity

Analytical procedures: Generally the methodes of SCHLICHTING & BLUME (1966) are followed.

Grain size distribution:

- dry sieving <2 mm; fine earth about 30-40 g
- destruction of organic matter by boiling with H_2O_2, decalcification with HCl at pH >4; dispersion with Na-pyrophosphate
- sieving >600 µm, >200 µm and >63 µm fraction from solution
- determination g <63 µm, <20 µm, <6 µm, <2 µm by Pipette-method

Pore volume and distribution:

- pF 0.6 and pF 1.0 at an equilibrium on a sand bed
- pF 1.8, pF 2.5, 3.2, 4.2 with "soil moisture" pressure plate extractors
- bulk density by balancing dried samples of 100 cm^3 volume
- pore volume calculated from specific weight of solid phase, determined by a pyknometer
- saturated water conductivity with a permeameter according to HARTGE

- unsaturated water conductivity from a desiccation curve according to BECKER

Chemical analysis:

- pH ($CaCl_2$ and H_2O) in a soil to solution ratio 1 : 2.5
- carbonates and org. C by burning and conductometric analysis of deliberated CO_2 (Wösthoff apparates)
- total N, C, S, with an elemental analyser on a gas chromatographic base (Carlo Erba)
- Exchange Capacity (CEC) according to MEHLICH or with Na-acetate or effective CEC in NH_4Cl
- weatherable nutrients(X_v) by digestion with 30% HCl at 100°C
- active nutrients with NH_4-lactate according to EGNER-RIEHM
- mobile heavy metals with EDTA-extraction (0.05 n EDTA for two hours)
- active oxides with NH_4-oxalat- extraction according to TAMM & SCHWERT-MANN
- pedogenic oxides with Na-Dithionite-citrate according to MEHRA and JACKSON
- total element content with acid digestion by HF/HCO_4 mixture and solution in HCl
- element determination:
  P kolorimetric as blue molybdate complex
  Na, K and Ca with emission photometer
  other elements with atomic absorption spectrophotometer
- clay minerals
  after destruction of humus with H_2O_2 and carbonate with HCl, collection of clay fraction in an Atterberg cylinder. Determination by x-ray diffraction of Mg and K as well as Glycerol loaded textured specimens. Further readings after heating to 200, 400 and 550°C

Abbreviations

grain size	pores
S - sand	pF - log mbar
U - silt	kf - saturated water conductivity
T - clay	ku - unsaturated water conductivity
f - fine	GPV - total pore volume
m - medium	
g - coarse	

chemical properties

CECp	- potent. CEC
CECa	- act. CEC
Ca, Mg, K, Na, H, Al:	exchangeable cations
V%	- potent. base saturation
$C_{org.}$	- org. Carbon
X_t	- total element content
K_a, P_a	- acetate soluble minerals
K_v, P_v, Mg_v	- weatherable minerals
Fe_d, Mn_d	- Dithionite-soluble minerals
Al_o, Mn_o, Fe_o:	Oxalate-soluble minerals
Cu_e-, Fe_e:	EDTA-soluble heavy metals

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Tour H

XIII th Congress ISSS

Raised Bogs in Natural and Cultural Landscapes of the Federal Republic Germany and the Netherlands

Part I: Cultivation and Conservation of Raised Bogs in North-West Germany

by

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Part II: Dutch Fen Cultivation and Polders in the Netherlands

by

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Soil Survey Institute
Wageningen

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Mitteilgn. Dtsch. Bodenkundl. Gesellsch. 50, 207 - 268 (1986)

Cultivation and Conservation of Raised Bogs in North-West Germany

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Introduction

"Development of a natural mire landscape into cultivated peatland" is the main topic of the present excursion.
It covers the part of the West European continent most abundant in moors. Fig.1 and 2 demonstrate the original and the actual distribution of raised bogs in Lower Saxony reduced by drainage, peat cutting and cultivation. In the following raised bogs and the anthropogenical change into peat soils (Histosols) shall be dealt with exclusively due to their special importance.

The first day of the excursion (21.08.1986) is dedicated to the "Teufelsmoor" north east of the city of Bremen (see route Fig.2 and Fig.3). A rest of the mire "Huvenhoop" put under nature conservation shall give an impression of the original landscape (Stop 1). The peasant peat cutting and cultivation of the 18th an 19th century is demonstrated at Stop 2 (cultivation of cut-over peatland).
A typical raised bog settlement shows the limits of German Raised Bog Cultivation. Industrial peat cutting (Stop 3) and the question of sequential utilization with raised bog regeneration or recultivation are discussed as actual problems of bog utilization with special regard to the strained relations of ecology and economy.

A visit of the Worpswede painter colony (Stop 4) demonstrates the reciprocal action between culture and land improvement policy as seen through the eyes of the artists.

The 2nd day of the field trip (22.08.1986) will begin with a visit of the first scientific institution concerned with bogs, the former Peatland Experimental Station in Bremen (Stop 5).
Today this is the Institute of Soil Technology, part of the National Soil Science Institute of Lower Saxony.

The trip continues through the moors of Oldenburg and Ems which were cultivated on a large scale not before the beginning of the 20th century. Along the coastal channel which links the rivers Weser and Ems (originally planned as a main discharge channel, now an important ship lane for barges up to 1300 tons) we will reach "Gross Hesepe" (Stop 6). Its Bog Museum contains exhibits of various peat cutting and recultivation technologies, especially about the Deep Plough Cultivation Method which has been extensively applied in the Ems area after 1948. A modern bog settlement on this versatilly utilized cultivation type will be inspected.

The 3rd excursion day (23.08.1986) leads into the Netherlands. There, bog cultivation has a much longer tradition compared to Germany because of the higher population density and lack of alternative fuels. Peat cutting for fuels and systematical recultivation of the partly excavated fields using a method called Dutch Fen Cultivation already started in the 15th and 16th century. Today these very fertile fields cultivated by sand covering and mixing have been recultivated by a (deep plough) mengwoeler, because compaction had occurred.

The tour will reach the Dutch Agricultural Research Center in Wageningen via the polder area. The International Soil Museum will be visited there.

The heart of the Netherland, the true Holland (Holz (=wood) land?) is located between Wageningen and Amsterdam, the endpoint of the excursion. On this traditional cultural area the raised bogs have early been cut right down to the marine underground. Not before the invention and introduction of windmills for pumping water these remainders partly below sea level could be drained and turned into good agricultural soils.

The Netherlands (low lands) have developed on these artificially drained polder soils. Only the old villages are located on bog rests some meters above the cultivated area.

The excursion ends in Amsterdam with opportunity to return to Hamburg (railway or bus) or airline departures from the International Airport.

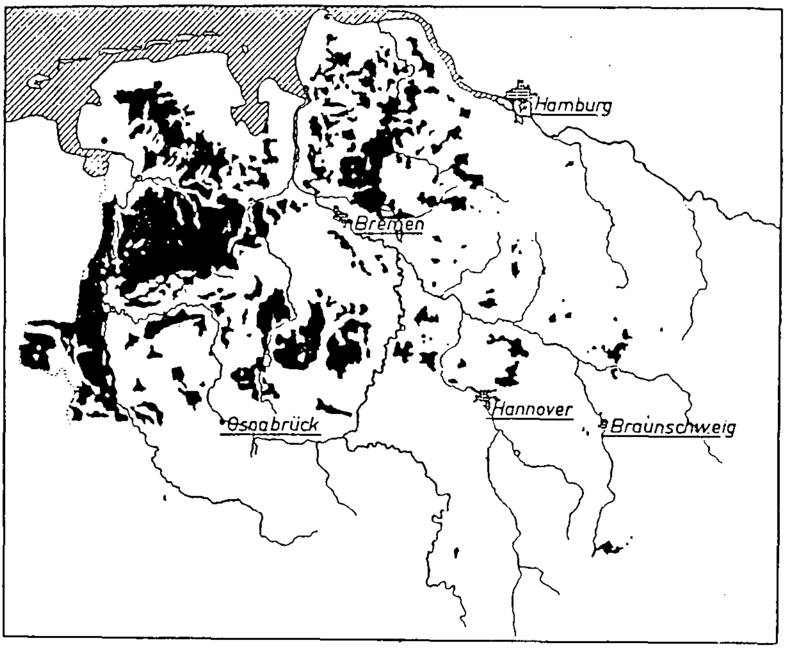


Figure 1: Raised bog distribution in Lower Saxony in the 18th century (acc. BADEN, 1961)

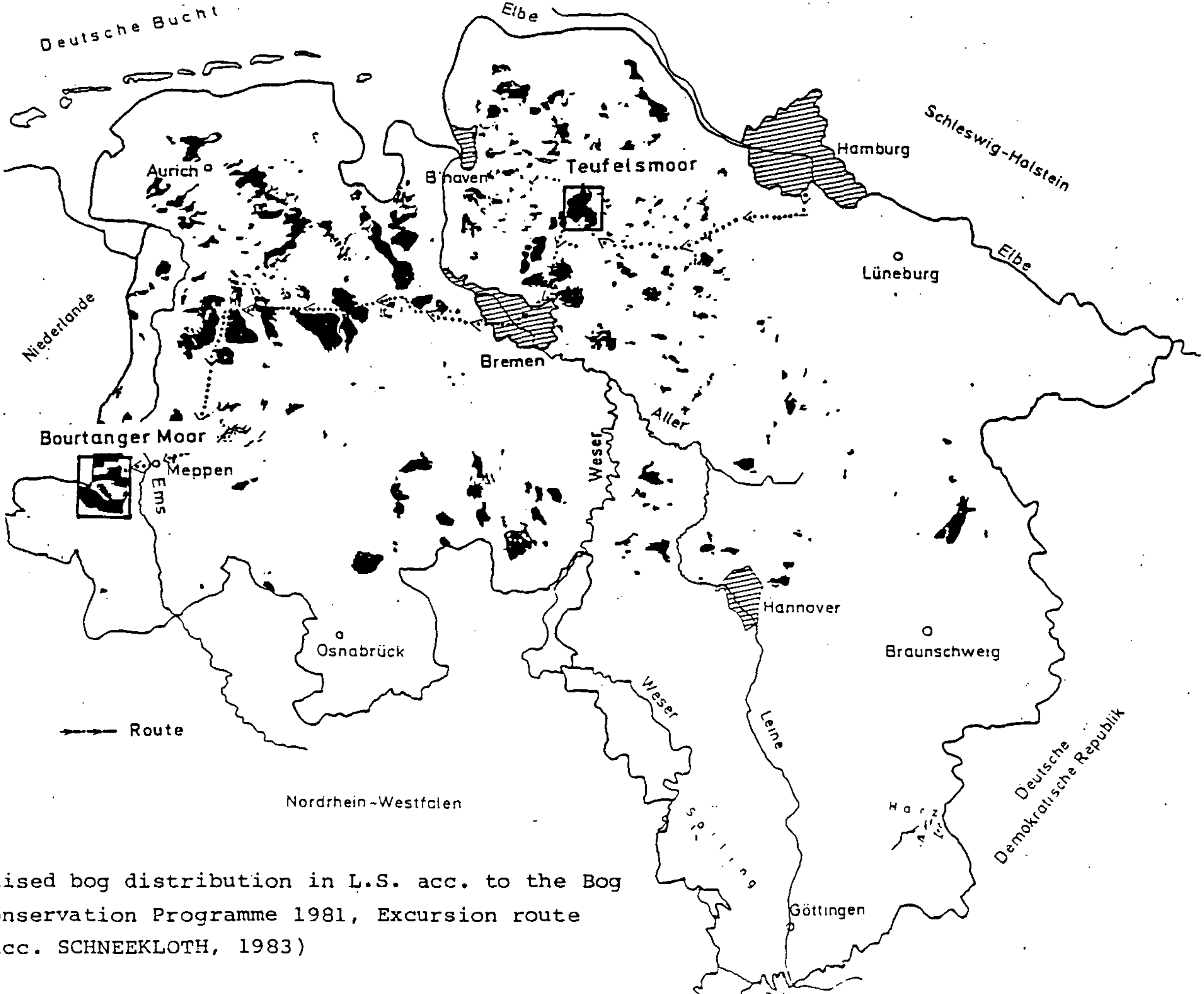


Figure 2: Raised bog distribution in L.S. acc. to the Bog Conservation Programme 1981, Excursion route (acc. SCHNEEKLOTH, 1983)

Cultivation and Conservation of Raised Bogs in North-West Germany

Teufelsmoor - German Raised Bog Cultivation

Name and Location

The TEUFELSMOOR is the largest bog area of Lower Saxony comprising 361 km^2. 153 km^2 and 208 km^2 are classified as low moors and raised bogs, respectively (SCHNEEKLOTH and TÜXEN, 1978). It is located in a funnel-like depression (Basin of BREMEN), reaching from the border of Bremen almost to Bremervörde (40-50 km). The boundary of these lowland is partly formed by the "Geest" (unfertile glacial sandy regions) rising up to 50 m above sea level. In the south the basin is limited by the dune ridges along the Weser river. The surface of the lowland shows a slight slope from 10 to 12 m in the northern to only 0,8 to 2 m above sea level in the southern part.

Within the lowland "Geest"-islands and sand ridges rise up to 51 m above sea level, e.g. the Weyerberg in the village of Worpswede (FLIEDNER, 1970). In the northern part the lowland is divided by a "Geest" ridge running southeast northwest (along the villages of Glinstedt, Karlshöfen and Gnarrenburg) cutting the actual southern Teufelsmoor from the Gnarrenburg Moor.

The Stops 1 to 3 in the moor village Augustendorf are located in the Huvenhoopsmoor, which again is part of the Gnarrenburg Moor.

The elevation in Augustendorf (Stop 2) ranges between 10 and 12 m a. sea level. Approximately 3 km further west runs the Oste-Hamme Canal built in 1766-1774. This is the outfall for the Augustendorf region. East of Augustendorf a Nature Reserve area with the Huvenhoops Lake (30 ha) (Stop 1) and a 6 km^2 large industrial peat cutting area (Stop 3) are located.

Geology

In the excursion area the pleistocene sedimentation started with a groundmoraine (Elster and Saale Glacial), which had been eroded later, however.

Near the surface of the pleistocene elevated plains surrounding the basin north of Bremen (e.g. Vegesack-, Osterholz Geest) one frequently meets sediments of the Saale Glacial. The clay-silt sediments (Lauenburg Clay) probably originate from an Elster Glacial water reservoir. In case these sediments come close to the surface stagnant-humid soils (gleylike) develop.

Today's geomorphological situation of the excursion area has been determined by the Saale Glacial. The glaciers of the Drenthe Stadial surpassed the area leaving behind the groundmoraines with their high plains.

During the following last phase of the Drenthe Stadial (Lamstedt Phase) the border of the ice stretched from Gnarrenburg to Rhade. This caused an end moraine chain seperating the Gnarrenburg Moor from the southern moor area, the Teufelsmoor.

At the time of the Lamstedt-Phase and also during the Warthe-Stadial huge masses of water ran south clearing the Bremen Basin. This brought forth a lowland, only the Weyerberg hill in Worpswede withstood the erosion. During the Weichsel Glacial eolian sand covers were formed. Fluvial sand deposits from the same period can also be found, e.g. southwest of Wilstedt and northwest of Breddorf. In some spots late glacial eolian sands (dunes) were deposited along the rivers Wümme and Oste. In the Holocene also dunes were formed, a process, which to some extent still continues.

Already in the late glacial fens were formed (OVERBECK, 1975) on a small scale. With rising sea level (Flemish Transgression) and the consequently rising water table low moors expanded on a large area around 6500 B.C.. Lateron raised bogs followed on a large scale in the Atlanticum period. During the Subatlanticum in some areas raised bogs started directly on the podzolized mineral underground (own-rooted raised bogs). On lowlands of the Hamme and Wümme rivers peat marsh soils formed under tidal influence.

In the southwest area (around Waakhausen) above raised bogs low moor peat formed due to the rising ground water level (drowned raised bog).

The greatest peat depth has been measured at Dannenberg reaching 6.2 m below surface (OVERBECK, 1975). In large areas the peat has been cut by peasant and industrial peat winning up to the mineral underground.

Climate and Hydrology

Table 1: Climatological data of the Teufelsmoor region

Average temperature	:	8,0°C
Total average rainfall	:	700-740 mm
Average evapotranspiration	:	400-450 mm
Climatic water balance	:	250-300 mm
Number of days with rainfall > 0,1 mm	:	185
" " " " groundfrost	:	205-215
" " " " > 25°C	:	17

The excursion area represents the typical climate of the northwest German plain (HOFFMEISTER, 1930) with a rainfall of 650 to 750 mm per year (Osterholz-Scharmbeck 664 mm, Hepstedt 687 mm, Kuhstedt 737 mm) and an average annual temperature of 8°C.

The evapotranspiration is about 450 mm/year, resulting in a climate water balance of + 200-300 mm. West and southwest winds prevail. The Teufelsmoor ist strongly endangered by frost with only 150-160 days without frost per year whereas on the elevated Geest 180 days are without frost.

Before the construction of dikes and artificial drainage through pumping the combination of heavy rainfalls, northwest winds and spring tides often caused an enduring flooding of the low moor areas. These lowlands have been protected against tidal waves by the water-gate at Lesum (197).

Vegetation

Pollenanalytical investigations for profiles at Worpswede, Dahldorf, Dannenberg, and Huxfeld were conducted by SCHRÖDER (1930) and OVERBECK (1975). Another publication treats the lowlands between the Hamme and Wümme river (CORDES, 1967). The results of these investigations give a good impression of the post glacial development of the vegetation, agreeing well with the central European succession. The course of development went through tundra, birch, birch-pine, pine, pine-oak forest finalizing in an oak-birch forest. On better soils beech and hornbeam were intermingled. In the lowlands alder swamps were found since the Atlanticum period. On dunes the pine prevailed. The wetlands were populated by reed bed and sedge (eutrophic) or raised bog cummunities (oligotrophic). The latter dominantly formed from Sphagnum imbricatum with some occurance of Sph.papillosum, Sph.magellanicum and species of the Acutifolia-Section as documented by macrofossile investigations (OVERBECK, 1975).

KRAUSE und SCHRÖDER (1979) report about the potential natural vegetation. Their investigations result in the following: The remaining raised bogs (peat deposits in the geological sense) naturally bear raised bog communities (Sph.magellanici, Rhynchosporetum albae etc.). According to our own observations the evolution of plant associations on nutrient enriched German Raised Bog Cultivation (grassland) will point towards fine sedge (Parvocaricetum) or birch swamp forest (Betuletum pubescentis). The potential natural vegetation of German Sand-mix Cultivation areas is not known yet.

The wide lowlands between Hamme and Wümme (low moor) would still be covered by elder swamp. Close to the rivers or oxbows (dead river) willows (Salicion albae) dominate. Depending on the environment (ecological conditions) the formation would range from a Carici elongatae-Alnetum with a transition to birch swamp (Betuleum pubescentis), bog myrtle stands (Myricetum gale) and birch cherry-ash forest (Pruno-Fraxinetum). Compared to this lowland vegetation the elevated mineral soils, were covered by beech-oak (Fago-Quercetum) and oak-birch forests (Betulo-Quercetum).

Beech-oak forests were restricted to better soils only. The "Geest" slope west of Osterholz-Scharmbeck (Lauenburg clay) would even bear a spreading millet grass-beech community (Milio-Fagetum). On seepage wet slopes oak-horn-beams (Querco-Carpinetum) were met.

Nowadays the landscape is dominated by cultivated areas. Most of it is used as grassland (Molinio-Arrhenatheretea) which is spread on German Raised Bog Cultivation as well as on cultivated low moors. In the surroundings of Wümme, Hamme and Beeke (Nature Reserve "Breites Wasser") reed beds (Phragmition), large sedges (Magnacaricion), and water plant associations (Potamo-getonetea) remained. Virgin bogs are very rare (Huvenhoops Lake). Raised bogs covered with heath (Stillstandskomplex) are frequently found, also heath on sandy sites (Genisto-Callunetum). A botanical jewel shall not be concealed: At the "Geest" slope west of Osterholz-Scharmbeck (Lauenburg clay) water rich in calcium emerges, which promoted the growth of a chalkgrass swamp (Schoenetum nigricantis) also containing Carex dioeca, Carex pulicaris, Dactylorchis majalis and Cratoneuron filicinum etc.

The Geest border is predominantly used as arable land. In some spots, however, there are beech-oak forests (Fago-Quercetum), e.g. the Weyerberg hill in Worpswede, Oldendorf, oak-birch (Betulo-Quercetum) grass -beech forest (Milio-Fagetum), e.g. Osterholz-Scharmbeck, oak-hornbeam (Querco-Carpinetum), e.g. Holthorst nearby Lesum, and bird-cherry-ash forest (Pruno-Fraxinetum), e.g. Oldendorf.

Under influence of eutrophic groundwater alder swamps still exist (Carici elongatae-Alnetum). At the interface with raised bogs these change into birch swamps (Betuletum pubescentis) and bog myrtle stands (Myricetum gale).

To give an impression about the former vegetation we cite a description of WEBER (1927) and OVERBECK (1975):

"At a certain time of the evolution of our area probably some centuries B.C. this has been a vast, hardly accessable swamp: Small river islets covered with an impermeable jungle of alder, birch, willow, hazel, elm, ash, oak, and spruce, inbetween wide and narrow pools with searoses and reed. Immense reed thickets and sedge reeds with floating mire. The affluent streams of the rivers were lined with reeds, the main streams lined with willows, interopened with large umbels, interlaced with spers and bittersweet, just as we may find it here and there along the Weser river. Above this rose the dune chain following the right river bank, now covered with red glooming heath, now crowned by a dark blue pine forest".

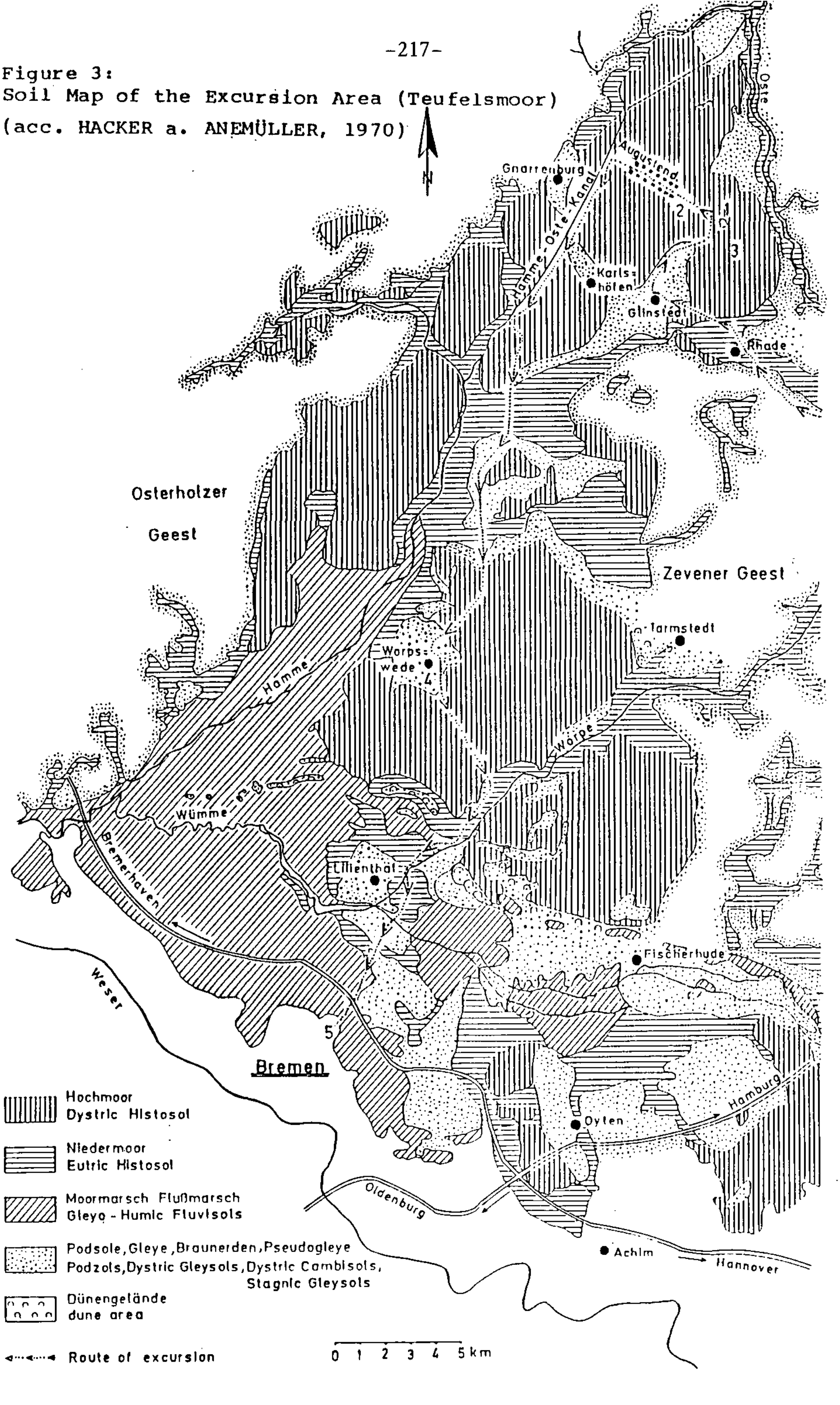
"It has been a landscape, in which beauty, majesty and horror existed closely to each other. As far as the eye could reach endless wideness without trees and bushes. Every step has been tiresome on the Sphagnum mire soaked with water".

Soils

(acc. FAO soil classification)

The actual lowlands of the Teufelsmoor are characterized by three soil types: Dystric Histosols, Eutric Histosols, and Gleyo-humic Fluvisols (Fig.3). On sand ridges and "Geest-islands" as well as on the surroundings elevated plains of the pleistocene moraine landscape, Podzols, Dystric- and Stagnic Gleysols, Dystric Cambisols and their subtypes developed.

Figure 3:
Soil Map of the Excursion Area (Teufelsmoor)
(acc. HACKER a. ANEMÜLLER, 1970)



1. Eutric Histosols

Genesis:

Large scale formation of eutric histosols started in the early Atlanticum period (6500 B.C.) due to the eustaticly increasing sea level (see page 6). In the beginning of the Subboreal period it probably reached its actual expansion. The bog depth ranges between a few decimeters and several meters. Eutric histosols predominantly consist of moderately to strongly decomposed sedge or reedsedge peat with varying percentage of birch and alder wood. At the basis of the eutric histosols one finds alder swamp, muds (indicating formerly open water in depressions), but also late glacial leafy moss peats.

Properties:

Eutric histosols are topogenous formations, which generally contain calcium and nitrogen in great quantities compared to ombrogenous raised bogs. Since the Hamme-Wümme-Lowland is surrounded by acidic mineral substrates with low base saturation only, which also determines the groundwater quality, the occurring low moors are predominantly acidic (ph $<$ 4.5). The water permeability (k_f) of low moor peat can be classified as "high" disregarding the strongly decomposed peat at the basis. The plant available water (available water capacity) of the effective root zone is high too (140-200 mm).

Distribution:

Eutric histosols are found along the river banks (Hamme, Wümme, Wörpe) as well as along their affluent streams (Fig.3).

Utilization:

After primary drainage by ditches, lateron by pipes eutric histosols are used mainly as permanent grassland, determined by a high groundwater table (40-60 cm), high water holding capacity and occasional winter flooding.

2. Dystric Histosols

Genesis:

Compared to the topogenous, groundwater influenced eutric histosols the oligotrophic, ombrogenous dystric histosols are formed in regions with a positive climatic water balance and precipitation poor in nutrients.

First growth of dystric histosols on top of eutric histosols already occured in the Atlanticum period (4000-5000 B.C.).

The rapid growth of Sphagnum moss lead to the formation of thick peat layers covering extensive areas. Finally in the Subatlanticum period peat spread over podzols (own-rooted raised bogs) due to perched water.

The actual raised bog formation was proceeded in almost every case by a short transition period of mesotrophic birch swamp or Scheuchzeria peat (see Stop 2).

Raised bog profiles are devided into the underlying older, strongly decomposed peat layers (black peat) and the younger, weakly decomposed peat layers (white peat) as frequently observed in North-West Germany. The convex growth is typical for raised bogs, i.e. their centre is elevated by accelerated Sphagnum growth due to worse natural drainage. In the centre small bog pools may develop (see Stop 1).

Properties:

(see Stop 2)

Distribution:

The central part of the Teufelsmoor and almost the total nothern part of the Huvenhoopsmoor is covered by dystric histosols. The individual dystric histosol complexes are separated by rivers and creeks lined with eutric histosols.

Utilization:

The largest part of the raised bogs in the Teufelsmoor is used for agriculture either as permanent grassland on German Raised Bog Cultivation or as arable land by German Sand-mix Cultivation.

(see chapter "Raised Bog Cultivation in Lower Saxony)

3. Gleyo-Humic Fluvisols and Fluvi-Humic Gleysols

Genesis:
These soils classified as semi-terrestric were formed by sedimentation under fluvial and tidal influence. With flooding silty clay was deposited. The mineral soil cover and intermedial peat layers can be several decimeters thick.

Distribution:
Due to the low elevation large parts of the lowland were regularily flooded with rising sea level. With flood-tides the river water could not drain in the Hamme and Wümme river. Gleyo-humic fluvisols can be found along the rivers up to Worpswede and Fischerhude, respectively (average hightide of the Wümme river + 1.7 m above sea level).

Properties:
The extensive floodings caused the formation of silty-clayey deposits, with no or little lime. Low moors close to the rivers Hamme and Wümme were burried under mud layers $>$0,4 m, classified as tidal river-marsh soils or Fluvisols (FAO). Peat marsh soils or Fluvi-humic gleysols (FAO) have a mud cover $<$ 0.4 m.
These soils are characterized by a high ground water table, a low base saturation, high acidity (pH about 4.0) and a high clay content. They are medium to high permeable due to a fairly good aggregation.

Utilization:
Because of the high and fluctuating groundwater table and because of the high clay content these soils are used as permanent grassland mainly.

History of Colonization

Originally the Teufelsmoor only comprised the area in the meander of the upper Hamme north of the village having the same name. Today - as mentioned in the beginning - we apply this description to the total peat lands of the northeastern Bremen Basin. The name "Teufelsmoor" is not derived from "devil=Teufel" but rather describes the unfertile mire derived from the old Low-German word: duven, i.e. deaf, empty, poor, unfertile.

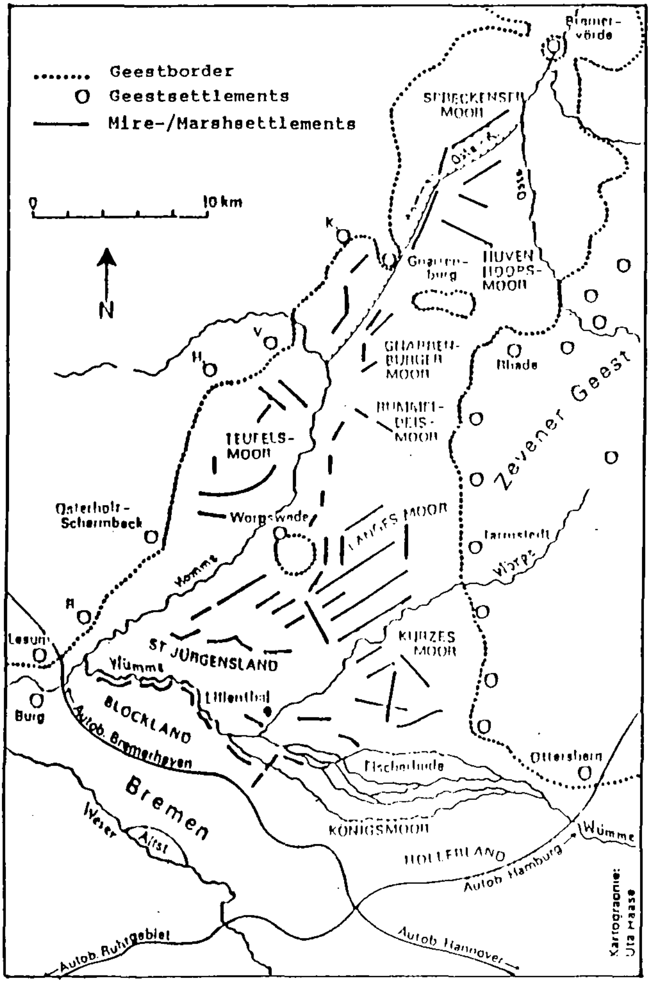


Figure 4: Settlements in the Wümme-Hamme-Oste lowlands (acc. FICK, 1980)

Results of recent pre-historical research clarified that pre-historic man intensively utilized the surrounding elevated sandy "Geest" (BRANDT, 1982). How far the Teufelsmoor itself has been traversed before the large scale paludification cannot be answered with certainty yet. However, below the peat of the Hamme-Wümme area there have been found mesolithic artifacts. A settlement in this area before the middle ages is most probably, since corresponding findings do exist for the area of the City of Bremen, dating back to the time Christ was born (BRANDT, 1980; SCHWAAR and BRANDT, 1984). The area further north probably has been unpopulated as can be concluded from the reports of annalist "Adam von BREMEN" (11th century). The first document of the high middle age colonization is a record of 1106 in which 6 Dutch people offered the cultivation of swamps to the Archbishop of Bremen. The so called Hollerland (= Dutch country) and Blockland were colonized until 1250 A.D.. Further centers of the ongoing settling have been the monasteries of Lilienthal in 1262 A.D. (Cistercian Order) and Osterholz (Benedictines). The fertile area around the lower Wörpe and Wümme river (low moors) were colonized by the monks. Spreading from the Osterholz Monastery the colonization of the Teufelsmoor started in the low moor areas of the Hamme river in the 14th century. The practical execution was handled by so called "Lokatoren" (FLIEDNER, 1970).

