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GLEYSOLS (GL)

The Reference Soil Group of the Gleysols holds wetland soils that, unless drained, are saturated with groundwater for long enough periods to develop a characteristic “gleyic colour pattern”. This pattern is essentially made up of reddish, brownish or yellowish colours at ped surfaces and/or in the upper soil layer(s), in combination with greyish/bluish colours inside the peds and/or deeper in the soil. Common international names are ‘Gleyzems’ and ‘meadow soils’ (Russia), ‘Aqu-‘ suborders of Entisols, Inceptisols and Mollisols (USA), ‘Gley’ (Germany), and ‘groundwater soils’ and ‘hydro-morphic soils’.

Definition of Gleysols

Soils,

1 having gleyic properties within 50 cm from the soil surface; **and**

2 having no diagnostic horizons other than an anthraquic, histic, mollic, ochric, takyric, umbric, andic, calcic, cambic, gypsic, plinthic, salic, sulfuric or vitric horizon within 100 cm from the soil surface.

3 having no abrupt textural change within 100 cm from the soil surface

Common soil units:

Thionic, Histic, Gelic, Anthraquic, Vertic, Endosalic, Andic, Vitric, Plinthic, Mollic, Gypsic, Calcic, Umbric, Arenic, Tephric, Stagnic, Tephric, Abruptic, Humic, Calcaric, Takyric, Alcalic, Toxic, Sodic, Alumic, Dystric, Eutric, Haplic.

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Summary description of Gleysols

Connotation: soils with clear signs of excess wetness; from R. gley, mucky mass.

Parent material: a wide range of unconsolidated materials, mainly fluvial, marine and lacustrine sediments of Pleistocene or Holocene age, with basic to acidic mineralogy.

Environment: depression areas and low landscape positions with shallow groundwater.

Profile development: mostly A(Bg)Cr- or H(Bg)Cr-profiles. Evidence of reduction processes with or without segregation of iron compounds within 50 cm of the surface.

Use: wetness is the main limitation of virgin Gleysols; these are covered with natural swamp vegetation and lie idle or are used for extensive grazing. Artificially drained Gleysols are used for arable cropping, dairy farming and horticulture. Gleysols in the tropics and subtropics are widely planted to rice.

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Regional distribution of Gleysols

Gleysols occupy an estimated 720 million hectares worldwide. They are azonal soils and occur in nearly all climates, from perhumid to arid. The largest extent of Gleysols is in sub-arctic areas in northern Russia, Siberia, Canada and Alaska, and in humid temperate and subtropical lowlands, e.g. in China and Bangladesh. An estimated 200 million hectares of Gleysols are found in the tropics, mainly in the Amazon region, equatorial Africa and the coastal swamps of Southeast Asia. See Figure 1.

