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Differences of Efficiency of Soils for Land Uses,
Expenditures and Returns



Tour Guide

**Use of sandy soils in the context
with regional soil diversity and soil productivity**

International Conference on Soil Fertility and Soil Productivity

Berlin, Germany

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Use of sandy soils in the context with regional soil diversity and soil productivity

Berlin, March 2010

International Conference on Soil Fertility and Soil Productivity

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Tour guide

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Berlin, March 2010

Preface

Welcome to Berlin. It is our pleasure to invite you on a tour of the area surrounding Berlin.

Our route will take us into a relatively young landscape that was formed at the end of the Pleistocene after the thick glaciers that covered northern and central Europe melted. The Holocene, and with it soil development, began in the Berlin-Brandenburg region around 10,000 years ago. Wind and water erosion in addition to land use, which started around 2,600 years ago, continue to form and influence the landscape and soils up to this day.

The area of interest lies in the State of Brandenburg around 50 km southwest of Berlin in a typical glacial landscape. Vegetation and land use pattern follow the geomorphology which varies over small distances. Here we can introduce you to the landscape, soils and varied land uses of the area. We will visit a farm where the wide range of site factors that are typical for the region present a challenge as well as an opportunity to farm in a sustainable and competitive manner. At the Teaching and Research station of the Faculty of Agriculture and Horticulture at the Humboldt-Universität zu Berlin you will get information about the long-term field experiments on sandy soils maintained here since more than 70 years.

Five soil profiles will be presented that represent typical sites for arable land, grassland and forest. For each profile, agronomic information for the crops cultivated including expected yield will be presented. In addition, the limitations for use resulting from site factors as well as the risks resulting from improper management practices will be discussed.

So we hope you get an impression of the varying natural conditions and land use potential, as well as the options for agriculture in the Brandenburg region.

Christina Hierath and Kathlin Schweitzer

Content:

1. Introduction to the landscapes, land use and soil productivity of Brandenburg

Landscapes

Based on geomorphology and climate, Germany's landscapes can be divided into three major natural regions: the North German Plain, the Central Uplands and the Alp Mountain Region.

Brandenburg is located in the Northeast German Plain, which can be distinguished from the Northwest German Plain by its more continental climate.

Elevation and climate are mostly constant throughout the Northeast German Plain. The differences in vegetation and land use type are primarily a result of the geomorphology.

Northern Germany's surface is made up exclusively of unconsolidated sediments from the ice ages. This material was transported south by continental glaciers from Scandinavia and the Baltic Basin, reworked and sorted in glacial melt waters. The glaciation in northern Germany resulted in a typical sequence of landscape forms:

- **Ground moraines** were formed under glacial ice and are now plateaux which rise up above the common land level. The ground moraines are primarily made up of glacial till which was modified at the end of the ice age through solifluction and cryoturbation. Through these processes, the top 50 - 70 cm were depleted of almost all clay resulting in a textural transition at this depth from sandy to loamy. The relief of the ground moraines is usually gently undulating with slopes of < 2 % to > 10 %. The ground moraines are often dissected by glaciofluvial channels filled with sands of varying texture.
- **End moraines** were formed at the edge of glaciers, which show typical ridges with elevations of up to 150 m above sea level and small-scale steep slopes. The sediments are characteristically heterogeneous and high in stone content.
- **Wide outwash plains** were deposited in front of the glacier edge. The sands are usually coarse textured and gravely. They are among the most nutrient poor and driest sites.
- **Broad, level glaciofluvial valleys** are found further south of the glacier edge at an elevation of 30 to 50 m above sea level. The glacial melt water flowing northwest to the North Sea deposited fine to medium textured sands.
- **High dunes** were formed from fine sands at the edge of the broad glaciofluvial valleys. Eolian sands can overlay till at the edge of ground moraines. Extensive loess regions are found south of the glaciated region.

As a result of the multiple glaciation phases in central Europe, these landforms are arranged in a typical sequence that is repeated across northern Germany.

In the Holocene Period, river valleys cut into the glaciofluvial valleys. These valleys are now composed of varying often loamy or clayey alluvial sediments.

Soil formation

Soil formation is closely linked to glacial geomorphology and to the periglacial processes of cryo-turbation and solifluction during the late glacial period.

Clay eluviation in the upper part of the till resulted in development of Luvisols on the ground moraines.

Weathering took place in the predominantly sandy deposits. However due to the low abundance of easily weatherable silacates and the low Fe and Al oxide contents significant cambic horizons were not formed. Therefore, Arenosols represent the prevalent soils in the glaciofluvial sands as well as aoelian sands if they are not influenced by ground water.

In the parts of the glaciofluvial valleys that have a high water table, Gleysols dominate. In addition, the accumulation of poorly aerated organic matter resulted in the development of Histosols. Histosols can also be found in wet depressions within the ground moraines and end moraines.

Later in the Holocene, soil development was closely linked to vegetation, land use and soil coverage. Soil erosion often determined soil development. In exposed positions, such as hilltops of ground moraines, the sandy layer has been completely eroded. The resulting soils are sandy-loamy, often carbonaceous, Regosols. Intense forest use, especially with conifers typically found on dry sites, results in weak podzolation. Pronounced spodic horizons are rare and only found in wetter areas.

The area of interest is located in the region called Central Brandenburg Plateaux and Lowlands (*Mittelbrandenburgische Platten und Niederungen*) in which uplands and lowlands regularly alternate. The uplands are the remnants of ground moraines that rise above the broad melt water valley, called the *Berliner Urstromtal*. The lowland areas drain into 2 rivers the Nuthe and Notte, into which the numerous drainage ditches flow.

Climate

After the ice age, the region was subject to climate fluctuations where the temperatures varied ±2 - 3° from the current temperatures. The current climate is a temperate suboceanic to temperate subcontinental climate (Climatic Areas of Europe). The average annual temperatures range from 5 to 10°and the precipitation ranges from 500 – 700 mm. Slightly more precipitation falls in the summer than in the winter. The annual potential evapotranspiration is equal to, or slightly greater than, annual precipitation.

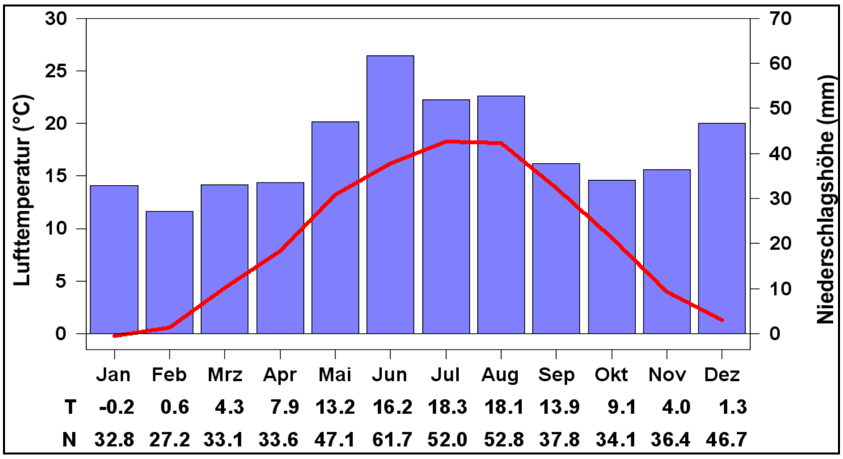


Fig. 1: Mean monthly temperature and precipitation during the last 3 decades at location Thyrow (Chmielewski, 2009)

Due to the meagre precipitation in the spring and simultaneous rising temperatures (Fig. 1), however, there is a danger that a noticeable water deficit occurs at this critical time of intense growth.

In the area of interest (Climate station Thyrow), the average annual temperature is 8.9˚C. The coldest month is January with a temperature of -0.2 ˚C, however yield depressions due to cold are rare. In the warmest month, July, the average monthly temperature reaches 18.3˚C. The average annual precipitation of 495 mm is small compared to the rest of Germany. Especially the winter and early spring, with average monthly precipitation of 27 – 32 mm, are relatively dry. The maximum average precipitation of 62 mm occurs in July.

Considerable differences in precipitation between April and June (Tab. 1) are the main factor for annual yield variation.