The modern colonization of the Teufelsmoor is entirely connected to the idea of Jürgen Christian FINDORFF (1720-1792). He was the Royal Moor Commissary, one of the leading people of the Hanovarian moor colonization. He founded 50 new villages with 6000 farms (KÜHLKEN, 1950). His basic idea has been to successively develop the peat cutting peasants (black peat for fuel) into farmers practicing fen cultivation. Along a channel, which served equally as a ship lane and discharge channel several ribbon-villages were built. The farm land of the settlers run rectangularly to the axis of the channel.

The colonizing generations had a hard life due to the motto:

For the First - the Death
For the Second - the Poverty
For the Third - the Bread

The extremely hard lot of the moor peasants is strikingly illustrated by the Worpswede artists (Mackensen, Modersohn, Hans am Ende, Paula Becker-Modersohn, Vogeler and Overbeck). The last noted painter is the father of the later and frequently cited botanist F. OVERBECK (1898-1983).

The sad situation of these farmers did not change before practical applications of the experiences of J.v.LIEBIG were carried out by the Prussian Peatlands Experimental Station in Bremen. Thus, since 1877 German Raised Bog Cultivation has been applied on a large scale. After World War II these areas have been increasingly recultivated by Deep Plough Cultivation (see 2nd day of the excursion).

Raised Bog Cultivation in Lower Saxony

The raised bogs, poor in nutrients, rich in water and extremely hostile to traffic have been populated very late. The cultivation of raised bogs became a primacy of the government in the second half of the 18th century ("domestic colonization"). The earliest moor utilization since Romat time due to increasing population density and land scarcity. Since then a number of bog cultivation methods adapted to the natural and technical conditions have been developed.

1. Burnt-over Peatland Cultivation

The raised bogs of the excursion area were primarily used by burnt-over peatland cultivation up to the end of the 19th century. After shallowing drainage during winter time the peat surface was burnt over for a few centimers in late spring. Buck wheat or rye were sown into the warm ash. After burning 7-10 times the peatland was "dead". Within a few decades of rewetting it was regenerated by fresh peat formation. However, the peat exploitation by this method was recognized early, and the smog was a considerable pollution annoyance.

2. German Raised Bog Cultivation

In cooperation with the Natural Sciences Society of Bremen the "North German Association against Peatland Burning" encouraged the foundation of a "Peatland Experimental Station" in 1877 in Bremen. Its intention was to develop adapted cultivation methods on the basis of scientific knowledge about the different kinds of mires.

According Liebig's ideas (1860) mineral fertilizers were applied to the drained peatland, which finalized in the development of the "German Raised Bog Cultivation" at Bremen in 1890. Many of the initial experimental sites since FLEISCHER, TACKE, BRÜNE and BADEN are located in the "Königsmoor". If sufficient drainage ($>$1.2 m) is provided this method may be applied under the following conditions:

1. Bog depth $>$1.4 m
2. $>$0.8 m of less decomposed peat (H $<$5)
3. Permanent grassland utilization

Drainage was initiated by ditches of at least 1.4 m depth at a distance of 25 m. Today the drainage is performed with pipes or mole drains. A subsidence up to 30% of the bog depth has to be accounted for (SEGEBERG). Therefore, single drains of a maximum length of 150m are preferred which run to open ditches at a distance of 300 m.

After clearing (if necessary) and levelling the topsoil (20 cm) is limed and fertilized. The following fertilizer quantities are to be given for ameliorating the oligotrophic soils:

50 dt/ha CaO to reach a pH ($CaCl_2$) of 4.5 aimed for grassland
4.0 aimed for arable land
16 " Basic-slag (15% P_2O_5)
8 " Potassium fertilizer (40% K_2O)
5 " Copperslag (10 kg/ha Cu)

Grassland can be sown immediately. The cost of this cultivation method (incl. fertilizers) is about 2.000.-- DM/ha.

Storage of phosphate and potassium is impossible due to insufficient sorption by the organic ion exchanger of the peat or humic substances (the organic matter has a high Ca-selectivity). High liming should be avoided by all means, because it promotes the mineralization of peat und thus the loss of it.

Extensive liming is unnecessary since plant toxicity due to low pH is of none importance because the missing of aluminium and very low iron contents. The dynamic of nutrients is optimal at a pH of about 4.0.
Originally on German Raised Bog Cultivation field crops like potatoes, oats and rye have been produced. Arable farming, however, increased the aeration and hence the peat loss (1 cm/year). Therefore, German raised bog cultivated areas only should be used with reduced tillage methods, which preserve the soil. The best conservation of peat is only possible under permanent grassland. This peat preserving, "natural" utilization is reasonable from the economic and ecologic point of view. With a large available water capacity and good capillary conductivity in less decomposed peat the grassland utilization is a safe and productive way of farming on such peatlands. Dairy farming is the best way of farming on these sites because the hygienic conditions on raised bog pastures are very well (missing parasites like liver leech).

The utilization intensity of pastures should not exceed 200 kg N/ha and year. A higher utilization intensity cause a nitrogen accumulation and low C/N ratios. This again reduces the bearing capacity.

Subsidence and decomposition causes compaction of the peat, and after a maximum of 3-4 decades the water regime of the German Raised Bog Cultivation becomes insufficient. Another drainage measure becomes necessary with more narrow spacing. If the water and soil conditions are suitable, these degraded secondary stagnant peat soils may be recultivated by deep ploughing or mechanical sand covering. Both methods intend to stabilize labile structure of peat soils and thus turn them into mineral-like soils (KUNTZE, 1974).

3. Forestry

Repeated attempts of afforestation on these localities failed due to several reasons. On young German Raised Bog Cultivation the trees root close to the surface thus being susceptible to wind break. Because of changing wetness the trees root deeper in dry years compared to rainy ones. Therefore, the roots become exposed to strongly reductive conditions from time to time. The tops of these trees e.g. pines and spruces, become dry.

Furthermore the acidity of raised bog promotes the early stage of mycorhiza better than the late. This causes the death of coniferous trees at the age of 25 to 30 years. It is also assumed, that accumulation of phytotoxic phenols occurs in the root zone because of the peat decomposition and litter accumulation. German Raised Bog Cultivated areas are suitable for forestry to a limited extent only, especially for conifers.

4. German Sand-mix Cultivation

The successful Heath Cultivation encouraged to increase the depth of ploughing suitable for ownrooted raised bogs. In principal the Heath Cultivation breaks the ortstein-horizon (iron-humus pan) and bringing it up to the surface thus regrading the podzolprofile.

First deep ploughing experiments have been done in "Königsmoor" (BRÜNE, 1938) on raised bogs overlaying podzols. Since 1948 BADEN and coworkers developed this method into the most important amelioration and cultivation method called "German Sand-mix Cultivation".

Meanwhile more than 150.000 ha of raised bogs have been deep-ploughed in North-West Germany with a maximum depth of 2.4 m (EGGELSMANN, 1984).
This bog cultivation method creates a safe agricultural site with a wide spectrum of utilization, if the following conditions are met:

1. Depth of bog $<$1.4 m
2. Raised bog only, eventually transition bog, independent of decomposition degree
3. Medium to fine sand with $<$10-15% particles $<$0.02 mm, free of toxic substances (e.g. FeS_2)
4. Depth of groundwater table $>$20 cm below plough depth.

Peat and sand layers are turned over with an angle of 135°. The ratio of peat depends on the bulk densities of the components and thus may range from 2:1 (low peat bulk density) to 1:2 (high peat bulk density).
For each case the fossile ortstein-horizon must be broken.

Peat and sand layers are turned over with an angle of 135°. The future crumb top soil (20-30 cm) is mixed and later on successively increased to 30-40 cm depth. The final aim is a mixed soil, which contains 6-8% org. matter in the top layer after soil ripening (KUNTZE, 1972).

The peat beams below the mixed top soil serve for water storage, whereas rooting is possible in the air and water containing sand beams. Due to the high water permeability of sand no additional systematic subsurface pipe drainage is necessary.

Table 2 lists the individual phases of a German Sand-mix Cultivation including equipment and purpose.

Table 2: Phases of a German Sand-mix Cultivation (acc. HOLDT, 1986)

Phase	Equipment	Purpose
Prelevelling	Caterpillar	surface levelling
Ploughing	Caterpillar Deep plough	deep ploughing destruction of ortstein layers
Pitting	Caterpillar Dredger	Sand mix cultivation at the headlands of the field or at bog depths from 1.5 to 2.5 m
Surface levelling	Caterpillar	levelling; mixing of the topsoil, sloping of the surface
Grubbing	Caterpillar and (heavy) ripper	mixing of the topsoil
Cultivating	"	preparation of the seed bed

The possible performance of such cultivation is given in Table 3 as a function of ploughing depth and other conditions.

Table 3: The Performance Efficiency of Deep Ploughing and Levelling under Various Conditions (acc. HOLDT, 1986)

	PLOUGHING DEPTH (m)					
	1.00 - 1.20		1.60 - 1.80		2.00 - 2.20	
	Pl.*	Lev.*	Pl.	Lev.	Pl.	Lev.
Power input (kW)	118	88	354	88	472	88
	Performance (ha/d)					
CONDITIONS						
1. Optimum	2.5	2.25	2.5	1.4	2.5	1.15
2. Average	2.0	2.0	2.0	1.2	2.0	1.00
3. Bad	1.5	1.75	1.5	1.0	1.5	0.85

* Pl. = Ploughing; Lev. = Levelling

The costs of a German Sand-mix Cultivation under average conditions are shown in Table 4.

Table 4: Costs of Ploughing, Levelling, and Fertilizer for 1985 at Several Ploughing Depths (acc. HOLDT, 1986)

	PLOUGHING DEPTH (m)		
	1.00 - 1.20	1.60 - 1.80	2.00 - 2.20
	- (DM / ha) -		
Ploughing and levelling costs	1.350,--	3.300,--	4.450,--
Fertilizer Amelioration	1.500,--	1.500,--	1.500,--
Total costs	2.850,--	4.800,--	5.950,--

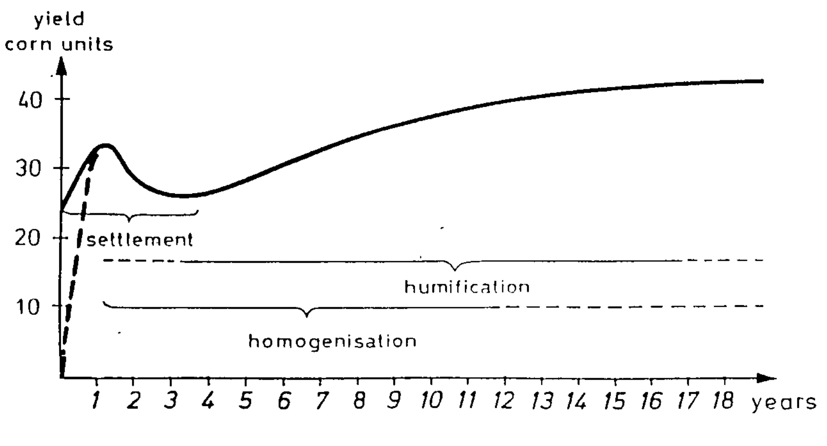


Figure 5: The development of Sand-mix cultivated bogs expressed by their productivity (acc. KUNTZE, 1972)

After soil ripening within 15 to 20 years with simultaneously occurring settlement, homogenisation and humification the peat in the top soil has been metabolized into humus. The primary rough mixture of peat and sand finally culminates in a plaggen-soil like soil (see also Fig. 5).

Approximately 150.000 ha of degraded German Raised Bogs and partially cut bogs have been ameliorated applying this method. Compared to the German Raised Bog Cultivation it is an expensive measure, however, the ameliorated areas can be used for various agricultural crops with high productivity.

Raised Bog Sand Cover Cultivation

In case of greater bog depth than 1.50 m deep plough cultivation becomes impossible. Degraded soils of the German Raised Bog Cultivation may be ameliorated or recultivated by mechanical sand covering. With this technique sand from below the bog (max.3.5 m) is brought up by a screw conveyor and spread on the surface. A depth of 7 cm to 20 cm sand cover is intended for grassland and arable lands, respectively. The sand is mixed with the top peat soil of the degraded and compacted Histosol. An initial organic matter content of 15% should not be exceeded. Peaty sand soils ($>$15% org.matter) are characterized by an unfavourable pore size distribution with an increasing water adsorption and decreasing water permeability (KUNTZE a.DJACOVIC, 1972). Shallow tillage is advisable, otherwise peat loss becomes exploitive due to an excessive mineralization rate.
The pore size discontinuity between mineral top soil and peaty subsoil can be overcome by a slit drainage (KUNTZE, 1974). Similar to the deep-ploughing technique the intention of this method is to create a mineral-like top soil leading to

1. Decrease of adsorbed water in the top soil
2. Improvement of the trafficability and bearing capacity
3. Conservation of the peat below the sand cover
4. Diminished frost danger compared with fen cultivation (BADEN and EGGELSMANN, 1964)
5. Improved drainage by the slit formed by the screw conveyor

Since about 1980 this procedure is increasingly applied on "German Raised Bog Cultivation" with a peat depth $>$1.4 m. Degraded Dystric Histosols due to intensive farming - i.e. too much cattles/ha and fertilization including liquid manure - need a peatland conservation like this sand covering method.

For successful sand covering the following conditions must be given:

1. Bog depth between 2 and 3 m
2. At least 0.8 m of less decomposed peat (H $<$5)
3. Thoroughly drained
4. Medium to fine sand with less than 10-15% $<$20 µm
5. No artesian water
6. Free of toxic substances (e.g.FeS_2)

Under favourable conditions the slit for excavating the sand may be used for subsurface drainage without additional pipe drains. The sand cover areas are primarily used for arable crops. However, an enduring cultivation is guaranteed with sand depth of at least 20 cm only. An uneven spreading may cause subsidence forming wet spots, which will lead to cultivation problems.

The costs of this amelioration is 5.000 to 6.000 DM/ha and decimeter of sand cover.
Figure 6 presents a comprehensive description of the different bog cultivation methods.

Figure 6: Methods of Soil improvement

peat-and heathland

natural soil condition soil type / soil profile	soil improvement method / equipment	artificial soil condition profile/utilisation/cultivation
fen HN > 8 dm Hn / S	surface tillage; fertilisation; drainage, levelling; milling; ploughing drain machine, leveller, mill, plough	Hn Gr low moor cultivation
raised bog HH Hh / S	surface tillage; drainage; levelling, milling; fertilisation; ploughing drain machine, leveller, plough, mill	Hh Gr/F German raised bog cultivation
fen HN > 8 dm Hn / S	sand covering (≥20cm); fertilisation sand covering machine	YDn Gr/A fen sandcover cultivation
fen HN < 8 dm Hn / S	deep ploughing; fertilisation peat : sand 1:1 1:2 deep plough	Un' Gr/A deep plough - sand covering cultivation
raised bog HH (cutover peatland) > 13 dm Hh / S	pitting dredger	YF A Dutch fen cultivation
raised bog HH > 13 dm < 10 dm weak decomposed Hh / S	sand covering; fertilsation; mixing; tillage sand covering machine	YDh Gr/A sand cover cultivation
raised bog HH < 13 dm Hh / S	deep ploughing; fertilisation peat : sand 2:1 1:1 deep plough	Uh A/Gr/F German sand mixed cultivation
raised bog HH (cutover peatland) > 13 dm Hh / S	surface tillage; mole drainage; levelling/leveller; fertilisation drain machine, mill	Hh Gr/F cutover peatland cultivation
podzol P podzolic gley P-G S; A, Ae, Bh, Bv, C	deep ploughing/deep plough >ortstein horizon, outfall installation, when needed	Up A/Gr/F heathland cultivation

A= arable land , Gr=grassland, F= forestry

Industrial Peat Cutting

Mires are deposits of the raw material "peat". Its utilization as a fuel resource in North West Germany reaches back to time before Christ. Especially the strongly decomposed, older raised bog peat served as the solely fuel for centuries, because wood was rare. "Black" peat, low in ash, gives about 23 MJ/kg dry matter (fueloil 42 MJ/kg). In the beginning peat cutting served only farmers own needs. Locally peat cutting permits were given to many citizens of neighbouring cities and villages. The peat cutting for fuel started from the edges of the raised bogs. There were no regulations and by wild cutting many pits irregularly exploited, cutover peatland remained, which on the other hand became valuable ecological niches.

Growing cities during the middle ages had an increasing demand for fuel peat. Peat for fuel got a market value, which favoured a systematic excavation on a large scale.

However, the peasants could not exist only by peat cutting. In the Netherlands the partially cut over peatlands were recultivated by fen cultivation since the 15th century.
The pits remaining after cutting the black peat were refilled with the topspit and the white peat, which was covered by a 15 cm sand layer. (The sand was taken from the bog basis with the spade if possible, or transported from elsewhere).

The missing nutrients were added to the oligotrophic peat and sand in form of wastes, brought from the cities or farmyard manure. Before the introduction of mineral fertilizers in argriculture these cutover peatlands were turned into highly productive and versatile arable lands.

The transport of the cut, dried peat to the cities was primarily performed with flat barges filled with city refuse and fertilizers, but also with sand on their way back. This necessitated a navigable channel system reaching each farm. Fen cultivation therefore typically resulted in row villages bilaterally along a channel, which served as main discharge channel and main traffic route. With time the peat cutting peasants more and more became farmers producing food on the cutover bogs cultivated subsequently. Since 1752 - beginning of Teufelsmoor colonization by Findorff - until the time after World War II, i.e. in approximately 200 years 16 Mio.m³ fuel peat (= 82 Mio.m³ fresh peat material) have been transported from the Teufelsmoor, preferrably to Bremen. With high quality fossile energies like coal - first brought by steam ships from overseas - and oil and gas later on transported through pipelines peat could not compete any more. Thus cutting black peat for fuel has been stopped since 30 years.

The less decomposed younger raised bog (white peat) is a resource much in demand for substrates in horticulture. Instead of thousands of small peasant peat cuts a few peat works serve the market by industrial peat cutting. About 110 peat works furnish the German and foreign market with peat for soil conditioning substrates and peat fertilizers. Presently 14% of the raised bogs in Lower Saxony (= 30.000 ha) are used for industrial peat cutting.

Of the total annual peat cutting (11 Million m³ 1985) comprise 8 Mio.m³ of white peat and 3 Mio.m³ of black peat. The latter is also increasingly in use for soil conditioning or serves as the basic material for the production of active charcoal.

The large scale industrial peat cutting has facilitated the (agri-) cultural development of the mire lands. It enabled the extensive use of deep ploughs for the recultivation instead of small scale fen cultivation. For optimising the recultivation after peat cutting the "Mire Conservation Law" was issued in 1923, which was adapted to the technical progress by the "Mire Conservation Order" in 1955. Both are regulating the cutting depth and sequential utilization under the aspect of later land improvement. In 1972 this old law has been abandoned in favour of the preservation of ecological valuable areas enacting the "Soil Exploitation Law", which led to the "Nature Conservation Law" in 1981. Agricultural over-production and the lack of nature biotops today restrict the peat cutting areas, where the reintegration into the natural concept of the landscape is guaranteed. Therefore, an ecological framework ist set.

Figure 7 schematically clarifies the depth of drainage, peat cut and remaining peat layer for various forms of the subsequent utilization (acc. KUNTZE, 1974) of the cut over bog.

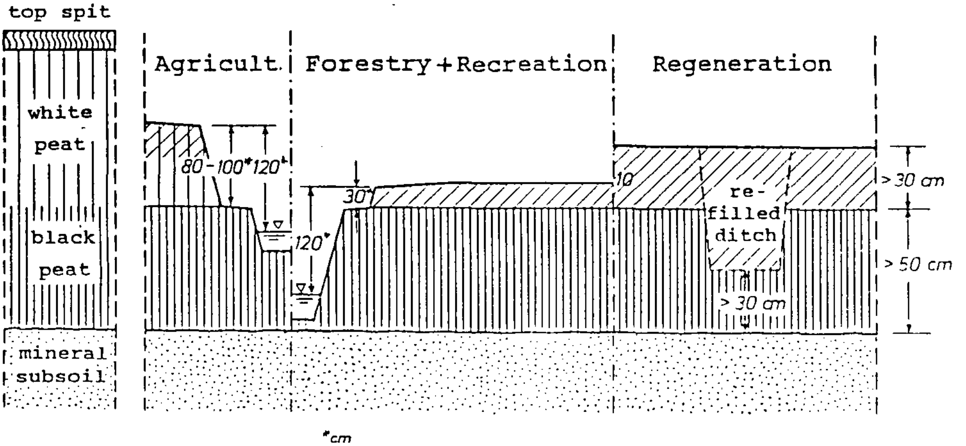


Figure 7: Partial Cutting of a Raised Bog and its Subsequent Utilization (acc. KUNTZE, 1974)

Raised Bog Regeneration

Partially cutover areas today shall be turned into "virgin" bogs by rewetting and renaturation. A humid climate enables a short-time rewetting, if the surface runoff and drainage discharge will be avoided. Within decades an obvious success of renaturation, i.e. resettlement of plants and animals typical for bog, will be possible if rests of virgin bogs could serve as a source of seeds and spores nearby the cutover peatland (KUNTZE a. EGGELSMANN, 1981). The long-term regeneration of bogs (within centuries) depends on the state of eutrophication. In a densely populated landscape mesotrophic bogs are more likely than originally oligotrophic raised bogs.

The Bog Conservation Law (1981) aims for the regeneration of 65.000 ha in Lower Saxony (which is a tenth of the former raised bog area). 50% of the area shall come from cutover peatlands. The remaining recources of peat will suffice for at least 3 to 5 decades of cutting activity projected by a bog survey on basis of today's peat consumption. Hence, peat cutting in Germany will become impossible due to lack of area.

Raised Bog Regeneration has to be performed in 3 phases to guarantee the success (KUNTZE a. EGGELSMANN, 1981):

a) Rewetting (short-termed phase)
   - precipitation $>$ evaporation ($P>E$)
   - discharge D $<$ ($P-E$)
   - $>$30 cm top spit with good physical and chemical qualities for germination.
   - Water regime should be well balanced, i.e. no extreme water-logging or draught in winter or summer time, respectively.

b) Renaturation (medium-termed-phase).
   Sufficient seed and spores for populating the area with plants typical for raised bogs.

c) Regeneration (long-termed phase).
   Peat formation under immission control.

In several peat cutting areas such experiments are conducted. To initiate rewetting the drainage ditches have to be refilled and sealed. At the mire basis a black peat layer of 0.5 m depth must remain. The reintroduction of bog forming plants has been successful if the top spit ($>$0.3 m) remained.

The long-term evaluation about the possible success of bog regeneration is not possible yet.

STOP 1

Site description

Location	:	Huvenhoopssee, TK 25 Gnarrenburg, Bl. 2620
Elevation	:	+12 m above sea level
Slope	:	Flat, levelled
Drainage	:	None
Vegetation	:	See below
Utilization	:	Nature conservation area (1.25 km²)
Parent material	:	Raised bog peat (3 m) Mineral subground: Fluvial sands
Soil classification	:	German: Typisches Hochmoor FAO : Dystric Histosol USDA : Typic Sphagnofibrist

Vegetation

The nature conservation area comprises the area around the Huvenhoop Lake (1.25 km²). It is covered by a virgin bog to a large extent, forming a floating bog. The thickness of the floating vegetation mat decreases towards the open water. Walking is rather risky.

The vegetation belongs to the plant association of Rhynchosporetum albae. In addition to R.albae Sphagnum cuspidatum dominates. Further species on the floating bog are Eriophorum angustifolium, Andromeda polifolia, Vaccinium oxycoccus and two Drosera species (D.rotundifolia, D.intermedia). A weak eutrophication by birds (guanotrophication) is indicated by the presence of Carex rostrata.
The area far from the lake is covered by a sparse birch-pine shrubbery with bog myrtle inbetween. In the open areas Calluna vulgaris, Erica tetralix and Eriophorum vaginatum are dominating.
In some spots Sphagnum species could prevail. A specialty growing here shall not be forgotten: The garden descendant species of the Amelanchier canadensis group grows here. The occurrence of the common viper (Vipera berus) is remarkable. The Huvenhoop Lake is a place of repose for birds on flight in autumn and early spring (grey geese, singing swans and others).

S T O P 2

Site description

Location	:	Augustendorf, TK 25 Gnarrenburg, Bl. 2620
Elevation	:	+10-12 m above sea level
Slope	:	Flat, levelled
Drainage	:	Pipes
Vegetation	:	Grassland
Utilization	:	Hand-peat-cutting area + German Raised Bog Cultivation
Parent Material	:	Raised bog peat (3 m), Mineral subground: Fluvial sands
Soil classification	:	German: Typisches Hochmoor FAO : Dystric Histosol USDA : Typic Sphagnofibrist

Micromorphology and Successions (Table 5)

According to pollenanalytical investigations and ^{14}C-dating peat formation started in the early Atlanticum period (4400 B.C.) with a Scheuchzeria-peat mixed with some Eriophorum vaginatum and Andromeda polifolia. This was followed by a Sphagnum cuspidatum peat containing Scheuchzeria and Eriophorum vaginatum.

The peak of the postglacial warming is indicated by the occurence of elms (4300 B.C.) during the black peat phase with Eriophorum vaginatum and Sphagnum cuspidatum. In the following the black peat is characterized by the alternation of Eriophorum vaginatum and Calluna vulgaris. There have also been some Sphagnum cuspidatum, Sph.papillosum and Sphagnum species of the Acutifolia-section.

Profile description Dystric Histosol (Augustendorf)

No.	Depth cm	Horizon	Description
1	0- 10	Y/hHp	Sphagnum-peat mixed with sand, black (5YR 2/1) many roots (grassland), main peat components: Sph.Acutifolia-Section, Sph. imbricatum
2	10- 80	hH_1	Sphagnum-peat (Hhs), reddish brown (5YR 4/3) very weakly to weakly decomposed (H^*2-3), Sph.Acutifolia-Section
3	80-105	hH_2	Sphagnum-peat (Hhs), dark reddish brown (5YR 2/2), weakly decomposed (H 3-4), Sph.papillosum. Sph.cuspidatum
4	105-120	hH_3	Sphagnum-peat (Hhs), d.reddish brown (5YR 2/2), weakly to medium decomposed (H4-5), E.vaginatum, Sph.cuspidatum
			^{14}C-Dating$^+$: 790 B.C., beginning of the white peat formation
5	120-140	hH_4	Eriophorum-Sphagnum-peat (Hhes), black (5YR 2/1), medium to stronly decomposed (H 6-7), E.vaginatum, Sph.cuspidatum, C.vulgaris
6	140-180	hH_5	Sphagnum-peat (Hhs), dark brown (5YR 2/2), stronly decomposed (H7-8), Sph.cuspidatum, E. vaginatum C.vulgaris
7	180-270	hH_6	Eriophorum-Calluna-peat (Hhei), black (5YR 2/1), strongly decomposed (H 7-8), E.vaginatum, C.vulgaris, Sph.cuspidatum
			^{14}C-Dating$^+$: 4300 B.C., beginning of the black peat formation
8	270-300	nH_7	Scheuchzeria-peat (Hna), d.reddish brown (5YR 2/2), weakly to medium decomposed (H 4-5), Scheuchzeria palustris, E.vaginatum, Sph.cuspidatum
			^{14}C-Dating$^+$: 4400 B.C., beginning of the transition peat formation
9	300-310	IIfAhe	Fossil Ah-horizon, black (10YR 2/1), fossil roots, medium-fine sand (msfS), humic, podzolized
10	310-320	IIfBh	Weakly compacted humic ortstein-horizon (fBh), dark brown (10YR 3/4), medium-fine sand (msfS), weak humic
11	320-360	IIC/Go	Medium-fine sand (msfS), yellowish-brown (10YR 5/6)

* = Degree of decomposition acc.v.POST

__ underlined = dominating species

The phase of white peat formation started with the dominance of Eriophorum vaginatum which, however, contained a large percentage of Sphagnum cuspidatum. The change from black to white peat can be timed in the Subatlanticum period (790 B.C.). Later on the white peat has been formed by Sphagnum species of the Cymbifolia-section (Sph.imbricatum, Sph.papillosum) as well as species of the Acutifolia-section.

From this succession it appears that an alternating hollow and hummock association of the vegetation did not occur. The raised bogs showed either no or a weakly expressed microrelief, or hollows and hummocks persisted for a long time simultaneously.

Table 5: Pollenanalytical and 14C-Investigations (Connection SCHWAAR, 1983)

No. Depth cm	Horizon	Diagnostic Species	% acc.to v.Post	Time and Zone +)	^{14}C-Datings BP (1950)
No.4/5 140-143	hH4 - hH5	alder lime beech	52.6 0.7 1.1	Pollenzone X (OVERBECK) Sub-Atlanticum 260 B.C.	2210 ± 65
No. 8 210-215	hH 7	alder lime elm beech	32.5 4.3 1.6 -	Pollenzone IX (OVERBECK) Sub-Boreal 2130 B.C.	3730 ± 130
No. 10 250-252	nH	alder lime beech	37.3 4.6 -	Pollenzone XIII (OVERBECK) Atlanticum 3420 B.C.	4670 ± 60

+) Dendrochronological Correction (WILLKOMM, 1974)

Soil Chemical Properties (Table 6a; 6b)

Plant associations forming raised bogs mainly receive their nutrients by rainfall. Therefore raised bogs are biogenic sediments with a lack of minerals and nutrients (oligotrophic) when compared to eutrophic low moor and muck peats influenced by ground water. Ash contents typically range from 1.2 to 2.7 wt% of the dry matter despite the upper layer (0-10 cm depth), which is changed by man, e.g. with addition of sand and farmyard manure. Black peat, which is more decomposed than white peat contains slightly more ash. A sudden rise of ash contents from 1.7% to more than 90% at a depth of 300 cm (No.8-9) clearly indicates the transition to mineral soil.

The total of major cations - Ca, Mg, K, Na - runs up to 0.5 wt% of the peat including iron and thus comprises about 1/3 of the total ash content. The major part of the remainder probably consists of silicates from aerial deposition. Base deficiency explains the low pH-values of peat layers in the range of pH 3.4-3.7 measured in 0.01 mol $CaCl_2$ solution (pH-values measured in water are approximately 1 pH unit higher).

