PODZOLS (PZ)

Podzols are soils with an ash-grey subsurface horizon, bleached by organic acids, on top of a dark accumulation horizon with brown or black illuviated humus and/or reddish iron compounds. Podzols occur in humid areas in the Boreal and Temperate Zones and locally also in the tropics. The name 'Podzol' is used in most national and international soil classification systems; the USDA Soil Taxonomy refers to these soils as 'Spodosols'.

Definition of Podzols

Soils, having a spodic horizon starting within 200 cm from the soil surface, underlying an albic, histic, umbric or ochric horizon, or an anthropedogenic horizon less than 50 cm thick.

Common soil units:
Densic, Carbic, Rustic, Histic, Gelic, Anthric, Gleyic, Umbric, Placic, Skeletic, Stagnic, Lamellic, Fragic, Entic, Haplic.

Summary description of Podzols

Connotation: soils with a 'spodic' illuviation horizon under a subsurface horizon that has the appearance of ash; from R. pod, under, and zola, ash.

Parent material: unconsolidated weathering materials of siliceous rock, including glacial till, and alluvial and eolian deposits of quartzitic sands. Podzols in the Boreal Zone occur on almost any rock.

Environment: mainly in temperate and boreal regions of the northern hemisphere, in level to hilly land under heather and/or coniferous forest; in the humid tropics under light forest.

Profile development: mostly O(Ah)EBhsC-profiles. Complexes of Al, Fe and organic compounds migrate from the surface soil to the B-horizon with percolating rainwater. The humus complexes precipitate in an illuvial spodic horizon; the overlying soil remains behind as a strongly leached Ah and a bleached albic eluvial horizon. Most boreal Podzols lack an Ah-horizon.

Use: severe acidity, high Al-levels, low chemical fertility and unfavourable physical properties make most Podzols unsuitable for arable cropping, unless improved, e.g. by deep-plowing and fertilization. Podzols have some potential for forestry and extensive grazing.

Regional distribution of Podzols

Podzols cover an estimated 485 million hectares worldwide, mainly in the temperate and boreal regions of the Northern Hemisphere (see Figure 1). They are extensive in Scandinavia, northwest Russia and Canada. Besides these ‘zonal’ Podzols, there are smaller occurrences of ‘intrazonal' Podzols, both in the Temperate Zone and in the tropics.
Tropical Podzols occur on less than 10 million hectares, mainly in residual sandstone weathering in per-humid regions and in alluvial quartz sands, e.g. in uplifted coastal areas. The exact distribution of tropical Podzols is not known; important occurrences are found along the Rio Negro and in the Guianas in South America, in the Malesian region (Kalimantan, Sumatra, Irian), and in northern and southern Australia. They seem to be less common in Africa.

