Map of global distribution of soils

Climate plays an important role in soil formation. Hence, soils generally differ from one major climatic zone to another. Equatorial regions, with high temperature and rainfall levels, have deep, strongly weathered and very leached soils with low nutrient levels. More arid conditions, with low precipitation and high evaporation, produce soils containing easily soluble components such as calcium carbonate or gypsum. Soils in temperate climates tend to have more organic matter while the effects of parent material and precipitation levels are more evident. In cold climates, soil formation is restricted and strongly influenced by freeze-thaw processes and the presence of ice in the subsoil ('permafrost'). Past climates also play an important role in determining current soil distribution, especially in the subarctic and northern temperate regions where glaciers have removed all soil material and new soils were formed after the retreat of the ice. Consequently, soils of these regions are relatively young or 'immature'.

Soil classification schemes generally reflect different concepts of soil formation. The boxes on these two pages are simplified descriptions of the world's major soil types according to the World Reference Base for Soil Resources (WRB), an internationally used soil classification system. More information on the WRB system can be found at:

www.fao.org/soils-portal/soil-survey/soilclassification/world-reference-base/en/

Arenosols: from Latin ***arena***, sand

Developed as a result of *in situ* weathering of quartz-rich parent material or in recently deposited sands (e.g. dunes in deserts and beaches). Among the most extensive soil types in the world. Soil formation is often limited by a low weathering rate. Prone to wind erosion. (ISRIC)

Durisols: from Latin ***durus***, hard

Associated with old surfaces in arid and semi-arid environments. They display hardened accumulations of silica (SiO_2) in the soil. Durisols develop over long periods during which the soil reaction is so alkaline (pH > 8) that the silica becomes mobile. Regarded as 'fossil' soils. (FE)

Calcisols: from Latin ***calcarius***, lime-rich

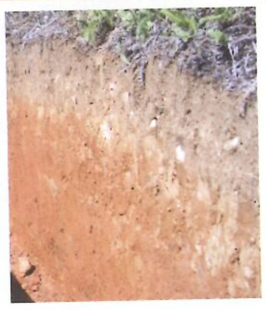
Formed through the leaching of carbonates from the upper part of the soil which precipitate when the subsoil becomes oversaturated or by the evaporation of water which leaves behind dissolved carbonates. Found in dry climates. (EM)

Ferralsols: from Latin ***ferrum***, iron, and ***alumen***, alum

Mostly associated with high rainfall areas and very old land surfaces, they are strongly leached soils that have lost nearly all of their weatherable minerals over time. Dominated by stable products, such as aluminium/iron oxides, which give strong red and yellow colours. Nutrient poor. (SD)

Acrisols: from Latin ***acer***, acid

Strongly acid soils with a clay-enriched subsoil and low nutrient-holding capacity. Mainly found in the wetter parts of the tropics and subtropics. Normally associated with acidic bedrock and deficient in nutrients. Thus requiring substantial applications of fertiliser to produce satisfactory crop yields. (OS)



Cambisols: from Latin ***cambiare***, to change

Young soils, generally lacking distinct horizons or with only slight evidence of soil-forming processes usually through variations in colour, the formation of structure or presence of clay minerals. Globally extensive – characteristics dependent on the nature of the parent material. (ISRIC)

Fluvisols: from Latin ***fluvius***, river

Occurring in all periodically flooded areas, such as flood plains, river fans, valleys, tidal marshes and mangroves. Fluvisols show a layering of sediments with pedogenic horizons as a result of deposition by water. Their characteristics depend on the nature and sequence of the sediments. (JD)

Albeluvisols: from Latin ***albus***, white, and ***eluere***, to wash out

Soils with a subsurface horizon that tongues into a horizon which has accumulated clay. Formed mostly in unconsolidated deposits on flat to undulating plains under coniferous or mixed forest in boreal and temperate climates with cold winters and short cool summers. (EM)