In addition to high water contents (i.e. oxygen deficiency) the mineral deficiency and the low pH contribute to a low biological activity in virgin bogs, hence a good preservation of the organic matter (peat).
White and black peat have, according to the decomposition, a total organic carbon content (C_t) of 52 wt% and 55 wt%, respectively. This clarifies the advanced degree of carbonization of black peat, also quantified by the (high) r-value (r) (KEPPELER, 1923), which is defined as the non-acid-hydrolysable residue of the peat.
The total nitrogen (N_t) content is low (0.7-1.4%) in comparison to the carbon content, causing a wide C/N-ratio typical for raised bog peat. This also contributes to the low biological activity.

Peat soils are characterized by a high cation exchange capacity (CEC) of the organic constituents, which is highly pH-dependent, however. Measured at pH 4.5 the CEC amounts to one third of the value determined at pH 7. For better comparison with mineral soils CEC is given in meq/l soil (because of low bulk density). The hydrogen iron is the dominating cation at the ion exchange surface due to the low pH that prevails in peat.

The narrow Ca/Mg-ratio documents the vicinity of the sea. Especially in black peat Mg- and Na-ions dominate over their antagonists, which

is interesting in respect of the high Ca-selectivity of organic matter.
Aluminium ions are usually missing in the raised bog peat, which explains the excellent growth of crops on Dystric Histosols despite their low pH (<3.5). The Al-ions become the prevalent ion at the ion exchange surface in the mineral underground (No. 9-11).

Soil Physical Properties (Table 6c)

While mineral soils are characterized by their particle size distribution, peat soils' physical properties are determined by plant residues and their decomposition degree.
The soil profile in "Augustendorf" today presents a stadium after strong primary drainage. Thus, the physical data do not describe a virgin bog (still growing). Virgin bogs have a dry bulk density of about 50 g/l. The actually measured dry bulk density of 71-164 g/l is typical for a drained raised bog. Initially, drainage leads to strong subsidence, thus increasing the bulk density. The subsidence to be expected can be predicted by application of an empirical equation acc. SEGEBERG and HALLAKORPI (1961). This is very important for all engineering projects since the subsidence may be as high as 10-30% of the bog depth. The bulk density of a peat soil is derived from the volume of substance (solid volume (SV)= PV - 100). 8-12 % vol. SV describes a bulk density of "relatively dense".

The mineral soil basis is clearly identified by a bulk density >1000 g/l.

The reciprocal value of the solid volume represents the total porosity (PV). Dystric Histosols have a total pore space of 88-92% vol. explaining their large field capacity (FC). This enormous field capacity, and especially its high percentage of plant available water (AWC) (54 to 66% vol.) is the reason for the excellent suitability of raised bog peat as a soil conditioner or substrate. The low degree of decomposition of the white peat is the reason for its high percentage (16-31% vol.) of large pores (>50 µm = pF <1.8). This causes a high air capacity (AC) after drainage, which correlates fairly good with a horizontal saturated water permeability (k_f) classified as "high" to "extremely high". These properties correspond to those of coarse sands.

The black peat is characterized by its significant lower air capacity (8-12% vol.) and higher percentage of adsorbed water (compared to white peat). Less large pores result in a strongly reduced saturated water permeability. Because of these unfavourable physical properties as well as strong shrinking at drought and bad rewetting, pure black peat is not used for soil improving. In former times black peat has been taken for fuel in households only. However, freezing improves aggregation and pore sizes distribution, which makes it a suitable substrate for cultivation called "humic peat".

Smallest saturated water permeability (k_f) has been measured in the black peat formation (180-270 cm) at the bog basis with a mean of 9 dm/d and in the fossil Ahe-horizon with a mean of 2 cm/d. Especially the low permeability of this horizon prevents large seepage from the bog into the underlying sand. The mean seepage from a raised bog amounts to only 50-100 mm/year.

The mineral underground at the bog basis is characterized by a high sand (91-98%), low silt (1-8%), and very low clay (1-2%) percentage.

Pedogenesis during the early holocene caused a podzolization of the sand forming an ortstein horizon, which is identified as a humic ortstein (humus pan) due to its low percentage of iron.

In the beginning of the Atlanticum period the climate became increasingly humid causing water logging, which lead to a formation of a Stagno-podzol.

Enduring waterlogging turned the area into a swamp with a pronounced Scheuchzeria palustris vegetation, indicating the beginning of bog formation in the profile. With increasing growth of the transitional moor the influence of the mineral undergrond deminished giving place to ombrotrophic plants. In the lower part of the profile the plants decomposed strongly due to the warm and humid climate, whereas from the colder subatlanticum time onward the younger peat remained less decomposed.

Table 6a: Analytical Data - soil chemical investigations (Augustendorf)

No.	Horizon	Depth	Ash	C_t	N_t	C/N	r	H	pH		formation
		cm	%	%	%		%	v.POST	H_2O	$CaCl_2$	
1	2	3	4	5	6	7	8	9	10	11	12
1	jY/hHp	0- 10	70.0	18	1.93	9	53	n.a.	5.3	4.6	surface soil cove
2	hH1	10- 80	3.6	52	0.71	74	48	2-3	4.2	3.4	white
3	hH2	80-105	1.8	52	0.94	55	43	2-3	4.2	3.5	
4	hH3	105-120	1.5	54	1.40	39	54	4-5	4.5	3.5	peat
5	hH4	120-140	1.8	57	1.06	54	70	6-7	4.3	3.5	black
6	hH5	140-180	1.4	57	1.07	54	66	7-8	4.5	3.6	
7	hH6	180-270	1.4	59	0.91	65	66	7-8	4.8	3.6	peat
8	uH7	270-300	1.7	56	1.22	46	61	6-7	4.6	3.7	transitio- nal peat
9	IIfAhe	300-310	96.1	2.4	0.7	34	n.a.	n.a.	4.9	3.6	fossil
10	IIfBh	310-320	98.3	1.0	0.3	34	n.a.	n.a.	5.0	4.1	mineral
11	II C	320-360	99.5	0.4	0.1	37	n.a.	n.a.	5.5	4.3	soil

Analytical Data - Mineral Subsoil (Augustendorf)

No.	Horiz.	Depth	texture in % of humus-/carb.free fine soil								Fe_o	Fe_d	$\frac{Fe_o}{Fe_d}$	Fe_{pyr}	Mn
			sand				silt			clay					
		cm	c	m	f	Σ	c	m+f	Σ		ppm	ppm	ppm	ppm	ppm
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
9	II fAhe	300-310	0.3	40	51	91	5	3	8	1	44	101	0.4	127	0
10	II fBh	310-320	0.2	37	55	92	4	1	5	2	26	63	0.4	272	0
11	II C	320-360	0.7	46	51	98	1	0.4	1	1	20	25	0.8	109	0

Table 6b: Analytical Data - soil chemical investigations (Augustendorf)

No	Horizon	Depth	CEC		exchang. cations						V	Ca/Mg	formation
			pH7.0	pH4.5	Ca	Mg	K	Na	H	AI	pH7.0		
		cm	meq/l		meq/l						%		
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	jY/hHp	0- 10	383	210	200.0	12	2.1	1.3	23	9.2	56	17	surface soil cover
2	hH1	10- 80	170	56	38	7	1.1	0.9	22	-	28	5	white
3	hH2	80-105	83	24	4	11	1.2	1.8	15	-	22	0.4	
4	hH3	105-120	112	28	4	11	1.0	2.1	13	-	16	0.4	peat
5	hH4	120-140	137	36	7	17	1.2	2.3	20	-	20	0.4	black
6	hH5	140-180	104	27	5	10	0.4	2.7	13	-	17	0.5	
7	hH6	180-270	141	37	5	14	0.2	2.6	17	-	15	0.4	peat
8	uH7	270-300	146	38	5	15	0.2	2.6	17	-	16	0.3	transitional peat
9	IIfAhe	300-310	192	50	6	10	0.4	2.1	47	36	10	0.6	fossil
10	IIfBh	310-320	68	24	0.6	2	0.2	0.6	32	26	0.05	0.3	mineral
11	IIC	320-360	22	11	0.0	0.6	0.0	0.1	12	12	0.03	-	soil

Table 6c: Analytical Data - soil physical investigations (Augustendorf)

No.	Horizon	Depth	bulk dens.	PV Vol.	Water content in Vol.% at pF				AC* pF<1.8	AWC** pF 1.8-4.2	k_f	formation
		cm	g/l	%	1.0	1.8	2.5	4.2	Vol.%	Vol.%	cm/d	
1	2	3	4	5	6	7	8	9	10	11	12	13
1	jY/hHp	0- 10	627	68	62	46	35	23	22	23	360	surface soil cover
2	hH1	10- 80	96	88	82	70	44	12	17	58	373	white
3	hH2	80-105	71	87	82	63	37	9	24	54	268	
4	hH3	105-120	113	92	90	84	55	17	8	67	34	peat
5	hH4	120-140	102	93	90	81	57	15	12	66	89	black
6	hH5	140-180	93	94	92	83	61	18	11	66	19	
7	hH6	180-270	105	92	91	85	63	20	8	64	9	peat
8	uH7	270-300	164	89	87	85	77	25	4	59	42	transitional peat
9	IIfAhe	300-310	1106	54	53	51	47	14	3	36	2	fossil
10	IIfBh	310-320	1593	33	32	24	15	6	9	19	42	mineral
11	IIC	320-360	1602	33	32	17	7	2	16	15	100	soil

* AC = air capacity ** AWC = available water capacity

Description of a typical "Findorff Farm on Raised Bog Cultivation" (1985)

1.	Owner:	Johann Meyer, Augustendorf, No. 30 2742 Gnarrenburg
2.	Colonization:	1828: Foundation of the village Augustendorf 1832: Foundation of the farm 1870: Building of the Augustendorf Canal for peat-boats (to Bremervörde)
3.	Farm size:	16,7 ha; 14,0 ha farmland, 2,7 ha farmyard, garden, road system
4.	Soil:	Raised bog (Dystric histosol) Cultivation: 14,0 ha German Raised Bog Cultivation 2,7 ha Dutch Fen Cultivation, cutover peatland
5.	Farm hands:	2,5 labour units
6.	Utilisation:	11 ha grassland 3 ha temporary grassland (4-10 years rotational arable farming) Crop rotation: grassland- oats- fodderbeet - potatoes- rye - grassland (sometimes 2 rotations arable farming)
7.	Yields:	Oats 20-40 dt/ha Rye 36 dt/ha Fodderbeet 200 dt/ha Potatoes 170 dt/ha Grassland 100 dt/ha hay

8. Livestock: 14 dairy cows
6 maiden heifers
6 calfs
7 sheep
30 pigs

1.8 livestock units/ha

9. Milk productivity: 5500 l; 216 kg fat yield/cow

10. Fertilization:

		Grassland	Cereals	Potatoes	Fodderbeets
		- kg/ha -			
mineral fertilizer	N	120	40	84	200
	P_2O_5	70	70	84	84
	K_2O	140	140	120	120
farm-yard manure	N	80			
	P_2O_5	36			
	K_2O	115			

11. Machinery: 3 tractors (26, 26 and 14 kW)
rotary cutter (½)
rotary tedder
plough, harrow, rotary cultivator
planter for fodder beets or potatoes

12. Peat cutting: fuel peat winning only for personal use
100 m^3/year
labour input: 5 man-work-weeks

S T O P 3

Peat works Gnarrenburg F. Meiners GmbH & Co. KG

Manager : H. Koschitzki

Industry : raw peat winning and treatment

Peat winning area : 1.000 ha

Winning methods : sod peat- and milled peat winning

Products : white peat: "Floratorf"
peat-mineral fertilizer "Super Manual"
peat substrates "TKS 1"; "TKS 2"

mixed white and black peat:

Floral	Humosoil
Florahum	Floradur
Rhodohum	flower potting soil
Humintorf	horticultural substrates

black peat:
fuel peat
orchid peat

Output (year) : 700.000 pressed bale (300 l) (20% Export)
800.000 pressed sack bale (80/110 l)
1.500.000 small packs (5-10 l)
3.000 t fuel peat

430.000 m³

Employees : 100 (permanent)
200 (seasonal)

Fieldtruck : 70 km permanent truck
30 diesel locomotives
500 trucks

Machinery : 6 sod peat cutting machines
several peat millers
3 fuel peat dredgers with mixer and peat spreader
11 bulldozers
27 tractors
2 sod collectors
several peat reloaders
" drain machines

manufacturing equipment

STOP 4

Worpswede

This name means wood(wede) near the river Wörpe. The highest point (Weierberg) has an elevation of 52 m m.s.l.
It is the rest of a moraine plaine which had been eroded by the melting waters of the elder Hamme and Wümme rivers. Their valleys later on had been filled up with fens and bogs (s.Geology). By this Worpswede became an island within the mires. In the 12/13th century only 7 to 8 farms belonged here to the monastery of Osterholz. In the 18th century the Royal Hanoverian Peatland Commissioner J.Chr. Findorff turned Worpswede into the cultural centre for the great Teufelsmoor Cultivation. Church, school and shops were built here.

At the end of the 19th century the quiet brightness of this original landscape inspired some famous painters - Fr. Mackensen, O. Modersohn, P. Becker-Modersohn, H. am Ende, Fr. Overbeck, H. H. Vogeler a.o - to live here. These have been less atelier than landscape painters. Their art was influenced by impressionism and youth stile. It shows a frame of mind of a poor wet landscape with virgin and cultivated bogs and fens in between heathland with a bright or cloudy sky peculiarly coloured but also the social misery of the people living and working there. Paula Becker-Modersohn brought a convinced expressionistic simplification of the painting to this art colony. Poets like R. Maria Rilke, Carl Hauptmann, Manfred Hausmann and sculptors (Clara Rilke-Westhoff, Hoetger) have been inspired by the irritation of this landscape too. Worpswede became a concept in the history of art and culture. The socialistic engagement of many of the artists was the reason for establishing special cooperations and for their refusal, prohibition and emigration between 1933 and 1945 (e.g. H. Vogeler emigrated to the USSR). Today we can see their renaissance. Nowadays Worpswede is an important place of recreation for the citizens of Bremen. Galeries and more and more arts and crafts attract thousands of visitors, especially in the summer months. It becomes increasingly difficult to preserve the originality of the place and its surroundings. Claims of agriculture, nature conservation and recreation demand a capable compromise for this unique landscape.

STOP 5

Lower Saxony Geological Survey

Institute of Soil Technology

Bremen

History

1877	**Peatlands Experimental Station** established in Bremen to improve methods of cultivation of peatlands, heathlands and marshlands.
1928	Placed under governmental control as **Prussian Peatlands Experimental Station**
1943	Institute destroyed by bombing raids; 1948-58 reconstruction
1946	**State Peatlands Experimental Station** in Bremen, under the authority of the Lower Saxony Ministry of Food, Agriculture and Forests
1969	Attached to the Lower Saxony Geological Survey (NLfB) as **Experimental Station for Peatland Research and Applied Soil Science**
1978	Extended to the **Institute of Soil Technology** of the Lower Saxony Geological Survey

Staff: 1986
11 scientists
5 administration employees
23 technical employees
12 apprentices

51 total (47% males, 53% fermales)

Functions of the Institute

The primary function of soil technology is to aid in making descisions between the various competing interests for land according to the existing properties of the soil or through soil-improvement measures. Soil utilization, conservation, and improvement constitute the chief tasks of the Institute of Soil Technology. The results of basic resarch cannot be put into general use until they have been tested for several years. Practical problems which are brought to the Institute are investigated by applied research methods. This important role of the Institute as an advisor is implemented in both these types of research in 4 stages:

- laboratory experiments (short-term) - chemical, physical, botanical laboratories
- pot trials (medium-term) - greenhouse (800 pots, 20 lyzimeters)
- field trials (long-term) - 42 experimental fields on different sites
- experimental results form the basis for expert assessment, advice, and training.

Excursionroute Bremen - Bourtanger Moor

The State of Bremen is the smallest of FRG - comprising the cities of Bremen (580.000 citizens) and Bremerhaven (100.000 citizens). (For further informations see guide "Bremen").

The trip is continuing south west, crossing the river Weser, leaving behind the Haake Beck brewery (Becks) on the left hand side. To the right handside the mercantile marine training ship ("Deutschland"), in the back the harbor can be seen. The distance from the Northsea is about 65 km, ships may have a draught of 9.6 m. The route continues through the Weser lowlands, a typical marsh land.
Near **Delmenhorst** the plain of the "Delmenhorster Geest" with many plaggen-soils follows. This Geest plain forms the southern border of the Weser and Hunte lowlands.
About halfway between Delmenhorst and Oldenburg we turn into a formerly characteristic mireland. The raised bogs, however, have been cut on a large scale and turned into arable lands by deep ploughing.

Oldenburg - (130.000 inhabitants) - has formerly been the residence of the dukedom Oldenburg, today it is the administrative and cultural center of the Weser-Ems area.

Coastal-Canal - see also guide sheet "Das Emsland" -.
This ship lane connects the rivers Ems and Hunte/Weser, an important link between the Rhein-Ruhr industrial area and the harbors at the Weser river, built in 1920-1935 (Length of 65 km, water level = +5 m above sea level. The construction of this canal was the prerequisit for the colonization (drainage, peat-cutting and cultivation) of the extensive raised bog areas in the Hunte-Leda-lowlands. The settlements were founded on either side of the canal and its parallel highway between 1850 and 1880. The raised bogs called Dose mire were drained and cultivated according to the "German Raised Bog Cultivation" (grassland). Today the area next to the canal has been cut over and cultivated by the German Sand-mix Cultivation (arable land). The rectangular interface from cut to non-cut raised bogs can be seen at some distance from the road.

Some great raised bogs are managed by the peat-cutting industry for white and black peat winning.
Rests of virgin raised bogs are generally predrained and usually covered with shrubbs (birches etc.). A recent raised bog growth (Sph.mosses) without special measures is impossible.

Hümmling - Area - we leave the course of the canal turning south in Börgermoor, and drive through the downs of the Hümmling before arriving in the lowlands of the Hase river.
The Hümmling area was formed in the early Saale glacial. The melting glacier left behind a ground moraine dome cut by several gullies. It has been periglacially changed during the Weichsel glacial by eolian and fluvial sands and dunes. The Hümmling - the village Sögel in its centre - has been populated very early as can be seen from about 90 preserved megalithic tombs from the early stone age (2500-1800 B.C.)

Meppen was foundet at the confluent of the rivers Ems and Hase. Already in 946 A.D. it was granted the right to hold markets. Today, Meppen is a district and administration center of the Emsland cultivation. West of the city of Meppen we reach the escursion area of the Bourtanger Moor near Rühle on the other side of the river Ems.

Bourtanger Moor

Name and Location

The area of the Heseper Moor belongs to the great Bourtanger Moor, which has been the largest raised bog of Central Europe (1200 km²) in its original extent (SCHNEEKLOTH, 1981). The name means farmers (bour) spit of land (tange) in the mire. The small town Bourtange was for a long period an important Dutch fortress against the Bishop of Münster and controlled this single way across the mires. The Bourtanger Moor stretches out from Wietmarschen more than 70 km north in the west of the river Ems. One third of it is located in FRG, two thirds belong to the Netherlands.
The German part of the Bourtanger Moor is bordered by the Netherlands in the west and the North-South Route in the east.

The village Groß Hesepe lies on this route in the southern part of the Bourtanger Moor. Two Stops - Moormuseum and German Sand-Mix Cultivation - are located in the Groß Heseper Moor.

Geology

The topography of the excursion area has been formed by the glacier of the Drenthe stadial (Saale glacial). The glacier lobes at Nordhorn have been the most protruding.
The glacier left behind several moraines. These moraines were changed perglacially (Weichsel glacial) by solifluction and partially eroded. However, the remainders still reach up to 80 m m.s.l. (HOPPENBERG). In a half cirle about 20-25 km in diameter they surround the excursion area in the south, reaching from Uelsen (west) via Nordhorn all the way to Lingen (east) (see Fig. 7).
The glacier bed 25 km wide was filled up with fluvial sands. On these valley sands dunes were blown up.
Eolian sedimentation had been most intensive during the late glacial and early holocene due to a sparse vegetation cover. A second phase of eolian sedimentation arose with the destruction of forests and extend grazing of the heathlands by sheep reaching its peak intensity in the 18th century.
The dune formation primarily occured along the rivers of Ems and Vechte running parallelly to the river. Due to prevailing west winds primarily the eastern banks of the Ems are covered with dunes.

Rising water table due to the rising sea level and an increasing humid-cool climate from the Atlanticum period onward (5500 B.C.) led to paludification of these glacier beds, especially in the numerous flat basins. Lateron raised bogs of great depth (3-6 m) occured on a large scale, covering the surrounding mineral, mostly podzolic soils (BOIGK et al. 1960).
The river Ems flows trough the pleistocene sandy valley in sweeping meanders characterized by frequent change of the river bed. The latest valley meadow is formed by more or less recent fluvial medium to fine textured sands with varying iron contents.

In some spots compact bog iron ore layers can be found. Loamy deposits occur to a variable extent; they are increasing in depth and frequency going north in the valley.
The Vechte valley is very similar to the Ems valley in respect to its holocene deposits.

Climate and Hydrology

The area is characterized by a mild humid temperate climate ("cool" summer, "warm" winter) with rather late frosts, typical for mire lands.

Table 7: Climatotogical Data of the Bourtanger Moor (yearly average)

Temperature	8.0°C
Rainfall	720 mm
Evapotranspiration	450-500 mm
Climatic water balance	+ 220-270 mm
Vegetation period (daily ave. temp. $>$5°C)	25.03 - 12.11. (230 days)
Ave. last day of frost at	
0.05 m height	13th June
2.00 m height	13th May
Ave. first day of frost at	
0.05 m height	31st August
2.00 m height	13th October
Mean free of frost period	152 days
Major wind direction	west/southwest

The main outfall of the German part of the Bourtanger Moor is the North-South-Canal reaching from the Haren-Rütenbrocker Canal in the north down to the city of Nordhorn in the south of the Bourtanger Moor. The southern part is additionally drained by the small river Grenzaa running westwards.

Vegetation

In general the postglacial development of vegetation follows the Central European succession (page 8). The area shows an increasing human activity with time: In the early middle ages the landscape was characterized by low moors and raised bogs in the valleys surrounded by dense woods on the (mineral) hills. The beech-oak and oak-birch forest, however, were pushed back more and more by fire wood winning grazing, litter utilization and sodding. Finally, in 1780, this region had less than 70 ha of forest. Heath vegetation spread out on the thus utilized areas.

At the end of the middle ages the district of Ems has been characterized by vast stretches of heath and moors surrounded by anthropogenically formed farmland (plaggensols).

In consequence of deforestation the heath stretches had been completely exposed to wind erosion. Strong sand drifts and dunes reached a threatening extent.

In the beginning of the large scale "Emsland" cultivation (1950) only 8% of the total area had been covered with forests. Since then more than 17.000 ha were afforested, mostly with pine, japanese larch and spruce. About 3.000 km shelter belts have been planted since that time.

Soils (acc. FAO soil classification)

Dystric Histosols

The centre of the excursion area is covered by the raised bogs of the Bourtanger Moor (see Geology).

Podzols, Gleyic-Podzols

Podzolic soils frequently occur in this area. On the elder fluvial sand deposits in the valleys gleyic podzols are typical. Pure podzols are found on elevated eolian sand deposits or dunes. On recent dunes along the river Ems the genesis of podzolic soils is weakly indicated.

Fluvi-Eutric Gleysols, Humic Gleysols, Eutric Histosols

These soils are met in the depressions and river lowlands (Ems, Vechte, Hase).

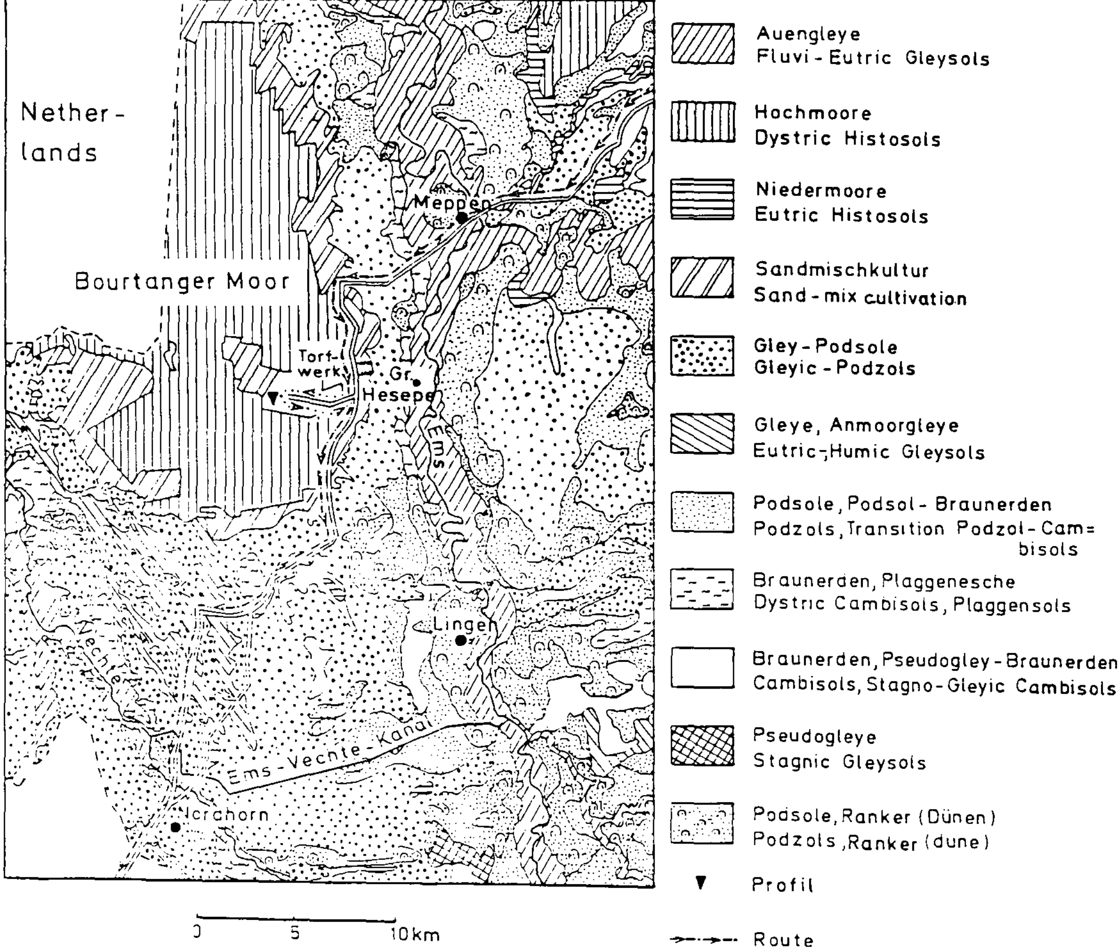


Figure 7: Soil map of the river Ems valley region and the Bourtanger Moor

Cambisols, Stagno-Gleyic Cambisols

were developed on sediments rich in silicates, like in the ground moraine, but also in the area of the (end)moraines, where pleistocene sands are mixed with tertiary, fine textural deposits.

Plaggensols

Old settlements, e.g. along the elevated river banks (Ems) are mostly surrounded by these artificially elevated plaggensols.

German Sand-mix Cultivation

The Bourtanger Moor area is encircled by these anthropogenical soils indicating the progressive cultivation of the raised bogs.

History

The development and population of the Bourtanger Moor happened in several phases:

17th century: The first settlement has been founded at the former south rim of the Bourtanger Moor by the physician Piccard in 1683. The peatland was used by burnt over cultivation.

18th century: Eight new villages (Moor Colonies) were initiated by the Bishop of Münster to fight landscarcity. The trade with (fuel) peat like in the Netherlands, however, had been impossible due to unfavourable drainage and transport facilities. Therefore, the Dutch Fen Cultivation combined with burnt-over peatland cultivation stagnated.

Late 19th century: 1871, the government started the construction of an extensive channel system (112 km), finished in 1903. By this better drainage and cultivation (German Raised Bog Cultivation) became possible.

First half of the 20th century: Governmentally ruled development on grounds of the "Reichssiedlungsgesetz" (1919) constituted the "Land Settlement Co-operative Emsland". A labour service was arranged during the time of world economic depression, followed by prisoners work before and during Word War II. Industrial peat cutting started in 1905. In the beginning, especially black peat was cut for fuel, serving the Hesepe power plant built in 1924/25. This power plant remained in action until 1974.

After World War II:

In 1950 the Emsland Programme has been initiated to provide farms for the German refuges expulsed from the east German and Prussian territories. Today, the aim of the Emsland Programme is not the agricultural development only, but also to favour the general economic conditions. Hence, the programme includes the support in the fields of agriculture, industry, trade, water supply and sewage disposal, traffic, health and education. (Infrastructure)

The Emsland Programme is managed and coordinated by the Emsland Association (Ltd) a governmental supported institution responsable for the distribution of public financial means. The administed area of the "Emsland GmbH" comprises about 8.000 km² with 750.000 inhabitants.

Achievements of the Emsland-Development

The greatest problem in the beginning has been the systematical drainage of the area and the soil amelioration, especially by the application of the German Sand-mix Cultivation Method. The most important results of this land improvement are listed in Table 8 and 9. Since 1965 predominantly on deep ploughing areas 1.256 farms were founded. In the beginning these farms had a size of appr. 15 ha, lateron they were enlarged to 25 ha each if possible.

Besides the cultivation and amelioration of mires and heathland for agriculture, afforestation has been prompted on about 17.000 ha which is about 15% of the Emsland district now.

As mentioned above, wind erosion had to be fought. Old as well as new farmlands were protected by shelter belts (2.900 km.)

The deep plough became the great symbol of the Emsland cultivation for decades. However, the importance of agriculture is declining: In 1950 about 50% of the population lived on farming, today it's about 15% only.

For the rural development a total input of about 2 billion DM has been necessary. The actual economic development is characterized by a low labour input of liberating agricultural labour for the upcoming industries.

The achievements of oil and gas drilling industries as well as oil processing are remarkable. The Emsland serves about 40% each, of the German oil and gas production. Two plants purify the oil, one of them is the oldest in Europe.

Land Settlement was stopped by the government in 1968.
Today, cutover peatland - unsuitable for a nature conservation area - is cultivated to a limited extent. Most of these areas are used for other public interests, e.g highway construction etc.

As mentioned above the Lower Saxony Bog Conservation Programme intends the renaturation of cutover peatland and the preservation of existing intact raised bogs. Some trials of this idea are to be found in the Emsland district too.