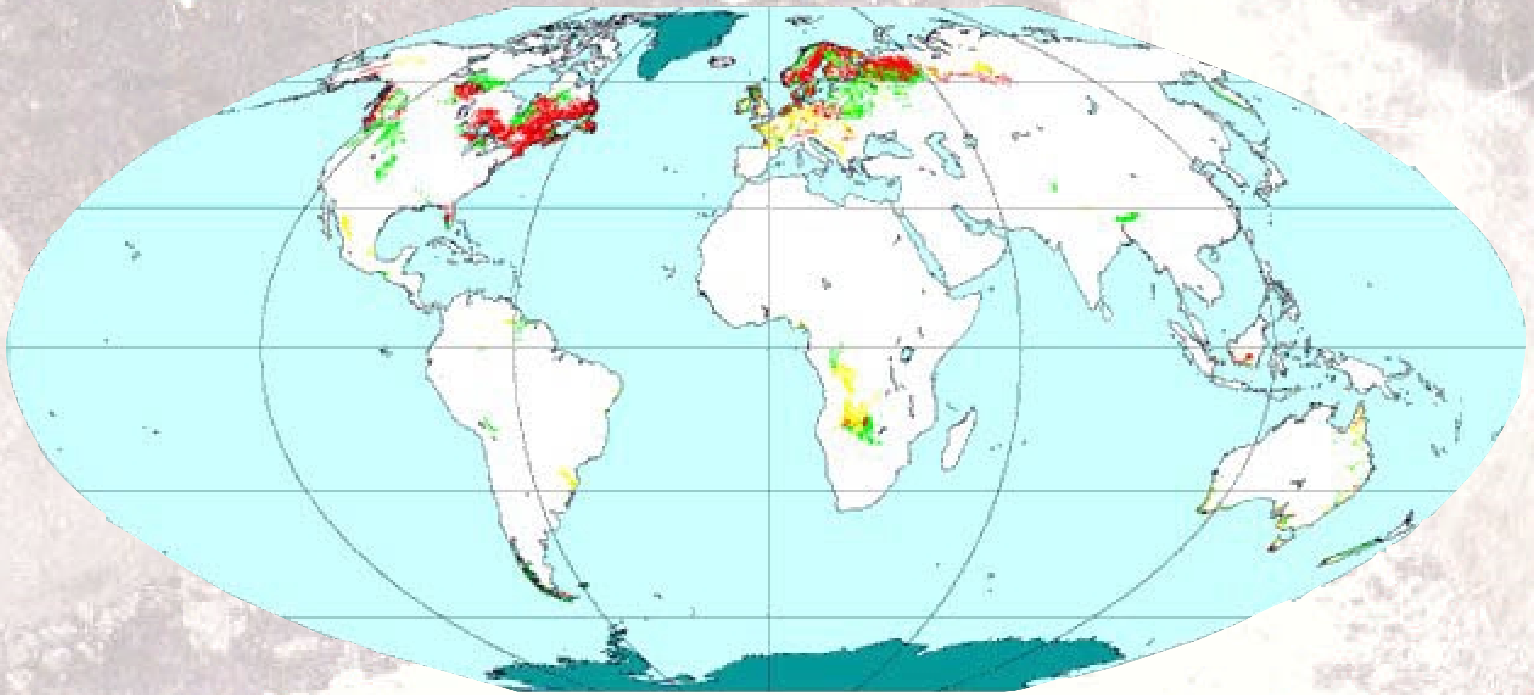

Figure 1. Podzols worldwide.

Associations with other Reference Soil Groups

Podzols occur together with soils that have evidence of displacement of organic-Fe/Al complexes but not strong enough to qualify as Podzols. Arenosols, Albeluvisols, Cambisols, Cryosols, Leptosols, Histosols and Gleysols are commonly associated with Podzols, but also Andosols, Anthrosols, Ferralsols and Planosols.

Podzol-Histosol-Gleysol combinations are common in plains with quartzitic sand and a shallow water table in the Temperate Zone. Cryosol-Podzol linkages are found at high latitudes and in places also at high altitude. Tropical Podzols are associated with poor quartzitic Arenosols, with Gleysols and with Ferralsols.

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Genesis of Podzols

'Podzolization' (the formation of a spodic subsurface horizon) is actually a combination of processes, including

1 '*cheluviation*', the movement of soluble metal-humus complexes (chelates) out of the surface layer(s) to greater depth, and

2 '*chilluviation*', the subsequent accumulation of Al- and Fe-chelates in a spodic horizon. (Soluble organic compounds can move to still deeper horizons.)

Soluble organic substances produced by microbial attack on plant litter, move downward with the soil solution and form complexes with Al^{3+}- and Fe^{3+}-ions. The rate of such processes depends strongly on the soil. In poor quartz sands, podzol morphology is visible after a hundred years of soil formation. Rates are much slower in richer parent materials but the humus fraction of most Podzols appears to have reached equilibrium in 1000-3000 years.

Carboxylic and phenolic groups of dissolved soil organic matter act as 'claws' (Gr. chela, hence the term 'chelation') and preferentially ‘grab’ polyvalent metal ions such as Al^{3+} and Fe^{3+}. This process continues until the binding capacity of the organic matter is saturated. Saturation appears to promote precipitation of the complex. It is likely that transfer of bound metals occurs between highly aggressive but easily decomposable Low Molecular Weight (LMW) acids and less acid but more stable 'humic compounds'.
It appears that uncharged organic matter is also transported by water. This is explained by '*hydrophobic arrangement*', or '*mycelle behaviour*': molecules arrange themselves in such a way that their hydrophobic parts are in contact with the interior of 'suprastructures', while their charged parts are in contact with water. This causes an apparent solubility of largely hydrophobic units.