Alisols: from the Latin ***alumen***, aluminium

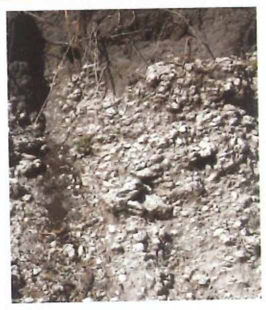
Very acid soils with a clay-enriched subsoil and high nutrient-holding capacity. Acidity is caused by the weathering of minerals which release a large amount of aluminium – often at levels that are toxic to most crops. They occur in humid tropical, humid subtropical and warm temperate regions. (ISRIC)

Andosols: from Japanese ***an***, black, and ***do***, soil

Soils developed from materials ejected from volcanoes (e.g. ash, pumice and cinder) which weather to produce specific clay minerals. In humid climates, many Andosols develop a thick, dark topsoil as a result of the fixing of organic substances by aluminium that is released from the weathering of the clay minerals. (ISRIC)

Chernozems: from Russian ***chern***, black, and ***zemlja***, earth

Soils with a very dark-brown or blackish surface horizon with a significant accumulation of organic matter and a neutral pH. Secondary calcium carbonate deposits occur within 50 cm of the lower limit of the humus-rich horizon. High biological activity. Typically found in grasslands in temperate climates. (EM)



Anthrosols: from Greek ***anthropos***, man

Soils that exhibit surface horizons that have been modified profoundly through human activities, such as addition of organic materials or household wastes, irrigation and cultivation. These include plaggen, paddy and oasis soils as well as the *Terra Preta do Indio* in Brazil. However, they are not evident due to the scale of the accompanying map. (JD)

Cryosols: from Greek ***kraios***, cold or ice

Soils from cold regions where permafrost is found. Water occurs primarily in the form of ice and cryogenic processes, such as freeze-thawing cycles, cryoturbation, frost heave and cracking, are the dominant soil-forming processes, often giving distorted horizons and/or patterned ground. (SB)

Gleysols: from Russian ***gley***, 'mucky mass'

Occurring in low-lying areas or depressions where groundwater comes close to the surface and the soil is saturated for long periods of time. Other than characteristic colours depending on whether oxygen is present, they display little soil development. Often found with wetland vegetation. (OS)

Gypsisols: from Greek *gypsos*, gypsum

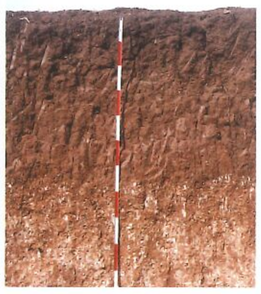
Similar to Calcisols, these are soils with secondary accumulations of gypsum ($CaSO_4 \cdot 2H_2O$). They are found in the driest parts of the arid climate zone and often reflect former lake beds that have dried up through evaporation. Vegetation is sparse xerophytic shrubs and grasses. (JD)

Histosols: from Greek *histos*, tissue

Also known as peat, Histosols contain a high amount of organic matter (more than 20 %), have a high water content and very low bulk density. When drained, they suffer from irreversible shrinkage and subsidence. Found in wetlands and cold climates, which slow the rate of organic matter decomposition. (SD)

Kastanozems: from Latin *castanea*, chestnut, and Russian *zemlja*, earth

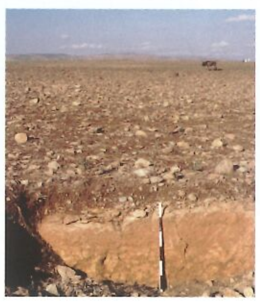
Soils with a deep, dark coloured surface layer with a significant accumulation of organic matter, high base saturation and presence of calcium carbonate in the subsoil. Found in drier parts of the grassland regions where leaching is low but sufficient biomass production to form the organic-rich surface layer. (SH)



Global distribution of the main soil types according to the WRB system. Colours on the map correspond to the colours on the soil name boxes around the map. (JRC) [23]

