BENEATH THE GROUND

THE INVISIBLE ECOSYSTEM

Soil fertility depends on several factors: the soil age, its parent material, its organic matter content, the climate – and people.

It takes centuries – more likely thousands or even millions of years – to create soil. That is how long it takes for the surface rock to be weathered down to a depth of several metres. Only half of what we call soil consists of mineral particles such as sand and clay. Roughly 20 percent is water, and another 20 percent is air. The remaining five to ten percent are plant roots and soil organic matter such as living organisms and humus.

Soil organic matter gives the surface soil a dark, brownish black colour. This topsoil teems with life: in addition to earthworms, lice, spiders, mites, springtails and others, a handful of soil contains more microorganisms – bacteria, fungi and archaea – than there are humans on earth. These organisms decompose plant residues, turn them into humus, and distribute this fertility-giving substance throughout the soil.

Humus stores nutrients and water, and gives the soil a stable structure with many pores. It also contains carbon that plants originally absorbed from the air in the form of carbon dioxide, a greenhouse gas. This makes soil one of the most important active carbon pools. The soil organic matter stores 1,500 billion tonnes of carbon, globally – this is almost three times more carbon than in all above ground biomass including trees, shrubs and grasses.

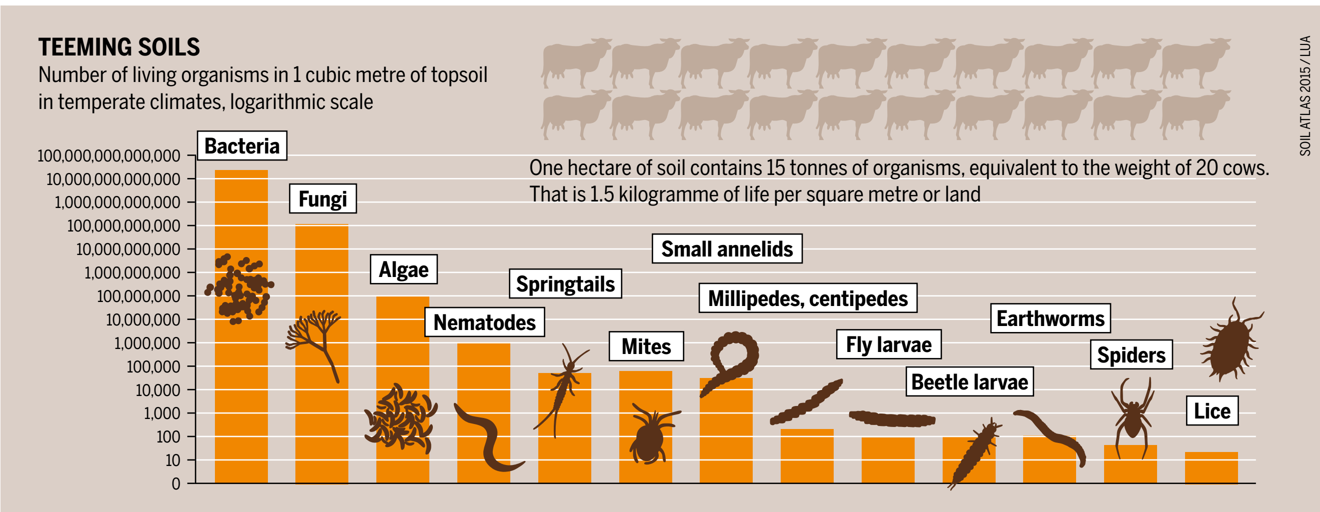
Soil is like cheese; the holes are just as important as the mass. The pores, or the voids between the solid mineral and organic particles, ensure that the soil is aerated, allowing roots and soil organisms to respire. Besides air, the pores may contain water, held there by adhesion and capillary forces. A cubic metre of soil may contain up to 200 litres of water, supplying the precious liquid to plants even though it may not have rained for a long time. The volume of pores in a soil depends on the size of the soil particles, the soil organic matter content, the presence of roots and the activity of soil organisms.