Tab. 1: Variation of monthly precipitation over the period 2001 – 2009 at location Thyrow (Baumecker, 2009)

Year	**1971-2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
April	**33,6**	33,4	41,8	16,8	17,0	11,2	29,1	1,1	60,5	2,8
May	**47,1**	49,1	114,2	19,7	42,3	91,3	47,9	140,4	6,8	91,4
June	**61,7**	54,0	29,4	40,8	54,7	27,7	16,0	109,5	23,0	48,4
Total	**142,4**	**136,5**	**185,4**	**77,3**	**114,0**	**130,2**	**93,0**	**251,0**	**90,3**	**142,6**

Vegetation and Land Use

Under the current climatic and soil conditions and without human influence, Germany would be covered by mostly deciduous broadleaf forest and broadleaf-coniferous mixed forest.

Depending on the water supply and soil conditions, the following forest types can be found as potential natural vegetation in Brandenburg:

- On acid soils, without groundwater influence (low to high natural fertility): pine forest, pine – oak forest, oak forest, in small areas beech forest and oak-beech forest.
- On sites with a high water table: alder swamp forest, riparian forests with pedunculate oak, ash, elm, willow, black poplar, alder

The land uses forest and arable land compete on the well-drained sites, while in the moist lower areas grassland and arable land are the dominant land uses. Brandenburg belongs to the federal states richest in forests. Forest covers 35% of the area, agriculture 49%, 78% of which is arable land and 21.5% grassland *(Amt für Statistik Brandenburg / Statistical Bureau of Brandenburg, 2007, 2008)*

In Brandenburg the ground moraines are mostly used as arable land. Shifts in land use over time, however, show that there have been historical periods where even very unfertile, dry sites have been used as cropland. In the middle ages, the cropping of poor sites was the cause for strong wind and water erosion. Evidence is visible in the form of colluvium that is several meters thick as well as eolian sands and sand dunes. Today, these sites are used as forest as the end moraines are typical sites for forestry. Traditionally, the fast growing pines dominate with a share of 79 % of the forest area in Brandenburg (*Landesforstanstalt Eberswalde, 2006*). Depending on the natural soil fertility, they are to be gradually converted to mixed broadleaf forests.

Large areas of mostly organic soils in the wet lowlands were converted to agricultural use through extended drainage ditches. Some of the drainage ditches date back to the 17th century, but the current system of drainage in northeast Germany is a result of the widespread amelioration 40 years ago. Within a few years, the increase of arable land area was contrasted by the decrease in fertility of the organic soils. The drainage of organic soils leads to shrinkage through decomposition, degradation of soil structure, worsening of both air regime and water regime. Water availability for plants decreased, hydraulic conductivity and infiltration rate were lowered.

Soil productivity

In Germany, a *Soil Assessment Rating System (Bodenschätzung*) is used to classify the productivity of agricultural land. This system, based on natural site characteristics, was developed in the 1930s for taxation of farms. On the basis of sampling in a 50 x 50 grid the soils are split into classes based on soil texture, soil condition and origin of parent material. These factors result in 222 soil classes for arable land and 225 classes for grassland where water table and climate are also taken into consideration. Each class is equivalent to about 6 points on the soil assessment scale from 16 to 100 points. The best soils, getting 100 point are Chernozems formed from loamy loess.

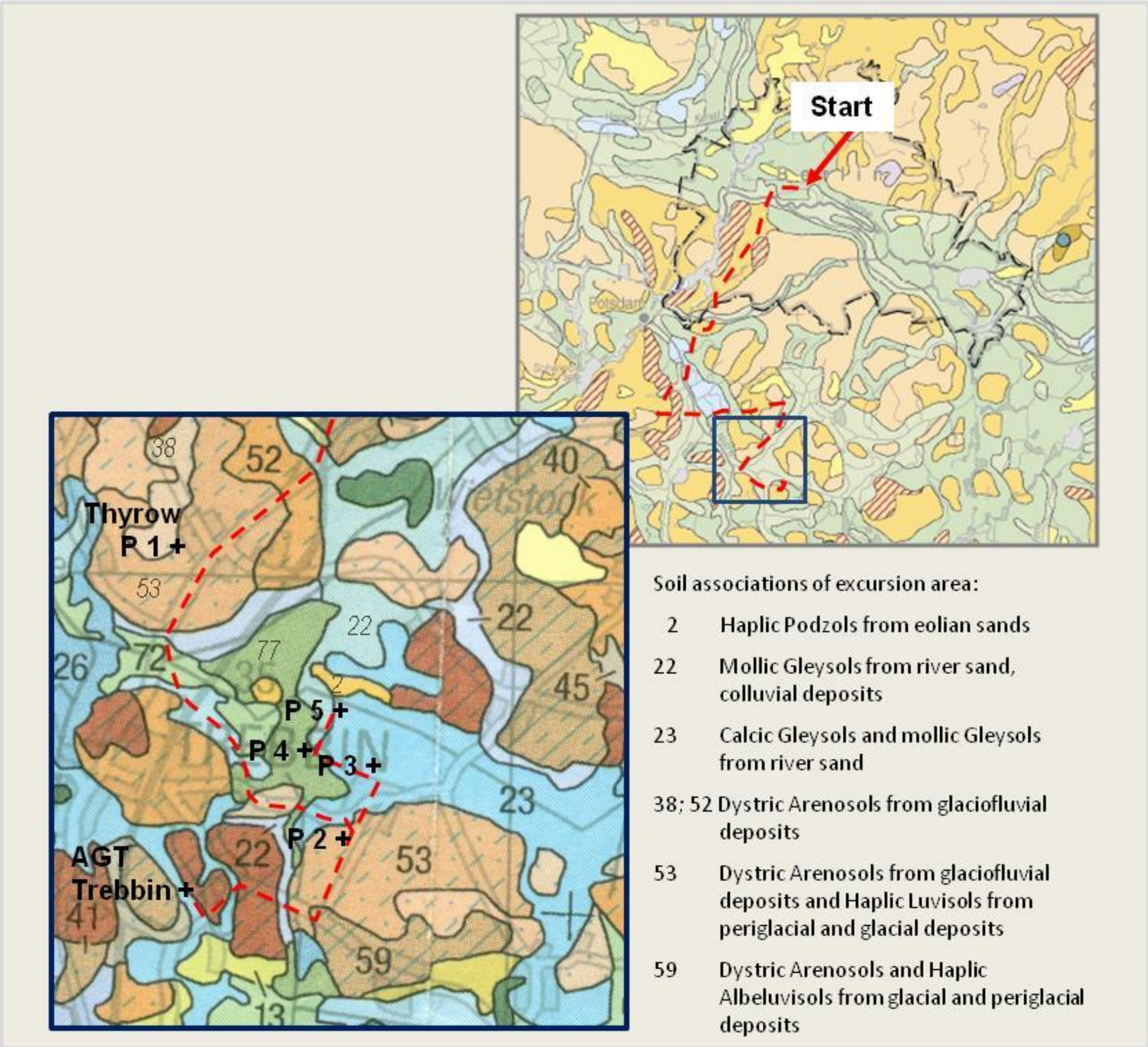
The vast majority of agricultural land has weak to moderate productivity with a rating range from < 30 to 50 points in Brandenburg. Around 9% are among the least productive sites. Areas where most of the soils are in classes > 50 only occur on 15% of agricultural land (LBGR 2007 in Heinrich & Hierold, 2009). These areas are concentrated in the floodplains of the Oder River and in the northeast corner of Brandenburg, where small areas of Chernozeme-like soils can be found. The low soil productivity is exacerbated by frequent drought spells.

Tab. 2: Areas and yields for the main crops in Brandenburg (*Agrarbericht 2008 and 2009*, *LVLF*)

Crop	Area (1,000 ha)	% of agricultural land in Brandenburg	Yield (2003 - 07) (100 kg ha^{-1})
Rye	227.0	17.1	40.2
Winter wheat	140.5	10.6	57.3
Canola	121.2	9.1	33.5
Winter Barley	76.2	5.7	53.6
Triticale	51.7	3.9	42.8
Total biofuels	64.2	4.8	
Silage maize (30%DM)	22.7	1.7	316
Canola	21.7	1.6	

Due to the mostly sandy soils and frequent drought spells, Brandenburg is the most important producer of rye in Germany. The areas and yields for the main crops in Brandenburg are summarized in the table above (Tab. 2). Yield and cultivation in the region of interest are discussed in context with the presented soil profile sites.