Table 8: Major achievements of the Emsland development (1950 - 1984)

River correction	697	km
Outfalls and Ditches	7.141	km
Subsurface drainage	16.708	ha
Farm road construction	2.928	km
German Sand-mix Cultivation	136.680	ha
Afforestation	17.279	ha
Shelter belts	2.912	km

Table 9: Emsland District Numbers compared with FRG

	Years	Emsland	FRG
Area (km²)		7.175	248.687
Population Density (Cit./km²)	1961/1984	84/100	226/246
Industrial labourers (%)	1956/1976	7/8	14/12
Labourers in Agric./Foresty (%)	1950/1979	49/19	25/6
Farms <20 ha (X1000)	1949/1983	34/22	1.342/651
>20 ha (X1000)	1949/1983	5/10	128/208
Farmland (X1000 ha)	1949/1983	569/830	17.441/19819
Arable land (%)	1950/1983	39/56	56/60
Grain yield dt/ha	1949/1983	14/35	23/46
Dairy cows (X1000)	1949/1982	160/225	5.530/5.530
Pigs (X1000)	1949/1982	438/2594	9.700/22.478

S T O P 6

Site description

Location:	Groß Hesepe, TK 25
Elevation:	+ 22 m m.s.l.
Slope:	Flat, levelled
Subsurface drainage:	none
Vegetation:	Cereals
Utilization:	Deep ploughing in 1976, Arable land since 1976, (German Sand-mix Cultivation) Cereals, maize
Parent material:	Own-rooted raised bog (overlaying a fossil podzol) Mineral subsoil: Fluvial Sands
Soil classifikation:	German : Deutsche Sandmischkultur English: German Sand-mix Cultivation USDA : Arents

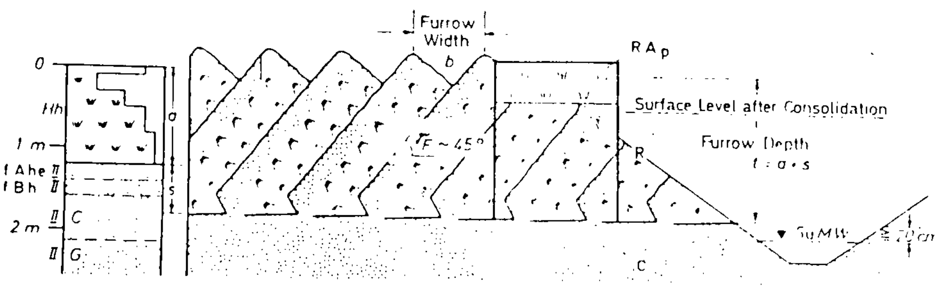


Figure 8: Scheme of Natural and Deep Ploughed Profiles of Raised Bog with Necessary Depth of Drainage (By R. EGGELSMANN, 1971)

Profile description

German Sand-mix Cultivation (Groß Hesepe)

No.	Depth	Horizon	Description
1	0- 30	R Ap	Plough layer, grey (10YR 3/1) medium-fine sand (msfS), very strongly humic
2	40- 50	R Hh	Peat layer of the deep-plough profile (=R-Horizon) (s.Fig.8), top spit, Sphagnum-peat (Hhs), dark reddish brown, (5YR 2/2), weakly to medium decomposed (H 4-5)
3-6			Sand-layers of the deep-ploughing profile (=R-Horizon) (s.Fig.8), fossil Ahe and Bh(=Ortstein)-horizon and C-Horizon of a podzol
3	40- 50	R fAhe	II fAhe = fossil Ah and Ae-Horizon, black (10YR 2/1), fossil roots, medium-fine sand (msfS), strongly humic, podzolized
4	40- 50	R fBh_1	II fBh_1 = fossil humic ortstein-horizon, compacted, dark brown (10YR 3/4), fine sand (fS), humic
5	40- 50	R fBh_2	II fBh_2 = fossil humic ortearth-horizon, weakly compacted, yellowish brown (10YR 5/6), fine sand (fS), weakly humic
6		R C	C = fine sand (fS), light yellowish-brown (10YR 6/4)
7	140-160	II C	medium-fine sand (msfS), light yellowish-brown (10YR 6/4)

Table 10a: Analytical Data - soil chemical investigations

German Sand-mix Cultivation, Groß Hesepe

No	Horizon	Depth	Ash	C_t	N_t	C/N	r	H	pH		DL		$CaCl_2$
											P	K	Mg
		cm	%	%	%		%	v.POST	H_2O	$CaCl_2$	mg/100cm³		
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	R Ap	0- 30	88	5.4	0.14	39	n.a.	n.a.	5.0	4.4	4	15	10
2	R Hh	40- 50	25	43.1	0.80	54	57	4-5	4.0	3.3	0.2	4	10
3	R fAhe	40- 50	92	5.2	0.10	52	n.a.	n.a.	4.2	3.4	0.3	3	4
4	R fBh_1	40- 50	96	2.7	0.06	45	n.a.	n.a.	4.7	3.8	1	2	2
5	R fBh_2	40- 50	98	0.9	0.02	45	n.a.	n.a.	5.4	4.4	1	3	2
6	R C	40- 50	99	0.5	0.01	50	n.a.	n.a.	5.8	4.6	1	3	2
7	II C	140-160	99	0.2	0.01	20	n.a.	n.a.	5.3	4.2	0.5	0.6	1

Table 10b: Analytical Data - soil chemical investigations
German Sand-mix Cultivation, Groß Hesepe

No.	Horizon	Depth	CEC		exchang. cations						V	Ca/Mg
			pH7.0	pH4.5	Ca	Mg	K	Na	H	Al	pH7.0	
		cm	meq/l		meq/l						%	
1	2	3	4	5	6	7	8	9	10	11	12	13
1	R Ap	0- 30	187	90	83	11	4	1	5	9	53	8
2	R Hh	40- 50	479	168	91	19	2	2	78	-	24	5
3	R fAhe	40- 50	252	82	18	4	1	0.5	20	62	9	5
4	R fBh$_1$	40- 50	205	74	13	2	1	1	1	72	8	7
5	R fBh$_2$	40- 50	84	35	10	2	1	0.2	4	24	16	5
6	R C	40- 50	47	22	10	2	1	0.3	3	12	28	5
7	II C	140-160	29	10	0	1	0.3	0.3	5	13	6	-

Table 10c: Analytical Data - soil physical investigations
German Sand-mix Cultivation, Groß Hesepe

No.	Horizon	Depth	bulk dens.	PV	Water content in Vol.% at pF				AC* pF<1.8	AWC** pF1.8-4.2	k_f
		cm	g/l	%	1.0	1.8	2.5	4.2	Vol.%	Vol.%	cm/d
1	2	3	4	5	6	7	8	9	10	11	12
1	R Ap	0- 30	851	56	52	40	24	11	16	29	113
2	R Hh	40- 50	243	84	80	68	54	33	16	35	75
3	R fAhe	40- 50	1325	43	41	35	26	16	9	19	157
4	fBh_1	40- 50	1422	39	37	25	15	8	14	17	175
5	fBh_2	40- 50	1522	35	34	23	10	4	12	19	228
6	RC	40- 50	1554	41	26	16	7	3	12	13	121
7	II C	140-160	1729	33	31	25	15	5	8	17	156

* AC = air capacity ** AWC = available water capacity

Table 10d: Analytical Data - German Sand-mix Cultivation, Groß Hesepe

No.	Horiz.	Depth cm	texture in % of humus-/carb.free fine soil								Fe_o ppm	Fe_d ppm	$\frac{Fe_o}{Fe_d}$ ppm	Fe_{pyr} ppm	Mn_d ppm
			sand				silt			clay					
			c	m	f	Σ	c	m+f	Σ						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	R Ap	0- 30	0.3	16	73	89	6	1	7	4	459	645	0.7	239	100
3	R fAhe	40- 50	1.0	12	77	90	6	1	7	3	50	63	0.8	45	0.5
4	R fBh_1	40- 50	0.7	11	79	91	5	0.4	5	4	39	38	1.0	256	0.0
5	R fBh_2	40- 50	0.4	8	81	89	7	0.1	7	4	53	50	1.1	252	0.0
6	RC	40- 50	0.4	13	79	92	6	0.3	6	2	55	38	1.4	204	0.0
7	II C	140-160	0.6	21	76	97	1	0.2	1	2	30	13	2.3	111	0.0

The deep ploughed profile is structured into 3 horizons:

1. RAp-horizon : top soil
2. R - horizon : peat and sand beams
3. C/G_o -horizon: mineral subsoil, undisturbed

The upper RAp-horizon represents the peat/sand mixture derived topsoil of 25 cm depth. Below that follows the tilted peat and sand beams with a ratio of 0,8:1,0. The C-horizon at the basis of the profile represents the fossil podzolic soil.
The ploughing depth is given by the formerly stagnant Bh-horizon (illuvial humus pan) which must be broken by the ploughshare. The hydraulically levelled deep plough enables a varying ploughing depth in case of variable depth of the bog and fBh-horizon. The mixture of peat and sand creates a new top soil whose physical properties are quite different from its original substrates' properties and more similar to the weak loamy, strong humic sand of a plaggensol.

Soil Chemical Properties (see table 10a, 10b)

The top soil contains about 11% of organic matter (strongly humic). It can be considered a young German Sand-mix Cultivation, which started with an org. matter content of 15% and needs still time to reach the climax stadium of 6-8% org. matter (see Fig. 5). This also is expressed by the pH-value of 4.4 after the usual liming and fertilizer application. The optimium pH for young German Sand-mix Cultivation soils ranges from pH 4.5-5.0, where the optimum pH of older deep ploughed soils after humification is between 5.0-5.5.

Compared to the original substrates (see RHh horizon No. 2 and 3) the C/N- ratio of the top soil (plough layer) is already smaller, 39 compared to 54. This indicates the relative nitrogen enrichment with peat decomposition and mineralization. The top soil has changed favourable for the biological activity and humus quality.

The top soil is well supplied with nutrients too, compared to the peat and sand beams (no 2-6). The magnesium content is sufficient. It is typical for bogs close to the coast showing high Mg-contents in the peat (see subsoil peat).

Soil Physical Properties (Table 10c)

Starting with bulk densities of 240 g/l (peat) and 1470 g/l (sand) and assuming a (layered) peat/sand-ratio of 0.8 one calculates an organic matter content of 13%. The measured still high org. matter content of 11% after 12 years of ripening is surprising, however, the successive top soil deepening by tillage up to 30 cm has to be accounted for.
A mixture of less decomposed white peat and fine sand reaches its maximum field capacity of approximately 55 % vol. at an organic matter content of about 8 wt %. Progressing mineralization and humification of the peat reduce the plant available water as well as the air capacity (pores $>$ 50 μm) and simultaneously increase the permanent wilting point (pores $<$ 0,2 μm).

The important (ecological) physical properties of plant available water and air capacity will be decicively determined by the peat/ sand-ratio:

1. With increasing contents of organic matter the available water capacity (AWC) (pores 0,2-50 μm) will increase. If the peat mixed with sand is weakly decomposed the available water capacity (AWC) remains smaller than the increase of the total porosity beyond 8 wt % o.m.
   Mixtures of strongly decomposed peat with sand have the highest air capacity at about 8 wt % o.m.
2. 12-15 wt % o.m. may induce oxygen deficiency by increasing soil wetness due to adsorptive and capillary water.

After 12 years of soil ripening this profile has reached in the mainly rooted Ap-horizon an available water capacity of 29 %vol. and a total pore volume of 56 % vol.. Large pores ($>$50 μm) comprise about 16 %vol. which is sufficient for crop production. A problem represents the bare soil during spring time exposed to wind erosion. With age, progressing homogenization and humification more stable sand-humus complexes are formed which are less susceptible to erosion.

Description of a typical new farm on German Sand-mix Cultivation (1985)

1. Manager : R. Horstmann, Hesepermoor

2. Colonization : 1974: Deep ploughing - German Sand-mix Cultivation, interim utilization by the governmental peatland administration

   1982: Foundation of the farm after initial soil ripening

3. Farmsize : 45 ha, 42,5 ha farmland

4. Soil : German Sand-mix Cultivation (cut-over raised bog before cultivation) ploughing depth: 1,80 m

5. Farm hands : 1,5 labour units

6. Utilization : 20,0 ha temporary grassland (4 years)
   22,5 ha arable land:
   crop rotation: silage maize - winterbarley - silage maize

7. Yield : Winterbarley 45 dt/ha

8. Livestock : 42 dairy cows
   37 maiden heifer
   49 calfs
   11 bulls (1-2 years)

   2.1 livestock units/ha

9. Milk productivity: 5700 l/ 13,5 dt/cow feed concentrate.

10. Fertilizing :

		grassland	barley	maize
		-	kg/ha	-
Mineral fertilizers	CaO	500	500	500
	N	325	120	150
	P_2O_5	95	70	160
	K_2O	160	150	200
Semiliquid manure	N	100	75	150
	P_2O_5	40	30	60
	K_2O	200	150	300

11. Machinery equipment : 2 tractors (52 kW, 37 kW)
    multi purpose trailer (6 t)
    slurry tanker (6 m³)

S T O P 7

Emsland-Moor-Museum

The area of the Dutch-German border is characterized by 400 years history of the Bourtanger Moor development and cultivation. In the Dutch part this has been achieved earlier by peasant fen cultivation i.e. use of spades.

Peat cutting and cultivation of the German part started later characterized by the application of large scale techniques (deep plough!). The Emsland-Moor-Museum in Gross Hesepe has the intention to exhibit and represent these technical achievements.

In the main hall of the museum the development of the Bourtanger Moor landscape and its different way of cultivation is shown. The open-air part of the exhibition demonstrates the machinery and tools for peat cutting and bog cultivation.

The highlight of the exhibits is the steam powered "Mammut" plough constructed by the Fa. Ottomeyer inspired by Max v. Eyth. This deep plough could reach a maximum plough depth of 2.00 m. Its working weight is about 28 tons. The steam engines pulling the plough have 336 kW each, and a weight of 18 tons. Two engines were neccessary standing at a maximum distances of 600 m pulling the plough forth and back by a win rope. At a speed of 6 km/hr the plough had a maximum result of 3 ha/day with 10-12 labourers. (Today the same result is possible by 3-4 labourers)

Furthermore, the Museum has an educative course for botanical and technical interests. A part of the neighbouring plots is rewetted to demonstrate raised bog regeneration.

Methods

Methods of peat soil analysis (acc.CAMPBELL a.KUNTZE, 1984):

r-Value: Non-hydrolysable (72 % H_2SO_4) organic residue (r) in % of the ashfree organic matter

Degree of Decomposition, H (von POST):
A sample of wet peat is squeezed in the closed hand and the colour of the liquid that is expressed between the fingers, the proportion of the original sample that is extruded, and the nature of the plant residues, are observed.

CEC and Exchangeable Cations (acc.FEIGE, 1969):
Exchange solution: 0,5 N Sr-acetate solution, pH varies between 4,5 and 7.

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Dutch Fen Cultivation and Polders in the Netherlands

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ENVIRONMENTAL CONDITIONS IN THE NETHERLANDS

Introduction

The Netherlands is one of the small countries in northwestern Europe. It is situated between the North Sea in the north and Belgium in the south (between latitudes 51° N and 54° N), and between the North Sea in the west and the Federal Republic of Germany in the east (between longitudes 3° E and 6° E). The total area of The Netherlands (1983) is 34 000 km² (exclusive of water). About 15% is built-up area (residential districts, industrial areas, roads, airports, parks); 9% is under forest, of which about half is coniferous forest; about 71% is agricultural land (of which 61% is grassland, 33% is arable land and 5,5% is horticultural land); the remaining area (5%) consists of heathlands, coastal and inland dunes, coastal marshes, reed marshes, these formerly were called waste land, but today they are very valuable for outdoor recreation and nature conservancy.

By enclosing new polders the area has been increased by about 5000 ha per year in the last decades, but urban expansion has claimed yearly 8000 to 10 000 ha in the same period.

Some information on environmental conditions is given in terms of the classical factors of soil formation in the following five sections entitled: Parent material, Climate, Time, Topography, and Biotic factors.

Parent material

Nearly all mineral soils in The Netherlands are developed from clastic sediments, with textures ranging from fine sands to clays. They may be aeolian (loess, cover sand, coastal and inland dune sands), fluviatile (sediments of the Rhine and the Meuse), marine (tidal sediments of the North Sea and its inlets), or glacial (glacial till and fluvioglacial). The only soils developed from solid rock in The Netherlands, are the rendzina soils developed from Cretaceous chalk outcropping on slopes in the south of the country. The parent material of the organic soils ranges from eutrophic wood peat to oligotrophic Sphagnum moss peat.

Figure 1 shows a generalized distribution of the various kinds of parent materials in The Netherlands, differentiated according to geological age, texture and origin.

Fine sands of coastal and inland dunes
The first mapping unit comprises coastal and inland dunes. The latter, being derived from the Pleistocene cover sand, is always non-calcareous. The coastal dune sand in the north

is also non-calcareous, the sands of the south are calcareous. It are fine sands with practically no clay and no silt, and 70-80% of the sand separate is between 100 and 350 µm.

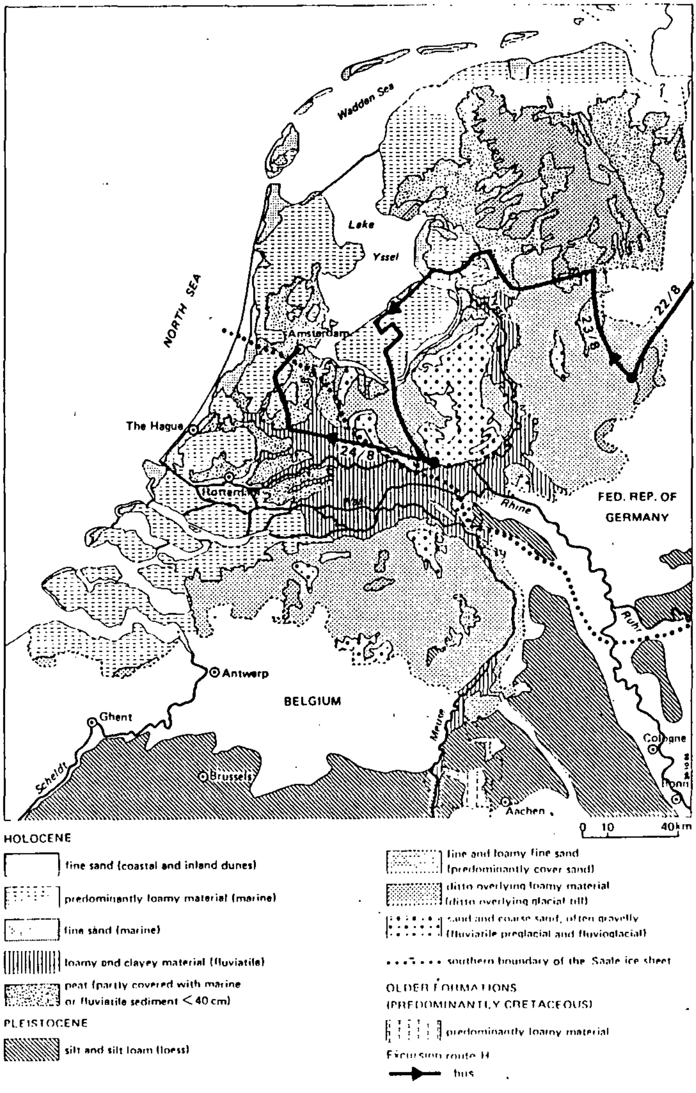

Fig. 1 Parent material and surface geology in The Netherlands. In Belgium and the Federal Republic of Germany only the loess is indicated (from De Bakker, 1979).

Loamy materials of marine origin
These materials range between 10 and 40% clay, and have practically no grains over 150 µm. They may be calcareous and non-calcareous (synsedimentary or decalcified). Soils developed from these materials will be shown during excursion B (August 9, 1986) and during excursion H (August 23 and 24, 1986).

Sands of marine origin
These sands have practically clay and no silt. Alongside the North-Sea coast they are fine, with the main bulk of the sand separate between 75 and 200 µm. The sand in the western part of the Lake-IJsselpoldders is much finer, it may have over 80% smaller than 150 µm; in the east these polders are part of the embanked foreset beds of the delta of the river IJssel, the sand here is much coarser (40-50% between 150 and 200 µm). These sands mostly are calcareous.

Loamy and clayey materials of fluviatile origin
The soils on the natural levees have 20 to 30% clay, the sand separate is much coarser than in marine parent material. In the backswamps soils with more than 50% clay occur. The soils on the levees of the Rhine are calcareous or shallowly non-calcareous, those of the Meuse are mostly non-calcareous. The fine-textured soils of the backswamps are always non-calcareous. During excursion B (August 10, 1986) both types will be demonstrated.

Organic materials
The o.m. content of these materials vary between 30% in the clayey wood peats to neraly 100% in the Sphagnum peats. Large areas of peats are disappeared, mostly by excavation for fuel, partly by erosion (e.g. in the Lake-IJsselpolders). In the north remnants of peat are topdressed with sand, such a soil will be shown on excursion H (August 23, 1986), an exposed bog floor and a wood peat also on excursion H (August 24, 1986).

Loamy materials derived from loess
The soil parent meterials in Belgium and Germany are not shown on figure 1, except for the loess, which has been put in to show that the Dutch loess region is part of the West European loess belt. Dutch loess has 10-20% clay and also 10-20% sand. No loess soils will be shown in The Netherlands.

Sandy materials derived from cover sands
Cover sand (the seventh mapping unit on Figure 1) is a widespread aeolian deposit mainly of late Weichsel age. In places it is several metres thick, elsewhere it veneers older sandy sediments, for example preglacial coarse river sediments and glacial outwash, hence its name: cover sand.

It is non-calcareous, at least in its upper part, its clay content is negligible, its silt content varies between 5 and 30%, between 50 and 70% is between 75 and 200 µm. During excursion B (August 10, 1986) soils developed from cover sand will be demonstrated.

Thin cover sands overlying glacial till
In the north of the country, cover sand overlies glacial till (the eighth mapping unit). The clay content of the till is rather low, mostly between 15 and 25%, it is a compact and cohesive material, excellently suited for dike-building. It outcrops on the sea bed near the enclosure dam in the north, it was dredged and used to build this dam in 1932. No soils will be shown of this unit.
Sandy and gravelly material of the ice-pushed ridges
Ice-pushed ridges and fluvioglacial plains form the ninth mapping unit. The ridges to the north of the dotted line on Figure 1 are preglacial deposits shaped into low hills by the Saale ice sheet at the end of the middle Pleistocene. The fluvioglacial plains date from the same period.

It are gravelly coarse sands, during the excursion the landscape will be shown in an area blanketed with cover sand.
Weathering residue
In the south 'real soils' developed from chalk are found. Partly the weathering product is thin and overlying chalk, partly thicker with a brown soil. Locally this product is thin and overlying chalk (rendzina), partly it is thick and has a brown soil. Locally it is rich in chert and comparable with the clay-with-flints in Britain and the argile à silex in France. No such soils will be shown in the excursions.

Climate

The climate of The Netherlands is a Cfb-climate according to Köppen's classification. The winters are mild, even the temperature in the coldest month is above 0°C; in summer there are four months with a mean temperature over 10°C, and the precipitation is evenly distributed over the year (Table 1).

Due to differences in evaporation there is a precipitation deficit during the growing season. For this reason the water supply of crops depends for a major part on the availability of soil moisture. Shallow soils or shallowly rootable sandy soils suffer from drought in dry summers, except when the lower boundary of the rooting depth is within the capillary fringe. Deep soils have a higher water-holding capacity, thus enabling crops to bridge dry periods more easily than crops on shallow soils.

There is a clear precipitation surplus in autumn and winter, dutch soils certainly undergo leaching, e.g. decalcification (see Van der Sluijs, 1970). There are podzols in The Netherlands, but these are only developed in sands of late-Pleistocene age; loamy materials of similar age carry Alfisols. Desalinization studies in Dutch polders flooded with sea water have indicated that on average 160 mm of precipitation is added to the groundwater yearly.

Table 1. Climatic data of The Netherlands; montly averages from 1951-80 at De Bilt (near Utrecht)

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Sunshine(hours)	48.9	68.5	111.3	160.8	202.5	209.0	184.0	182.4	140.5	102.5	52.6	43.8	1506.[illegible]
Temperature (°C)	2.0	2.3	4.8	8.0	12.1	15.2	16.6	16.4	14.0	10.3	5.8	3.2	9.[illegible]
Maximum temperature below 0°C(days)	9	3	0	0	0	0	0	0	0	0	2	3	17
Minimum temperature below 0°C(days)	15	15	12	5	1	0	0	0	0	1	7	6	62
Maximum temperature 20°C or above(days)	0	0	0	2	7	13	18	18	10	2	0	0	70
Maximum temperature 25°C or above(days)	0	0	0	0	2	4	4	5	1	0	0	0	16
Maximum temperature 30°C or above(days)	0	0	0	0	0	0	1	1	0	0	0	0	2
Precipitation (mm)	66.6	51.7	51.3	52.3	54.1	69.5	76.8	88.2	64.9	68.9	74.7	78.6	797.[illegible]
Days with at least 1.0 mm precipitation	13	10	11	10	10	10	11	13	10	11	13	13	135
Evaporation (Eo) in mm.acc. to Penman	2	13	42	70	105	119	111	90	57	27	7	1	644

In Soil Taxonomy there are five main classes of soil temperature regions, clearly ours has be called: mesic. Soil Taxonomy also defines soil moisture regimes; the Dutch climate is such that nearly all soils satisfy the definition of the udic moisture regime. Only the soils of the coastal marshes (such as soils B-NL3 and B-NL4) have a peraquic moisture regime. Because practically all our hydromorphic soils are artificially drained there are hardly any soils left with an aquic soil moisture regime.

Time

In roughly half of the area of The Netherlands the parent materials are of Holocene age (British equivalent: Flandrian); in the other half they are of Pleistocene age, and in less than 1% older formations outcrop (Fig. 1).

The parent materials of Holocene age are mineral and are of marine or fluviatile origin (mostly loamy and clayey), or are organic; the Pleistocene sediments are all mineral and are predominantly sandy (cover sands) with only a small part loamy (loess and glacial till).

The boundary between the Holocene and Pleistocene sediments has been put at 8000 B.C., but more than three-quarters of the surficial Holocene sediments are less than a thousand years old. The upper part of the 100 000 ha of the drained lake-bottoms (e.g. soil H-NL6) was deposited in the mid-Holocene age, and sedimentation ceased between 3000 and 2000 B.C., depending on the site. However, these sediments were covered with peat shortly after sedimentation had stopped, and have only recently been revealed by peat cutting and subsequent drainage. Thus soil formation has only been under way in the last few hundred years since the reclamation of these shallow lakes. Only some of the marine sediments have been exposed for more than a thousand years, and surfaces of Roman age occur only locally, while older surfaces (late-Neolithic) are even rarer.

In the fluvial district nearly all superficial deposits predate the construction of the artificial levees (between 1000 and 1300 A.D.). Few predate Roman times; but in those that do there is evidence of progressive soil formation, not only decalcification but also translocation of clay.

The upper part of the sediments in the Pleistocene district of the country consists of cover sands, an aeolian sediment from late-Weichsel ice age (British equivalent: Devensian). The oldest cover sands date from 10 000 B.C., in many places the superficial sands are somewhat younger, locally from the boundary between Pleistocene and Holocene (8000 B.C.).

The sediments forming the coarse-textured hills in central Netherlands, are mostly Rhine sediments from the pre-Saale interglacial period, the Holsteinien (British equivalent: Wolstonian). The glacial till in the north of the country also dates from the Saale ice age. Due to erosion and solifluction in the tundra climate of the Weichselien the actual surface of these sediments is much younger than the age of the sediments themselves: it is also about 10 000 to 12 000 years old.

The loess in the south of The Netherlands is mostly as old as the older cover sands, namely dating from about 10 000 B.C.

Topography

Broadly speaking, The Netherlands slopes from the southeast to the north-west (Fig. 2), the highest point (321 m above sea level) being near the meeting point of the boundaries of The Netherlands, Belgium and the Federal Republic of Germany; the lowest point is just north of Rotterdam, and is 6.6 m below sea level on the bottom of a reclaimed lake. The coastal dunes generally are between 10 and 30 m above sea level, the highest point being 56 m.

There are two irregularities in this general pattern: the hills in the centre of the country (highest point 103 m, north of Arnhem), and the 'holes' in the west of the country, scattered areas below the minus 2.5 m contour. The hills were formed by the Scandinavian ice sheet that pushed coarse sediments into low hills in the Saale ice age; the holes are reclaimed lakes, initiated by peat cutting, the larger areas

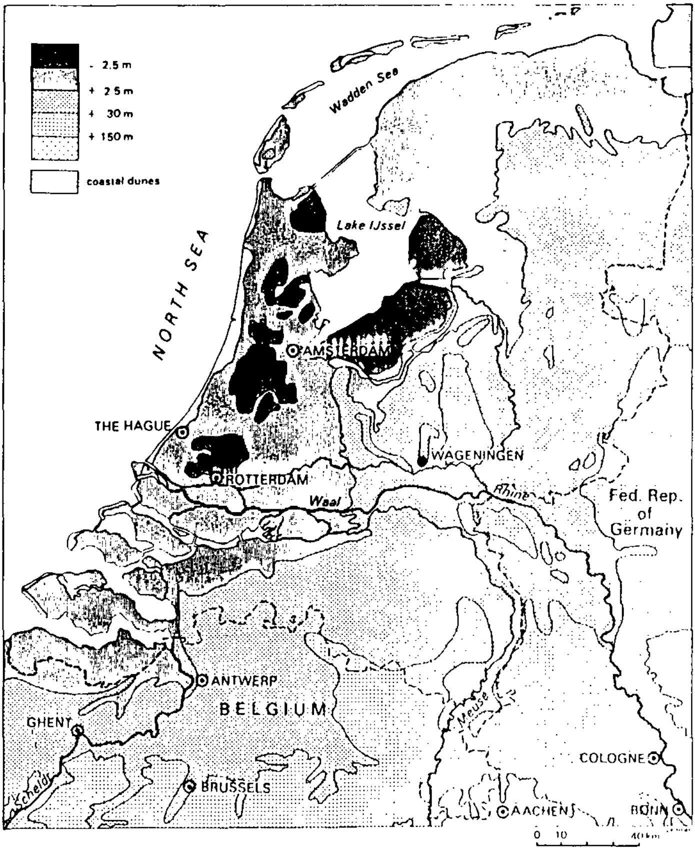

Fig. 2 Contour map (below or above sea level) of The Netherlands and the adjacent parts of Belgium and the Federal Republic of Germany (from De Bakker, 1979).

below sea level are the Zuyderzee Polders (both shown on excursion H).

The general relief is mainly explained by the geological situation of The Netherlands: it forms a part of a large depression that is gradually sinking and being infilled with Quaternary sediments.

Far more important for pedology (and for agriculture) are the small differences in elevation above the gently sloping ground-water table. The soil-forming factor 'relief' or 'topography' could better be replaced by 'depth to ground water' in The Netherlands.

Most subsoils of Dutch soils are moderately to rapidly permeable, and the water in the saturated zone can be characterized as Grundwasser (free ground water) and not as Staunässe (excess surface wetness). This is an important distinction made in the German and British systems of soil classification.

The ground-water table fluctuates in the course of the year; even in artificially drained soils this fluctuation may be between 90 and 130 cm the depth of the fluctuating ground water varies between just below ground level and a depth of several metres. This phenomenon is classified in seven 'water-table classes'. The definitions of these classes are based on the depths of the mean highest (MHW) and mean lowest water (MLW) tables (Van Heesen, 1970). On modern Dutch soil maps all mapping units are annotated according to soil and ground-water class. Only about 10% of the Dutch soils have the MLW deeper than 2 m.

Biotic factors

Animals

In the Department of Soil Science and Geology of the Wageningen Agricultural University some research has been done on burrowing animals, such as earthworms and moles, which have obviously been active in the well-drained calcareous fluviatile soil B-NL9. The process whereby these animals cause the gradual disappearance of soil lamination has been labelled 'homogenization'.

Vegetation.

In the Netherlands there is hardly any 'natural' vegetation, only some semi-natural and near-natural vegetations. The latter are only found in those areas called 'waste lands' in the introductory section to this contribution; these occupy 5% of the country.

The climatic climax vegetation on the mineral soils and the eutrophic organic soils must have been a forest, with alder, ash, beech, birch, elm, hornbeam, oak and willow in different combinations and with different undergrowth, depending on the site (rich or poor, calcareous or acid, waterlogged or well drained, or subject to flooding with fresh, brackish or saline water); on the oligotrophic raised bogs the natural vegetation was a treeless wilderness with peat mosses predominating.

However, many soils never had a forest vegetation before being used for agriculture; some never had a vegetation at all. All the coastal polders (De Bakker and Kooistra, 1982) that were enclosed and drained were reclaimed partly from saltings supporting a vegetation of salt-tolerant grasses and herbs (soils B-NL3 and 4) and partly from bare tidal mud flats. The Zuyder Zee Polders were reclaimed from the sea bottom (soils H-NL3 and 4), and only a few years supported a reed vegetation that had been sown deliberately to accelerate the ripening of the mud (Pons and Zonneveld, 1965). The hypothetical climax vegetation on these fertile, calcareous, well-drained polder soils would probably be an ash/elm forest.

Other soils, such as the base-rich well-drained soils of the natural levees in the fluviatile district (soil B-NL9) carried some kind of ash/elm forest before reclamation, but there are no records or relics of such forests, for they have disappeared more than a thousand years ago.

The Pleistocene district must have known the whole vegetational sequence after the tundra vegetation, followed by hazel, oak and alder and later the beech and hornbeam and the arrival of cultivated plants and their accompanying weeds, indicating the start of man's agricultural activities.

Every treatise on vegetation as a soil-forming factor in the Pleistocene district in northwestern Europe has to take into account that vegetation has changed considerably since soil-formation time zero (roughly 10 000 to 12 000 years ago).