Leptosols: from Greek *leptos*, thin

Shallow soils over hard rock, very gravelly material or highly calcareous deposits. Limited pedogenic development gives a weak soil structure. Globally present, especially in mountainous and desert regions where hard rock is exposed or comes close to the surface and weathering is active. (JD)



Lixisols: from Latin *lixivia*, washed-out substances

Slightly acid soils that show a distinct increase in clay content with depth (predominantly kaolinite with limited capacity to hold nutrients). Found in the dry savannah regions with low biomass production, they have low organic matter content and lack a well developed soil structure. Prone to erosion. (EM)

Luvisols: from Latin *luere*, to wash

Soils with a distinct increase in clay content with depth as a result of clay movement from the upper part of the soil to the lower part. The clay gives a high nutrient-holding capacity. In general, Luvisols have a well-developed soil structure, which contributes to a good water-holding capacity. (ISRIC)

Nitisols: from Latin *nitidus*, shiny

Developed mainly from basic iron-rich rocks such as basalt in tropical climates. They have a dark red colour and a well-developed structure. The iron content is high, which enforces strong bonding of clay particles and the formation of the nut-shaped aggregates with shiny surfaces. (OS)

Phaeozems: from Greek *phaios*, dusk, and Russian, *zemlja*, earth or land

Soils with a thick, dark-coloured surface layer, rich in organic matter and nutrients. Their development requires a reasonable amount of precipitation and lush vegetation, preferably grasses. Similar to Chernozems and Kastanozems but more intensively leached. (ISRIC)

Planosols: from Latin *planus*, flat

Soils with very low permeability in the subsoil which causes water entering the soil to stagnate above this layer. The transition to the low permeability layer is very abrupt and the clay content increases significantly. Most Planosols have a structureless topsoil due to the removal of iron in waterlogged conditions. (EVR)

Plinthosols: from Greek *plinthos*, brick

Identified by the accumulation of iron (and manganese) in the subsoil as large mottles or concretion that develop under fluctuating groundwater. While buried, the layer (called plinthite) is soft and can be cut by a knife. However, once exposed to air and sunlight, it hardens irreversibly and becomes what is known as ironstone. (ISRIC)

Podzols: from Russian *pod*, under, and *zola*, ash

Soils with a distinctive ash-grey horizon which has been bleached by the loss of organic matter and iron oxides. This sits on top of a dark accumulation horizon of redeposited humus and/or reddish iron compounds. Typically occurring in humid temperate climates in coarse sand deposits. (AR)

Regosols: from Greek *rhegos*, blanket

Soils in unconsolidated medium and fine-textured material showing only slight signs of soil development (e.g. some accumulation of organic matter producing a somewhat darker horizon). Similar to Arenosols (sand) or Leptosols (gravel). Soil development limited by low temperatures or aridity. (OS)

Solonchaks: from Russian *sol*, salt

Strongly saline soils with high concentrations of soluble salts. Mostly associated with arid regions and areas where saline groundwater comes close to the surface. Their characteristics and limitations to plant growth depend on the amount, depth and composition of the salts. (AR)

Solonetz: from Russian *sol*, salt, and *etz*, strongly expressed

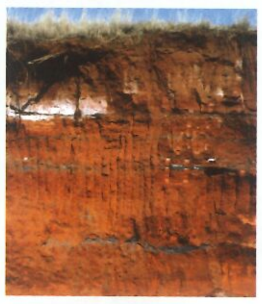
Strongly alkaline soils with a dense, columnar, clay-rich subsoil containing a high amount of exchangeable sodium, which has the ability to disperse clay particles and organic matter from the topsoil to the subsoil. Normally found in flat lands in climates with hot, dry summers or former salty coastal deposits. (EM)

Stagnosols: from Latin *stagnare*, to flood

Soils with a perched water table, often caused by the presence of an impermeable barrier deep in the soil, leading to temporary water logging and the mobilisation of iron and/or manganese. This process gives rise to a characteristic colour pattern. Commonly referred to as pseudogley. (RS) – not visible due to the scale of the map.