2. Tour overview



above: Overview of the geology along the tour (yellow: holocene eolian sands and dunes; blue: peat and fluvial sands of broad valleys; reddish: ground moraines; brownish: glaciofluvial deposits; hachure: end moraines). (Map from “Atlas zur Geologie von Brandenburg”; LGBR, 2004)

below: Soil associations of the area of interest (Detail of the 1 : 300.000 Soil Map of Brandenburg state, LGBR, 2001; italicized legend numbers were inserted by the author)

Point	Information	
Thyrow	Experimental station of applied crop sciences of Humboldt-Universität zu Berlin	
AGT	Farmers‘ cooperative “Agrargenossenschaft Trebbin eG”	
P1	Profile 1: Luvisol from sand overlying periglacial loam	Arable land
P2	Profile 2: Luvisol from loamy sand overlying periglacial loam and glacial till	Arable land
P3	Profile3: Gleysol from river sand	Arable land
P4	Profile 4: Gleysol from peat overlying river sand	Grassland
P5	Profile 5: Arenosol from eolian sand overlying river sand	Forest

3. Experimental Station of Applied Crop Sciences in Thyrow

Thyrow, around 30 km southwest of Berlin, is the location of one of the four experimental stations belonging to Teaching and Research Station of the Faculty of Agriculture and Horticulture of the Humboldt - Universität zu Berlin.

The experimental station is the first stop of the tour where **Profile 1** is located. This profile is used as a teaching profile for students of agriculture and geography at the Humboldt - Universität and is permanently open.

Thyrow is among the few research sites representing poor to marginal arable sites in Europe. Since optimisation of land use has become a main focus of agroecology, this topic is of increasing interest.

The experimental station Thyrow is a part of the European Phenological Network (EPN) as well as the global SOMNET program (Network of Soil Organic Matter Models). It is mainly known for its long-term field studies on sandy soils that are up to 70 years old.

Long term field experiments and research focus

Thyrow's experimental station was founded in 1936. The first experiments were arranged in that time, some of which still exist today. The initiator was Prof. Opitz, the former department head of the Institute for Agronomy and Plant Sciences at the Friedrich - Wilhelm - Universität which later became the Humboldt - Universität zu Berlin.

The *Nutrient Deficiency Experiment* (since 1937), the *Continuous Fertilization and Irrigation Experiment* (since 1968) and the *Long-Term Soil Fertility Experiment* (since 1938) are among the most important long-term experiments in Thyrow. Due to a few special characteristics, these experiments are unique not just on a regional level. The oldest experiment, which has barely been changed since the founding of the experimental station, is the *Nutrient Deficiency Experiment*. This fertilisation experiment follows the tradition of the long-term experiments in Rothamsted (UK), Halle (Germany) and Bad Lauchstädt (Germany). The *Continuous Fertilization and Irrigation Experiment* is the only long-term experiment in which the long-term effect of irrigation on soil and plants is measured. The use of soil texture as an experimental variable through the addition of clay as a soil supplement in the *Long-Term Soil Fertility Experiment* is unique in Europe (Ellmer et al., 1999). In addition, the experiment *Crop Rotation* and *Straw Incorporation* is particularly relevant in light of the current discussion of providing organic matter soil inputs despite the rise in demand for straw for biofuel production. The *Rye Monoculture and N-Fertilisation Experiment* was designed in 1988 for this typical grain crop for sandy sites. New experiments, designed in 2005 as long-term experiments, include the *Management Systems Experiment* as well as *The Demonstration and Research Site of Cropping Systems.*

Until the end of the 60s, the research focus for the long-term experiments was the maximum yield on sandy soils with different levels of fertilisation and the exhaustion of soil fertility without fertilisation. The effect of organic fertilisers, and later, the interaction between organic fertilisers and humus level on yield was always the primary interest. In the 70s, the experiments to maximize yields were intensified. In that period the objective was the access to nutrients in the subsoil (sustainability of amelioration by deep ploughing) and the effectiveness of irrigation. In the 80s, detailed investigations involving soil humus- and Nitrogen balances were started. In the 90s, environmental aspects became a priority such as sustainability (balanced nutrient management), nutrient leaching as well as exhausting subsoil nutrients. The new experiments, started in 2005, take into account organic management systems, conservation tillage as well as biomass production as an energy source.

General soil site characteristics

The normally undulating relief of a ground moraine is only very weakly expressed on the experimental station. The slopes are rarely above 1 % and do not reach 2 %. The soils are well-drained, there is no groundwater influence and stagnating water plays no role since it is only found at deeper depths.

The experimental station is located on the transition between glacial till and sandy glaciofluvial deposits (see *Tour map*). Arenosols are associated with Luvisols (German classification: *Braunerden, Fahlerde-Braunerden*, and on forest sites *Podsol-Braunerden*). The Arenosols dominate in the sandy glaciofluvial deposits. In the glacial deposits Luvisols alternate with Arenosols depending on the thickness of the sand overlying the glacial till (German classification: *Fahlerden, Braunerde-Fahlerden*).

This soil profile is a Luvisol with a 90+ cm thick sandy albic horizon overlying a loamy argic horizon.

Long-term and detailed soil investigations on the experimental site can be summarized in the following site characteristics:

The topsoil and subsoil texture is sand to loamy sand. Starting at a depth of 60-70cm a small-scale textural change occurs from sand to sandy-loam or loam (Fig. 2)

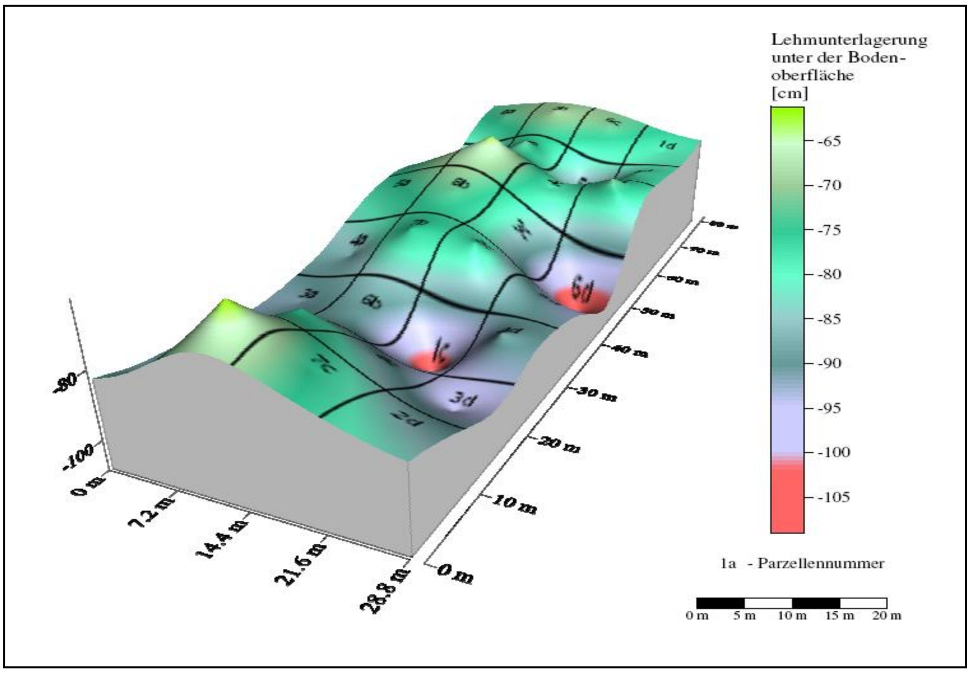


Fig. 2: Variation of the textural change from sand to loam at the site of the Nutrient deficiency experiment (Vogel, 2006)

The organic matter content in the topsoil is very low, which is typical for dry sandy sites. In the long-term fertilisation experiments the treatments with no fertilizer inputs resulted in minimal C_{org}

concentrations of between 0.3 and 0.4%. The treatments with a combination of organic and mineral fertilisation showed maximum C_{org} contents of 0.7 – 0.8%. The C:N ratio is mostly high (up to 29).