Earthworms are especially important; some of them burrow vertically down into the soil, allowing water to drain into the subsoil quickly during heavy rain. The subsoil contains less humus and fewer living organisms than the topsoil. It is lighter in colour, often yellow-ochre or reddish because of various iron compounds. A deep subsoil, that allows roots to penetrate and extract water even when the topsoil has run dry, is important for soil fertility.

Location often determines how much time was available for soil to form. In Central Europe during the Ice Ages, advancing and retreating glaciers wiped the slate clean by scraping off and churning up existing soils and depositing new sediments. The brown soils typical of the region are only about 10,000 years old – very young and little-weathered compared to most other soils. They often contain minerals that slowly release nutrients such as phosphorus and potassium into the soil. The red soils typical of the tropics, on the other hand, have undergone millions of years of weathering; many of their original minerals have been dissolved, transformed or washed out. Much of the phosphorus that has been mobilized is now firmly sorbed by iron and aluminum oxides and is thus unavailable to plants.

Soil properties depend in large part on its parent material. A rock that is rich in quartz will result in a light, coarse-grained and sandy soil that is well-aerated but stores relatively little water and nutrients. If the parent rock is rich in feldspar, the resulting fine particles will finally form a heavy soil, rich in clay. Such soils can store more nutrients and water, but are poorly aerated. They partially hold onto water so

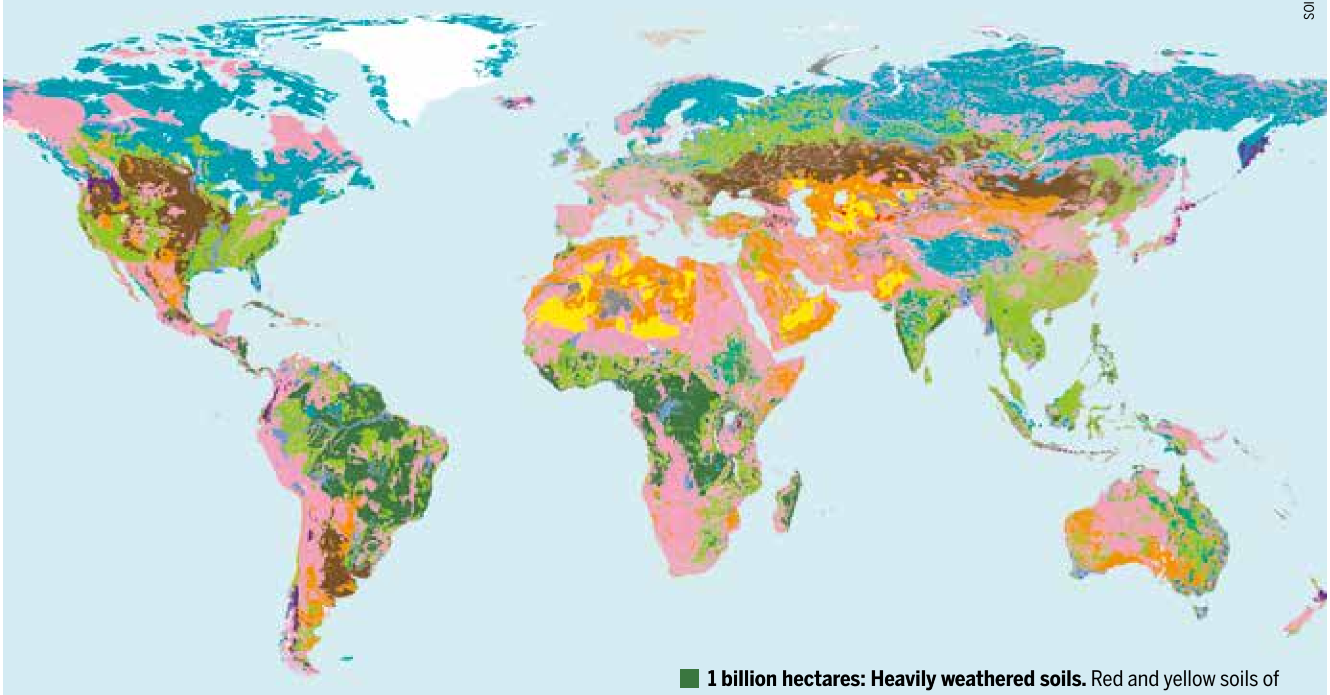
Humus harbours many secrets. Only a fraction of the many species that live in it have been identified