Technosols: from Greek *technikos*, skilfully made

Soils containing man-made artefacts (e.g. household or industrial waste), material that has been brought to the surface (e.g. mine dumps, oil spills) or soils sealed by an artificial surface (e.g. roads, hard-standing areas). Often contain toxic material. (OS) – not visible due to the scale of the map.



Umbrisols: from Latin *umbra*, shade

Soils with a deep, dark-coloured surface layer that is rich in organic matter but has a low nutrient content. They are mainly associated with acid parent materials and areas with high rainfall. Umbrisols are the counterpart of nutrient-rich soils with a dark surface horizon (e.g. Chernozems and Phaeozems). (EM)

Vertisols: from Latin *vertere*, to turn

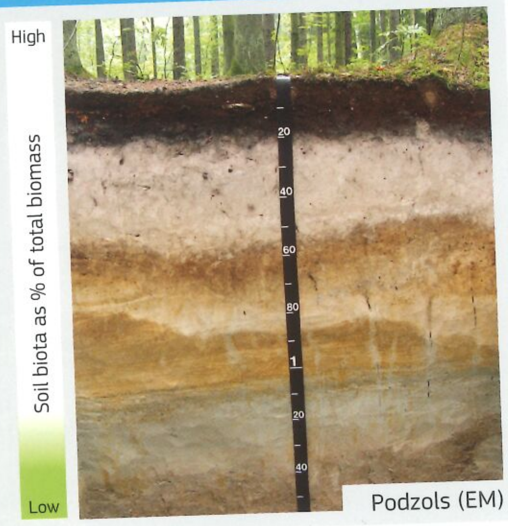
Clayey soils that exhibit cracks which open and close upon drying and wetting due to the presence of the clay mineral, montmorillonite. This process brings material from the surface into the subsoil, giving rise to a 'churned' soil. Typically found in lowland areas that are periodically wet. (EVR)

Soil biodiversity and ecoregions – Map of distribution across ecoregions

Temperate and Boreal Coniferous Forest

Temperate and boreal coniferous forest soils have fungal-dominated microbial communities; rich in decomposer and ectomycorrhizal fungi. Microarthopods and enchytraeid worms dominate the soil fauna, and ants are also abundant.

Podzols are distinctive soils characterised by the leaching of organic material, iron and aluminium from the A and E horizons, leaving behind a bleached layer. Leached material is redeposited as an organic/iron-rich cemented layer in the B horizon.

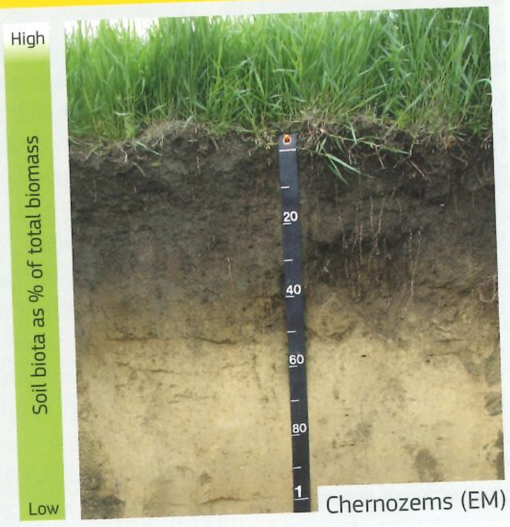


Podzols (EM)

Temperate Grassland

This ecoregion supports a high level of microbial and faunal diversity. Soils are characterised by a high abundance and diversity of arbuscular mycorrhizal fungi, earthworms, microarthropods and nematodes.

Chernozems are well-structured soils with a dark, organic-rich topsoil and secondary calcium carbonate in the subsoil. They support abundant natural grasses, typical of prairie or steppe landscapes. They grade to Phaeozems (wetter) or Kastanozems (drier).