Buffering capacity and nutrient retention in the topsoil is low, risk of leaching high. The pH drops within a few years if liming is stopped (minimum pH 4.0). N-leaching has been measured up to a depth of 3.5 m. The low P sorption capacity (< 20 mmol kg^{-1}) and the low Potassium sorption (40 – 100 mg kg^{-1}) results in a high P and K mobility.

Despite the low total P content (273-473 mg P kg^{-1}) the P mobilisation rates are considerable. These rates allow an adequate long-term P supply. In contrast, a lack of K fertilisation cannot be compensated over a period of a few years. Lack of N-fertilisation leads to immediate yield reduction.

The soils have an unfavourable water regime. The mostly sandy texture in the main rooting zone (0-60 cm) can only store around 81 mm of plant available water. Considering that the precipitation is only 250 mm (Fig. 1) during the vegetation period the soil water reserves are insufficient for high yields.

The soils are easily compacted due to lack of soil structure, and the presence of a small percentage of silt. If the slopes were steeper, the soils would have a medium risk of water erosion when lacking a protective vegetation cover.

Soil productivity and yields

According to the *German Soil Assessment Rating System* (*Bodenschätzung*), the productivity of the Thyrow soils is classified as low to middle (16 – 33 points).

Given the characteristic site conditions at Thyrow, the following yields (long-term averages) were reached in the long-term experiments without irrigation (Tab.3:

Tab. 3: Minimum and maximum yields in the long term field experiments in Thyrow (100 kg ha^{-1})

Treatments	Winter rye	Winter barley	Summer barley	Silage maize (DM)	Potatoes (tuber FM)
1	4 – 53		8 - 35		
2			0 - 12	8 - 128	36 - 535
3	7 - 49			35 - 146	105 - 274
4	22 – 55	17 – 45			120 – 280

1 … different N-fertilisation, straw incorporation and crop rotation

2 … nutrient deficit, with and without liming

3 … different organic fertilisation and N-fertilisation

4 … different manuring and N-fertilisation

Irrigation only becomes effective with a well-balanced organic-mineral fertilization, yielding 14% more winter rye and 16% more winter barley.

Slightly increased clay contents (8.2% compared to 4.5%) lead to 17 - 108% higher yields of silage maize, 23 - 51% of potatoes, and 4 - 60% of winter rye. A highest yield increase is reached without mineral N fertilization.

4. Farmers’ cooperative *Agrargenossenschaft Trebbin eG*: farm management under regional soil and site conditions

Farming in Brandenburg is traditionally operated on a large scale.

At present, about half of the agricultural area in use is cultivated by 6% of the farms, each with an acreage of at least 1000 ha (Amt für Statistik Brandenburg, 2006).

The farmers‘ cooperative Trebbin (abbreviated AGT), with an acreage of 4140 ha, is among the eight largest farms in Brandenburg.

AGT (www.agt-eg.de) was established in 1990 after the merging of five farm cooperatives formed in the former GDR. Since then, the farm has evolved from a crop and animal production business to a modern agrarian service enterprise. AGT has operated a 1 MW (megawatt) biogas plant since 2005.

AGT is located about 60 km southeast of Berlin in a typical glacially formed landscape. The area under cultivation comprises a broad range of different habitats from swamps and ground water influenced sites, via extremely low-yielding dry and sandy soils to relatively good loamy soils.

On average, the agricultural productivity of AGT is rather low (Soil Assessment Rating: average of agricultural land 23 points, of grassland 27 points). Sites influenced by ground water are drained, and parts of the loamy soils are irrigated.

The varying sites are cultivated differentially. Altogether, AGT cultivates 2872 ha of agricultural land (70% of the land use) and 1268 ha of grassland (30% of the land use). The most important crops are grain (42% of the area), thereof predominantly winter rye, winter barley and triticale, as well as silage maize (30%) and canola (14%).

The livestock amounts to 3085 animals, which corresponds to 0.53 head ha^{-1}. Dairy cows make up 20% of the livestock with a yearly production rate of 9505 kg milk. The accruing slurry, maize and grass silage are used in the biogas plant. The remaining digestate is the major component of the organic fertilization, therefore significant amounts of nutrients remain on-site, and in the intra-farm nutrient cycle.

Overall, due to the farm size and varying cultivation, AGT has yield stability, a profitable combination of animal and plant production and allows an effective operation of the biogas plant.

5. Soil profiles

Detailed soil description was carried out according to the German guidelines in: Ad-hoc-AG Boden (2005): Bodenkundliche Kartieranleitung. 5. Auflage. Ed. by Bundesantalt für Geowissenschaften und Rohstoff und Niedersächsische Landesamt für Bodenforschung. Hannover 2005.

Information about soil associations is taken from: Bodenübersichtskarte des Landes Brandenburg, 1 : 300.000, Kleinmachnow 2001. Landesamt für Geowissenschaften und Rohstoffe und Landesvermessungsamt Brandenburg (Editors)

Soil profile 1: Luvisol

Cutanic Albic Luvisol (Abruptic Arenic) from sand overlaying periglacial loam

German: Fahlerde-Braunerde aus Decksand über tiefem Fließlehm

Geomorphology: ground moraine

Soil association: Dystric Arenosols from glaciofluvial deposits and Haplic Luvisols from periglacial and glacial deposits

Land use: arable land

Characteristics of soil location:

Altitude:	44 m a.s.l.
Relief:	level land (gradient < 2 %)
Erosion:	no water erosion
Water regime:	well drained
Topsoil properties (0 – 20 cm):	very low humus content, low CEC, low FC (23% Vol), medium capacity for plant available water (18% Vol)
Storage of plant available water (0 – 60 cm):	81 mm
Field capacity (0 – 100 cm):	194 mm
Agricultural soil productivity:	28-34 points

Rye yields 2001 -2009 (100 kg ha^{-1})

Year	Yield	Year	Yield	Year	Yield
2001	84	**2004**	80	**2007**	70
2002	62	**2005**	65	**2008**	45
2003	44	**2006**	46	**2009**	67

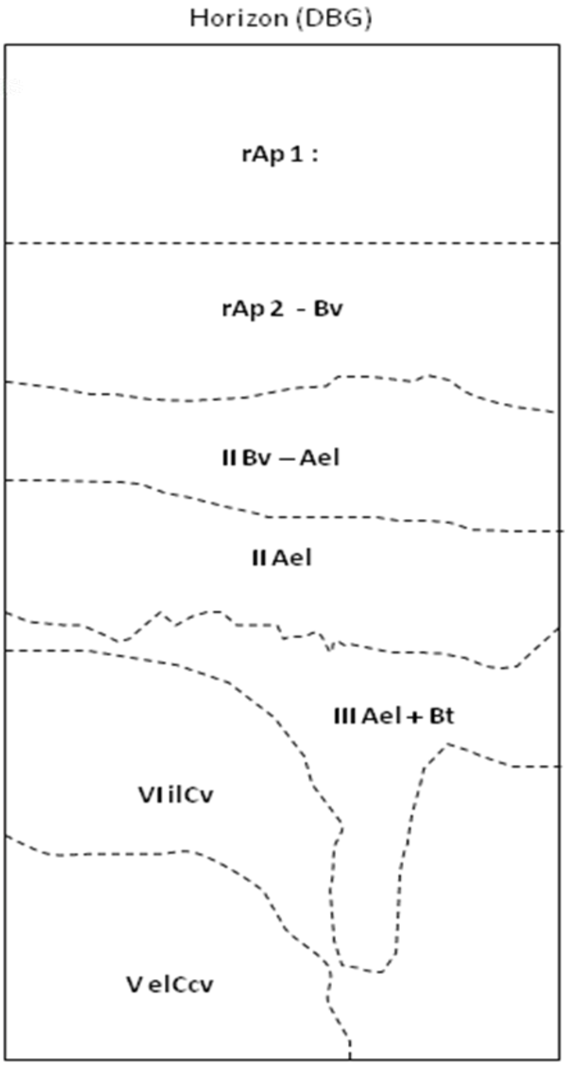
The soil profile is characteristic of a poor ground moraine site. Due to overlying glaciofluvial sands the sand layer is more than 90 cm thick. Water reserves are also low in the deeper subsoil and can hardly be reached by roots. The underlying loam and the deep lying calcareous glacial till are without significance for arable cultivation.