An important change in vegetation in the Pleistocene district is the gradual transformation of the forests on the poor sands into heathlands. This started about 5000 years ago and it is assumed that Neolithic people induced this change by felling the trees for timber and for fuel and then burning and grazing the vegetation on soils that had a low potential for forest regeneration.

Man.

In the densely populated Netherlands (14.3 million inhabitants, i.e. about 420 inhabitants per km^2) human influence is an important soil-forming factor. When using the old saying 'God created the earth, but the Dutch made their own country', most people point to the polders, particularly to the Zuyder Zee Polders. However, there are other soils modified and reshaped by man, e.g. the plaggen soil (soil B-NL7).

Not only soil morphology but also soil fertility has been changed by man. As the result of the heavy application of fertilizers (see section 'Soil Fertility and Soil Testing in The Netherlands') the chemical fertility of Dutch soils is generally high, even of soils that were orginally poor or acid. The fertility of the same kind of soil may differ depending on the kind of land use and the skill of the farmer or horticulturist.

To give an idea bout the intensive Dutch agriculture some statistical data are given below. There are 5516 thousand cattle in The Netherland, of which 2549 thousand are dairy cows (= 1.89 cows per ha of grassland and fodder crops): the dairy cows produced 12 415 million kg of milk in 1983. Three quarters of the consumption of nitogen fertilizers is used on grassland, which occupies 61% of the agricultural land. The increasing application of fertilizers and other agricultural improvements has considerably increased crop yields. In 1984 the average yield of winter wheat was 7900 kg/ha, of potatoes 42 700 kg/ha and of sugar beet 54 000 kg/ha. The growers of vegetables and flowers are organized in auction societies. All their produce has to be marketed in central auction buildings. In 1984 2192 million kf of vegetables were auctioned, worth Dfl 3038 million; and in the same year the turnover all flower auctions was Dfl 3031 million.

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SOME INFORMATION ABOUT ITC

Aerospace survey as a source of geo-based information

Aerospace survey of the earth's surface by remote sensing is an efficient method of obtaining reliable information on the topography of an area, the availability and status of its natural recources and the degree to which the environment has been modified by human activity. The term "remote sensing" includes both conventional photographic and non-photographic techniques of data collection-especially electro-optical sensing in a wider spectral range than the optical wavelengths in which conventiional photography operates.

ITC has always given much attention to the use of aerial photographs for deriving information on the natural environment and its recources. Increasing emphasis has been placed in recent years on similar applications of data derived from satellites, including the use of multispectral and thermal infrared scanning, radar and other data acquisition techniques.

ITC's educational programme deals with the various forms of information which aerial photographs and remote sensing data provide, differentitating in general between geometric and thematic approaches.

Photogrammetry courses are directed to the production of general topographic maps as well as large scale special purpose maps.

Thematic information is obtained by photo or image interpretation, it is one of the tools that can be applied to a variety of disciplines using geologic, geomorphologic, soil scientific, agricultural and forestry interpretation to provide data which have great importance for economic development.

The Institute also gives courses on the production of aerial photographs-from flying and navigation using ITC's own airplane, to taking the photographs and processing them in well equipped laboratories.

In the past, surveys often tended to be isolated academic exercises, the results of which were of limited relevance for development planning. The recognition, analysis and evaluation of this problem led to the formulation of a number of training programmes for more efficient organization, management and data presentation better fitted to the information requirements for development planning. The target groups of these training programmes are surveyors, planners and decision-makers.

History of the Institute

As a Dutch contribution to international development cooperation and in response to a United Nations recommendation, Professor Willem Schermerhorn, a noted photogrammetrist, founded the Institute in 1951. Its original name was "The International Training Centre for Aerial Survey (ITC)". For con-

venience, the traditional abbreviation "ITC" has been retained.
Nearly 7000 graduates of some 145 nationalities have attended the 50 different courses at ITC. The student capacity is approximately 400 per year. There are 250 employees, almost half of whom are academic staff.

Aims

The Institute aims at providing mainly post-graduate education and carrying out research and consulting in the applications of aerial photography and other remote sensing techniques. The education system is international and intended primarily for participants from developing countries.
Within ITC's research programmes, it will become possible, starting in 1985, for interested scientists (who will preferably be ITC MSc degree holders or possess equivalent qualifications from an internationally recognized university) to apply for PhD degree programmes. Consulting tasks include advising on the set-up of production organizations for aerial photography and mapping; support for development of education facilities for aerial survey techniques and applications in educational institutions in developing countries; assistance during planning, design, implementation and control of surveys for specific projects. In the period 1958-1984, ITC was involved in 250 consulting projects in 60 countries-all over the world. ITC has supported the establishment of affiliated institutes in developing countries, including the following: Colombia, India, Indonesia and Nigeria.

Courses

All courses are given in English; some photogrammetry courses are also given in French in even numbered years. In many cases, the exact duration of courses cannot be stated because the educational system at ITC is such that it can be adapted to the individual needs of each student. The educational background, age and practical experience of applicants from all over the world may differ substantially; some may be able to complete their studies in the minimum period indicated, but others may need longer.
ITC's study system is based on a combination of lectures and exercises, ie, both theory and practical training. Most course curricula include field work or study trips of two to six weeks duration.
Detailed and specific information on each course is contained in brochures which will be provided on request.

ITC Journal

The institute publishes a quarterly journal which is distributed free to alumni and also to survey organizations in the developing countries. With a circulation of 4800 in 145 countries, it is one of the largest journals in the world dealing with earth science applications of aerospace surveys.

SOIL FERTILITY AND SOIL TESTING IN THE NETHERLANDS

The Institute for Soil Fertility (Haren, Gr.)

Established in 1890 as a State Agricultural Experiment Station in Groningen, the Institute for Soil Fertility (IB) conducts research on soils and plant nutrition for field crops and grassland an for horticulture. The research is aimed at the study of the relation between the soil and the growth of agricultural crops, trees, and other types of vegetation; further, the consequences of the effects of human activities on the soil as a natural resource are studied. The concept "soil" is broadly defined to include artificial substrates. The research is approached from different angles:

Soil biology
Relation between farming systems and biological soil fertility and soil quality; the consequences of the use of biocides and other "xenobiotic" compounds for the soil ecosystem, and the biological decomposition of such compounds; biological waste disposal; the potential of the soil's microbial population to control soil-borne plant pathogens.

Soil physics
Significance of soil physical factors, as temperature, texture, structure, transport potential of water, gases, heat, nutrients and contaminants, for yield and quality of agricultural crops.

Soil chemistry
Various factors and processes that determine the uptake of plant nutrients, heavy metals, and organic pollutants by crops, and their effects of the biological activity, structure, and long-term quality of the soil.

Fertilization
The importance and efficiency of organic and inorganic fertilizers and waste products in relation to yield and quality of agricultural and horticultural crops; their short-term and long-term effects on soil properties and productivity.

Plant nutrition
The relation between soil properties and plant growth; development and functioning of plant roots; this research is conducted in collaboration with that on soil biology, soil physics, soil chemistry and fertilizer research.
In recent years, the Institute has further developed its ties with agricultural research institutes in developing countries. It has committed more than 5% of its own budget to joint research activities with institutes in Nigeria and Indonesia, and on consultancy and training.
With its scientific and technical staff of 170, the Institute is able to conduct a diverse research program. It is well-equipped for soil, plant and water analysis, and for field and greenhouse trials. Its facilities include two experimental farms (17 and 38 ha), a workshop, computer centre and library.

Laboratory for Soil and Crop Testing (BLGG)

This laboratory is the largest organization of its kind in the country and perhaps in the world, originally came into being as a scion of the old Agricultural Experiment Station in Groningen, now the Institute for Soil Fertillity. In 1927 it was taken over by the combined farmers 'and market gardeners' organizations; representatives of these organizations now constitute the Management Board. The laboratory later moved to Oosterbeek near Arnhem.
The laboratory, which has a staff of more than 200, annually processes a total of more than 300,000 samples (soil, crop, manure, sewage sludge, water, feeds, fertilizers) in which some 250 different determinations (including nematode counts) are made, mainly as a basis for recommendations to growers. The samples are taken by about 60 fieldmen, who operate in their own regions. To process the tremendous amount of data, computers are used, which also issue fertilizer recommendations based on the results of soil analysis.
Although the laboratory is an independant organization, it maintains close contacts with a number of research institutes, specialists groups and coordinating committees. The fertilizer recommendations, although issued to the grower by the laboratory, are the responsibility of the State Advisory Service which, in turn, is guided by committees whose membership includes the Institute for Soil Fertility. This institute keeps itself informed of developments in soil analysis at home and abroad and evaluates new methods.

Participants in excursions B and H will receive, on the spot, soil fertility data and fertilizer recommendations pertaining to the soil types and/or regions that will be visited.

CLAY MINERALOGY OF HOLOCENE SEDIMENTS IN THE NETHERLANDS

The holocene fluviatile and marine soils cover about 9 and 33%, respectively, of the country. The fluviatile deposits have been transported by the Rhine and , to a smaller extent, by the Meuse. The river sediment has been formerly characterized as an illitic clay. However, besides illite the clay fraction has also appreciable amounts of vermiculite and/or smectite. Following AIPEA-nomenclature the river clays are now identified as an illite-vermiculite-smectite complex and the marine clays as an illite-smectite complex. The occurrence of vermiculite differentiates the fluviatile clays from the marine clays (Table 1). This mineral accounts for the high K-fixation by the fluviatile clays and also for the higher cation exchange capacity. The smectite minerals in both clays are in fact interstratified illite-smectites as shown by studies of the fine clay fraction (0,04 μm). The percentage of expandable layers is usually less for the river clays, and the K-content somewhat higher.

Table 1 Major differences between the clay fractions of the most recent fluviatile and marine sediments.

sediment	colour (aerated soil)	K-fix	CEC mmol(+)g^{-1}	K_2O	vermiculite	smectite interlayering (% exp. layers)
				——— % ———		
fluviatile	10 YR	high	0,50	3,5	10-15	30
marine	2,5 Y	low	0,45	3,2	< 5	50

The differentiation between fluviatile and marine soils is important for agriculture in relation to soil fertility. The K-fixation is now being used by the Dutch Soil Survey as a differentiating criterion in addition to colour, texture and sedimentation pattern.

General information

Cut-over raised bog soils cover an area of about 100 000 ha in the northeast of the Netherlands. The greatest part (about 70 000 ha) occurs as a coherent area in the provinces of Groningen and Drenthe. Further south some smaller areas are found in the provinces of Drenthe and northeast Overijssel. The excursion passes through one of these, the Vroomshoop - Vriezenveen area, and visits the raised bog area between Hoogeveen, Dedemsvaart and Coevorden. With exception of the Vroomshoop - Vriezenveen area the cut-over raised bog soils are used for arable farming. The crop rotation on these soils comprises potatoes for starch production (50%), sugar-beet, small grains and silage maize.

During the Holocene the raised bogs were formed in depressions in light undulating deposits of wind blown 'old cover sands' surrounded by cover sand ridges. About 3000 years BC the peat layer had grown so thick that the peat formation became dependent on rain water and Sphagnum became the most important peat forming organism. From 2000 BC the Sphagnum peat spread over the surrounding higher mineral soils and became ever more oligotrophic.

The thick peat layers were an attractive source of energy. Already in the twelfth century sporadic peat-harvesting took place along the higher sand ridges. In the seventeenth century a more systematic peat-harvesting and reclamation started. For the transport of dried peat by ship main canals were excavated. In the excursion area these are the Dedemsvaart from Coevorden to Hasselt and the Hoogeveense Vaart from Klazienaveen to Meppel, both running in east-west direction. In the reclamation areas a regular system of mutually perpendicular water courses was constructed, consisting of main canals and smaller laterals, the so-called 'wijken'. The latter mostly have mutual distances of 150 to 200 m. Fig. 1 shows an example of such pattern with the approximate years of construction for a part of the Groningen-Drenthe cut-over peat soil region (VAN BAKEL, 1986).

The reclamation of the area was closely related with the peat harvesting (BOOIJ, 1956). Excavation of a new 'wijk' started with harvesting a strip of peat with the width of the planned canal. The next year a parallel strip was harvested to create a dumping place for the sand from the canal to be excavated. Between the 'wijken' every year a strip of peat was harvested. The upper 0.5 m of white loose peat ('bolster') which was not very suitable for fuel was dumped in the previously excavated pit. After completion of the peat harvesting, the area was levelled and the sand depot along the 'wijk' was spread over the field. For drainage purposes a main ditch called 'zwetsloot' was excavated midway between the 'wijken'.

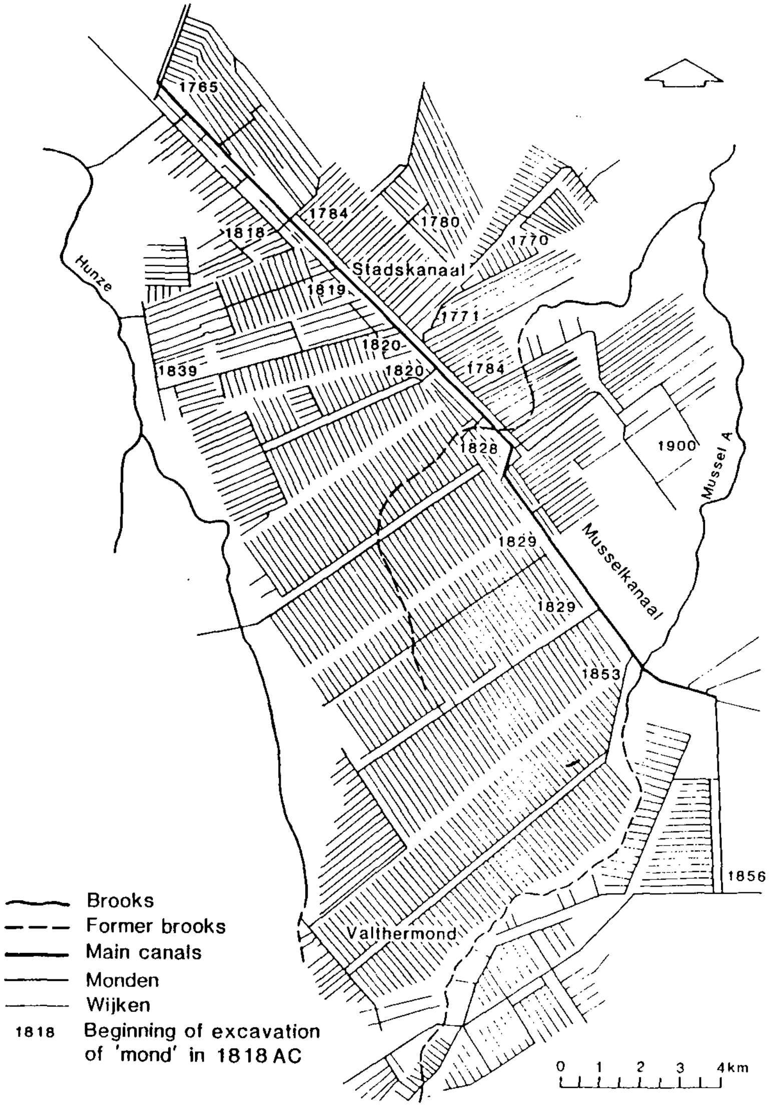


Fig. 1. Pattern of main and secondary canals in the reclaimed Groningen - Drenthe cut-over raised bog region (after: Van Bakel, 1986)

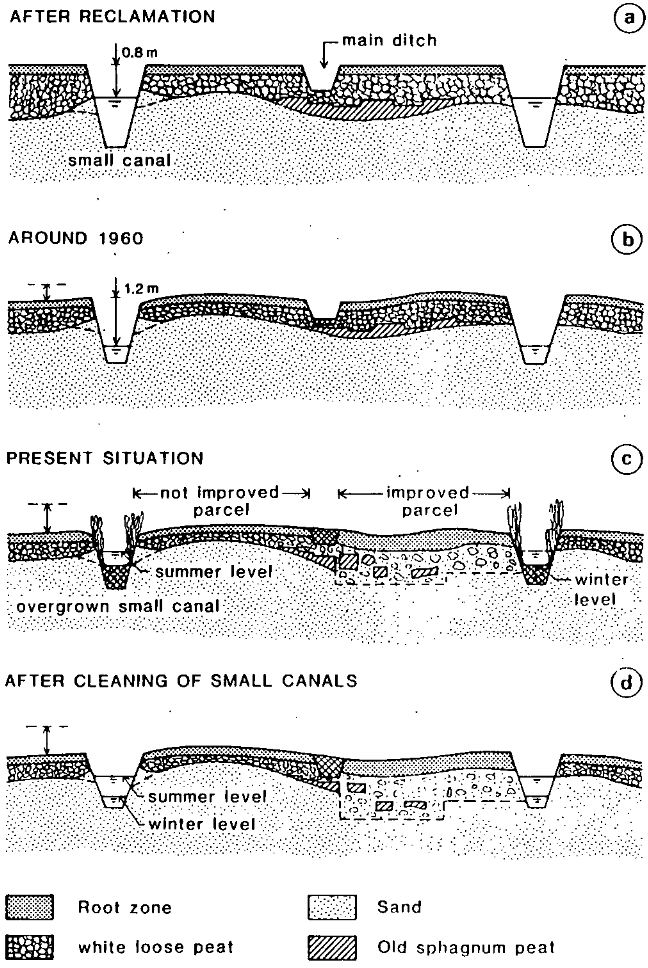


Fig. 2. Schematic presentation of development stages in the water management situation (after Van Bakel, 1986)

The system of main canals and small canals ('wijken') excavated for the peat harvesting was very suitable for the discharge of drainage water from main ditches and field ditches. Besides these watercourses themselves had a drainage function. Due to the loss of organic matter in the topsoil and subsidence of peat layers in the subsoil the soil surface became uneven and the drainage situation deteriorated (Fig. 2a, VAN BAKEL, 1986).

Till about 1960 the transport of agricultural products took place by ship, so high water levels in the canals were needed. Therefore farmers started to dam off the small canals in order to create a lower open-water level during periods without transport.

In the beginning of the sixties road transport became common in the area and so the water level could be lowered in all canals (Fig. 2b). Next for mechanization purposes the small field ditches and some of the main ditches were filled in by the farmers.

Maintaining a low water level throughout the year caused, however, a shortage of water during dry periods in summer. In order to prevent this shortage, at least partially, the water level should be raised in spring before the end of the period with a rainfall surplus, in order to conserve water. In dry growing seasons, however, this water conservation is insufficient to meet evaporation demands. To overcome this problem soil improvement and additional water supply are needed. By maintaining a high open-water level during the whole growing season, subsurface irrigation occurs (Fig. 2c).

To improve conditions a new type of water management was required consisting of a combined system of drainage, water conservation and sub-irrigation. In some areas of the cut-over peat soil regions this was realized by constructing a number of new weirs and inlet structures. To manipulate open-water levels weirs were made adjustable with a capacity of about 0.3 $l \cdot s^{-1} \cdot ha^{-1}$ (2.5 $mm \cdot d^{-1}$).

Soil improvement

The soil obtained after reclamation consists generally of three layers. A 10 to 25 cm thick top layer of humous (>10%) sand (pH(KCl): 5.0 to 5.2) overlying a peat layer of a thickness varying between 0 to >200 cm. The larger part of the sandy bog floor has podzols, with in the depressions gley soils. Within this general profile type four main groups can be classified:

- deep peat soils. These soils have more than 40 cm peaty material (>15% organic matter) between 0.0 and 0.8 m and the upper boundary of the sandy subsoil is more than 1.2 m below soil surface. Soil profiles of this group are situated in the depressions between sand ridges;
- moderately deep peat soils. As above, but with the upper boundary of the sandy subsoil within 1.2 m below soil surface. These soils are found in places with a relatively higher elevation of the sandy subsoil;
- peaty soils. The thickness of the peaty layer is less than 0.4 m. Most of the soils of the reclaimed peat area below to this group;
- sandy soils. The thickness of the peaty layer in this soil type is smaller than 0.05 à 0.15 m. The geographical position coincides in general with sand ridges.

The cut-over raised bog soils have two main shortcomings. Firstly, the acid peat layer mostly is unaccessible to plant roots (the pH varies between 2.7 and 3.7). A pH-value of 3.5 is prohibitive for root growth (WIND, 1967). Moreover the peat is often poorly aerated due to a great density of the peat in the presence of high moisture contents. Therefore the plant roots are confined to the thin top layer and drought damage occurs

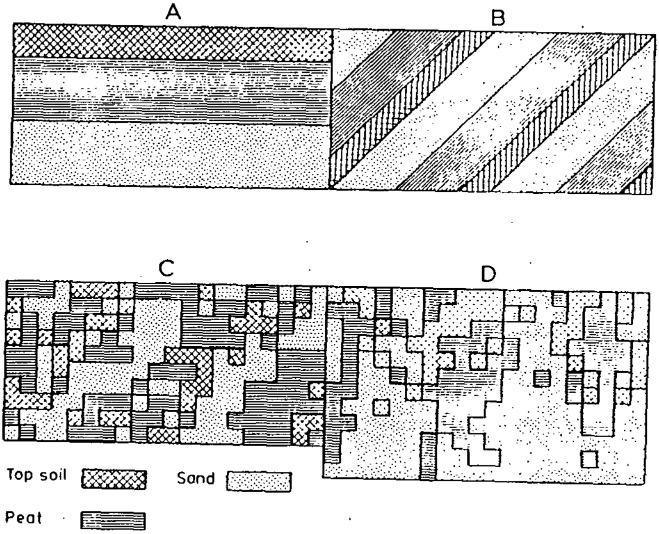


Fig. 3. Outline of the distribution of soil material in some mixed profiles of cut-over peat soils (after Wind and Pot, 1976)

A = original profile
B = regular and proportional, made by a steam-plow
C = irregular and proportional, made by a more modern plow
D = irregular and conservative, made by a mixing-rooter

frequently. Available water amounts to about 70 mm, while 150 mm is required to cover the mean evapotranspiration surplus.

The second defect concerns organic-matter contents in the arable layer, too high (>15%) for good bearing capacity.

Rooting depth can be increased as well as the organic matter content in too humous sandy top layers can be lowered by mixing the three layers of the soil. To prevent wind erosion and to assure good working conditions an organic-matter content in the top layer of 10 to 15% is pursued. A third effect of this mixing operation is the loosening of the upmost part of the sandy subsoil, often very poorly permeable and therefore cause of high water tables in wet periods due to stagnant water.

For soil mixing different types of machines have been developed: deep ploughs, rotary mixers, mixing rooters. Nowadays mixing ploughs are mostly applied which combine the relatively low pull power of the deep plough with the adjustable mixing of the mixing rooter. Mixing ploughs having a working depth over 2 meter enable to mix the three soil layers from conservative (>50% of the arable layer remains in the top) to proportional (a homogeneous distribution of the three layers with depth). See Fig. 3. Mixing rooters and ploughs give coarse mixtures which appear to be better than fine mixtures from rotary mixers. The reason for this are chemical

Table 1. Weather and extra yields obtained by deep ploughing in Borgercompagnie (Wind and Pot, 1976)

Year	Rainfall - evaporation ($N - 0.8E_o$) in mm							Extra yield			
	M	A	M	J	J	A	S	summer wheat 100 kg /ha	oats 100 kg/ha	sugar beet t/ha	potatoes t/ha
1962	+14	+ 6	+10	- 42	-17	+32	+ 29	-	+ 5.2	+ 7.2	+ 6.3
1963	+25	- 8	-18	- 60	-23	+58	+ 16	-	+10.6	+ 6.8	+ 0.4
1964	+10	-15	-61	- 35	-37	- 2	- 10	+ 9.0	+12.0	+ 1.8	+ 6.7
1965	+10	+19	+26	+ 36	+71	-19	- 7	-	- 4.4	+ 1.2	+ 1.9
1966	+24	+24	-34	- 35	+27	-18	+ 15	+ 2.3	+ 4.8	-	+ 3.9
1967	+21	+ 7	+ 1	- 54	-34	+ 1	+ 36	+ 6.7	+ 6.1	+ 1.3	+ 3.9
1968	+ 3	-28	+22	+ 16	-11	- 8	-154	+ 2.2	- 2.8	+ 0.5	+ 6.6
1969	+ 5	+13	+16	- 57	-24	+72	- 68	+ 0.8	+ 7.9	+11.2	+ 3.2
1970	+41	+44	-66	-111	+60	-43	+ 19	+22.5	+ 9.8	+ 4.2	+ 4.6
1971	+ 3	-41	-59	+ 10	-54	+ 8	- 24	+ 4.4	+ 6.6	+ 1.0	+12.0
1972	+ 9	+22	+18	- 47	+14	+29	+ 13	+ 1.6	+ 4.8	+ 7.0	- 0.8
1973	+ 5	+ 2	- 4	- 75	+10	-43	+ 7	- 3.4	+ 5.0	+12.8	+ 3.0
1974	+10	-59	-36	- 54	+26	-21	+ 61	+ 1.0	+ 6.8	+ 3.6	+ 8.8
1975	+18	+28	-18	- 49	-35	-74	+ 22	- 1.8	+ 7.4	+12.4	-

alterations of the peat much more intensively distributed through the sand, what immobilize much nitrogen during many years.

The improvement of the cut-over raised bog soils is very profitable and is applied over great areas. Table 1 shows results of long-year field experiments. The extra yield obtained by soil improvement depends on rainfall (N) and evaporation (E_o) during summer. For small grains soil improvement has the same effect as irrigation has, such as appears from combined soil improvement and sprinkling irrigation experiments. In that way soil improvement can be an alternative for irrigation. Extra yields of sugar beet and potatoes did not show that relation. Some other factors, not known until now, will be responsible. The rainfall in April seems to be important (WIND and POT, 1976).

Rural reconstruction of the Groningen - Drenthe cut-over peat soil region

About five years ago reconstruction works started in the Groningen - Drenthe raised bog region, covering an area of about 70 000 ha. This reconstruction improves living and working conditions for the rural population and stimulates the economic and social development of the whole area.

For realizing this objective following measures and provisions will be carried out co-ordinated and if possible integrated:

- improvement of the infrastructure and the agricultural structure;
- re-allotment of the real estate;
- the dissolving of the Groningen municipality rights;
- delegation of roads and canals, owned by the municipality of Groningen but situated outside its boundaries;

- making provisions in behalf of the landscape and the open-air recreation;
- saving and development of nature areas and cultural - historical elements;
- drafting and executing of a social - cultural plan;
- contributing to completion or reconstruction of the centres of towns and villages;
- demolition or renewal of old cottages and low-standard dwellings and (financial) contribution in this;
- making provisions in the public interest for discharge and treatment of waste water.

The execution of the reconstruction program lies in hands of the Reconstruction Committee. Members of this committee are representatives of the two provinces of Groningen and Drenthe, 30 municipalities, farmers organizations, the polder boards, the chambers of commerce, the trade unions, environmental organizations and socio-cultural institutions. The reconstruction will take about 20 years. The total costs, estimated at 2.6 x 10^9 Dfl. will be borne by the Dutch government (2/3), and provinces, the municipalities, polder boards and private persons.

Description of the excursion route

The province of Overijssel (1 000 000 inhabitants) consists of an area of 340 000 ha, from which 250 000 ha is cultivated land. In this province 54 reallotments (103 400 ha) have been executed, among which along the excursion route the areas Wierden, Vriezenveen, Vroomshoop, Hardenberg-Oost and Vollenhove (see excursion map). At the moment there are 11 reallotments in execution (51 800 ha) among which the areas Weerselo-Dulder, Daarle-Hellendoorn, Stegeren, Dedemsvaart-Noord and Giethoorn-Wanneperveen. Ten reallotments (37 900 ha) are in the stage of preparation, among which the areas Saasveld-Gammelte and Rouveen. Yearly the Government Service for Land and Water Use invests between 25-30 million of guilders in land development projects in Overijssel.

In 1984 the following investments have taken place:

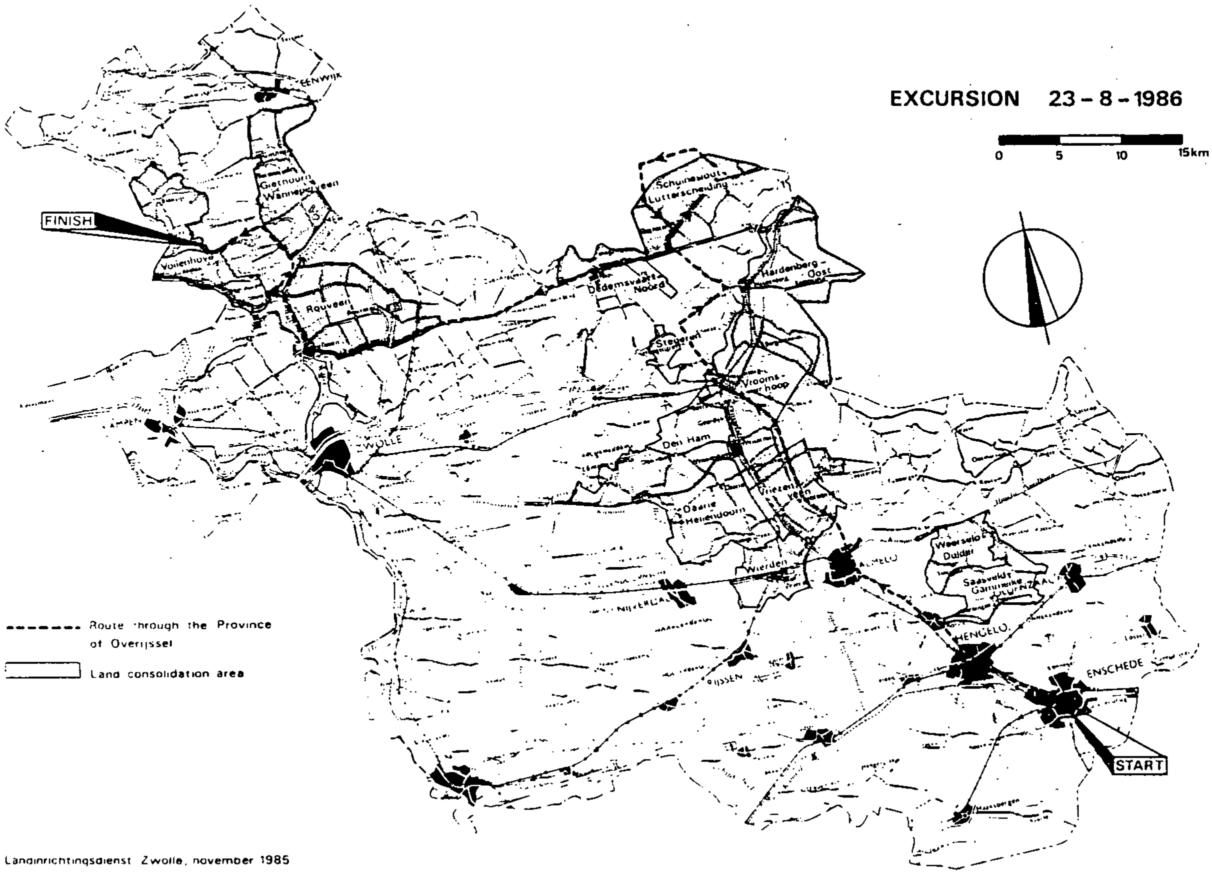
- accessibility (roads)	ƒ 8.7 million
- water control	ƒ 8.0 million
- land forming	ƒ 3.4 million
- recreation	ƒ 2.1 million
- landscape and nature	ƒ 1.4 million
- various (farm buildings)	ƒ 3.6 million
total	ƒ 27.2 million

In Overijssel has been invested in 1984 at about 7% of the annual credit provision for land development projects of the Ministry of Agriculture. In seven of the eleven provinces is more invested in 1984 than in Overijssel.

An average reallotment in Overijssel demands about ƒ 8000/ha investments. After subtraction of all subsidies the land-owners have to pay an amount of ƒ 1500/ha for the improvements. They are allowed to pay back this amount in 26 years at 6% rent and redemption a year.

In the stage of preparation for every reallotment a soil survey will be executed by the Soil Survey Institute by order of the Government Service of Land and Water Use. Among other things there will be made a soil map (scale 1:10 000), a ground-water map and a single-value map. The soil map is one of the most important data in the preparation and the execution of land development projects. Soil improvement areas can be located as well as areas where drainage has to take place. On the execution the soil map will be used for the evaluation of the agricultural land. For each soil type farmers estimate the value against which the lots can be exchanged in the allocation plan.

