Soil of the year 2016: Groundwater soil (Gley)

(WRB: Group of Gleysols)

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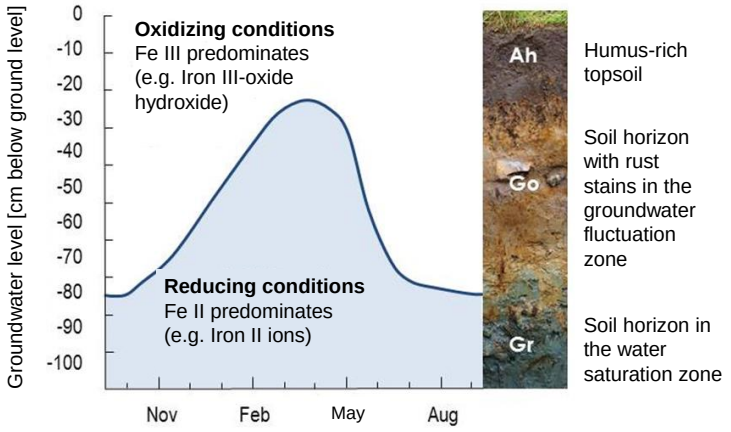
Profile of a Gleysol (Photo: S. Polte)

The Groundwater soil is termed as „Gley“ according to the German soil classification or “Gleysol” according to the international WRB. It primarily occurs in depressions and lowlands, which collect the seepage water from surrounding areas. This results in an all-the-year groundwater-logged soil with a seasonally fluctuating groundwater table.

What do groundwater soils look like and what are typical characteristics?

Gleysols are influenced by groundwater all-the-year; it affects the site like no other factor. The typical soil profile of a Gleysol mirrors seasonal fluctuations in the groundwater table. This is revealed by the formation of a mostly red-orange-stained soil zone (Go-horizon) with seasonally alternating water saturation above a permanently waterlogged, grey- to blue-colored horizon (Gr-horizon = reduction horizon).
A humus-rich topsoil (Ah-horizon) covers the soil surface. Groundwater soils can look differently depending on the parent soil material and substances in the groundwater.

Which processes are involved in groundwater soils?



Variations in groundwater table throughout the year
(Fig.: B. Burbaum)

Formation of bog iron ore in a Petrogleyic Gleysol
(photo: A. Mordhorst)

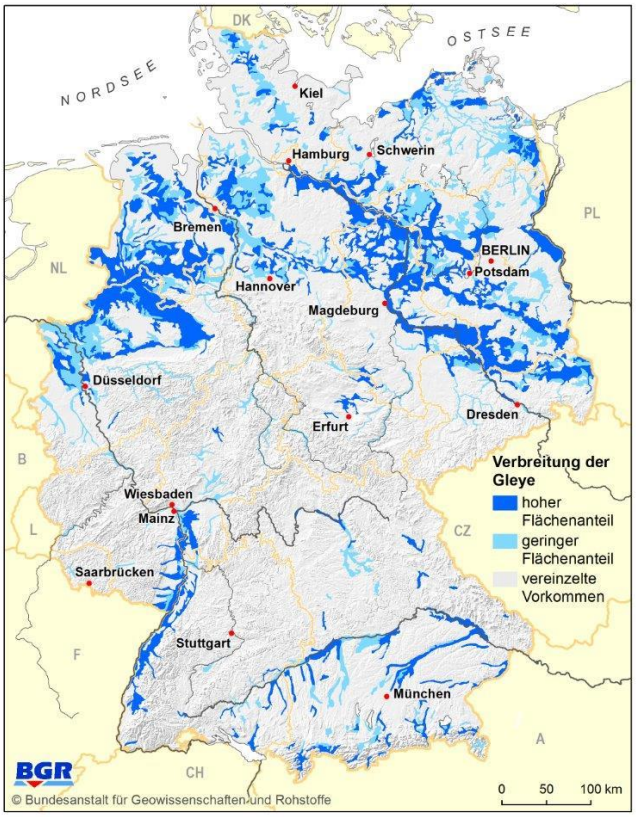
In winter and early spring the soil is waterlogged close to the surface. With the beginning of the growing season plants extract increasingly more water from the soil. The soil dries out stepwise from above and aerated. This leads to a higher availability of oxygen. Hence, dissolved iron in the soil solution oxidizes (rusts). It adsorbs as visible patches or as solid precipitations preferentially on the surfaces of associated soil particles (aggregates) in the oxidation horizon Go.
With beginning aeration of the Go-horizon, reduced iron compounds migrate out of aggregates and deeper soil horizons toward already aerated aggregate surfaces or into coarse pores, where they precipitate as iron oxides also referred to as “extroverted iron”.
Manganese compounds are subjected to the same process sequence resulting in black-colored aggregate surfaces.
The deeper soil layer (Gr-horizon) is water saturated throughout the year and is therefore low in oxygen. Here, iron and manganese exist in water-soluble compounds (Fe II, Mn II) and the grey- to blue-colored horizon does not show any patches. The higher the amount of iron and manganese compounds transported by the groundwater, the higher the enrichment with solid iron concretions
Extremely high accumulations of iron (Fe III) lead to the formation of bog iron ore that often contains more than 30 % iron and act as a strong barrier that is impenetrable for plant roots. In the past, bog iron ore was used for iron production or as building material.
Besides iron and manganese also other substances originating from influxes from the more elevated surrounding areas can be enriched in groundwater soils. Depending on the catchment area, parent material and groundwater level e.g. “Kalkgleye” (Calcaric Gleysol), “Brauneisengleye” (Petrogleyic Gleysol), “Humusgleye” (Humic Gleysol) and “Auengleye” (Fluvic Gleysol) have developed.