Soil use at the profile site often changed – the agricultural land was used intermittently as storage site for potatoes and sugar beets. This may be the reason for the accumulation of organic C at lower depth.

Agricultural production was stopped at this site 10 years ago. Due to the discontinuation of liming, the pH of the surface soil dropped. The low pH values of the illuvial horizon are geogenic.

The comparatively high bulk density in the subsoil is characteristic of ground moraine sites.

Profile description



Horizon (DBG)	Depth (cm)	Parent material	Description	Diagnostic properties (WRB)
rAp1	0 - 15	redeposited natural material	10YR4/3, loamy sand, very low humus content (OC < 0,6%)	
rAp2 - Bv	- 30		10YR4/4, 10YR4/6, medium to fine sand, very low discontinuous humus content (OC < 0,6%), increased bulk density	
II Bv - Ael	- 50	periglacial sand	10YR5/4, 10YR6/4, loamy sand, very low discontinuous humus content	
II Ael	- 95		10YR6/4, loamy sand	albic
III Ael + Bt	- 90-130	periglacial loam	10YR6/4, 5YR5/8, 7.5YR5/8, loamy sand and sandy loam, clay films	argic, cutanic
IV ilCv	- 130-155	glaciofluvial sand	10YR5/6, 10YR5/8, loamy sand	
V elCcv	>200	glacial till	10YR5/4, 10YR5/6, loamy sand, high carbonate content (< 15%), carbonate veins and pseudomycelia (> 5%), lamellae structure	

Analytical data:

horizon No.	horizon (DBG)	average thickness cm	Sand	Silt	Clay	Bulk density $g\ cm^{-3}$	soil moisture per 20.03.2009 % Vol
			% fine earth				
1	rAp1	30	87.7	10.1	3.3	1.62	7.7
2	rAp2 - Bv	20	90.3	6.5	3.2	1.67	10.5
3	II Bv - Ael	30	83.3	14.3	2.4	1.67	17.2
4	II Ael	12	80.9	16.3	2.8	1.70	17.8
6	III Ael+Bt	23	72.8	15.0	14.4	1.79	24.4
7	IV ilCv	27	75.8	15.0	9.3	1.79	19.2
8	V elCcv	> 58	72.7	19.3	8.1	1.80	17.1

horizon No.	horizon (DBG)	Fe_o	Al_o	Mn_o	Fe_d	Al_d	Mn_d	Fe_o/Fe_d
		mg kg^{-1}						
1	rAp1	1017	542	282	1660	469	217	0.61
2	rAp2 - Bv	663	455	235	1339	478	178	0.50
3	II Bv - Ael	426	239	110	1593	293	105	0.27
4	II Ael	316	144	73	1103	172	49	0.29
6	III Ael+Bt	1314	504	79	4854	782	63	0.27
7	IV ilCv	741	273	133	3281	400	102	0.23
8	V elCcv	375	151	92	2263	206	81	0.17

horizon No.	horizon (DBG)	Carbonate	pH		C_{org}	N_{total}	C:N	P sorption capacity	CEC_{pot}
		%	(H_2O)	($CaCl_2$)	%	%		mmol kg^{-1}	$cmol_c\ kg^{-1}$
1	rAp1	-	5.8	5.1	0.52	0.035	15	19.1	4.1
2	rAp2 - Bv	-	6.3	5.5	0.21	0.013	16	14.4	2.0
3	II Bv - Ael	-	6.5	5.1	0.09	0.006	-	8.2	1.7
4	II Ael	-	5.9	4.6	0.05	0.004	-	5.5	1.2
6	III Ael+Bt	-	6.1	4.7	0.13	0.015	-	21.1	4.4
7	IV ilCv	-	6.6	5.3	0.09	0.012	-	11.7	4.5
8	V elCcv	8.5	8.1	7.4	-	0.006	-	6.2	3.6

Soil profile 2: Luvisol

Cutanic Luvisol (Anthric Abruptic) from loamy sand overlaying periglacial loam and glacial till

German: Fahlerde aus Decksand über Fließlehm

Geomorphology: ground moraine

Soil assocoaiation: Dystric Arenosols from glaciofluvial deposits and Haplic Luvisols from periglacial and glacial deposits

Land use: arable land

Characteristics of soil location:

Altitude:	44 a.s.l.
Relief:	slope
Relief position:	upper slope (gradient 4%)
Erosion:	slight water erosion (active at present)
Water regime:	well drained
Topsoil properties (0 – 20 cm):	low humus content, low CEC, low FC (26% Vol), medium capacity for plant available water (20% Vol)
Storage of plant available water (0 – 60 cm):	108 mm
Field capacity (0 – 100 cm):	301 mm
Agricultural soil productivity:	40 – 45 points

Yields 2002 -2009 (100 kg ha^{-1})

Year	Crop	Yield	Year	Crop	Yield
2002	winter barley	37	2006	peas	19
2003	lettuce (FM)	220	2007	carrots (FM)	402
2004	silage maize (30% DM)	525	2008	silage maize (30% DM)	457
2005	beetroot (FM)	603	2009	triticale	49

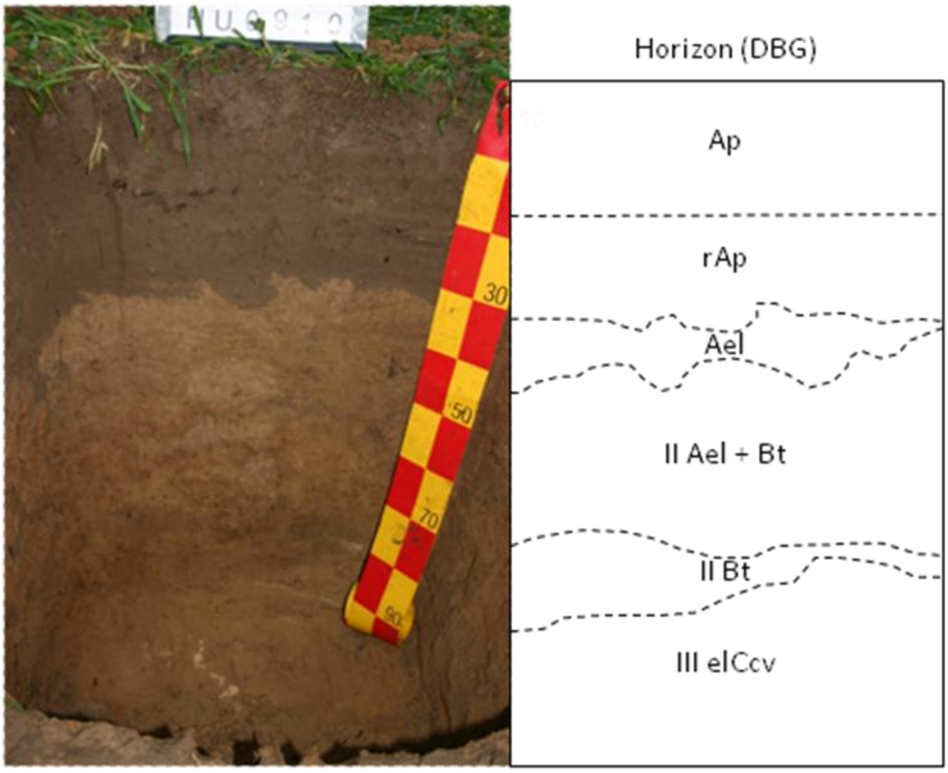
The soil profile is characteristic for the upper slopes of ground moraines. The site is exposed to erosion, soil compaction and drought.