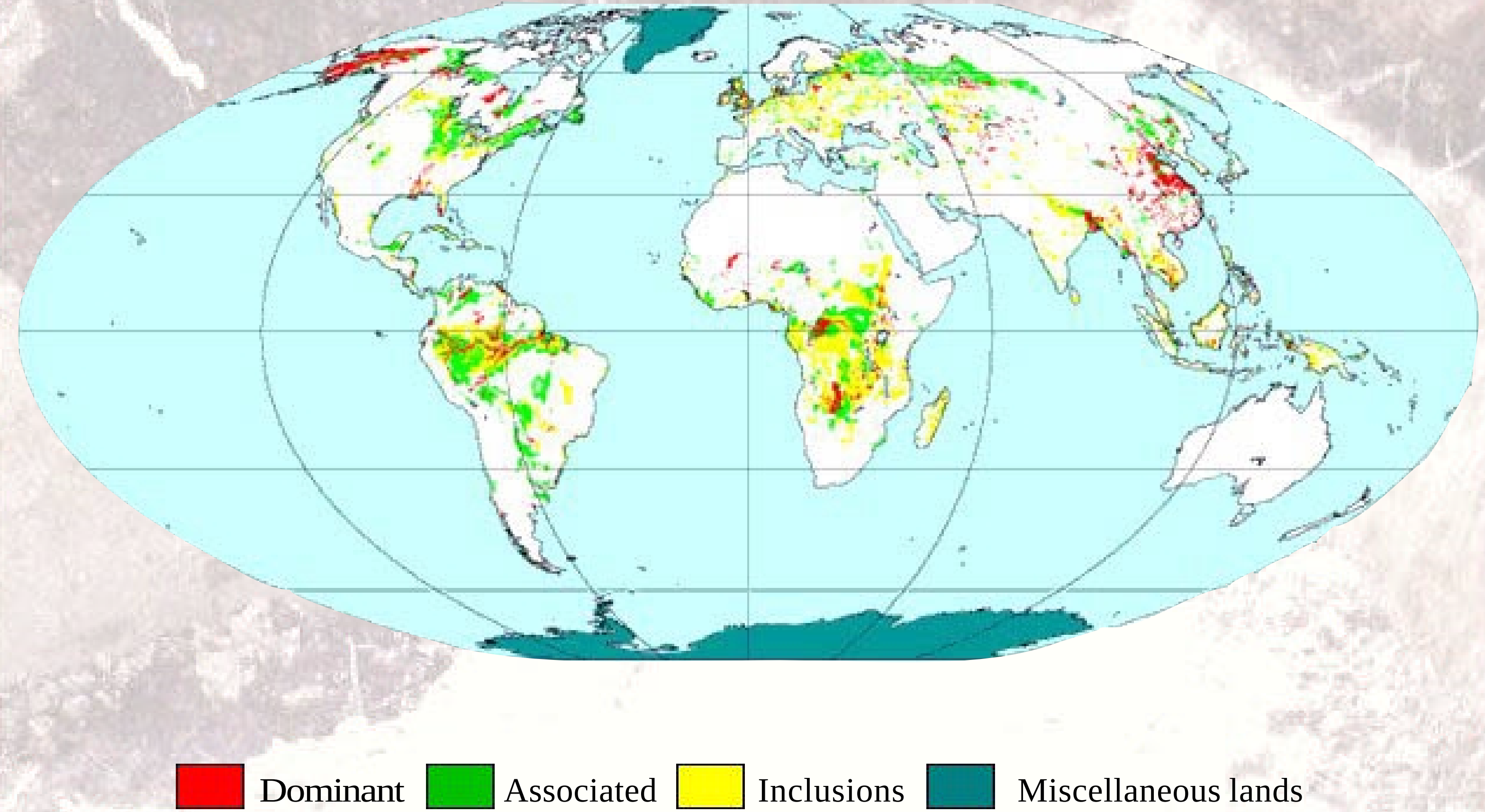

Figure 1. Gleysols worldwide.

Associations with other Reference Soil Groups

Gleysols of the sub-arctic and temperate latitudes are associated with Histosols and with Fluvisols (in riverine and coastal areas). Gleysols at higher landscape positions are confined to depression areas with shallow groundwater where they occur adjacent to Luvisols and Cambisols. Gleysols in the steppe zone are found together with Chernozems and Phaeozems. Gleysols in arid regions occur predominantly in fluvial and marine lowlands, often together with Solonchaks and Solonetz. A wide variety of soils (e.g. Calcisols, Gypsisols, Cambisols, Regosols, Arenosols and Leptosols) can be expected on adjacent up-lands.

Gleysols in the humid tropics are confined to structural wetlands; Acrisols, Lixisols, Nitisols, Alisols and Ferralsols occur in (better-drained) adjacent uplands.

Genesis of Gleysols

The formation of Gleysols is conditioned by excessive wetness at shallow depth (less than 50 cm from the soil surface) in some period of the year or throughout the year. Low-redox conditions, brought about by prolonged saturation of soil material in the presence of organic matter, cause reduction of ferric iron compounds to (mobile!) ferrous compounds. This explains why the permanently saturated subsoil layers of Gleysols have neutral whitish/greyish or bluish to greenish matrix colours: with the iron compounds mobilized and removed, the soil material shows its own colour, normally with a Munsell hue notation that is less red than 2.5Y.
Note that reduction of oxides to soluble Fe^{2+} and/or Mn^{2+} compounds will only take place if the soil is periodically saturated with water that contains the dissolved products of organic matter decomposition.

Subsequent oxidation of transported Fe^{2+} and/or Mn^{2+} compounds (back) to oxides can take place near fissures or cracks in the soil, along living roots that have “aerenchym” (air ducts, e.g. in the roots of paddy) and along former root channels where there is supply of oxygen. Hysteresis between oxidation and (slower) reduction processes results in net accumulation of oxides near aerated spots. The soil develops a characteristic *‘gleyic colour pattern’*, with *‘redoximorphic features’*. These comprise *‘reductomorphic’* and *‘oximorphic’* properties.