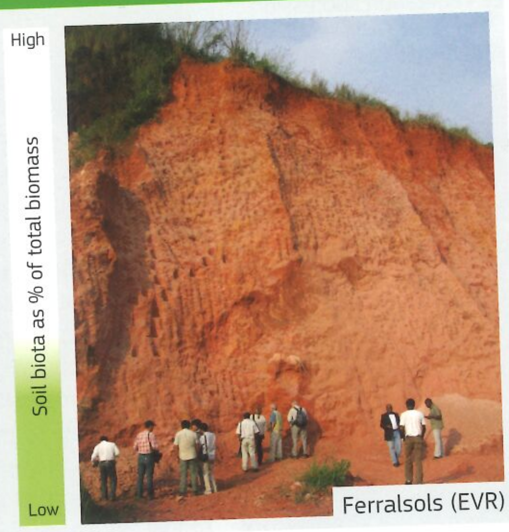


Chernozems (EM)

Tropical and Subtropical Forest

This ecoregion is characterised by highly diverse soils, with both arbuscular mycorrhizal and ectomycorrhizal fungi, and diverse and abundant communities of fauna, especially of termites, dung beetles, earthworms and nematodes.

Ferralsols are highly weathered coarse-textured soils with low pH, and are red or yellowish in colour due to high concentrations of iron and aluminium oxides. Organic matter levels are low. Horizons are absent due to intensive bioturbation, largely by termites.

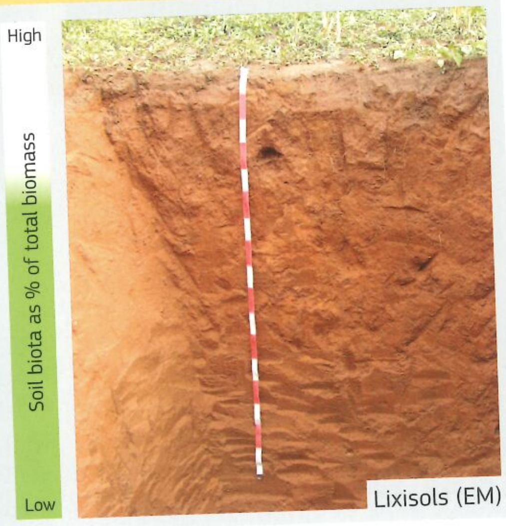


Ferralsols (EVR)

Tropical and Subtropical Grassland

Characteristic soil fauna in this ecoregion are termites and dung beetles, along with earthworms, microarthropods and nematodes. These soils contain a rich diversity of microorganisms, including arbuscular mycorrhizal fungi and nitrogen-fixing bacteria.

Lixisols are characteristic of drier conditions and exhibit subsurface accumulation of low activity clays with high base saturation as a result of limited leaching or inputs of airborne dust from adjacent deserts. Low in plant nutrients and prone to erosion.



Lixisols (EM)

Temperate Broad

Soil communities of this bi levels of microbial and fa and contain abundant communities of fungi and especially earthworms.

Luvisols are characterised subsoil, often the result of clay particles from the u destruction of clay in the u soil. In general, neutral or s they exhibit a well-defined Horizon.

Antarctica

Soils with low divers deserts. Besides m species, such as ne rotifers and collemb Relatively species- microarthropods ca while cyanobacter widely distributed.

The term ornithog soil has been stron activity of birds (e.g. of penguins) and sl phosphorus, calciu

…roadleaf and Forest

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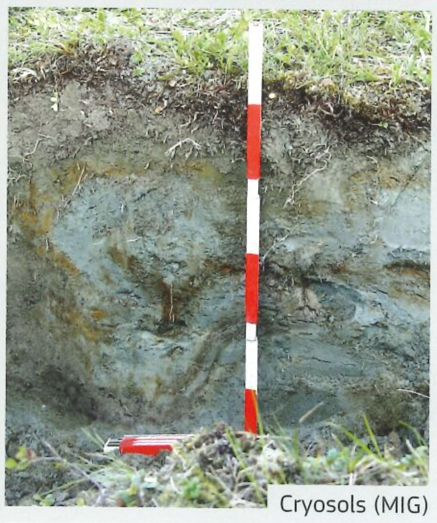
Luvisols (EM)

Tundra

Tundra soils support a relatively high diversity of fungal (both decomposer and mycorrhizal) and bacterial communities, together with a high diversity of nematodes and microarthropods, although, in terms of biomass, the dominant fauna are enchytraeid worms.