From beginning to end of the route through Overijssel different soils can be met. From Enschede to Almelo we see sandy soils: plaggensoils, gleysoils and podzols. Especially on the plaggensoils silage-maize will be grown; the gleysoils are used as grassland. The podzols are used as grassland as well as for silage-maize. This depends also on the level of the groundwater. From the areas Vriezenveen up to Dedemsvaart-Noord we see peat soils, with sandy soils in the neighbourhood of Hardenberg. The peat soils (cut-over raised bog) are in use as arable land (starch potatoes) and as grassland. From the areas Dedemsvaart-Noord to Rouveen we see also sandy soils. The western part of Rouveen consists of peat soils, just as the area Giethoorn-Wanneperveen. These soils are used as grassland. A part of the area of Vollenhove consists of loamy sandy soils on gravel loam (glacial till). These soils are mainly in use as grassland.


EXCURSION 23 - 8 - 1986
0 5 10 15km
FINISH
START
Giethoorn
Wanneperveen
Vollenhove
Rouveen
ZWOLLE
Schuinesloot
Lutterscheiding
Dedemsvaart Noord
Hardenberg - Oost
Steenwijk
Vroomshoop
Den Ham
Vriezenveen
Daarle
Hellendoorn
Wierden
ALMELO
Weerselo
Dulder
Saasveld
Gammelke
HENGELO
ENSCHEDE
RIJSSEN
NIJVERDAL
Route through the Province of Overijssel
Land consolidation area
Landinrichtingsdienst Zwolle, november 1985

Stop 1, soils H-NL1 and 2

Site description

Location	: Elim/De Krim, on the boundary of the Drenthe and Overijssel provinces H-NL1 236.870 W/E - 521.140 S/N H-NL2 236.825 W/E - 521/070 S/N
Parent material	: Humose sand (topsoil, man-made), overlying a thin layer of disturbed, oligotrophic peat, overlying coversand from the Weichsel Age with a buried podzol (soil H-NL1) Same material, but disturbed by subsoiling (soil H-NL2)
Topography	: Level
Elevation	: About 11 m above sea level
Drainage	: Drained by narrow canals and ditches, spaced 100 m apart, the fields are tile-drained about 15 m apart
Ground-water level	: Fluctuating between 20 and 140 cm depth (soil H-NL1) Fluctuating between 120 and 140 cm depth (soil H-NL2)
Land use (in 1985)	: Sugar-beet (soil H-NL1), silage maize (soil H-NL2)
Range in land use	: The most important crop is starch potatoes, followed by sugar-beet, silage maize and small grains, some crops for canneries like carrot, beans and peas

Profile description (soil H-NL1)

1Ap	0- 15 cm	Black (10YR2/1) wet and moist; dark grey (10YR4/1) dry; loamy fine sand, mixed with peat-particles, non sticky, loose moist, loose dry; abrupt, smooth boundary
2Hp	15- 25 cm	Dark reddish brown (5YR3/3) wet and moist; reddish yellow (7.5YR6/6) dry; oligotrophic-peat; by peat-digging disturbed young Sphagnum-peat (Sph-papilosum/Sph-imbricatum), mixed with some parts of old-Sphagnum peat (Sph-rubellum), cotton-gras (Eriop-vaginatum) and waterlavender (Scheuchzeria palustris)-peat; mostly spongy material, abrupt smooth boundary
3Ob	25- 35 cm	Black (N2) wet, moist and dry; mucky oligotrophic peat; the original sod of the buried podzol, filled with amorphous organic material seeped from the peat-topsoil, (organic B-horizon), mostly in small vertical rootspots of Molinia coerulea); sticky (greasy), very friable, hard; local covered with a thin layer of very fine stratified peat (Sphagnum-cuspidatum and Scheuchzeria-palustris, smooth boundary

3ALb	35- 50 cm	Very dark greyish brown (10YR3/2) wet; dark greyish brown (10YR4/2) moist; greyish brown, (10YR5/2) dry; fine sand; non sticky, loose moist, loose dry, moderate bleacked, vertical speckled with some fossil roots of Molinia-coerulea; speckles filled with weak amorphous organic material; clear, smooth boundary
3Eb	50- 65 cm	Grey (5YR5/1.5) wet; greyish brown (10YR5/2) moist light brownish grey (10YR6/2) dry, fine sand; non sticky, loose moist, loose dry; bleached vertically mottled with some fossil roots of Molinia coerulea; abrupt, smooth boundary
3Bhb1	65- 90 cm	Dark brown (7.5YR3/3) wet and moist; brown (7.5YR4/3) dry, loamy fine sand, non sticky (wet), compact (moist), hard (dry) hardened by coatings of amorphous organic matter, with common, very dark brown (7.5YR2/2), distinct, coarse mottles (old root system of Betulya); clear, smooth boundary
3Bhb2	90-120 cm	Dark brown (7.5YR3/2) wet and moist, and (7.5YR4/2) dry, fine sand; non sticky (wet) in situ extremely compact (moist), in situ extremely hard (dry); when removed it falls by heavy pressure apart in thin, horizontal stratified layers; hardened by coatings of relative very young amorphous organic matter which not belongs to the buried podzol; few cracks are filled with weak black amorphous humus (dopplerite); abrupt, smooth boundary Nota bene: This 3Bhb2 is formed in the BCb-horizon of the original podzol
3Cb	>120 cm	Yellowish brown (10YR5/4) wet and moist and (10YR5/6) dry loamy fine sand; non sticky very loose moist, very loose dry, uncoated sand
		All horizons are non-calcareous and practically ironless

Profile description (soil H-NL2)

This mixed soil cannot be described in the usual way. Before subsoiling in 1984 it probably had the same morphology as soil H-NL1. The original plough layer got some admixture of the subsurface peat layer and of the sandy bog floor. Six samples taken over a distance of 130 cm showed an average o.m. content of 26%, but a variation between 7 and 41%. The subsurface peat layer was mixed with the sandy, podzolized material from the bog floor (the soil was mixed to a depth of 115 cm). The mixed layer (20-115 cm) showed fragments of all described horizons from soil H-NL1, the separate lumps of the Bhb2-horizon still are very hard, but most of the material in-between the lumps is friable.

Analytical data

Soil H-NL1

Depth (cm)	Horizon	Bulk density (g/cm^3)	o.m. (%)	p.v. (cm^3/cm^3)	moisture (cm^3/cm^3)	air (cm^3/cm^3)	pH-KCl	Texture (%)						
								<2	2-50	50-105	105-150	150-210	210-300	>300 μm
0- 15	1Ap	0.83	18.9	0.64	0.50	0.15	4.97	0.5	9.0	14.0	22.3	31.0	15.2	7.9
15- 25	2Hp	0.18	82.6	0.89	0.73	0.16	3.27	-	-	-	-	-	-	-
25- 35	3Ob	0.34	57.9	0.82	0.79	0.04	2.94	-	-	-	-	-	-	-
35- 50	3	1.49	2.8	0.43	0.35	0.08	3.31	0	4.9	13.7	22.9	34.4	16.9	7.2
50- 65	3Eb	1.59	1.6	0.39	0.27	0.13	3.40	0	3.8	16.8	25.3	33.2	15.2	5.8
65- 90	3Bhb1	1.65	1.5	0.37	0.26	0.11	3.57	0	6.7	19.4	25.4	30.1	13.1	5.4
90-120	3Bhb2	1.75	1.7	0.34	0.31	0.03	3.99	0	4.8	11.1	18.0	33.0	21.9	11.3
> 120	3Cb	1.74	0.5	0.34	0.29	0.05	4.36	0	4.9	14.3	21.7	34.8	17.3	6.9

Soil H-NL2

Depth (cm)	Horizon	Bulk density (g/cm^3)	o.m. (%)	p.v. (cm^3/cm^3)	moisture (cm^3/cm^3)	air (cm^3/cm^3)	pH-KCl	Texture (%)						
								<2	2-50	50-105	105-150	150-210	210-300	>300 μm
0- 20	1Ap	0.67	26.2	0.70	n.d.	n.d.	3.72	0.2	9.0	11.2	17.9	31.4	18.6	11.8
20- 35	mixed material	-	19.8	-	n.d.	n.d.	3.63	-	-	-	-	-	-	-
35- 50	mixed material	-	7.5	-	n.d.	n.d.	3.52	-	-	-	-	-	-	-
50- 65	mixed material	-	5.3	-	n.d.	n.d.	3.56	-	-	-	-	-	-	-
65- 80	mixed material	-	6.5	-	n.d.	n.d.	3.48	-	-	-	-	-	-	-
80- 95	mixed material	-	4.0	-	n.d.	n.d.	3.48	-	-	-	-	-	-	-
95-110	mixed material	-	2.7	-	n.d.	n.d.	3.80	-	-	-	-	-	-	-

Site interpretation soil H-NL1

Originally this soil was a humic podzol. The peat started to accumulate in a depression with open water. After filling this water with topogeneous, eutrophic peat (a ground-water peat), a topogeneous, mesotrophic peat (so-called fen-wood peat) accumulated. During its upward growth this peat lost contact with the relatively base-rich ground water and changed into a rain-water peat, an ombrogeneous, oligotrophic raised bog with mostly Sphagnum peat. This raised bog spread over the surrounding humic podzols and changed them into gleyic podzols. Eventually the raised bog reached on this site a thickness of more than 3 m.

Nearly a century ago the peat was excavated for fuel, only a thin layer of the original old Sphagnum peat remained, because it was too sandy for fuel. The upper 80 cm of the original bog, a young Sphagnum peat with a low caloric value was returned into the open turbary. Because of its spongy structure this peat layer acts as a 'wick' between the plough layer and the wet subsoil. After excavation of the peat its remnants were covered with about 8 cm of cover sand (spoil from the sandy bog floor out of the canals). By ploughing sand with some peat an homogeneous humic topsoil was formed. In this reclaimed area the village De Krim was founded (named after the Crimean War).

Every year the farmer ploughs some of the peat into the topsoil. This peat partly oxidises and partly becomes amorphous and seeps into the subsoil. By this process the peat layer decreases, in nearly 100 year 80 cm of peat is lost. The peat soil changed into a sandy podzol with an intermediate thin peat layer and a man-made sandy topsoil: the actual soil.

The amorphous organic matter formed in the topsoil accumulated partly in the Ob-horizon of the buried podzol, this is called an 'organic B-horizon' (VAN HEUVELN and DE BAKKER, 1972). Another part illuviated deeper in the subsoil into the Bhb-horizon of the buried podzol and cemented these horizons. These secondary hardened horizons stagnate water transport, both up- and downwards. During dry spells there can be moisture deficit, and after wet periods the crop can 'drown'.

Site interpretation soil H-NL2

Until two years ago this soil was nearly the same as soil H-NL1. It had the same history: peat growth, peat cutting for fuel, topdressing the peat remnants with sand, wastage of the subsurface peat layer and the resulting physical disadvantages.

This soil was subsoiled, the mixture of the soil components improved the suitability: it increased the bearing capacity, thus enabling heavier machinery; enlarged the rooting depth; stretched the margin of the plough, seeding and harvesting time and raised the water capacity. Furthermore the subsoiling decreased the acidity, improved the drainage and reduced the hazard of late-spring frosts.

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SOME INFORMATION ABOUT "NATUURMONUMENTEN" AND "DE WIEDEN"

"Natuurmonumenten"

The Society for the Preservation of Nature Reserves (in Dutch shortly "Natuurmonumenten") is a private society with about 300 000 members, it was founded in 1905.
The main purpose of "Natuurmonumenten" is to purchase and manage nature reserves, today nearly 40 000 ha. "De Wieden" is one of those areas.

"De Wieden"

In the north-west of the Province of Overijssel lies an extensive area made up of lakes, reedlands, fen-scrub and meadows. The district between places such as Blokzijl, Zwartsluis and Wanneperveen is referred to as "de Wieden" (fig. 1).

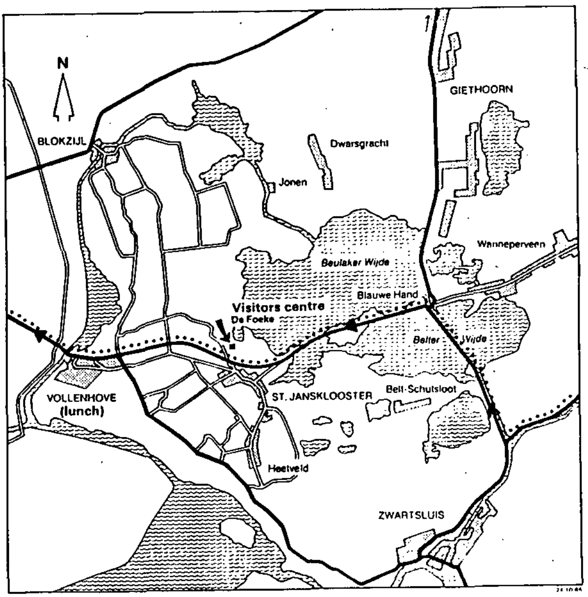


Fig. 1 Surrounding of the nature reserve "De Wieden".

Its comparatively isolated location, far removed from large urban developments has given nature a chance to attain a stage of optimum development in the course of ages. Part of the area owers its existence to the former Zuyder Zee, which flooded the land several times, washing away large sections of the former peat layer (see afternoon programme). Man also dug away large quantities of peat for that matter. For many ages peat-digging provided an economic basis for the area, together with fishing, reed culture and a primitive form of agriculture. Large stretches of open water, separated by narrow strips of land, were formed through the peat-digging operations. In the

course of years, the water between the narrow dikes was overgrown with plants. The successive stages form the so-called land-formation processes. Sometimes, the strips of land were washed away under the influence of wind and water, and the water surface grew larger.
It is due to the widely different growth conditions that the vegetation of "de Wieden" shows such variety. Specific for the land-formation process is the presence of reed, reedmace, the bulrush, the water soldier, the slender sedge, the common sallow, and the alder. A wide variety of herbs, each adapted to its most suitable habitat, can be found in the area as well.
Whoever gets better acquainted with this part of the country will notice that all stages from open water to fen-scrub are present. The varied vegetation is largely due to the influence of man, and this is why human activities like reed-cutting and haymaking are still carried on.
It is only natural that the fauna is largely in keeping with the varied vegetation. Many birds, including heron and cormorant colonies are present in the area. Roedeer are found in the fen-scrub. Other animals include the otter, the bat and a few amphibian species.
The rapidly shrinking peat-digging operations in the first decades of the century, the continuous unemployment, and the necessity of increased agricultural output, soon led to large-scale reclamation plans for the area. In the twenties, reclamation work was taken in hand and prospects were that a large area of natural beauty would be lost forever. In the thirties the Society for the Preservation of Nature Reserves first acquired a few sections of the area, including two decoys. After 1948 the Society acquired several other parts of "de Wieden" in rapid succession. At the moment the Society is the owner of 4000 hectares. As "Staatsbosbeheer" (the State Forestry Department whixh is also engaged in the preservation of nature) owns some 3000 hectares of land elsewhere in the north-west of Overijssel, a -by Dutch standards - large area of natural beauty has been safeguarded. Many plots of land in the area are not yet in the possession of the Society so that an active purchasing policy is still being pursued.

The Wieden area has much to offer to lovers of plants and animals. The area is visited by nature-lovers throughout the year. Part of the area is closed to the public for fear of damage being done to the scenery. In other parts only non-power-driven boats are admitted. A village like Giethoorn is an attractive spot for day-trippers and the number of people buying a cottage in the area for use as a weekendhouse increases every year. All this affects the peace, the quality of the water, and the future development of the area.
Management of the Wieden area ia aimed at preservation of the landscape and at giving nature a change in as many different ways as possible. Measures are being taken to guide recreation activities into the proper channels. Those who want to know more about the Society's work in the Wieden area should visit the visitors' centre "de Foeke", close to the village of St. Jansklooster. Visitors to "de Foeke" can also obtain detailed information about the general activities of the Society.

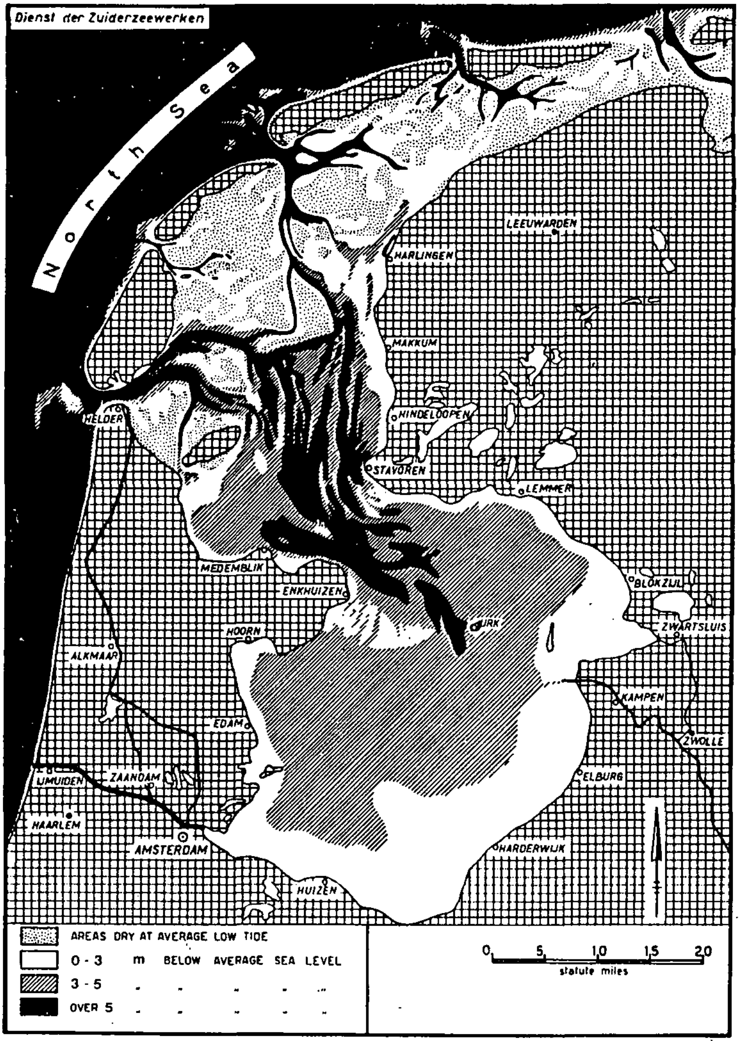
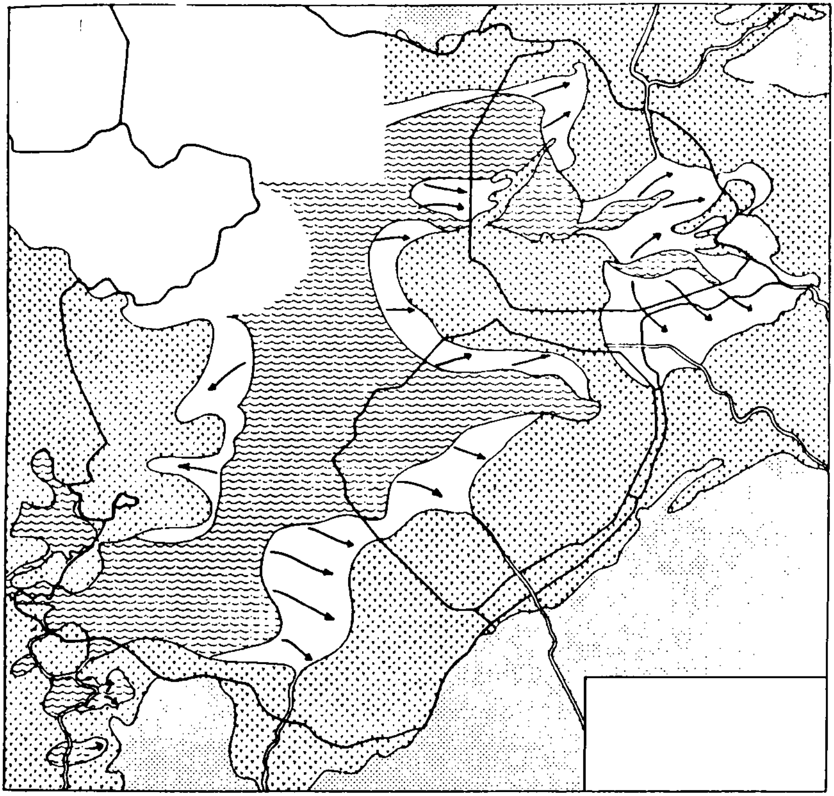


Fig. 1. Depth of the Zuyder Zee before the enclosure



Lakes formed by inroads of the sea into a peat area between 2000 and 1250 B.C.

Peat

Enlargement of the lakes between 1250 B.C. and 0 A.D.

High-lying sand deposits

Fig. 2. The origin of Lake Flevo

THE IJSSELMEER-POLDERS

Area description

The IJsselmeer (Lake Yssel) polders are found on the bottom of the former Zuyder Zee, in the heart of the Netherlands (fig.1).

About 2000 BC this area was part of the large coastal belt of peat overlying Pleistocene sand and, farther west, overlying older Holocene marine deposits.

After that time the North Sea invaded the area from the west-north-west and eroded much peat. The inlet/outlet silted up before 1250 BC and left behind a complex of lakes in which some rivers debouched.
The Romans called this, in course of time enlarged complex of lakes "Lake Flevo" or "Flevomeer" (fig.2).

Since Roman times this lake found an outlet via the north to the North Sea. This outlet/inlet extended specially since the 8th Century.
The extended, now brackish bay was called Almere (since 755) and later Zuyder Zee (since 1340). The latter became almost saline as the debouching river Yssel lost importance about 1600.

In 1932 the enclosure of the Zuyder Zee created a fresh-water lake, called Lake Yssel or IJsselmeer.

Table 1. Nomenclature of sediments

Geological phases of deposition

in Zuyder Zee / Lake Yssel region						in W.Netherlands
	IJsselmeer	(IJm)	(fresh)			
1932						
	Zuiderzee	(Zu)	(saline)			
1600				1600		Duinkerke
	Almere	(Al)	(brackish)		IJsseldelta	
0				1200		
	Flevomeer	(Fl)	(fresh)			

In the process of sedimentation the amount of organic matter (peat fragments, detritus) decreased. Specially in the Almere phase much sand was swept into the central part of the area (see soil map underlying excursion route; fig.3). The IJsselmeer phase concerns erosion and deposition of the Zuiderzee deposit.

Four polders have been reclaimed in the area (fig.6). The first, the Wieringermeerpolder (real Zuyder Zee polder) emerged in 1930 (20.000 ha), the second, the North Eastern Polder in 1942 (48.000 ha). The third and the fourth polder together form a double polder, the eastern half of which emerged in 1957 (54.000 ha) and the southern half in 1968 (44.000 ha).
A fifth polder, the Markerwaard is under discussion.

The polders are embanked and reclaimed by Governmental Authorities, which are responsible not only for constructing dikes and pumping stations, but also for digging canals, laterals, ditches, for tube draining of the fields, farming during the initial five to six years, for construction of roads, farmsteads, villages and towns. Afterwards the farms are leased to individual tenants.

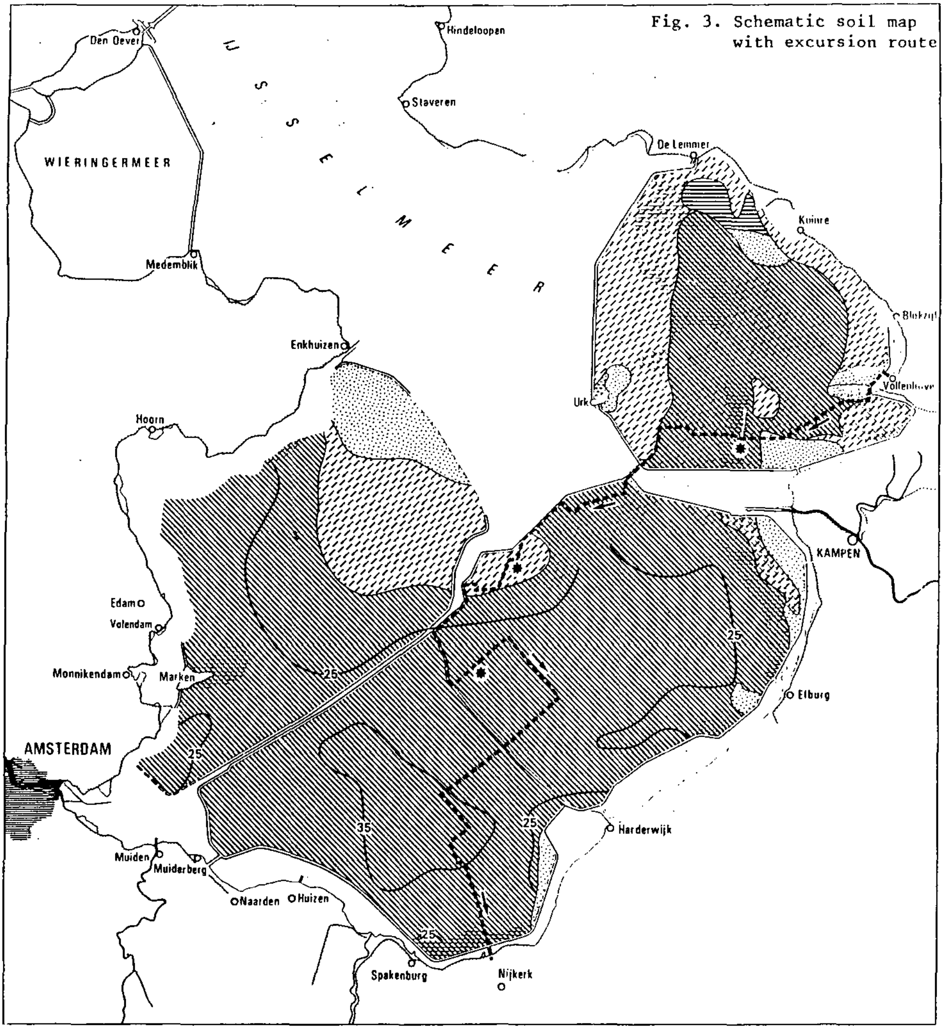
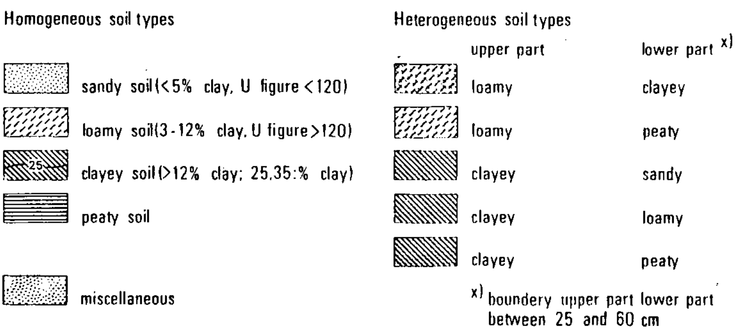


Fig. 3. Schematic soil map
with excursion route
Den Oever
Hindeloopen
IJSSELMEER
Staveren
WIERINGERMEER
De Lemmer
Kuinre
Medemblik
Blokzijl
Enkhuizen
Vollenhove
Urk
Hoorn
KAMPEN
Edam
Volendam
25
Monnikendam
Marken
25
Elburg
AMSTERDAM
25
35
25
Harderwijk
Muiden
Muiderberg
Naarden
Huizen
25
Spakenburg
Nijkerk


Homogeneous soil types
sandy soil (<5% clay, U figure <120)
loamy soil (3-12% clay, U figure >120)
25
clayey soil (>12% clay; 25,35:% clay)
peaty soil
miscellaneous
Heterogeneous soil types
upper part
lower part x)
loamy
clayey
loamy
peaty
clayey
sandy
clayey
loamy
clayey
peaty
x) boundery upper part lower part
between 25 and 60 cm

Route description 23.08.1986 p.m.

The polder excursion starts with the crossing of a border lake.

In the North Eastern Polder the route leads along an area originally developed with subirrigated grasslands on sandy soils derived from outwash of a boulderclay outcrop (Pleistocene moraine). The boulder clay area itself has been afforested.

In the neighbourhood of the village Kraggenburg fruitgrowing is practiced on homogeneous clayey soils and is surrounded by arable farms.

In the neighbourhood of Ens the sandy underwater delta of the river Yssel is used as subirrigated grasslands and market gardens.

Arable lands are found on and around the former island of Schokland.

Schokland (excursion item) forms the remainder of a clay-on-peat island (fig.4) and contains remnants of former villages of Emmeloord/Middelbuurt/Ens.

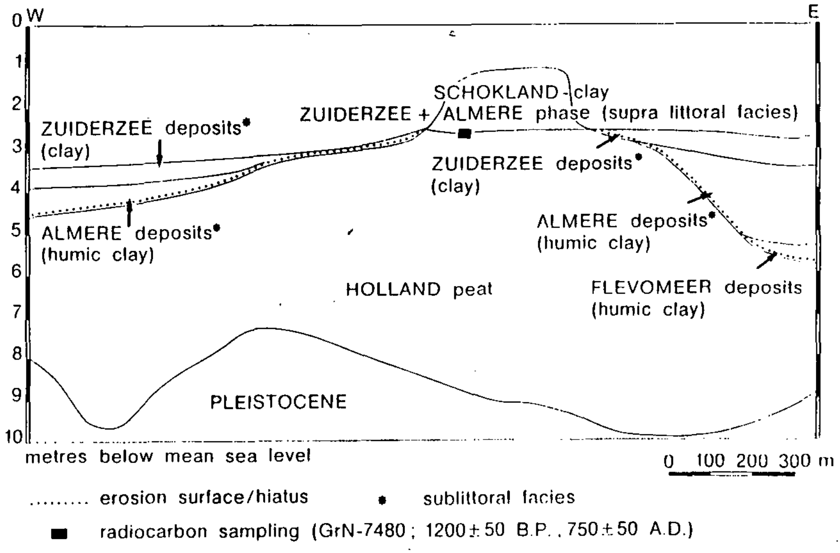


Fig. 4. Section over the former island of Schokland

The inhabitation ended abruptly with the evacuation by governmental order in 1859. The struggle against the "waterwolf" is illustrated by figure 5. Since the lowering of the watertable in 1941/'42 the subsidence amounted 1.0 m.

The route leads along Nagele through arable lands to the Ketelbridge (Ketel = mouth of the Yssel) in the motorway Emmeloord-Amsterdam. Backwards to the right the former island of Urk (high boulderclay outcrop) shows in the distance.

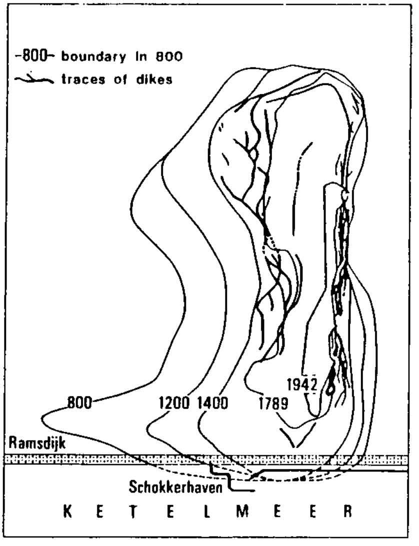


Fig. 5. The decreasing size of the island of Schokland since 800 AD

In the northwest of Eastern Flevoland landuse is both arable and grassland. The latter on the somewhat lighter textured soils. Farms are on the average larger than in the North Eastern Polder (40 against 25 ha). After crossing the motorway the main items are the electricity plant on an island outside the polder and the fish-hatchery inside.

Excursion item: ditch soil H-NL3 in the urban margin of Lelystad.

The new town Lelystad has been developed since 1965. Now it counts about 65.000 inhabitants. Municipality since 1980. Province Flevoland since 1986.

The western outfall from Lelystad leads to Houtrib-sluizen (locks), a view on the Markermeer (lake, possible future Markerwaardpolder), Lelystad-Haven (harbour) and over the Knardijk, separating Eastern and Southern Flevoland (emergence 1957 and 1968 respectively). In Southern Flevoland the wetland birds nature reserve Oostvaardersplassen is situated (about 6000 ha).