- *Reductomorphic properties* signify permanently wet conditions and reflect the redox gradient between the groundwater and the capillary fringe. They are expressed by neutral whitish/greyish or bluish to greenish ‘gley colours’ in more than 95 percent of the soil matrix. Near the capillary fringe, the (subsoil) layer with reductomorphic properties may include up to 5 percent oxidation colours, e.g. as mottles (around air pockets) or 'root prints' (former root holes lined with iron oxide).

- *Oximorphic properties* indicate alternating reducing and oxidizing conditions, as occur near the capillary fringe and in the surface layers of soils with fluctuating groundwater depth. Oximorphic properties reflect the redox gradient between the reduced soil matrix and air inclusions in the soil matrix such as (former) root holes. They are expressed by reddish brown or bright yellowish brown mottles on aggregate surfaces and on walls of pores. Acid sulphate soils feature bright yellow mottles of *jarosite* (at pH < 3.5) or *schwertmannite* (at pH 3.0-4.5).

Note that 'gleyic properties' are strictly associated with movement of the *groundwater table*; mottled, oxidized horizons occur on top of a fully *reduced* subsoil. A different type of mottling is found where perched water occurs on top of a slowly permeable subsurface horizon while the real groundwater table occurs at greater depth. In this case, the reduced horizon overlies an oxidized subsurface horizon. (Figure 2). This configuration occurs in soils that have 'stagnic properties' and show a *'stagnic colour pattern'*.

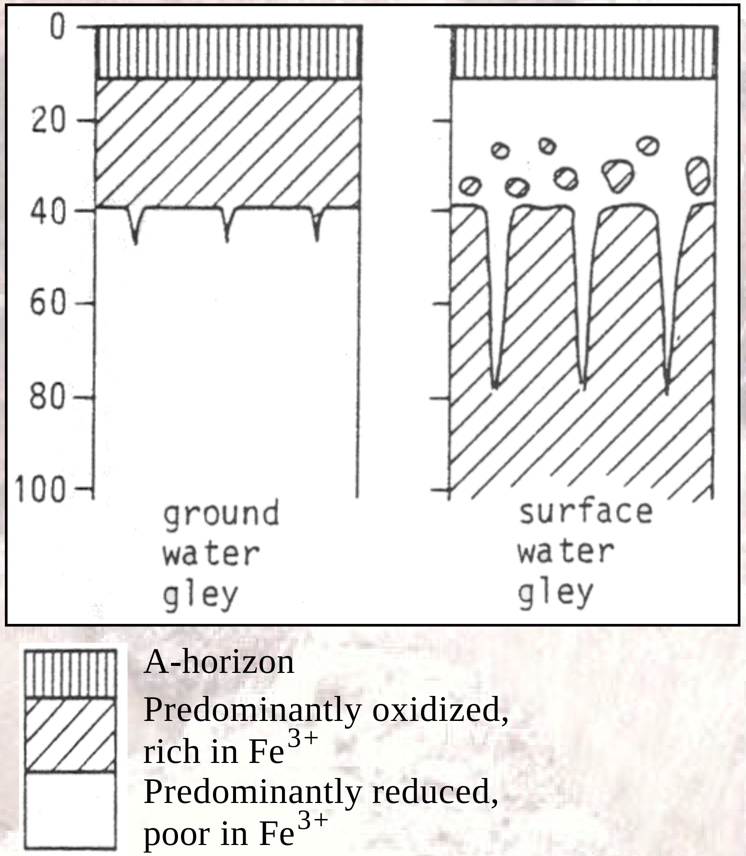

Figure 2. Schematic horizon configurations of soils with gleyic properties and soils with stagnic properties

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The stagnic colour pattern differs from the gleyic colour pattern in that surfaces of peds (or parts of the soil matrix) are lighter and paler, and the interior of peds (or parts of the soil matrix) are more reddish and brighter than the (mixed average of the) non-redoximorphic soil material of the layer. The stagnic colour pattern may occur directly below the surface horizon or plough layer, or below an albic horizon.

The soils of rice paddies

The soils of rice paddies may be true Gleysols but are more often anthraquic units of some other Reference Soil Group. 'Paddy Soils' developed stagnic soil properties after long continued irrigation or inundation. By and large, there are two broad categories of 'paddy soil':

1 *Paddy Soils in wetlands*, e.g. Gleysols and Fluvisols (with a completely reduced subsoil), and
2 *anthraquic* paddy Soils formed in originally well-drained land.