Cryosols are mineral or organic soils characterised by the presence of permafrost and waterlogging during periods of thawing. Cryosols can show distorted horizons, cracks or patterned surface features due to ice formation and melting.

High – Soil biota as % of total biomass – Low


Cryosols (MIG)

Montane Grassland and Shrubland

Soils of this ecoregion are very variable, containing a high diversity of bacteria and fungi, and both arbuscular and ericoid mycorrhizal fungi. Nematodes, microarthropods and enchytraeid worms are species rich, but few earthworms are present.

Leptosols are shallow soils, often with large amounts of gravel, lacking well- defined horizons or strong signs of soil-forming processes. Generally found under natural vegetation, specific characteristics reflect local climatic and topographic conditions.

High – Soil biota as % of total biomass – Low

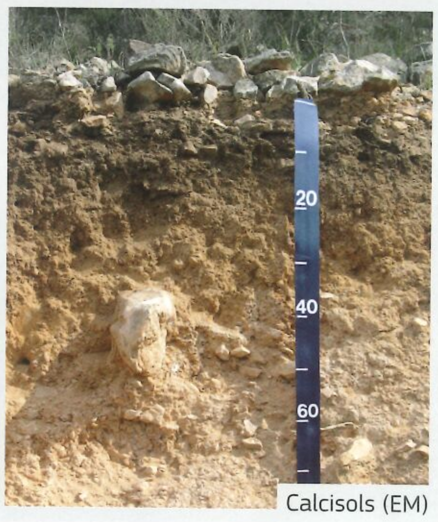

Leptosols (EM)

Mediterranean Forest, Woodland and Shrubland

Mediterranean soils are usually low in organic matter and, consequently, in soil biodiversity. The profusion of shrubs leads to an abundance of mycorrhizal fungi, and biocrusts are abundant. Soil fauna that withstand high temperatures (e.g. ants) are also widespread.

Calcisols are generally well-drained soils with high pH, fine- to medium-textured with a layer of migrated calcium carbonate in the subsoil which can be soft, powdery, hard or cemented. Their chief use is for animal grazing or grapevine, citrus fruit and olive cultivation.

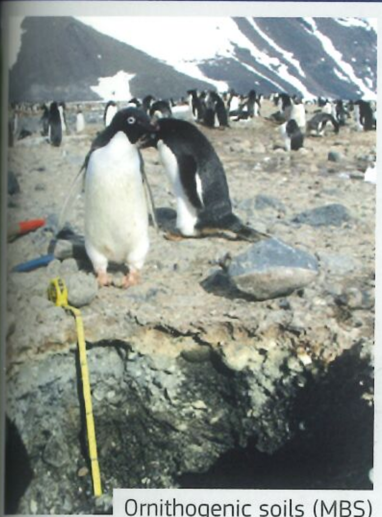
High – Soil biota as % of total biomass – Low



Calcisols (EM)

…specially in pola… …pes, only a fe… …des, tardigrade… …s, are supporte… …communities … …ur in some par… …ommunities a…

…means that th… …nfluenced by th… …ontinuous nesti… …an enrichment … …potassium.