Due to soil erosion, the thickness of both the periglacial sand cover and the in-situ developed eluvial horizon (Ael) decreased. The characteristic thickness of 60 to 70 cm is limited to a depth of 45 cm. The eluvial horizon is followed by a layer of clay accumulation ongoing with a change of soil texture from loamy sand to loam. Compared to profile 1 this profile has higher water storage in the rooting depth of 0 to 60 cm. But the lateral water flow downhill negatively influences the water balance of this site.

The soil underlying the plough layer is compacted. The current depth of tillage is 15 cm, the former depth 30 cm. An increase of bulk density is recognized between 15 - 30 cm and 30 - 35 cm

Due to its low clay and humus content, the topsoil has a low CEC and is prone to nutrient losses and acidification. It has a low water retention capacity and dries up quickly. This is enforced by its position at the upper slope.

Profile description



Horizon (DBG)	Depth (cm)	Parent material	Description	Diagnostic properties (WRB)
Ap	0 - 15	periglacial sand	10YR3/2, loamy sand, low humus content (OC > 0,6%), active plough layer	anthric
rAp	- 30		10YR3/2, loamy sand, low humus content (OC > 0,6%), abrupt lower boundary at the former ploughing depth	
Ael	- 30-40		10YR4/4, sandy loam, very low humus content, plough pan	
II Ael + Bt	- 75	periglacial loam	10YR3/4, 7.5YR4/4, sandy loam and loam, very low humus content, clay films	argic, cutanic
II Bt	- 80-90		7.5YR4/4, loam, very low humus content, clay films	
III elCcv	- 195	glacial till	10YR4/6, sandy loam, medium carbonate content, few carbonate veins (< 5%)	
IV ilCv	>200	glaciofluvial sand	10YR4/6, loamy sand	

Analytical data:

horizon No.	horizon (DBG)	average thickness cm	Sand	Silt	Clay	Bulk density $g\ cm^{-3}$	soil moisture per 15.12.2010 % Vol
				% fine earth			
1	Ap	15	79.0	16.5	4.7	1.62	25.9
2	rAp	15	76.0	18.3	5.7	1.74	22.1
3	II Ael	5	68.0	21.0	11.0	1.84	21.3
4	III Ael+Bt	40	53.0	27.1	19.8	1.70	23.3
6	IV elCcv	110	74.4	16.5	9.0	1.73	20.7

horizon No.	horizon (DBG)	Fe_o	Al_o	Mn_o	Fe_d	Al_d	Mn_d	Fe_o/Fe_d
					$mg\ kg^{-1}$			
1	Ap	1002	427	261	1534	292	166	0.65
2	rAp	1025	414	268	1896	362	183	0.54
3	II Ael	1108	515	425	3258	481	261	0.34
4	III Ael+Bt	1619	847	318	5803	810	235	0.28
6	IV elCcv	462	198	70	2196	253	63	0.21

horizon No.	horizon (DBG)	Carbonate %	pH (H_2O)	pH ($CaCl_2$)	C_{org} %	N_{total} %	C:N	P sorption capacity $mmol\ kg^{-1}$	CEC_{pot} $cmol_c\ kg^{-1}$
1	Ap	-	6.6	5.7	0.81	0.04	20.4	16.9	4.97
2	rAp	-	6.8	6.0	0.73	0.04	17.1	16.8	5.56
3	II Ael	-	6.7	5.8	0.20	0.00	-	19.5	6.65
4	III Ael+Bt	-	6.9	6.3	0.20	0.01	-	30.2	10.62
6	IV elCcv	4.6	8.5	7.6	-	-	-	7.8	3.80

Soil profile 3: Gleysol

Mollic Gleysol (arenic) from river sand

German: Gley aus Flusssand

Geomorphology: lowland

Soil association: Calcic Gleysols and Mollic Gleysols from river sand

Land use: arable land

Characteristics of soil location:

Altitude:	37 a.s.l.
Relief:	level land (slope < 1%)
Water regime:	influenced by groundwater
Human influence:	artificial drainage (distance to drainage ditch 40 m)
Hydraulic conductivity (saturated soil):	extremely high (> 300 cm d^{-1})
Field capacity (above capillary fringe):	118 mm
Storage of plant available water (0 – 60 cm):	96 mm
Topsoil properties (0 – 20 cm):	medium humus content, high CEC, medium FC (31% Vol), medium capacity for plant available water (21% Vol)
Agricultural soil productivity:	28 – 34 points

Yields 2002 -2009 (100 kg ha^{-1})

Year	Crop	Yield	Year	Crop	Yield
2002	carrots(FM)	480	2006	silage maize (30% DM)	343
2003	peas	15	2007	silage maize (30% DM)	708
2004	canola	28	2008	rye	54
2005	winter barley	77	2009	canola	40

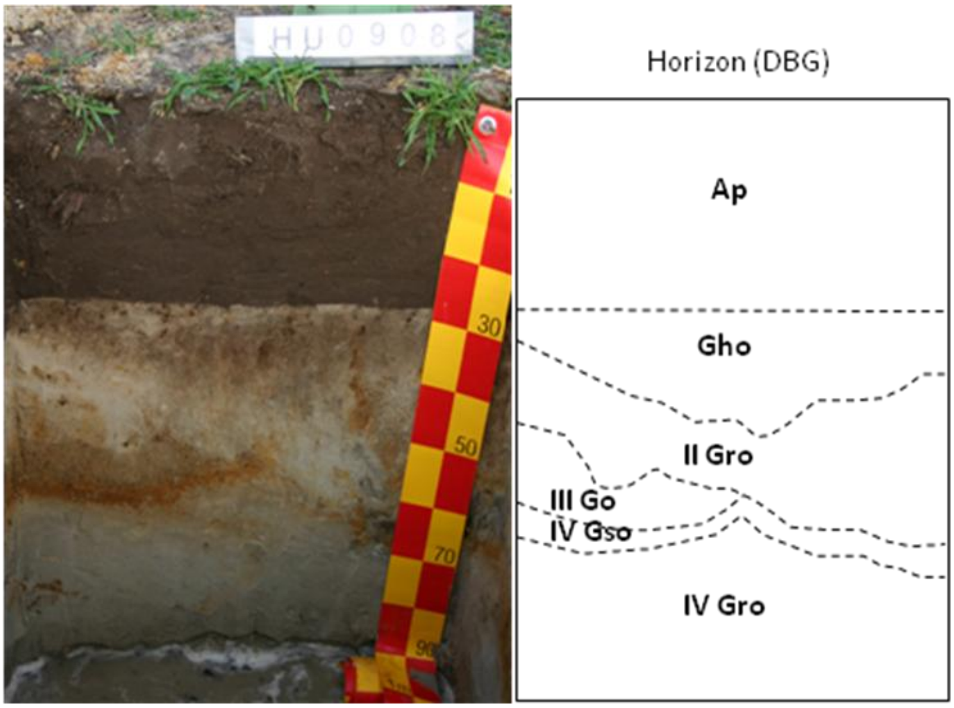
The soil profile developed from a nutrient poor river sand influenced by groundwater. The nutrient-rich and calcareous groundwater originates from the surrounding ground moraine.

For arable cultivation the site is periodically drained in spring. Therefore, the groundwater table is subject to extreme fluctuations (at time of inventory Dec 14, 2009: 90 cm). The upper boundary of the capillary fringe reaches up to 45 cm of the soil surface.

The storage capacity of plant available water in the rooting zone is insufficient. This can lead to water shortage in summer, whereas in winter, when the groundwater level is raised, nutrients may leach into the groundwater.

Compared to dry sandy sites, both the elevated C_{org} content (1.36%) and the low bulk density (1.44 g cm^{-3}) favorably influence soil fertility.