What are the characteristics of groundwater soils?

Gleysols represent site conditions with temporary or permanent oxygen deficiency. Root growth is restricted for most crops due to lacking oxygen in the subsoil resulting from high groundwater levels. They are often rich in nutrients due to their location in depressions with laterally inflowing water. The availability of nutrients depends on humus and clay content as well as on pH-value. The humus content in groundwater soils is normally higher than in other mineral soils because the decomposition (of organic material) by soil organisms is inhibited due to the lack of oxygen. Gleysols are characterized as “cold” soils because of the delayed warming in spring time due to high water contents.
Groundwater soils with high groundwater levels notably provide habitats for rare animal and plant communities. The western marsh orchid (in wet meadows) and the marsh hawk's-beard (in the wood) are mentioned as representatives for a number of threatened species which rely on wet soil conditions.
Groundwater soils without drainage store high amounts of water and slowly lead it towards surface water bodies.
Therewith, they hold back the water in the landscape and importantly contribute to flood protection.
Via the high evaporation capacity of soil and plants throughout the year, Gleysols have an important function as cooling system.

Where are groundwater soils located in Germany?

Groundwater soils are widely spread covering about 10 - 15% of the country. They are predominantly present in the lowlands and often close to water bodies. The North German Plain and river valleys are the main distribution area while spatial associations with water bodies and bogs are typical. Hence, Gleysols often develop in sediments of the lowlands and valleys like basin depositions or lowland sands, but in principle their genesis is independent from the parent material. The next figure shows the geographical distribution pattern of Gleysols in Germany with connected areas larger than 16 km².



Distriubtion of Gleysols in Germany (A. Richter, BGR)

The map does not include groundwater related soils like e.g. the groundwater influenced marshlands at the North Sea coast. In many landscapes in Germany groundwater soils, which are only locally present in depressions, are related to soil associations with deeper groundwater levels.

How should groundwater soils sustainably be used?

The usability of Gleysols is mainly defined by the level of drainage. It is assumed that in intensively used agricultural landscapes almost all groundwater soils are drained. Drained sites are commonly used as arable land which is in part associated with substantial environmental problems. Greenhouse gases are released due to accelerated humus decomposition and nitrates are leached out into the groundwater mostly as a result of overfertilization. The use of groundwater soils for crop production is therefore considered as not in accordance with the location. Traditionally, they are used for grassland or forest. Both management forms are in principle soil-conserving. The preservation of a widely natural water balance and the renunciation of drainage activities are crucial for the protection of these essential soils in the landscape. Typical tree species under near-natural forest use are common oak, ash, European white-elm, common hornbeam, alder and small-leaved lime.

The use of Gleysols for intensive grassland with yearly 3 – 4 grass harvestings requires special care regarding the water management which depends on the moisture level.

For a site adapted soil management, especially the soil moisture level should be considered when these soils are wheeled with machinery. Only dry conditions represent adequate soil sustainability ensuring a soil conserving machinery use.

According to landscape conservation measures this is also true for conservative grazing up to extensive grazing systems under a near-natural water level.

Special habitat: moist forest
(Photo: B. Burbaum)

Western marsh orchid (Red List)
(Photo: B. Burbaum)

Marsh hawk's-beard (Red List)
(Photo: K. Romahn)

How are groundwater soils endangered?

In Germany, the greatest endangerment is given by lowering of the groundwater table. The loss of the natural groundwater dynamic alters the environmental conditions for plants and animals. A lower groundwater table causes humus losses in topsoils as a result of improved living conditions for humus-consuming microorganisms due to higher oxygen availability.
During the humus decomposition carbon dioxide and other gases are produced reinforcing the greenhouse effect. In addition nitrate can be formed and washed-out into the groundwater. Most of the groundwater soils in Germany are characterized by a lowered groundwater table and are termed as relictic Gleysols. Prospecting an increase in summery dry periods and increasing evaporation in Germany as a consequence of climate change, the groundwater table will also be lowered resulting in enhanced humus decomposition. Gleysols are like all wet soils very susceptible against mechanical loading accompanied with soil compaction. In addition, due to their location in lowlands and depressions they are often covered with eroded soil material from surrounding slopes.

Soil compaction and structural damages due to crop cultivation
(Photo: F. Steinmann)

Deep draining for crop cultivation endangers groundwater soils
(Photo: M. Dworschak)

Adequate grassland management prevents structural deterioration under high groundwater tables.
(Photo: M. Filipinski)

Wetness adapted forests offer best protection
(Photo. O. Ehrmann).

Further information is provided here:
Website „Soil of the Year“ (www.boden-des-jahres.de)
German Soil Science Society (www.dbges.de)
Federal association Soil (www.bvboden.de)
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Curatorship „Soil of the Year“ <boden@gd.nrw.de>
Soil science-orientated institutes of universities and universities of applied science.

Information material (Posters 2016, Flyer 2016, CDs of all soils):
Federal Environment Agency: www.umweltbundesamt.de/publikationen/poster-boden-des-jahres-2016
CDs for all Soils of the Years 2005 to 2016: E-Mail: frielinghaus@zalf.de