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In well-drained soils, transport of solutes is restricted to the penetration depth of rainfall events. Organic matter, with its bound metal ions, precipitates either through saturation (loss of surface charge), or where the waterfront stops. In most cases accumulation of saturated complexes occurs within one metre from the soil surface. Accumulations of different organic matter in irregular bands that reflect the depth of water penetration and the porosity of the matrix material may occur deeper than this illuviation horizon. However, only in extremely poor parent materials, or after extremely long periods of soil formation, will accumulation horizons reach greater depths.

In hydromorphic Podzols, dissolved organic matter, with its bound Al, can be transported laterally and over considerable distances. Hydromorphic Podzols with lateral water flow are associated with 'black water' rivers and lakes in boreal, temperate and tropical areas. The limited depth of the phreatic zone usually restricts vertical transport in the soil. Hydromorphic Podzols tend to have slightly deeper eluviation horizons than well-drained relatives in the same climatic zone; their illuvial horizons extend down to greater depths (1-3 metres) and are more vaguely defined. Many hydromorphic Podzols in stratified materials have well-defined humus bands in the subsoil.

The accumulation process is to some extent reversible. If unsaturated organic substances reach the top of an illuviation horizon, the Al,Fe-humus complexes will re-dissolve. Ultimately, an entire spodic horizon slowly moves to a greater depth. Strongly podzolized soils with a very thick albic eluviation horizon occur on poor quartz sands, notably in the humid tropics. The illuvial horizon of such soils occurs at a depth of several metres ('Giant Podzols'), and may even be absent altogether if the mobile humus is removed by lateral groundwater flow.

Podzolization versus ferralitization

In terms of soil formation, opposite processes take place in Podzols, where Fe- and Al-oxides dissolve and iron and aluminium are leached out, and in Ferralsols where Fe- and Al-oxides remain stable and increase in content through relative accumulation. The main reason for the difference is that in Podzols, organic acids are the main weathering agent, whereas carbonic acid plays this role where organic matter decomposition is more rapid, such as Ferralsols.

Strongly leached Ferralsols, although very low in cations and with a pH of 4.0 or less, show no tendency to develop an eluvial horizon because the production of organic acids is too slow, their decomposition too fast, and the high content of iron oxides would immediately precipitate such complexes. Such soils may podzolise only when iron compounds are removed and the clay is decomposed by *ferrolysis* under conditions of periodic water stagnation.

In the wet tropics, soil formation will produce a Ferralsol in most well drained parent materials that are rich in iron and not too siliceous. A Podzol will result in imperfectly drained, coarse-textured and quartz-rich materials, which receive organic matter that decomposes slowly under conditions of oligo-trophy.

Characteristics of Podzols

Morphological characteristics

A typical *zonal* Podzol has an ash-grey, strongly leached eluvial horizon under a dark surface horizon with organic matter, and above a brown to very dark brown spodic illuviation horizon. Most Podzols have a surface litter layer (an H-horizon) that is 1 to 5 cm thick, loose and spongy, and grading into an Ah-horizon with partly humified organic matter. In the litter layer in particular, most of the individual plant fragments are still recognizable and live roots may be beset with mycorrhizae. The Ah-horizon consists of a dark grey mixture of organic matter and mineral material (mainly quartz). The underlying bleached E-horizon has a single grain structure whereas the structure of the brown to black illuviation horizon varies from loose (rare) through firm, subangular blocky to very hard and massive.

At the drier end of the climatic range for zonal Podzols, the illuviation horizon has commonly a high chroma signifying accumulation of iron oxides (together with aluminium oxides). In more humid regions, the Bhs-horizon is darker and has a higher content of translocated organic matter.