Repetitive puddling of the surface soil of Paddy Soils has produced a thin, compacted and slowly permeable plough sole at the depth of cultivation. Most Anthraquic Gleysols have a reddish brown to black accumulation horizon of iron and/or manganese oxides at some depth below the plough sole. This accumulation layer formed as a result of intensive reduction processes in the puddled surface layer and translocation and precipitation of iron and manganese compounds in the (oxidized) subsoil. The accumulation layer may indurate to an impenetrable hardpan.

Characteristics of Gleysols

Morphological characteristics

Soil morphological features are valuable indicators of a soil's water regime but correct interpretation of such features is not always easy.

- A soil may be saturated with water and have a low redox potential but not show any redoximorphic features because very stable iron minerals such as coarse-grained hematite are not dissolved.
- Redoximorphic features may also be absent if water-saturation occurs under extremely cold conditions, in chemically poor environments with little or no organic matter, or by rapidly flowing oxygen-rich water.

Interpretation of oximorphic features is further complicated by the possibility that the features may be 'fossil'. Soils, which were water-saturated and reduced in early Holocene or in Pleistocene times, may still show the signs today, even though they now have an entirely different water regime. The same may happen where soils are artificially drained.

Gleysol profiles have normally a spongy or matted litter layer resting on a dark grey Ah-horizon that changes sharply into a mottled grey or olive Bg-horizon. With depth, the Bg-horizon grades into a grey, olive or blue anaerobic Cr-horizon. Gleysols in fluvi-glacial sands in Central Europe may contain accumulations of hardened '*bog iron*' (smelted by Iron Age man).

Gleysols of the savannas have normally very dark grey to black, heavy clay surface layers that continue down to 2 metres or more in some profiles but give place to pale grey subsurface soil with prominent mottling in others (Fitzpatrick, 1986). The soil structure is medium blocky or even crumb near the soil surface but becomes coarsely prismatic at some depth. The soil material is hard when dry and sticky when wet.

Where Gleysols remain waterlogged throughout the year, except perhaps for short periods, the topsoil is typically a mixed organic and mineral (muck) H-horizon. It tops a mottled clay or sandy clay subsurface horizon over permanently anaerobic subsoil.

Mineralogical characteristics

Reddish brown (*ferrihydrite*) or bright yellowish brown (*goethite*) mottles are indicators of oximorphic properties. Reductomorphic properties are not evidenced by specific minerals but rather by absence of iron (hydr)oxides and by 'neutral whitish/greyish or bluish to greenish' matrix colours. Gleysols of coastal areas with salt meadows may feature 'blue-green rust', i.e. the interior of structural peds is coloured greenish by Fe^{2+}/Fe^{3+}-oxides.

Hydrological characteristics

The dominant attribute of Gleysols is prolonged saturation with water, associated with lack of aeration, poor rooting conditions for most crops and poor conditions for soil fauna.

Physical characteristics

Repeated wetting and drying may cause soil densification due to weakening of interparticle bonds during saturation and contraction of soil particles upon desaturation. The soil structure is likely to deteriorate if the soil is cultivated in too wet a condition. Trafficability is a problem with many Gleysols;

Chemical characteristics

Gleysols in depressions or at the lower ends of slopes are generally considered to be 'comparatively fertile soils' because of their fine soil texture, slow rate of organic matter decomposition and influx of ions from adjacent uplands. They have more organic matter, greater cation exchange capacity, higher base saturation, and usually also higher levels of phosphorus and potassium, than adjacent upland soils.

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Management and use of Gleysols

The main obstacle to utilisation of Gleysols is the necessity to install a drainage system, designed to either lower the groundwater table, or intercept seepage or surface runoff water. Adequately drained Gleysols can be used for arable cropping, dairy farming or horticulture.
Soil structure will be destroyed for a long time if (too) wet soils are cultivated. Gleysols in (depression) areas with unsatisfactory drainage possibilities are therefore best kept under a permanent grass cover or (swamp) forest. Liming of drained Gleysols that are high in organic matter and/or of low pH value creates a better habitat for micro- and meso-organisms and enhances the rate of decomposition of soil organic matter (and the supply of plant nutrients).

Gleysols can be put under tree crops only after the water table has been lowered with deep drainage ditches. Alternatively, the trees are planted on ridges that alternate with shallow depres-sions. In the 'sorjan' system that is widely applied in tidal swamp areas with pyritic sediments in Southeast Asia, rice is grown in the inundated depressions between ridges. The difficulties discussed for Thionic Fluvisols apply also to Thionic Gleysols (see under Fluvisols).