The magic of soil

Soil: an amazing and vital mechanism... under our feet

Soil is the thin layer (a few centimetres to several metres) of **loose earth** covering the surface of our planet. Far from being a simple inert medium, soil is alive : it breathes, transforms, absorbs, stores, filters, purifies, nourishes, shelters and recycles.

Without soil, life on earth as we know it today would be impossible.

Warning: vulnerable!

Soil relies on complex mechanisms and is sensitive to pressure applied on the environment.
It takes a long time for soil to form, but it can deteriorate very quickly. Understanding and protecting soil means safeguarding our future.

Let's take a closer look...

Soil can be

- Bare: earth is visible
- Covered with concrete, asphalt, pavement, gravel or buildings
- Covered with grass (lawn), very "tidy"
- Cultivated (fields, private gardens, etc.)
- **Covered with vegetation**, of varying density (trees, shrubs, bushes, grass, fungi, etc.) **and plant debris** (dead leaves, dead wood, pine needles)
- …

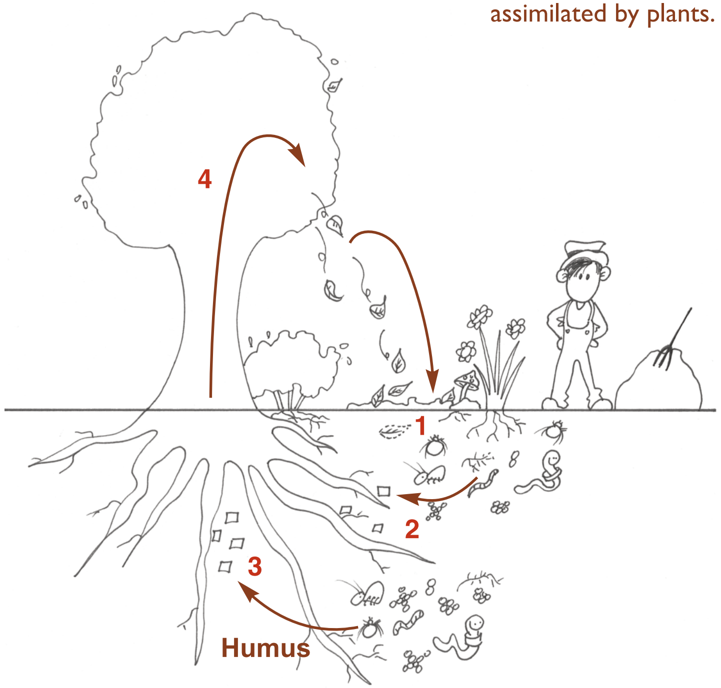
In forests, the ground is covered by a layer of **plant debris**, called "litter", made up of dead leaves, dead wood, seeds, rotting fruit and twigs. Closer inspection reveals that it also contains other organic waste, of animal origin: dead animals, dung, shedded skin, etc.

If annual accumulations of all this **organic matter** were not recycled, life on earth would have long since disappeared, suffocated by its own waste.

Soil recycles organic matter and makes the nutrients it contains available to plants once again

1 When living organisms (plants and animals) die, organic matter is returned to the soil.

2 Soil organisms consume and digest this matter, transforming it into mineral elements which can be assimilated by plants.



3 Organisms transform the part of organic matter that is most difficult to decompose (lignin, tannins) into **humus**, and then, very slowly, into mineral elements.

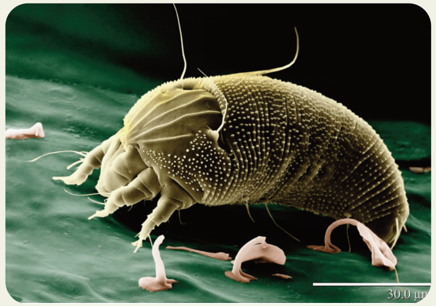
Humus can remain in soil for several years. It is humus that gives earth its distinctive smell and dark colour. By combining with fine particles of clay and silt, it helps soil to develop a structure conducive to its effective functioning.

4 Mineral elements are assimilated by plants and the cycle begins again.

Soil organisms, essential agents in the recycling process

Soil is teeming with life: bacteria, fungi, algae, protozoans, spiders, mites, springtails, wood lice, millipedes, insect larvae, worms, small mammals and more. Billions of organisms are continuously working to recycle our planet's organic matter!