Profile description



Horizon (DBG)	Depth (cm)	Parent material	Description	Diagnostic properties (WRB)
Ap	0 - 30	river sand	10YR3/2, loamy sand, medium humus content (OC > 0,6 %), abrupt lower boundary	mollic
Gho	- 35-55		10YR3/6, loamy sand, very low humus content, many faint rust mottles (> 5%)	gleyic colour pattern, arenic
II Gro	- 45-60		10YR6/3, fine to medium sand, moderate rust mottles	
III Go	- 60		10YR4/6, 10YR5/6, very fine sand, many faint rust mottles (> 5%)	
IV Gso	- 65		5YR4/6, fine to medium sand, dominant rust mottles (> 5%)	
IV Gro	-90		2.5Y7/2, fine to medium sand, very few faint rust mottles, wet	
IV Gr	>200		2.5Y7/2, fine to medium sand, water saturated	

Analytical data:

horizon No.	horizon (DBG)	average thickness cm	Sand	Silt	Clay	Bulk density $g\ cm^{-3}$	soil moisture per 15.12.2010 % Vol
			% fine earth				
1	Ap	30	86.0	7.7	6.2	1.44	20.5
2	Gho	15	84.9	6.2	8.9	1.62	13.3
3	II Gro	7	95.2	2.2	2.6	1.62	16.5
4	III Go	18	95.9	1.1	2.9	1.62	19.4
5	Gso	5	95.5	0.6	3.9	1.65	22.3

horizon No.	horizon (DBG)	Fe_o	Al_o	Mn_o	Fe_d	Al_d	Mn_d	Fe_o/Fe_d
					mg kg^{-1}			
1	Ap	2200	507	101	3306	488	85	0.67
2	Gho	1143	495	43	2472	457	49	0.46
3	II Gro	314	190	16	695	188	11	0.45
4	III Go	1445	196	104	2461	227	82	0.59
5	Gso	2914	166	66	3639	180	55	0.80

horizon No.	horizon (DBG)	Carbonate	pH		C_{org}	N_{total}	C:N	P sorption capacity	CEC_{pot}
		%	(H_2O)	($CaCl_2$)	%	%		mmol kg^{-1}	$cmol_c$ kg^{-1}
1	Ap	-	5.0	4.4	1.36	0.09	14.6	29.1	8.7
2	Gho	-	5.8	5.3	0.21	0.00		19.4	8.3
3	II Gro	-	5.9	5.2	0.11	0.01		6.3	3.1
4	III Go	-	5.4	4.8	0.09	0.01		16.6	2.5
5	Gso	-	5.6	5.1	0.09	0.00		29.2	3.1

Soil profile 4: Gleysol

Histic Gleysol (endoarenic) from peat overlying river sand

German: flacher Gley über kultiviertem Moor aus umgelagerten Sand über Niedermoortorf

Geomorphology: lowland

Soil association: Histic Gleysols from peat overlying river sand

Land use: grassland

Characteristics of soil location:

Altitude:	35.5 m a.s.l.
Relief:	level land, depression (slope < 1%)
Water regime:	influenced by groundwater
Human influence:	artificial drainage (distance to drainage ditch 40 m)
Hydraulic conductivity (saturated soil):	low (< 10 cm d^{-1}) in the upper part (0-60 cm), below 60 cm extremely high (> 300 cm d^{-1})
Topsoil properties (0 – 20 cm):	high humus content, high CEC, high FC (46% Vol), high capacity for plant available water (28% Vol)
Agricultural soil productivity:	30 – 36 points

Yields 2002 -2009 (Hay, dry matter 100 kg ha^{-1})

Year	Yield	Year	Yield
2002	35	2006	63
2003	55	2007	49
2004	63	2008	67
2005	59	2009	68

The site is on the edge of a depression. The soil has developed from a sedge peat which later was covered by sandy material. The origin of the sandy material is not precisely known. A former sandy path in the direct vicinity represents a possible source. North of this site an area has been ameliorated by adding a sand cover.

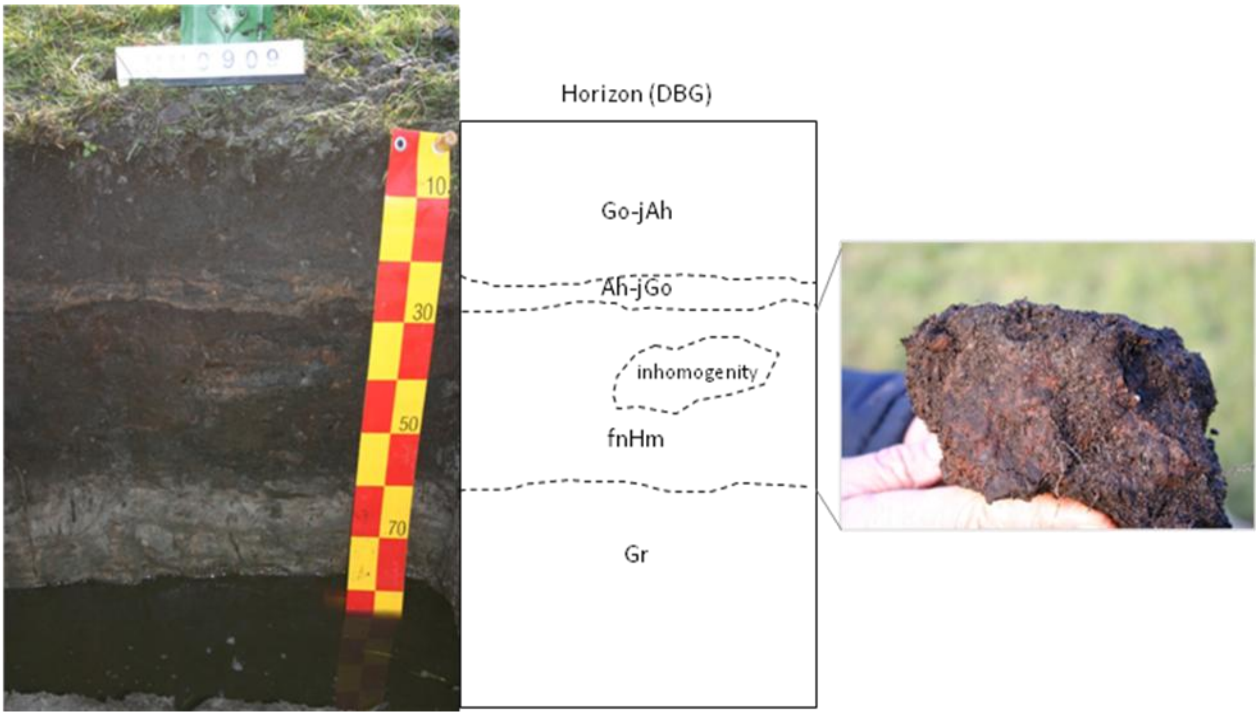
Due to artificial drainage the groundwater table fluctuates tremendously (at the time of inventory Dec 14, 2009: 70 cm). The high content of free iron indicates that the impact of the groundwater ranges up to the soil surface. Thus, a humus-rich Gley developed in the sandy layer overlying the former peat soil.

Drainage and aeration of the peat soil resulted in peat destruction and decomposition followed by impairment of the water and air supply. The soil has a high water storage capacity, however, one third is not plant available. Moreover, the wetting resistance is high. Therefore, following long lasting summer droughts, the rainfall is discharged in shrinkage cracks without moistening of the soil.

The hydraulic conductivity especially of the subsoil is reduced, leading to delayed drainage.

Due to the high C_{org} content the CEC is very high. However, drainage and fluctuating groundwater table lead to tremendous nutrient losses. Amongst others, the sites are rapidly depleted in potassium because of the low in-situ K reserves.