The profile of a typical *intrazonal* tropical Podzol has a surface layer of poorly decomposed ('raw'), acid humus with a high C/N-ratio. The underlying humus-stained A-horizon is poorly developed and rests on top of a light grey to white eluvial E-horizon of sand texture that can be from 20 cm to several metres thick ('Giant Podzols'). The still deeper illuvial horizon is commonly dark brown and irregular in depth. Rarely, one finds mottles or soft concretions of iron and aluminium oxides, and/or slightly more clay in the illuvial horizon than higher in the profile. Brightly coloured B(h)s-horizons with sesquioxides accumulation as occur in the temperate zone (not in ‘groundwater Podzols’), are uncommon in the tropics where podzolization is largely restricted to iron-poor parent materials under the influence of groundwater.

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Mineralogical characteristics

The mineralogy of Podzols is somewhat variable but is nearly always marked by a predominance of quartz. In cool, humid climates where leaching is intense, the parent material may originally have been of intermediate or even basic composition.

Iron and aluminium maxima may occur at different depths in the B-horizon, depending on the genetic history of a particular soil. Podzols in the USA tend to have the maximum iron content above the Al-maximum. Well-developed intrazonal Podzols in Western Europe normally have the maximum Al-content in the top of the B-horizon, with the Fe- maximum at greater depth.

Weathering processes in the A- and E-horizons of well-developed Podzols on clay-poor materials cause transformation of clay to smectite (beidellite), and sometimes kaolinite, whereas clays in the B-horizon, may be Al-interstratified. Allophane (amorphous Al-silicate) appears to accumulate in B-horizons in rich parent material.

Hydrological characteristics

Hydromorphic Podzols are structurally wet because of climate and/or terrain conditions. Water movement through the soil may be impaired even in dryland areas if the soil has a dense illuviation horizon or an indurated layer at some depth. A thin iron-pan may form upon periodic water stagnation in the soil, either in the B-horizon or below it. (e.g. in Densic and Placic Podzols). Even though Podzols are associated with regions that have an annual precipitation surplus, their low water holding capacity may still cause drought stress in dry periods.

Physical characteristics

Most Podzols have a sandy texture and weak aggregation to structural elements; their bleached eluviation horizon contains normally less than 10 percent clay but the clay content could be slightly higher in the underlying illuvial horizon.

Chemical characteristics

The organic matter profile of Podzols shows two areas of concentration, one at the surface and one in the spodic horizon. The C/N-ratio is typically between 20 and 50 in the surface horizon, decreasing to 10 to 15 in the bleached horizon and then increasing again to 15 to 25 in the spodic horizon. Nutrient levels in Podzols are low as a consequence of the high degree of leaching. Plant nutrients are concentrated in the surface horizon(s) where cycling elements are released upon decomposition of organic debris, but phosphates may accumulate in the B-horizon (as Fe or Al-phosphates). The surface horizons are normally acid, with $pH_{(H2O,1:1)}$ values between 3.5 and 4.5. The pH-value of zonal Podzols increases with depth to a maximum of about 5.5 in the deep subsoil, whereas soil-pH in intrazonal Podzols tends to be lowest in the top of the B-horizon.

Biological characteristics

In boreal and temperate climates, ‘large’ soil animals such as earthworms are scarce in most Podzols; decomposition of organic matter and surface soil homogenization are slow and are mainly done by fungi, small arthropods and insects. Many Australian Podzols show signs of earthworm activity. The activity of moles and earthworms increases sharply when Podzols are fertilized.

Management and use of Podzols

Zonal Podzols occur in regions with unattractive climatic conditions for most arable land uses. Intrazonal Podzols are more frequently reclaimed for arable uses than zonal Podzols, particularly those in temperate climates. The low nutrient status, low level of available moisture and low pH make Podzols unattractive soils for arable farming. Aluminium toxicity and phosphorus deficiency are common problems. Deep ploughing, to improve the moisture storage capacity of the soil and/or to eliminate a dense illuviation horizon or hardpan, liming and fertilization are the main ameliorative measures taken.

Most zonal Podzols are under forest; intrazonal Podzols in temperate regions are mostly under forest or shrubs (heath). Tropical Podzols normally sustain a light forest that recovers only slowly after cutting/burning. By and large, mature Podzols are best used for extensive (sheep) grazing or left idle under their natural (climax) vegetation.