We still know relatively little about this very diverse soil life, but we do know that it plays an essential role in soil's functioning, fertility, consistency, resistance to various types of pollution and more.



Organic matter in transit

A single particle of organic matter makes its way through the digestive tubes of around twenty different species before being mineralised.

Organic matter must return to the soil

The simplest method of encouraging the return of organic matter to soil and the production of humus by soil micro-organisms is to leave residue from crops, weeding, foliage, etc. to decompose rather than systematically removing it. Soil that is deficient in organic matter will become increasingly impoverished and less fertile.

The organic matter cycle is part of **two far more extensive cycles** which operate on a global scale: **the carbon cycle and the nitrogen cycle**. Carbon and nitrogen are the two main components of organic matter.
To perpetuate the organic matter cycle (and the cycle of life), these elements must be assimilated by plants. However, plants cannot use simply any chemical or physical form of carbon or nitrogen. They therefore need to be transformed.

Soil plays a vital role in this transformation process.

Role of soil in the carbon (C) cycle

Soil plays an integral role in an amazing mechanism called "photosynthesis", which involves producing life from non-living elements (and vice-versa)!

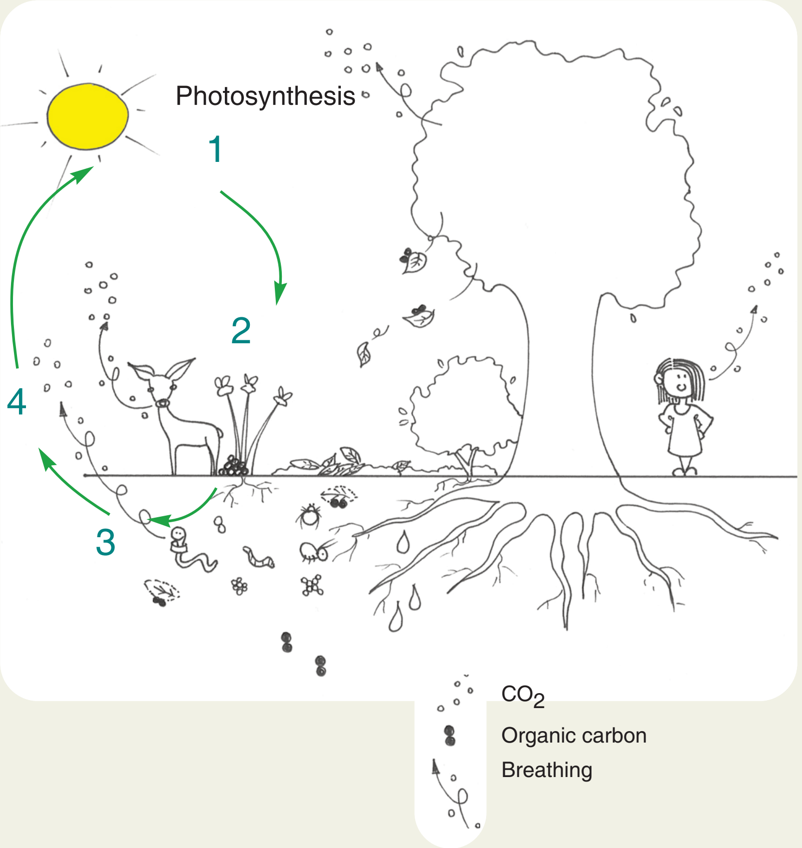
1. Chlorophyll* allows plants to use solar energy, **atmospheric carbon** (or CO_2, mineral form of carbon), water and mineral elements contained in soil (nitrogen, phosphorus) to produce their own organic matter: wood, leaves, etc. Carbon changes to its organic form.

2. These plants are then ingested by creatures which are incapable of carrying out photosynthesis, and which need to consume organic matter in order to live and grow. Animals and human beings draw their energy from breathing. During this process, some of the carbon ingested in organic form is returned to the atmosphere, transformed into CO_2.

3. Ultimately, animal and plant organic matter (dead leaves, dead wood, dead animals, organic residue, dung, etc.) returns to the soil, where it is then chopped up and decomposed by the billions of organisms and micro-organisms which feed on it.