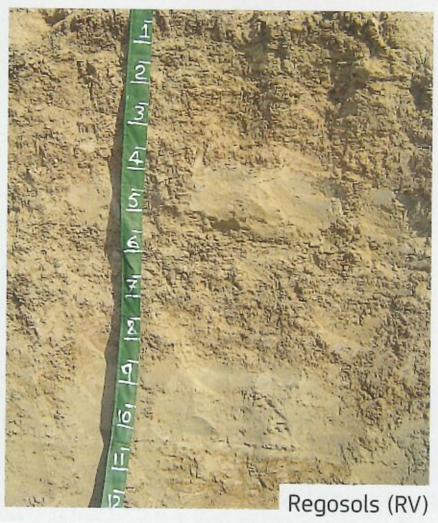

Ornithogenic soils (MBS)

Desert and Dry Shrubland

Soils of this ecoregion are mostly species poor with relatively few faunal species; ants and termites are the most abundant. Soil crusts, dominated by cyanobacteria, are common and include diverse communities of lichens, fungi and bacteria.

Regosols are poorly developed or shallow soils in unconsolidated parent materials with medium to fine textures. Aridity inhibits the development of distinct soil horizons. Organic matter content is low. They can contain significant levels of calcium carbonate or gypsum.

High – Soil biota as % of total biomass – Low


Regosols (RV)

Bars indicating proportion of soil biota in the total biomass of each region are based on compilations of expert judgements.

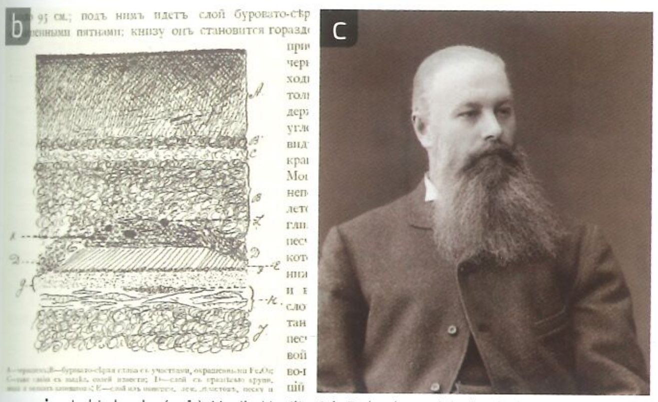
Where do soils come from?

Soil-forming factors

As can be seen from the pictures on this page, the appearance and characteristics of soils can vary considerably from place to place. The next few pages of the atlas will outline the main soil-forming factors and illustrate how they dictate the properties of a particular soil.

The Russian scientist Vasily Vasilievich Dokuchaev is commonly regarded as the father of pedology, the scientific discipline concerned with all aspects of soils. He was the first person to articulate that geographical variations in soil characteristics were related to climatic, topographic conditions, time and vegetation as well as geological factors (parent material). His ideas were further developed by a number of soil scientists, including Hans Jenny who, in 1941 [4], established a mathematical relationship that states that the observed properties of soil are the result of the interaction of many variables, the most important of which are: parent material, topography or position in the landscape, climate, living organisms/soil biodiversity, human activities and time (see following pages). According to this relationship, variations in living communities, parent material, climate or the age of the soil will result in specific soil characteristics.

Рис. 5. Степь, заселенная сурками.



In his books (**a–b**), Vasily Vasilievich Dokuchaev (**c**), the father of pedology, was the first to present the factors influencing soil formation. (TBL, IV)

For example, the weathering of solid bedrock through processes such as heating-cooling or freeze-thaw cycles (determined by topography and climate) produces a matrix of rock fragments (also known as regolith). Furthermore, weathering leads to the production of finer structures containing crystalline minerals that have been liberated from the rock. These fine-textured materials provide ideal conditions for seeds to germinate and lichens, mosses and higher plants to become established. The growth of vegetation is supported by the decomposition of minerals into simple molecules or compounds that act as plant nutrients. As plants become established, dead leaves will fall on the surface and decay to form thin organic layers, which in turn, support the next cycle of plant growth by returning the nutrients to the soil. Over time, the parent material is buried by more and more organic matter, thus allowing larger plants to grow. The slope or aspect of the site may determine growing conditions, but also the drainage and inputs or removal of materials. In this way, a soil will form with characteristics that reflect the interplay among the various factors.