Excursion item: profile soil H-NL4 the afforested margin of the town.

The last section of the polderroute leads through the arable lands on the clayey soils of E. and S.-Flevoland. Private farming in S.-Flevoland started in 1978. Every year new areas are added.

In the southern part a relatively large afforestation Horsterwold is planned (on the left). The polderexcursion ends with the crossing of a border lake.

The route on the bordering "old" land firstly crosses the flat clay-on-peat soils, secondly the slightly undulated landscape of the Pleistocene sandy soils.

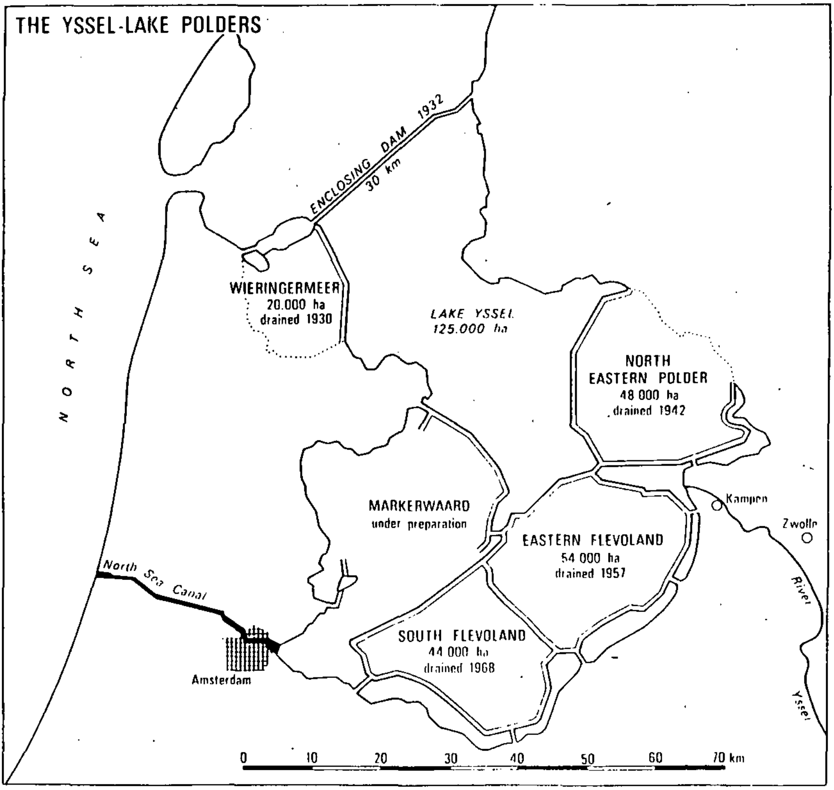


Fig. 6. The Yssel-Lake polders

Table 2. Soil analyses soil H-NL3 E.Flevoland

depth in cm	geol. phase local*	in g per 100 g soil			in % of min.matter			bulk dens. in g/cm^3	por.vol in %	A (spring) ***	water-factor n ***
		clay	o.m.	$CaCO_3$**	< 2	2-50	> 50 µm				
0- 25	IJm/Zu	6-8	1 - 2	6½- 7				1.5	44	17	< 0.5
25- 30	Zu	5-6	½ - 1	6 -13	7	8	85	1.45	45	20	< 0.5
30- 40	Al	5-9	1½	4 - 5	7	20	73	1.3/1.4	43	30	0.5/1.5
40-175	Al	3-7	1½- 5	5½-6½	6	29	66	1.4/1.1	43/50	30/ 40	1.8
175-235	Al	18	12	4				0.5/0.6	60/70	50/150	2.0
235-265	Fl	20	20/40	3/½				0.4	70/80	200	2.0

deeper subsoil

265 Erosion surface
265-345 Holland peat (reed-sedge)
345-675 Calais deposits (clayey)
675-695 Holland peat (reed-sedge)
> 695 Pleistocene (sand)

* see table 1

** pH ± 7½

*** standard of physical ripening (waterfactor) n

$$n = \frac{A - 20}{L + bH} \quad \text{in wich:}$$

A = total water content per 100 g dry soil
L = clay content (lutum <2 µm)
b = ratio of water absorption capacity of organic matter to that of clay

Soil H-NL3 E.Flevoland

Elevation	4m below mean sea level
Landform	Flat former sea/lake bottom
Landuse	Arable
Parent mat.	Loamy sand to sandy loam
Geol.age	Holocene. Duinkerke Formation. Loc. subdiv. table 1
Soil type	Calcic Fluvisol/Hydric Fluvaquent
Hydrology	(Gt VI) Mean highest water-table 40-80 cm Mean lowest water-table 120 cm Tube drainage 12 m Polder-water level 6.20 m below mean sea level
Pedogenesis	Since 1957

Profile description H-NL3 E.Flevoland

Ap	0- 25 cm	(IJm+Zu) Dark greyish brown (2½Y4/2m) loamy fine sand to sandy loam with many very fine marine shell fragments; single grain to very fine subangular blocky structure; very friable; irregular boundary.
C1g	25- 30 cm	(Zu) Light greyish brown (2½Y6/2m) loamy fine sand with many marine shells (erosion surface);some mottling; clear smooth boundary.
C2g	30- 40 cm	(Al) Grey (2½Y5/1m) loamy fine sand without shell fragments; yellowish brown (10YR5/8m) mottles; diffuse boundary.
C3g	40-100 cm	(Al) Grey to dark grey (N4m) very fine sandy loam, stratified with lenses of organic debris (wave ripples); yellowish brown (10YR5/8m) mottles along old root channels increasing with depth in size from very fine to medium; diffuse boundary.
C4g	100-120 cm	Ditto with a few coarse yellowish brown (10YR5/8m) mottles around old root channels; diffuse boundary.
Cr	≥ 120 cm	

Discussion H-NL3 E.Flevoland

Subaqueous specially fine sandy or loamy sandy deposits are characterized by low pore volumes. Consequently after emergence the aeration process and root penetration are impeded, whereas the water table is "nervously" fluctuating due to variations in rainfall. Shallow rooting results in dry summers in a moisture deficit. Subsoiling is a necessity; usually 70 cm; pore volumes are increased to an average of ± 51%. Evaluation depends on the remaining moisture deficit (clay content). A risk of once in ten years is accepted for arable land. For grassland in dry spells farmers have realized subirrigation by pumping up polder water in the ditches. Narrow tube drainage spacing (12 m) because of low permeability. Time of drainage: free. Initial fertility depends on the clay content (see fig. 7). Subsoiling contributed to the N-mineralization. Within 15 years no detoriation of the effects occurred.

Table 3. Soil analyses soil H-NL4 E.Flevoland

depth in cm	geol. phase local*	in g per 100 g soil			in % of min.matter			bulk dens. in g/cm³	por.vol in %	A (spring) ***	water-factor n ***
		clay	o.m.	$CaCO_3$**	< 2	2-50	> 50µm				
0- 25	(IJm)+Zu	30à32	4½	9				1.2	55	22	< 0.5
25- 30	Zu	37	3½	9	43	43	14				
30- 32	Zu	1-3									
32- 90	Al	30	4	7½	34	57	9	1.0	60	40- 50	0.75
90-190	Al	30	5/13	9/7	38	59	3	1.0/0.55	63/80	57/140	1.0/2.0
190-230	Fl	20	20/40	3/½				0.4	70/80	200	2.0

<u>deeper subsoil</u>

230 Erosion surface
230-255 Pleistocene (displaced sand)
> 255 Pleistocene (sand, undisturbed)

* see table 1

** pH ± 7½

*** see profile A 23

Soil H-NL4 : E.Flevoland

Elevation	4m below mean sea level
Landform	Flat former sea/lake bottom
Landuse	Deciduous forest of mainly poplar
Parent mat.	Clay loam
Geol. age	Holocene. Duinkerke Formation. Loc. subdiv. table 1
Soil type	Calcic Fluvisol/Cracked Hydric Fluvaquent
Hydrology	(Gt VII) Mean highest water-table 80-100 cm
	Mean lowest water-table 120 cm
	Tube drainage 48 m. Ditches 500 m
	Polder-water level 6.20 m below mean sea level
Pedogenesis	Since 1957. Subsidence 1957-1980 90-100 cm

Profile description H-NL4 E.Flevoland

Ap	0- 25 cm	(IJm+Zu) Dark grey brown (10YR4/2m) clay loam with many very fine marine shell fragments; fine blocky structure, very friable, slightly hard; irregular boundary.
C1g	25- 30 cm	(Zu) Dark grey (10YR4/1m) to dark greyish brown (2½Y4/2m) silty clay with many fine marine shell fragments; fine yellowish brown (10YR5/8m) and very fine black mottles in peds; cracked into strong, fine, sometimes medium prisms; very firm; abrubt, smooth boundary.
C2g	30- 32 cm	(Zu) Light brownish grey (2½Y6/2m) fine sand, stratified with marine shells and ditto fragments.
C3g	32- 65 cm	(Al) Very dark grey brown (10YR3/2m) silty clay loam, decreasingly intercalated with very fine to medium loamy sand strata; no shells; many yellowish brown (10YR5/8m) fine mottles, specially around ancient root pores; some very fine black mottles; coarse to very coarse prisms, becoming larger downwards; some finger-wide to wrist-wide cracks between very coarse prisms; diffuse boundary.
C4g	65- 90 cm	(Al) Very dark greyish brown (10YR3/2m) non-stratified; silty clay loam, coarse to very coarse prisms, with some wrist-wide cracks; can be squeezed with difficulty between fingers; diffuse boundary.
C5g	90-135 cm	(Al) Ditto; with very fine organic debris; can be squeezed between fingers; diffuse boundary.
Cr	⩾ 135 cm	(Al) Ditto, with cracks reaching to about 135 cm.

Discussion H-NL4 E.Flevoland

After digging of the ditches in the reed marsh (created by sowing reed seed by plane after emergence) a widely-spaced field trenching promotes the ripening process in advance of the agricultural use (state farm), whereas during the agricultural use a narrower trenching is practiced. Depending on the progress of the ripening the tube drainage is installed, here with a spacing of 48 m. The physical ripening leads to fragmentation structures of finer (above) and larger (below) prisms, wide cracks and very high permeabilities. Chemical "ripening" concerns the process of formation of natural gypsum (abundance of $CaCO_3$ over sulfides: see fig.7) in the aerobic environment and replacement of Na^+ for Ca^{++} on the adsorbtion complex (table 4).

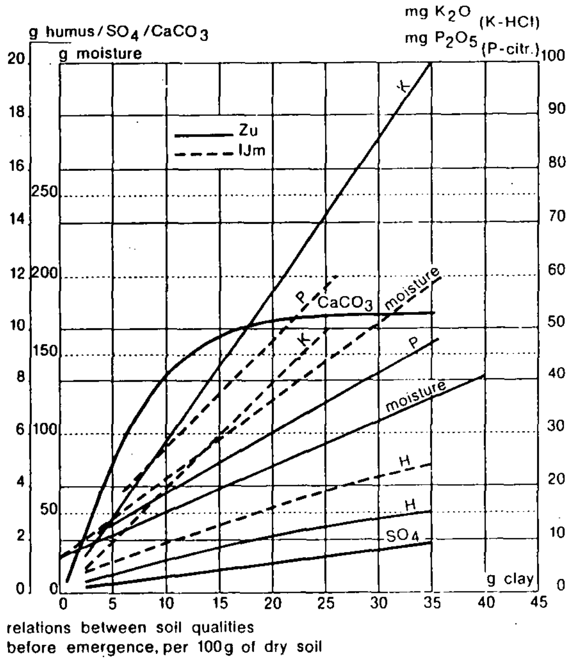


Fig. 7. Relations between soil qualities before emergence, per 100 g of dry soil

Table 4. Chemical "ripening" of top soil

IJSSELMEERPOLDERS	ratio adsorbed cations in %			
	Ca	Mg	K	Na
before desalinization of lake Yssel	28	42	8	22
initially	54	33	6	7
after 5 years	80	15	4	1
final?	88	8	4	0

SOME INFORMATION ABOUT ISRIC

History

ISRIC (International Soil Reference and Information Centre) was born out of an initiative of the International Society of Soil Science. It was founded in 1966 by the Government of the Netherlands, upon assignment by the General Conference of Unesco. Up to 1984 the name was International Soil Museum.

Aims and Programme

- To serve as a documentation centre on land resources, with emphasis on the developing countries (see 1-4).
- To improve methods of soil analysis, with emphasis on soil characterization and classification (see 5).
- To transfer the collected information by lecturing and publishing and by advising on the establishment of natural soil reference collections (see 6-9).
- To stimulate and contribute to new developments in soil genesis and classification, soil mapping and land evaluation (see 10, 11).

1. Soil monolith collection

   To assemble and analyse representative samples of the major soils of the world and display a reference collection of soil profiles and related information.
   Each of the soils is represented by a soil monolith: an artificially hardened soil profile. This collection, now comprising nearly 700 monoliths from over 50 countries, is a helpful instrument for instruction and demonstration. It enables scientific research to be carried out on a large number of soils.

2. Laboratory

   To analyse samples, mostly of the collected soils;
   To test and improve methods and procedures of soil analysis;
   To support/instruct guest researchers.
   The laboratory is equipped to carry out most of the physical, chemical and mineralogical analyses necessary for soil characterization. Research is, in part, aimed at improvement of methods with emphasis on the suitability of a method to be used in laboratories with relatively simple equipment.

3. Micromorphology

   To prepare, study and describe thin sections of soils belonging to the collection, or for other purposes.
   Most thin sections prepared belong to the soil monolith collection. Others are made for special purposes, e.g. the ISSS Subcommission on Soil Micromorphology has requested ISRIC to set up a reference collection of thin sections, to support the new ISSS-sponsored "Handbook for Soil Thin Section-Description.

4. Documentation.
   To build up a collection of soil and related maps and reports.
   A systematic collection of soil maps and reports, with emphasis on the developing world, is built up. This is available for consultation and needed for updating the 1 : 1 million FAO-Unesco Soil Map of the World and the compilation of a new, computerized world soil map at 1 : 1 million. ISRIC aims at a collection of small-scale maps at a scale of 1:200,000 or smaller of each country, and a reference system of soil surveys carried out at any scale.

5. Laboratory exchange programme (Labex)
   To compare and possibly standardize methods and procedures of laboratory analysis, accompanied by the exchange of sample material.
   Soil material, representing a range in chemical and physical properties, serves as reference samples. Subsamples are sent to participating soil laboratories. The results of the analyses from 85 laboratories are collected, together with a description of the methods used, and compiled into a report.

6. Visitors services
   To give information on soils of the world, soil impregnation and display techniques, etc.
   Visitors in groups are mainly from higher educational institutions, international training courses and participants of meetings. Individual visitors are mostly professional soil scientists from all over the world.

7. Guest research
   To host soil scientists who will study the collection for comparison and correlation.
   This relatively new programme aims at the preparation of scientific papers en presentations.
   Guest researchers are usually experts from non-European countries, who study for a half to one year ISRIC's soils in relation to soils of their own country/region. They also may develop and test new analytical procedures.

8. National soil reference collections (Nasrec)
   To help in establishing Nasrec's for research, land use planning, extension, etc.
   For nearly a century, soil profile bodies have been collected in the field and put on display. The development of easier methods of impregnation with suitable chemicals has prompted a number of institutions to set up modern Nasrec's.
   ISRIC advises and assists in, and gives a training course on the collection of soil profiles, their impregnation, and in displaying and using them.

9. Publications
To issue publications on the collected soils, analytical methods and techniques, and make available teaching materials.
The publication programme includes:
Soil Monolith Papers: deal with one soil monolith as an example of a soil unit of the FAO-Unesco Soil Map of the World legend. Each SMP has a colour photograph and 8 slides.
Monographs: give results of studies in soil genesis and classification, soil analysis and land evaluation of a major group of soils. These are usually written by guest researchers.
Technical Papers: contain methods, procedures and standards and field extracts of major soil classification systems.
Annual Reports.
Working Papers and Preprints.
Consultancy/Mission Reports.
Slides.

10. Soil classification
To study and correlate soil classification systems that have an international reach;
To assist in the elaboration of new classification systems.
ISRIC assembles documentation on all national and international soil classification systems. Principles and the criteria used are compared and evaluated. Active support is given to the establishment of an International Reference Base for soil classification (IRB), to the elaboration of an improved and more detailed legend of the FAO-Unesco Soil Map of the World.

11. Reference laterite collection (Corlat)
To build up a reference collection of whole laterite profiles (CORLAT);
To develop a descriptive terminology and classification of laterites.
Recently, the need for a Corlat was expressed. ISRIC was chosen to provide reference material for objective and standardized descriptions of laterites and for their classification. It will be an important tool to facilitate communication in laterite research, both at international and interdisciplinary levels.
To date, two profiles of 15-20 m depth have been collected.

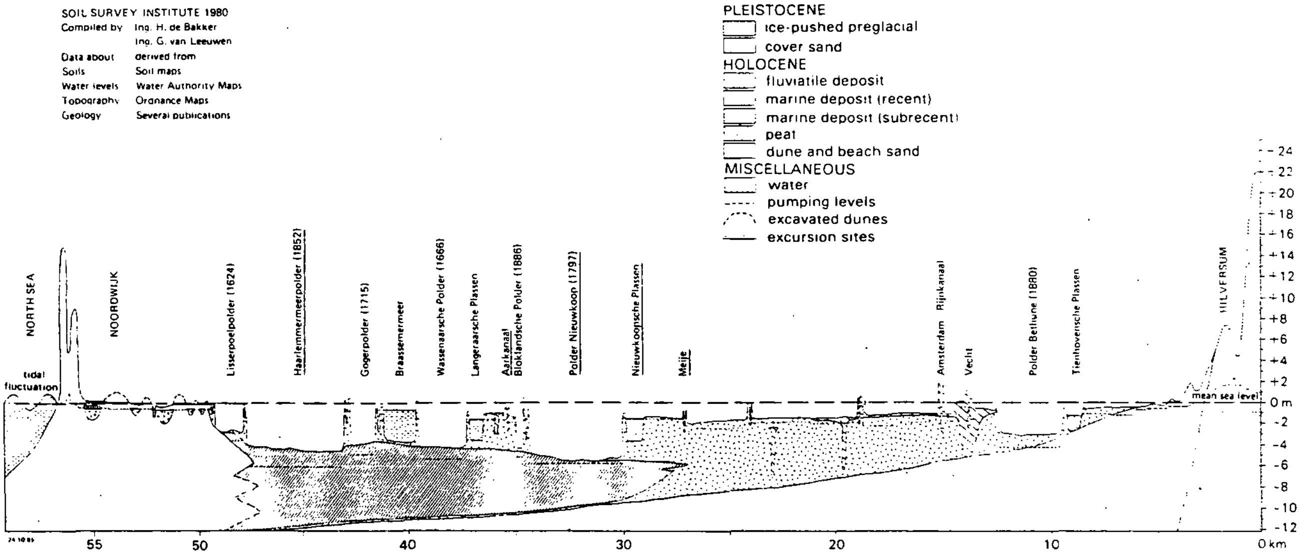


Fig. 1 Transect of the excursion area

PEAT LANDS BELOW SEA LEVEL

Introduction

The excursion H on 24th of August 1986 takes us to the western part of The Netherlands, an area with a high population density and intensive land use on peat land and excavated peat areas in drained lakes (inlandpolders). A coastal dune system protects this area against the sea. The whole area behind the coastal dune system is lying 1 meter to 6 meter below mean sealevel. This requires a highly developed water management system, which came in use as early as the 12th century.

General itinerary

23-8-1986 - 24-8-1986		Overnight stay at the International Agricultural Centre, Wageningen
24-8-1986	8.30	Departure from I.A.C. Wageningen
	8.30- 9.15	drive along motorway A1 Wageningen-Woerden
	9.30	Arrival at Stop 1 - Meije Walk through countryside
	11.00	Arrival at Stop 2 - Experimental Farm Soils and Landuse
	12.30-13.45	Lunch stop - Nieuwkoop View on Lake side
	14.00	Arrival at Stop 3 Bog floor soils
	15.15	Arrival at Stop 4 Watermanagement
	16.15	Arrival at Stop 5 Historical site - Museum "Cruquius"
	17.45	Aproximal arrival at Central Station Amsterdam End of the excursion

Excursion area

Geolcgy

In the western part of The Netherlands Holocene sediments and peat, cover a Pleistocene base. The later is build up by fluvitile sediments of major rivers and of wind-blowm "cover sand". The Pleistocene base dips towards the west. The Holocene cover reaches its maximum thickness of about 25 meters near the present coastline (Fig. 1). When early in the Holocene the rise of the sealevel started the drainage of the land deteriorated and peat started to grow. With the continuing rise of the sealevel, the coastline shifted gradually eastwards, the sea invaded the peat areas and covered them with tidal flat deposits (subrecent deposits in Fig. 1). The peat was partly eroded by the tides and strongly compressed.
Approximately 4000 years B.C. the western part of The Netherlands was a coastal lagoon with many tidal creeks and some rivers, as the Old Rhine. This area was protected by low coastal barriers. About 2100 years B.C. the coastal barrier system gradually closed and only a few estuaries continued as river outlets. The marshes in the lagoon became desalinized by river water and rain and renewed peat growth started over the whole area.

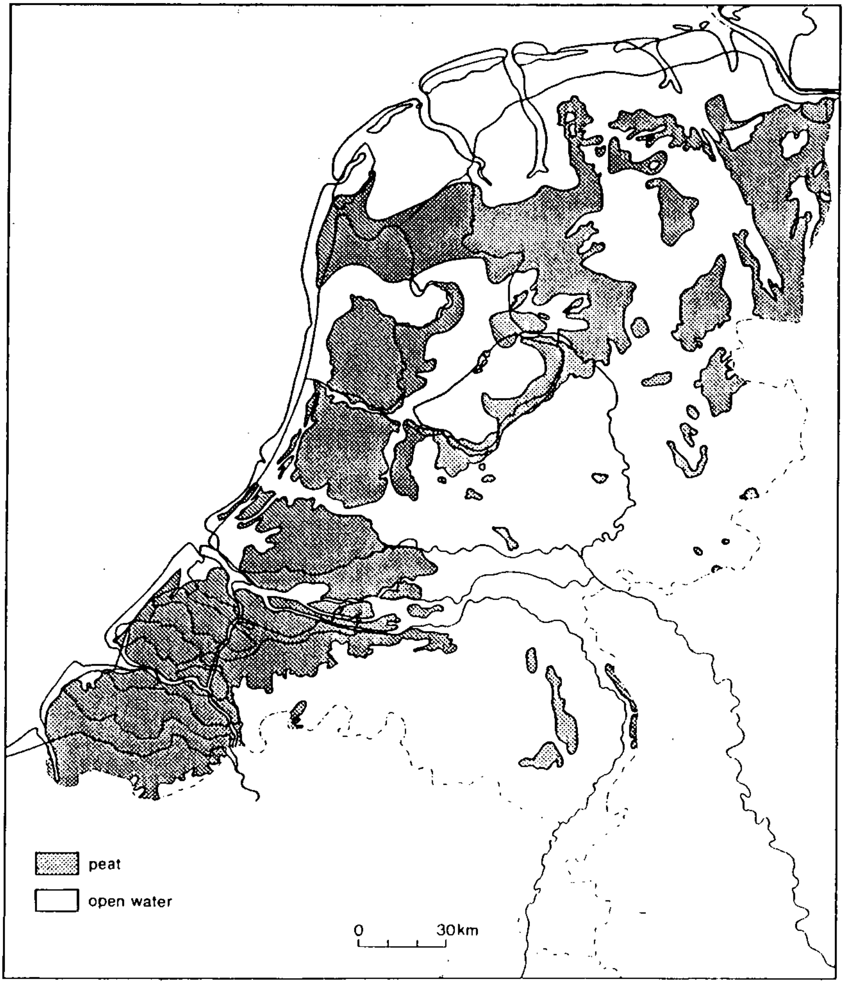


Fig. 2 Paleogeography of peat areas in the Netherlands in Roman Times: after W.H. Zagwijn in: Atlas van Nederland, 1985

This younger peat is the so called "Holland peat". Along the courses of the river branches which crossed the area, a wood peat mixed with clay was developing. Beyond the influence of the eutrophic water the originally reed swamp changed into a raised bog with peat mainly derived from sedge, Sphagnum moss, and birches.

Human occupation since Roman Times

When the Romans arrived in this area they found small rivers with natural levees covered with oak forest. Behind the levees there was a forest with willow and alder alongside the very small fenstreams and sedge and reed between them. Behind this area the wilderness of the raised bogs was dominant (Fig. 2, 3).

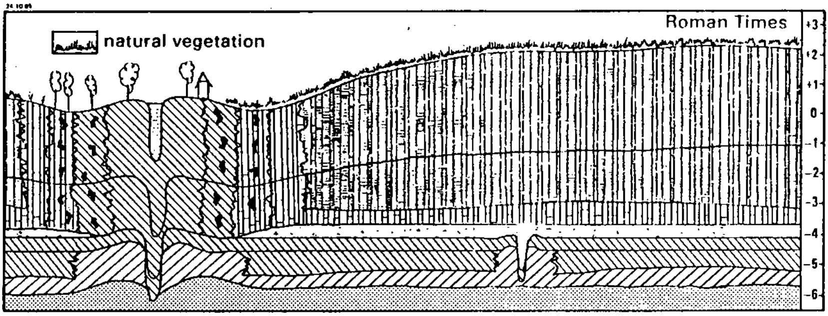


Fig. 3 Man living alongside rivers. The raised bogs are uninhabited.

The Holland peat kept growing until the 10th century. Peat growth came to an end by human occupation in the tenth century. After this century, man started to reclaim the raised bogs Fig. 4. The main reclamationphase started around 1200 A.D. In a very systematic way blocks of individual farm fields were laid out. Each farm field was 1300 m long and 120 m wide. Parallel ditches separated the fields, draining freely the raised bogs. They still exist in the present day peat lands, Fig. 5.

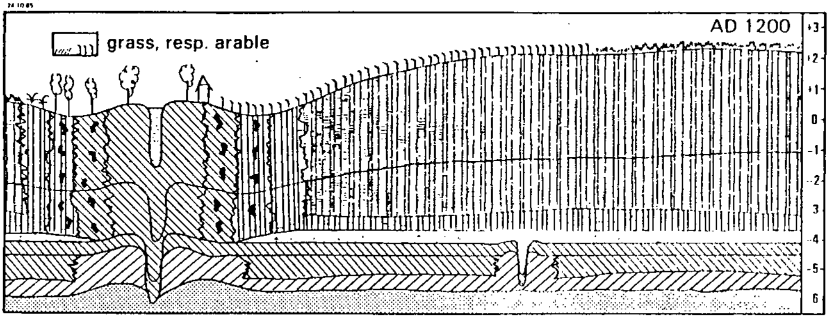


Fig. 4 Growing rye and barley and cattle grazing on raised bogs

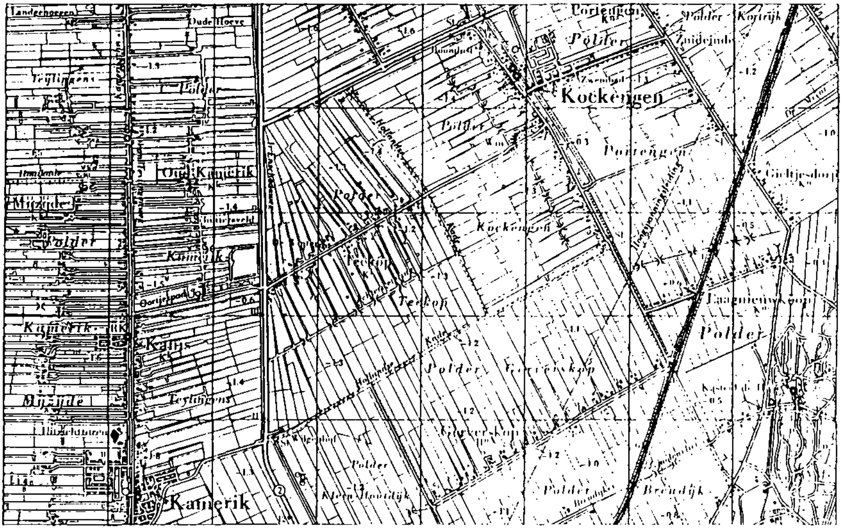


Fig. 5 Topographical map (1:50 000) of a part of the excursion area West of Utrecht showing the regulary laid out fields in the peat area

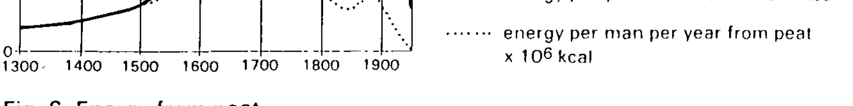


Fig. 6 Energy from peat

Due to oxidation and shrinkage the "raised" bog became saucer shaped (Fig. 7). The drainage of the fields deteriorated as well as the land quality. Fortunately increasing demands for fuel came from the growing cities because of the expanding trading activities. The so called "Golden Age" started, Fig. 6. Because of the absence of wood, energy demands were met by digging peat. The devastation of the peat area started (Fig. 7) where suitable oligotrophic peat with a low ashcontent was plentyful available.

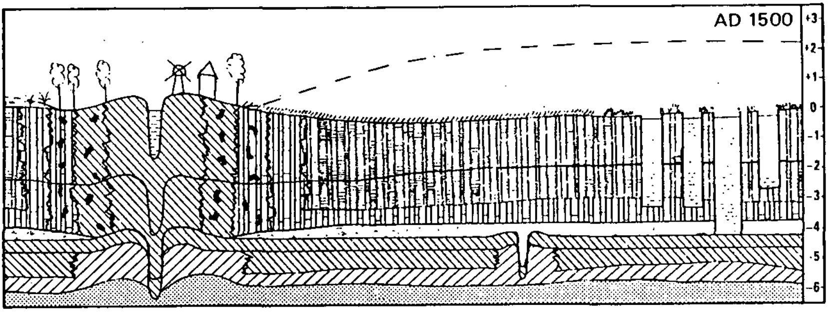


Fig. 7 The original raised bog has become saucer shaped, resulting in degradation of the land qualities. Peatdigging replenishes the loss of income.

Extended oligotrophic- and mesotrophic peat areas turned into large man made lakes, because of peat digging continued since 1500 AD (Fig. 8). Wave erosion along the shorelines of the lakes created serious landloss, thus forming a layer of detritus at the bottom of the lakes. This lake mud contained all kinds of remmants of the flora and fauna found in the original lake. Finally this layer of lake mud became the main source of the present dark topsoil of the lake bottom soils. The lake mud was mixed with the (marine) clay of the bog floor after drainage and reclamation of the former lake (Fig. 8, 9).
The drainage and reclamation of the man made lakes started in the 17^{th} century and ended in the 20^{th} century.

Conclusion

From this geological and human history is appears that the reclaimed lakes and the present-day lakes practically coincide with the area of the original raised bogs. The remaining uplands were not cut over because wood peat is not suitable for fuel.
The river clay soils accompany the present and former branches of rivers (Old Rhine) and fen streams. The levee soils, mostly calcareous and well drained are situated on relatively high ridges. Behind these levee soils are the backswamps with non-calcareous clay soils partly overlying peat. Between the river-clay soils and the soils of the former lakes the peat soils are situated in non-cut "upland" areas. Most of these upland areas have ditches with a high water level. The peat soils are used for grassland (dairy farming) and horticulture. The reclaimed lakes expose the former bog floor. In the western part of the area they are sandy, loamy or clayey, calcareous or shallowly decalcified and well drained by means of tiles and ditches. These soils are generally low humic except where the topsoil contains remains of the former peat cover or lake detritus. Further eastward, the lake-bottom soils are non-calcareous, imperfectly drained and fine-textured. The topsoil contains remains of peat of lake detritus and the subsoil is non-ripened. Many of them are acid sulphate soils and have in the non-ripened subsoil high contents of pyrite (see also description soil H-NL6, stop 3).
The soils in the former lakes are used for arable land, grassland and horticulture (flowers, garden plants and vegetables, often grown in hot-houses).