SOIL GROUPS AROUND THE WORLD

Simplified presentation based on the World Reference Base for Soil Resources (WRB), excluding Antarctica

SOIL ATLAS 2015 / ISRIC



- **> 5 billion hectares: Little to moderately developed soils.** Young soils; periodically flooded sediments in river beds, deltas and coastal areas; sandy or rocky soils with restricted root zone. Some extensively grazed. Cultivation of easily harvested roots and tubers. Some good farmland (if moderately weathered).
- **> 2.5 billion hectares: Soils concentrated in boreal and polar regions.** Permafrost or forest in cold regions. Also organic soils, especially peats and bogs. In temperate zones often converted to arable land.
- **2.4 billion hectares: Soils with clay-enriched subsoils.** Result of strong weathering and leaching. Dependent on soil chemistry, nutrient availability may be poor (often in forested taiga, soils with livestock raising or careful cultivation) or good (arable land with deep ploughing).
- **1.1 billion hectares: Soils with oxygen deficiency.** Influence of groundwater or temporary waterlogging. Mostly swamp forest or permanent pasture. Arable use requires drainage (then often wet rice cultivation).
- **1 billion hectares: Heavily weathered soils.** Red and yellow soils of the humid tropics humid tropics; deep, well-drained and mostly easy to work, but low water and nutrient storage capacity. With year-round rainfall, either low fertility (with continuous or shifting cultivation or extensive grazing) or good, deep rooting (often with plantations).
- **1 billion hectares: Soils with pronounced accumulation of organic matter in the mineral topsoil.** Heavy chestnut-brown to black "steppe" soils. Grasslands, sometimes irrigated, partly used for intensive cropping and animal husbandry.
- **500 million hectares: Arid-zone soils other than steppe climate.** Accumulation of calcareous, saline or alkaline materials; often extensively grazed or unused.
- **>300 million hectares: High clay content soils of the alternating wet-dry tropics.** Swelling clays cause wide cracks under dry conditions. Often unused, or with extensive grazing or cotton cultivation. Cropping is only possible under strict water control.
- **>100 million hectares: Soils from volcanic ash.** Mostly black soils, often with tuff or pumice. Generally fertile, with favourable properties for cultivation, plant roots, and water storage.
- **Soils with strong human influence**
- **Rock and rubble**
- **Glaciers and permanent snow cover**
- **Sand and dunes**

Scientists classify soils according to their properties, such as the degree of weathering or the impact of water

tightly that plant roots cannot absorb much of it. The best soils are neither sandy and light, nor heavy and rich in clay. Instead, they mostly contain medium sized particles called silt. Silt combines the advantages of both sand and clay: good aeration, along with the ability to store lots of water and nutrients.

Soils that are especially fertile are good for growing crops, while less-fertile soils are more suited for meadows, pastures and forest. For ecological reasons, even less fertile soils can be valuable. Peat soils are too wet for intensive farming, but store huge amounts of carbon. If the soil is used too intensively or in an inappropriate way, its functions decline and it starts to degrade. An estimated 20 to 25 percent of soils worldwide are already affected, and another 5 to 10 million hectares – about the size of Austria (8.4 million hectares) degrade each year. Arable land is particularly affected. But cultivation does not necessarily damage the soil: the floodplains of the Tigris and Euphrates in Iraq, and the highlands of New Guinea, have soils that are still fertile despite being farmed for 7,000 years.