A changing climate may reduce the weathering processes and, consequently, halt the supply of parent material and the release of minerals. Alternatively, climate change may favour a more luxuriant vegetation community, leading to the production of more plant matter, and resulting in deeper organic layers. In both cases, the soil characteristics will be different from the initial example.

Much more information on soil-forming processes can be found in most general soil text books (see pages 172–173).

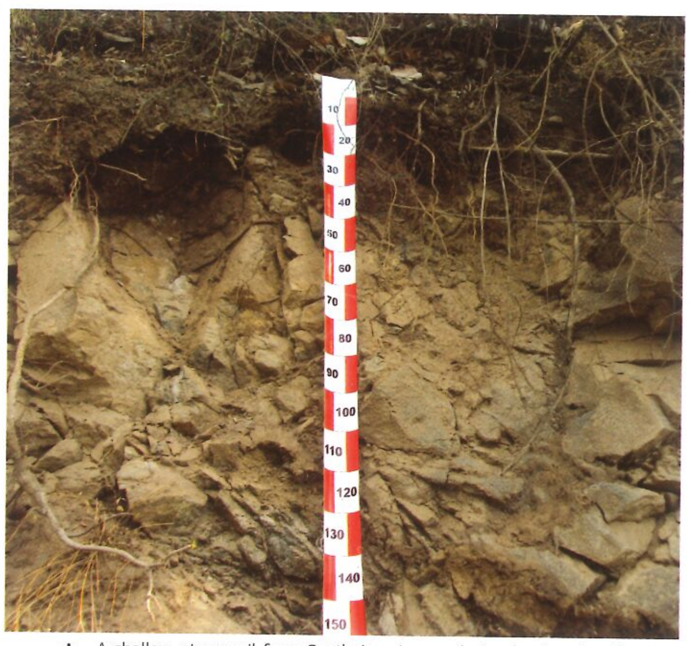

This photograph from Africa shows a deep, coarse-textured, iron-rich soil that has developed under a tropical climate. The darker band just below the surface (0–20 cm) is the result of ploughing. (VL)

This profile from North America shows a stratified soil that has developed on volcanic material (ash and ejecta). The different colours reflect the weathering of minerals (predominantly iron and aluminium oxides) and can contain significant amounts of volcanic glass. The uppermost 15 cm shows a dark, organic-rich horizon. Such soils are typically very fertile and can usually support intensive cropping or forests. (EM)

This soil from Europe is characterised by a surface layer (0–50 cm) rich in humus and calcium ions bound to soil particles. This gives a well-aggregated structure and supports abundant natural grass vegetation. Such soils occur in climates with an annual and seasonal rainfall of 450–600 mm, cold winters and relatively short, hot summers (e.g. North American prairies, Eurasian steppes). In colder areas, the surface horizon can be as much as two metres deep. Due to the low rainfall, lime is not leached from these soils, making them some of the most naturally fertile soils on the planet. (EM)

A fine-textured soil from Australia with high levels of swelling and shrinking clay minerals. Initially derived from the weathering of basic rocks, such as basalt, the clays were later redeposited in still water conditions. The dark colour indicates that iron is virtually absent from this soil. Note the cracks and smooth surfaces of sheer planes, which are evidence of churning within the soil as a result of shrinking and swelling in wet and dry conditions. (SD)

This fine-textured soil from the Russian Arctic is characterised by distorted and homogenised horizons as a result of cryoturbation – the mixing of a soil due to alternating thawing and freezing cycles. Such soils are typical of very cold climates with permafrost. The dark colour in the profile is patches of organic matter that has been dragged from the surface into the soil profile. Consequently, these soils are very important in the global carbon cycle and climate change assessments. (SG)


A shallow, stony soil from South America overlaying hard rock, reflecting very recent soil formation. This is the most widespread soil type on the planet; such soils are particularly common in mountain areas, notably in Asia, South America, northern Canada, Alaska and in the Saharan and Arabian deserts. However, they are unsuitable for agriculture because of their inability to hold water. They are generally used for extensive grazing or to support natural woodlands. (JN)