Profile description



Horizon (DBG)	Depth (cm)	Parent material	Description	Diagnostic properties (WRB)
Go- jAh	0 - 25	redeposited natural material	10YR2/1, loamy sand, very high humus content (OC ≥ 0,6% and < 12 %), fine dispersed iron oxide, abrupt lower boundary	mollic
Ah- jGo	- 30		10YR3/2, 5YR3/4, 10YR2/1, sand unsorted, abrupt lower boundary, medium humus content (OC ≥ 0,6% and < 12 %) , many rust mottles (≥ 5%), abrupt lower boundary	gleyic colour pattern
II fnHm	- 60	peat	10YR2/1, 7.5YR2.5/3, organic (OC ≥18%), abundant rust coatings (≥5%), very strong decomposition and humification of peat, buried horizon, very moist	histic, gleyic colour pattern
III Gr	>140	river sand	2.5YR4/1, 2.5Y5/2, medium sand, very low humus content (< 0,5%), reductimorphic colours (> 90%), water saturated	gleyic colour pattern

Analytical data

horizon No.	horizon (DBG)	average thickness cm	Sand	Silt	Clay	Bulk density $g\ cm^{-3}$	soil moisture per 15.12.2010 % Vol
			% fine earth				
1	Go - jAh	25	83.8	7.9	8.4	0.98	45.7
2	Ah - jGo	5	93.3	2.1	0.3	1.40	25.5
3	fnHm	30	-	-	-	0.32	75.3
4	Gr	> 140	97.8	0.2	1.9	1.11	46.8

horizon No.	horizon (DBG)	Fe_o	Al_o	Mn_o	Fe_d	Al_d	Mn_d	Fe_o/Fe_d
		$mg\ kg^{-1}$						
1	Go - jAh	6615	465	158	6568	315	156	1.01
2	Ah - jGo	2831	177	46	2520	101	30	1.12
3	fnHm	12560	780	40	10490	438	106	1.20
4	Gr	442	39	1	495	23	<2	0.89

horizon No.	horizon (DBG)	Carbonate %	pH (H_2O)	pH ($CaCl_2$)	C_{org} %	N_{total} %	C:N	P sorption capacity $mmol\ kg^{-1}$	CEC_{pot} $cmol_c\ kg^{-1}$
1	Go - jAh	-	6.8	6.7	6.43	0.53	12.0	67.8	32.3
2	Ah - jGo	-	7.0	6.7	1.45	0.07	19.8	28.6	13.5
3	fnHm	-	5.6	5.5	36.94	2.62	14.1	-	84.5
4	Gr	-	4.1	4.0	0.50	0.01	-	4.7	1.5

Soil profile 5: Arenosol

Arenosol from eolian sand overlying river sand

German: Regosol über Reliktgley aus Dünensand über Flusssand

Geomorphology: dune

Soil association: Haplic Podzols from eolian sand

Land use: forest

Vegetation: coniferous forest (pine)

Characteristics of profile site:

Altitude:	38 m a.s.l.
Relief:	slope
Relief position:	foot slope (gradient < 1%)
Erosion:	wind deposition (active in recent past)
Water regime:	groundwater ($\leq$ 140 cm)
Human influence:	artificial drainage, distance to drainage ditch 120 m
Topsoil properties (0 – 20 cm):	medium humus content, low CEC, FC very low (16% Vol), capacity for plant available water low (9% Vol)
Storage of plant available water (0 – 60 cm):	48 mm
Field capacity (above capillary fringe):	123 mm
Agricultural soil productivity:	16 -20 points
Annual biomass production (forest)	2,5 - 3,5 t ha^{-1} a^{-1} (Dry matter)

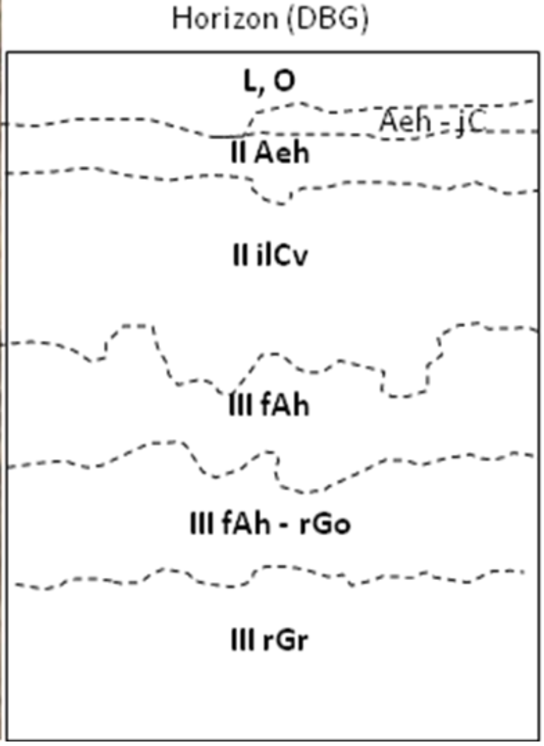
The soil developed at the foot-slope of a small dune. The original humus horizon is buried below a 30 cm deep layer of eolian sand.

Five hundred meters to the north, dunes stretch from west to east in the lowland. Until the 19th century soil erosion caused by wind was of great importance in this region. The reason was the deforestation of vast areas to provide the growing city of Berlin with construction material and firewood. Dry and nutrient-poor sandy soils became prone to wind erosion. The eolian sand was accumulated to small dunes in the humid areas in the lowland. Since the end of the 18th century the uncovered sandy sites have been afforested.

Today, these extremely dry dunes are typical pine forest sites. The annual biomass production of 3 t $ha^{-1}a^{-1}$ is lower than that of the formerly arable sites.

Moreover the extensive drainage in the lowlands further caused a degradation of these soils. The current groundwater influence only ranges to 1 m of the soil surface. Rust mottles in the buried humus horizon indicate that the groundwater originally range up to the surface, later 30 cm below the surface, similar to profile 3. This might be the reason why the today‘s forest was registered as arable cultivation site until the middle of last century.

Profile description



Horizon (DBG)	Depth (cm)	Parent material	Description	Diagnostic properties (WRB)
L O	+8		Organic (OC > 18 %), undecomposed and partially decomposed litter	
Aeh -jC	0 - 3	redeposited natural material	10YR3/6, low humus content , fine to medium sand	
II Aeh	- 10	eolian sand	10YR3/3 (dry 10YR4/2), fine to medium sand, medium humus content (OC > 0,6), extremely high content of fine roots	arenic
II ilCv	- 35		10YR3/6, 10YR4/2, fine to medium sand, very low humus content (OC < 0,5 %), medium content of fine roots	arenic
III fAh	- 50-55	river sand	10YR3/2, fine to medium sand, low humus content (OC > 0,6), high content of fine roots	arenic
III fAh-rGo	-70		7,5YR3/4, 7,5YR4/6, 10YR5/6, fine to medium sand, rust mottles (>30%), high content of fine roots,	gleyic (no active)
III rGr	- 100		10YR6/4, 10YR4/6, fine to medium sand, rust mottles (3-5%), very low content of fine roots	
III Go	- 140		2.5YR6/3, medium to fine sand, very moist to wet	gleyic
III Gr	>200		2.5YR6/2, medium to fine sand, water saturated	

Analytical Data

horizon No.	horizon (DBG)	average thickness	Sand	Silt	Clay	Bulk density	soil moisture per 15.12.2010
		cm	% fine earth			g cm^{-3}	% Vol
2	Of	5				0.20	21.7
4	Aeh	10	94.5	2.7	2.9	1.19	12.6
5	ilCv	25	97.0	0.8	2.1	1.56	2.5
6	fAh	15	90.7	6.3	3.0	1.43	14.8
7	fAh-rGo	20	90.5	5.7	3.8	1.47	10.0
8	rGr	30	95.2	2.4	2.4	1.59	7.6

horizon No.	horizon (DBG)	Fe_o	Al_o	Mn_o	Fe_d	Al_d	Mn_d	Fe_o/Fe_d
		mg kg^{-1}						
2	Of	732	414	267	1021	300	265	0.72
4	Aeh	559	337	10	946	285	10	0.59
5	ilCv	255	218	17	602	217	12	0.42
6	fAh	571	361	1	583	295	<2	0.98
7	fAh-rGo	847	704	23	1133	638	17	0.75
8	rGr	130	291	6	226	190	3	0.58

horizon No.	horizon (DBG)	Carbonate	pH		C_{org}	N_{total}	C:N	P Sorption capacity	CEC_{pot}
		%	(H_2O)	($CaCl_2$)	%	%		mmol kg^{-1}	$cmol_c$ kg^{-1}
2	Of	-	4.6	4.0	24.20	1.30	18.7	-	47.6
4	Aeh	-	4.3	3.5	2.38	0.11	22.6	11.3	7.8
5	ilCv	-	4.8	4.1	0.20	0.00	-	6.3	1.7
6	fAh	-	4.3	3.7	1.09	0.03	32.3	11.8	6.0
7	fAh-rGo	-	4.8	4.0	0.83	0.03	27.9	20.7	6.5
8	rGr	-	4.9	4.2	0.11	0.00	-	6.6	1.9