Fig. 8 The Ronde Venen (Circular Peats) in the northeast of the Holland-Utrecht lowland plain during the peat-digging (1854) and the creation of polders, showing the systematics of the reclamation

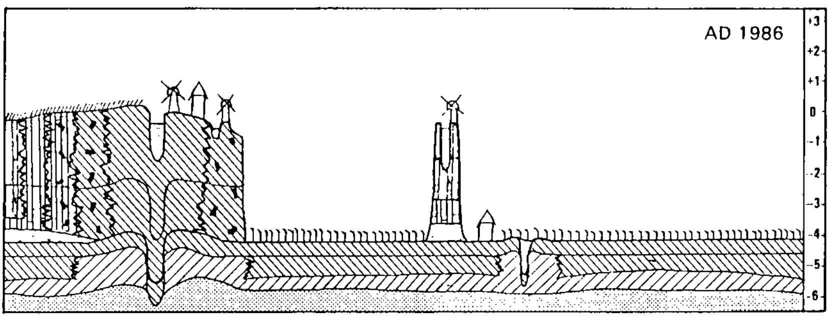


Fig. 9 Schematic cross section through reclaimed man made lake location fig. 8

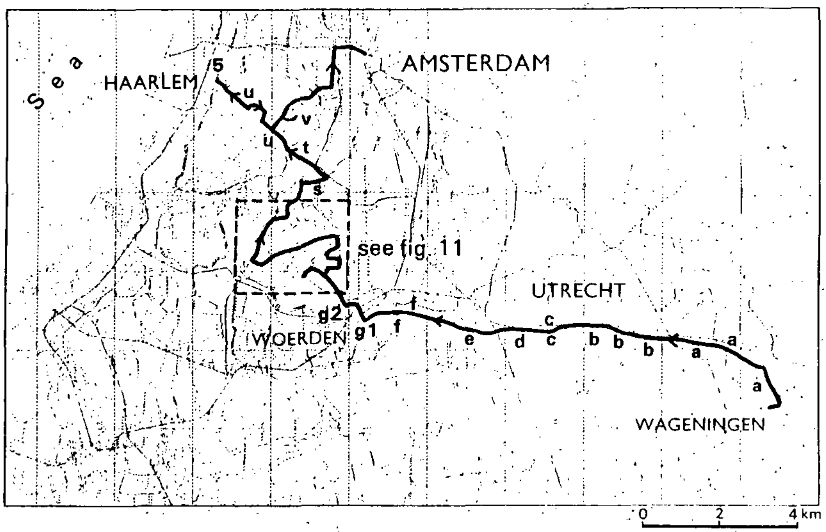


Fig. 10 EXCURSION ROUTE August 24 th 1986

Route description (Fig. 10 and 11)

The first part of the excursion-route from Wageningen to Driebergen shows us an undulating Pleistocene sandy area. The eastern part of the Pleistocene area is relatively open, with grasslands, some arable land (a). It consists of cover sands with very low ridges. A part of this area was once covered by peat. Already in the 13th century the peat was excavated. The western part of the Pleistocene area consists of ice-pushed ridges from the Salien-time. It has deep groundwater-tables and is forested (b).

Near Driebergen we cross the boundary between the Pleistocene area and Holocene area (c) and we follow our route in a riverclay area till Utrecht. The brown-coloured riverclay has been deposited by the Rhine. Landuse: grassland, arable land and some fruitgardens (d).

South of the town of Utrecht after the junction of motorways (e) we follow the motorway to the western part of the country. The subsoil consist of peat and construction of a motorway in such areas is very expensive. This level area (f) is used as grassland for dairy farming. It is dissected by a many ditches at regular distances.

South of the town of Woerden we leave the motorway (g1) and we follow our route through Woerden to our excursion route in the peat area, north of the river Old Rhine. Woerden is situated on the levees of this river.

We start our excursion on the northern levee of the Old Rhine, with on your right the new suburb of Woerden and on your left farm houses on the levee (g2). Following the road to Zegveld.

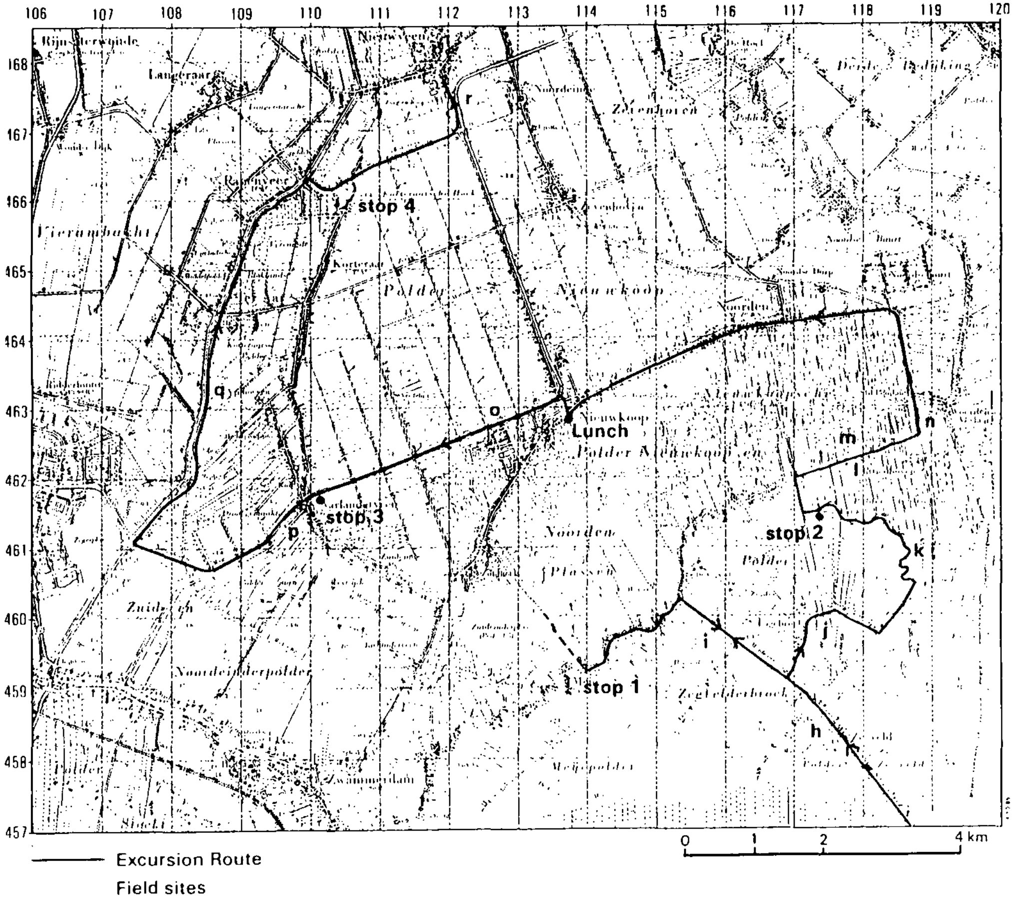


Fig. 11. Excursion route stop 1 - 4

The increasing width of the parallel ditches, the old farm houses and the landuse as grassland can be noticed. The peat area near the village of Zegveld is dominated by a systematic outline of the parcels (h). Originally each farmer had a field of 1200 of 2400 meter long and 120 meter wide. Now the spacing of the ditches is different and the width varies from 30-80 meter. Reallocation in the sixties resulted in new roads and new farmhouses to provide shorter length of the fields. North of Zegveld we drive on such a new road to a former fenstream (i). This section of the route to Stop 1 (Meije) lies alongside the fenstream.
After Stop 1 we follow the route again through the peat area (Fig. 11) to the Experimental Farm (Stop 2). In this part (j) the pattern of the ditches is not parallel but diverging, possible an indication that this area of the former peat bog had been left over after several regular blocks had been occupied earlier.

Near Stop 2 the road follows again a former fenstream (k). After the visit to the Experimental Farm, we follow the road with on the right side non-excavated peatland (l) and on the left side partly excavated peatlands (m), simular system as we have seen on Stop 1.
We arrive now the main road from Zegveld to Nieuwkoop. Near Woerdensche Verlaat (n and Fig. 11) we come to the boundary between two main Water Board Authorities, The Rijnland Boezem Authority and The Amstelland Boezem Authority. From historical times on they keep different waterlevels in the main waterways. The connection between these two systems is therefore formed by a shiplock.
For the last part of the route to the lunch-stop see Figure 10. Lunch-stop in Plaszicht, an old farmhouse, with to the south a nice view on the Lake Nieuwkoop.
After the lunch we follow our route on the bottom of a former lake, ca. 5 meters below mean sealevel (o). The landuse is grassland, the fields are regular. Stop 3 shows a lake bottom soil.
The route to Stop 4 takes us first into a drained lake (p). The floor of this lake lies about 4 meters below mean sealevel. In this drained lake about one meter of peat has been left after the excavation. On the left side we see a series of windmills used for pumping the water from polder to the former peatstreams and canals. For a photo of a simular series of windmills see hand out. After the drained lake, we follow the route in a non-excavated wood peat area (q) alongside the former fenstream "The Aar". The land is used for horticulture in glasshouses (flowers, vegetables, tomatoes and cucumbers).
The route form Stop 4 to the Cruquius Museum takes us through upland areas and different drained lakes. First we come through the village of Nieuwveen, a former strip of peat within the man made lake. The old church (r) is situated on non-excavated mosspeat. The second part of the route to the village of Uithoorn follows the fenstream Amstel (s). Amstel is also the name of a kind of Dutch beer and the name of the capital Amsterdam = dam in the fenstream Amstel.
We follow the route through the village Uithoorn and its recent urban extension. Through two drained former lakes with calcareous soils used for arable land, grassland and horticulture in glasshouses we come in the village of Aalsmeer, a flower centre, partly on a former lake-bottom, partly on non-excavated peat land. East of the village of Aalsmeer the auction-hall for flowers (t). West of the village of Aalsmeer lies the "Haarlemmermeerpolder", the largest inlandpolder (18 000 ha), 3,5 - 4,7 meters below mean level (u). Landuse: mainly arable, some grassland and some horticulture. Most of the soils are calcareous. In the west of this inlandpolder lies alongside the ring-canal the old pumping station Cruquius with an old steam engine. Nowadays it is a museum (Stop 5).
After Stop 5 we follow the route to Amsterdam and we pass the International Airport Schiphol (v).

Stop 1, short walk

Site description

Topographic sheet	: 31w, coord. 114-459, 20 km w of Utrecht, near the Village Meije, see also Fig. 11
Elevation	: 1.50 m below mean sealevel
Geomorphology	: level peat land dissected by clay ridges 25 cm above the average landsurface see also hand out at the excursion
Drainage	: ditches 25-80 m apart waterlevel -1.70 below sealevel
Vegetation	: grassland on non cutover peatland shrubs and reedland on cutover peat
Parent material	: wood peat dissected by small linear clay plugs see also hand out at the excursion
Soil classification	: FAO Eutric Histosol

Site interpretation
During this short walk from a former peat stream to a man-made lake the original situation will be explained. There existed a gradient of different peat types going from the small peat stream to the centre of the former raised bog (see also Fig. 3). Only the oligotrophic and mesotrophic peat centre has been excavated for fuel. After excavation of the peat a man-made lake remained.

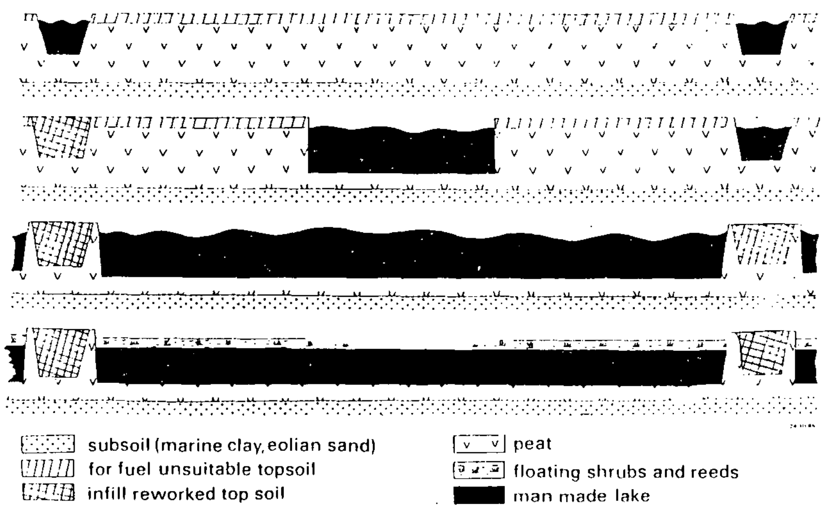


Fig. 12 Schematic picture showing the development of a man-made lake (see also fig. 8)

Stop 2, Visit to an Experimental Farm and soil H-NL5

General

The "Foundation Regional Centre for cattle husbandry in the Western pasture district" is operating the experimental farm (49 ha) in Zegveld. The purpose of this foundation is the promotion and development of the cattle husbandry in this area. The foundation tries to attain this goal by executing practical research concerning cattle husbandry and by propagating the results.

Site description

Topographic sheet	: 31w, coord. 117-461, near the Village of Zegveld, 15 km NW Utrecht, see also Fig. 10, 11
Geomorphology	: level peat land, surface 1.9 m below MSL
Drainage	: ditches 30-60 m apart waterlevel: experiments are caried out with different waterlevels varying between 0.70 m - 0.20 m
Vegetation	: grassland; rooting depth ± 30 cm
Parent material	: wood peat, mucky material with remnants of roots and branches, sedges, some reed to a depth of 6-7 m, overlying pleistocene sands
Soil name	: FAO '74: Eutric Histosol USA '75: Typic Medihemist Others : Niedermoor (Germ.) Sol à tourbe semi-febreuse eutrophe (France), Earthy eutro-amorphous peat soil (Engl. and W.), 'Koop' peat soil (Neth.)

Profile description

H_1	0-8 cm	Black to dark reddish brown (5YR2.5/1-2) clayey peat; no distinct mottles; moderate medium subangular blocky structure; moulded; friable when moist; few sand grains; clear and smooth boundary.
H_2	8-15 cm	Very dark grey (5YR3/1) clayey peat; no mottles; moderate medium prismatic structure; moulded; friable when moist; few sand grains, gradual and smooth boundary.
H_3	15-25 cm	Black (5YR2.5/1) peat; strongly oxidised wood peat with some remnants of roots and branches; weakly moulded; moderate medium prismatic structure; no mottles and sand grains; gradual and smooth boundary. This horizon is a transition between earthy clayey topsoil and the non-moulded subsoil.
H_4	25-65 cm	Black to very dark grey (5YR2.3/1) peat with remnants of branches and other recognisable plant remains; oxidised; gradual smooth boundary.
H_5	65-80 cm	Dark reddish brown (5YR3/3) peat; changing rapidly into very dark gray (5YR3/1) on exposure to air; non- oxidised and reduced wood peat with many recognisable remnants of plant remains.

Table 1 Analytical data

Nr.	hor.	depth in cm	pH H_2O	pH KCl	organic matter %	C org.	Nt	C/N	$CaCO_3$ %
1	H1	2- 8		4.3	51				0
	H2	8- 15		4.2	47				0
	H3	15- 25		4.4	56				0
	H4	25- 65		3.8	76				0
	H5	65- 80		3.9	78				0
2	H1pg	0- 22		4.0	30.1	18.1	1.5	12.1	0
	H2	22- 39		3.5	56.1	31.2	1.55	20.1	0
	Bg1	40- 50		5.0	12.0				0
	Bg2	50- 70		3.3	5.1				0
	Cr	80-100		7.0	3.8				7.5

Site interpretation

The soil is typical for the present low-lying peat soils in this region, all left over from the former bogs covering the major part of the western Netherlands (Fig. 2). The main soil forming processes are: ripening, oxidation and weathering, moulding of the topsoil. The main results of these processes are subsidence and a moderate firm topsoil under good drainage conditions. These soils have earthy (moulded) topsoils with organic matter contents of 25-55%, pH's (KCl) of 4.0-5.5. The C-N ratio is low, which is normal for soils developed from wood peat. Sand has been used as absorbing substance in the stables, and when mixed with spoil dredged from the ditches this sand-containing manure was spread over the field. Some parts of these soils, especially the soils with low pH's are more or less hydrophobic.

Subsidence and drainage

The appearance of subsidence of the farm yard will be shown.
Due to an elevation with 1 m sand in relation with yard metalling the surface subsided also 1 m.
Equal appearances happen at silage of fodder grass. Concrete bottoms for storage of fodder grass subsided about 30 cm within 2 years, therefore the bottom layer of the silage got into the ground water resulting in loss of quaility of the silage.
In the field you can have a look at the system of different ditch water levels. Deeper drainage is executed by small simple electric pumps. The subsiding ground level is followed at a reference point since 1969. The data are taken from iron pole founded in the underlying pleistocene subsoil.
Since 1969 a total subsidence of 18 cm has been established (see Table 2).

Table 2 Subsidence (cm) due to the different components and as a total over the years 1969-1983

Location Zegveld	h_s	$z_o + z_k$	z_i	z_t	Source
	0.2	5	4	9	ICW 1983
	0.3	7	0	7	
	0.6	15	5	20	
	0.7	13	3	16	
	0.7	15	3	18	

h_s ditch water level (m)
z_o oxidation
z_k shrinkage
z_i settling
z_t total subsidence

Stop 3, soil H-NL6

Site description

Topographic sheet : 31w, coord. 110-462, near the Village of Aarlandsveen, 27 km W of Utrecht.

Geomorphology : level bog floor adjacent to ringdyke foot; surface 5 m below MSL. The landsurface is also the bottom of a former lake drained between 1797 and 1809

Drainage and groundwater : no tile drains: ditches spaced at intervals of 30-80 m. The ground-water-table fluctuates between 25 and 80 cm

Vegetation : grassland with rooting depth 30-40 cm some roots alongside cracks into the Bgl horizon

Parent material : thin peaty lacustrine deposit overlying a remnant of peat, overlying marine sediment the latter about five thousand years old

Soil name : FAO '74: Thionic Fluvisol
USA '75: mesic Sulfaquept
Others : Organomarch (Germ.), Sol humique à gley (France), Sulphuric humic alluvial gley soil (Engl. and W.), 'Plas' earth soil (Neth.)

Table 3 Analytical data

Nr.	hor.	depth in cm	texture in % sand >50 µm	silt 2-50 µm	clay <2 µm	bulk density g/cm³	pv in cm³/cm³	moisture in cm³/cm³ at pF 0.6	1.8	2.5	4.2
1	H1	2- 8	-	-	-	0.52	0.73	0.75	0.70	0.64	0.32
	H2	8- 15	16	16	68	0.51	0.74	0.74	0.72	0.65	0.31
	H3	15- 25	-	-	-	0.35	0.81	0.80	0.73	0.65	0.30
	H4	25- 65	-	-	-	0.17	0.89	0.87	0.75	0.67	0.23
	H5	65- 80	-	-	-	0.12	0.92	-	-	-	-
2	H1pg	0- 22	17	48	35	-	-	-	-	-	-
	H2	22- 39	-	-	-	-	-	-	-	-	-
	Bg1	40- 50	-	-	50	-	-	-	-	-	-
	Bg2	50- 70	2	42	56	0.68	0.74	-	-	-	-
	Cr	80-100	-	-	51	-	-	-	-	-	-

Profile description

Hlpg 0-22 cm	Very dark grey (10YR3/1) peaty silty clay loam; common fine distinct mottles; moderate medium to coarse prismatic structure and in the soil moderately weak very fine subangular blocky structure; friable, slightly hard; non-calcareous, hydrophobic; clear and smooth boundary
Bgl 40-50 cm	Dark grey brown (10YR4/2) silty clay; non-calcareous; nearly ripened; many fine to medium mottles; moderate medium prismatic structure; clear and smooth boundary
Bg2 50-60 cm	Grey (25Y5/1) silty clay, non-calcareous; partly ripened; common to many distinct pale yellow mottles of jarosile and common distinct brown mottles, mainly alongside cracks and fossil reed-root channels; weak coarse prismatic structure; gradual and smooth boundary
Cr 80-120 cm	Grey (10GY5/1) silty clay; calcareous; no mottles; remnants of reed; non-ripened slushy material

Site interpretation

The soil pattern in the bog floor shows a dendritic pattern of filled-in tidal creeks and basins in-between. This parent material contains 1-6% pyrite (FeS_2) and has been deposited about 4500 B.P. This, partly still unripened, sediments were overgrown by peat (see soil map in hand set) and are now exposed after the great cutting and drainage of the man-made lake (1809) after airation the clay turned extremely acid. During the process of ripening and oxidation pyrite is changing in sulphuric acid and Fe oxides. One of the important Fe oxides is jaronite $K_1Fe(SO_4)_2(OH)_6$. This forms the yellow mottles in the Bg2-horizon.

The main problems of these soils are:

- a low pH
- the hydrophobic characteristic of the top soil

Formation of acid sulphate soils

Microbiological processes under the presence of organic matter and anaerobic circumstances, result in formation of pyrite

1. $Fe^{2+} + H_2S \rightarrow FeS + 2H^+$

2. $FeS + S \rightarrow FeS_2$ (pyrite)

By ripening of the sediment, oxidation of pyrite follows

3. $3\ FeS_2 + 6\ H^+ + 10\frac{1}{2}\ O_2 + 3\ H_2O \rightarrow 3\ Fe^{2+} + 12\ H^+ + 6\ SO_4^{\ 2-}$
(sulfuric acid formation)

4. $12\ Fe^{2+} + 30\ H_2O + 4\ O_2 \rightarrow 12\ Fe(OH)_3 + 24\ H^+$

If the sediment in calcareous, sulfuric acid (3) will be neutralised.

5. $6\ CaCO_3 + 12\ H^+ \rightarrow 6\ Ca^2 + 6\ H_2O + 6\ CO_1$

6. $6\ Ca^{2+} + 6\ SO_4^{2-} + 12\ H_2O \rightarrow 6\ CaSO_4 - 2\ H_2$ (gypsumformation)

In case of deficiency of $CaCo_3$ step 4 is followed by step 7.

7. $3\ Fe(HO)_3 + k^+ + 2\ SO_4^{\ 2-} + 3\ H^+ \rightarrow KFe(SO_4)_2(OH)_6 + 3\ H_2O$
(Jarosite formation)

Stop 4, short walk

Site description

Topographic sheet	: 31w, coord. 110-466, near the Village of Papeveer, 25 km WNW of Utrecht, see also Fig. 11
Geomorphology	: conjunction of different polders with different height of the landsurfaces between 4.40 m - 1.40 m below MSL, see also Fig. 13
Drainage	: different pumping levels belonging to the different polders will be shown

Site interpretation

Several waterlevels can be seen at this point: they belong to three different groupw:

I Boezem level of Rijnland, 0.60 m below Mean Sea Level (MSL). this water level is controlled within a few cm. All lands in these surrounding are below this water level and consequently their water has to be pumped into the boezem. We will see this boezem level at the end of the walk.

II Shallow polders where the peat is still present:
   a) Polder Nieuwkoop & Noorden, polder level 1.50 m below MSL. This polder is lying further south, but the small canal at our right forms part of this polder.
   b) The small Schilkerpolder (only 65 ha) behind this canal, with polder level 2.00 m below MSL. Subsidence of the peat has caused a decline in elevation from above MSL to the present land level of 1.40 m below MSL. Direct drainage into the boezem became impossible around 1500 A.D. and a windmill was installed. At present it drains by gravity into the deep polder Nieuwkoop (see III).

III Deep polder Nieuwkoop at our right, drained after removal of the peat, 1890 ha, with water level 5.85 m below MSL. From an earlier shallow polder, the peat was dredged for fuel and a lake remained. The bottom of this lake consisted of potentially fertile "old sea clay". The level of the lake was the same as that of the small canal at our right; in fact, the dam on which we are walking was not existing at that time.

Drainage of the lake was started by constructing this dam and the circular canal all around the future deep polder. After these were completed, the remaining isolated lake was drained by a series of windmills in 1797.

In the field the remnants of such a serie of mills can still be seen. It consisted of four windmills operating "in series" which pumped the water directly into the boezem. The small canal at the old lake level was crossed by a culvert underneath. At present the deep polder is drained by an electrical pumping station further S. (not to be seen) and the windmills are no longer there. Instead, the old culvert and part of the system of waterways are used to drain the small Schilkerpolder (behind the canal) into the deep polder Nieuwkoop via an overflow. So the direction of flow is just opposite as it used to be.

At the overflow the water smells of H_2S liberated from the peat still present in Schilkerpolder. It is being oxidized by sulfur-forming bacteria (the whitish sticky skins) into H_2O and elementary sulfur.

In the deep polder natural gas is collected for domestic use. The methane gas (CH_4) stems from the basal peat which is found under the old sea clay now exposed in the deep polder. This gas has accumulated in the underlying Pleistocene sands, which occur at 6-7 m below the surface. Wells in the sand are artesian and yield a mixture of water and gas. This mixture is separated and the gas is collected in a small resevoir. The brackish water flows into the ditch and is finally pumped into the boezem. As such gas wells are important sources of salinization of the boezem waters, most of them have been closed and construction of new ones is not allowed.

We cross the canal with the level of 1.50 m below MSL.
After passing the farmhouse, we see:
- to our right: one of the canals of the boezem system, level 0.60 m below MSL
- to our left : a branch of the circular canal at 1.50 m below MSL, which we have crossed earlier.

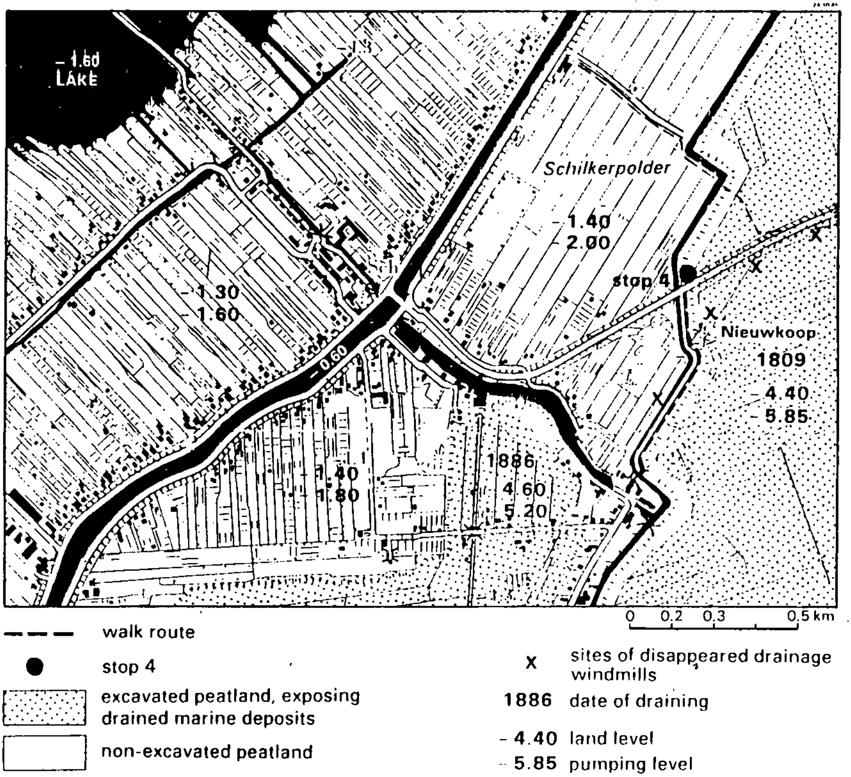


Fig. 13 Topography and maintained water levels in the peat area, see also fig. 14 and 11

Stop 5, the Cruquius Museum

The museum is housed in one of the three steam-driven pumping stations, that drained the Haarlem-Lake in 1852. Gradually the two other pumping stations have been modernised and enlarged, since 1933 the Cruquius became a museum, a relic from the Steam Age.
A model of the country at full springtides, models of windmills, steam engines, maps and drawings show how the Dutch Low Lands are protected by dikes and drained by pumping.

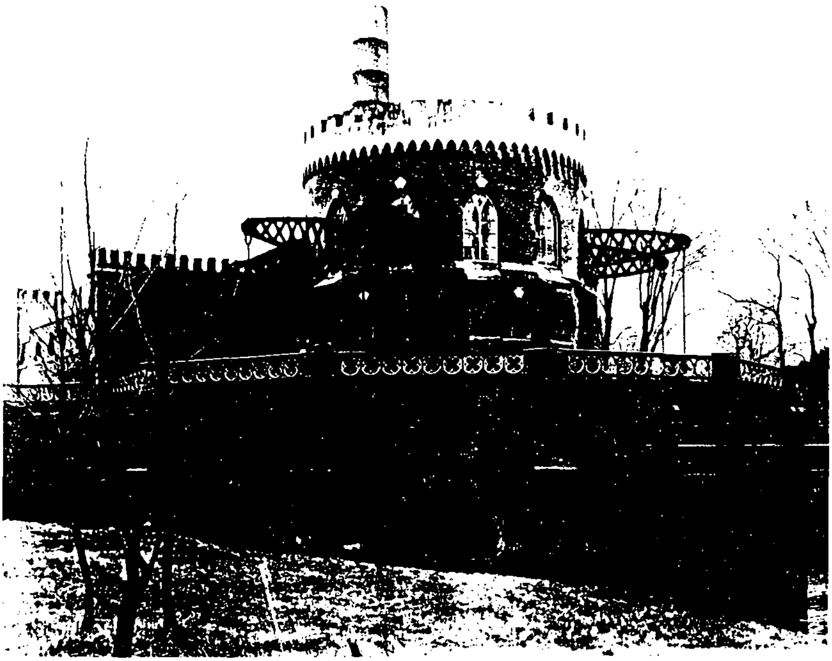


Fig. 14 The Cruquius

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EXCURSION H

General itinerary

First day (21/8/1986)

8:00	Departure Hamburg
9:30	STOP 1 (page 27) Huvenhoopsmoor - nature reserve
10:30	STOP 2 (page 28) Dystric Histosol - German Raised Bog Cultivation Raised bog colony "Augustendorf"
12:15	Lunch in Gnarrenburg Preliminary instructions "Industrial Peat Cutting"
14:00	STOP 3 (page 39) Industrial peat cutting "Peatworks MEINERS GmbH & Co.KG"
16:30	STOP 4 (page 40) Worpswede - art exhibition
18:30	Arrival in Bremen Dinner, bed and breakfast - Hotel IBIS, Bremen
20:00	Sightseeing tour Bremen

Second day (22/8/1986)

8:00	STOP 5 (page 41) Institute of Soil Technology, Bremen
9:30	Transfer to the excursion area "Bourtanger Moor" (Emsland) Route description on page 42 - 43
12:00	Lunch in Groß Hesepe Preliminary instruction "Emsland colonization"
14:00	STOP 6 (page 51) German sand-mix cultivation - Profile and farm - Deep ploughing
16:30	STOP 7 (page 60) Moormuseum Groß Hesepe Emsland colonization
18:30	Arrival in Enschede (Netherlands) Dinner, bed, and breakfast in ITC
20:00	Evening programme in ITC

Third day (23/8/1986)

8:00	Departure Enschede
8:30	Excursion (page 78)
11:00	Visitors centre "De Foeke" from the Dutch Society for Preservation of Nature Reserves (page 92)
12:15	Lunch in Vollenhove Introduction to the afternoon excursion
13:30	Afternoon excursion (page 96)
17:00	Trip form the Ijsselmeerpolders to Wageningen Dinner, bed and breakfast in IAC (International Agricultural Centre)
20:00	Evening programme in ISRIC (page 106)

Fourth day (24/8/1986)

8:30	Departure Wageningen
9:30	STOP 1 (page 119) Meije-Walk through countryside
11:00	STOP 2 (page 120) Experimental Farm - Soils and Landuse
12:30	Lunch in Nienwkoop View on Lake side
14:00	STOP 3 (page 122) Bog floor soils
15:15	STOP 4 (page 124) Watermanagement
16:15	STOP 5 (page 126) Historical site - Museum "Cruquius"
17:45	Arrival in Amsterdam Central Station
	End of excursion

Acknowledgements

Part I :

Contributers	Contributions
Mr. R. Horstmann Hesepermoor	Farmer, STOP 6 German Sand-mix Cultivation
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