4. Some of the carbon remains temporarily in the soil in the form of non-decomposed organic matter (humus). However, soil micro-organisms breathe too and some carbon is therefore released into the atmosphere in the form of CO_2. The carbon cycle is then perpetuated indefinitely.

*chlorophyll: green pigment in plants which plays a vital role in photosynthesis



Soil's role in the nitrogen (N) cycle

Soil allows plants to assimilate atmospheric nitrogen, thanks to the work of its organisms and micro-organisms!

1. Exception*, in gaseous state, atmospheric nitrogen (N_2) cannot nourish plants: to reach the roots, it must be present as a solution in water within the soil.

2. Dead plants, as well as dead animals and dung (including slurry and manure), provide some of the nitrogen present in soil in organic form. Once again, plants cannot use this organic nitrogen directly.

3. Micro-organisms transform the organic nitrogen into ammonium (NH4), already a good source of nitrogen for plants.

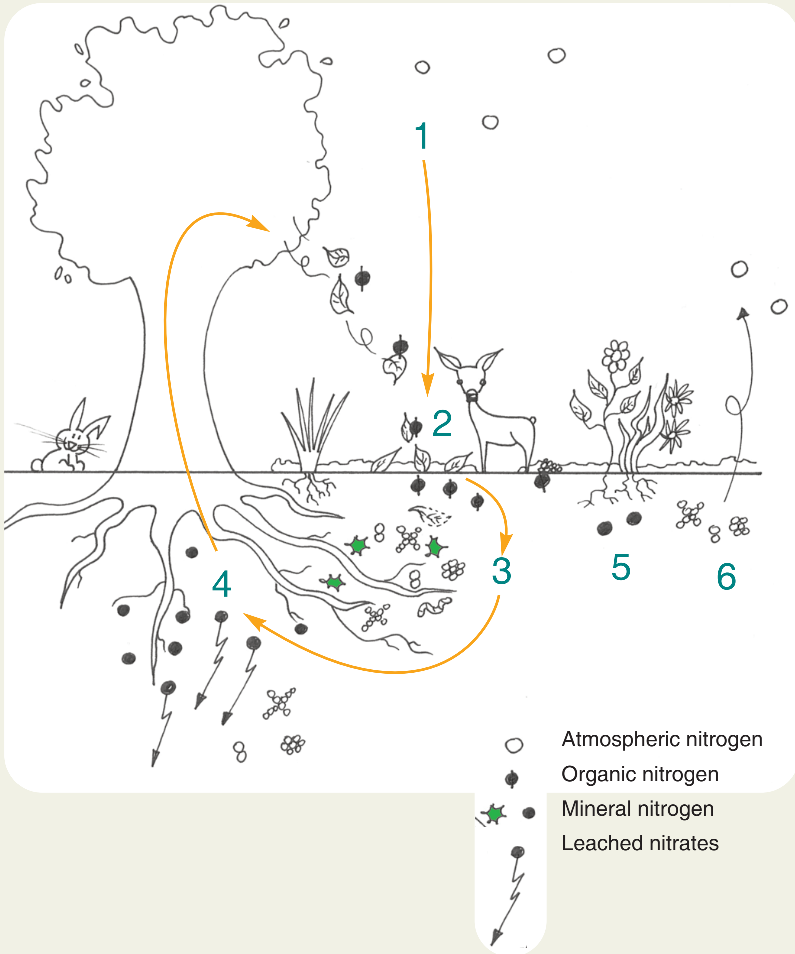
4. A very specific category of bacteria ("nitrifying" bacteria) then transforms the ammonium into nitrates (NO3), which are more mobile and easier to assimilate. Excess nitrates that have not been used by plants are swept away by rain water until they reach groundwater bodies. Some organic nitrogen remains in the humus until it is mineralised by bacteria.

5. From plants, nitrogen can pass into the food chain.

6. Some plants are capable of holding atmospheric nitrogen directly in their roots. This is because they live in symbiosis with bacteria which transform nitrogen gas into nitrates. Legumes (clover, peas, alfalfa, etc.) have this ability. They provide soil with direct supplies of nitrogen which can be assimilated by plants.

7. The activities of other soil bacteria, known as "denitrifying bacteria", cause some nitrogen to be released into the atmosphere. The cycle starts again.

*see point 6



A dynamic balance, an alchemy…
But what would happen if all the world's soil was covered with concrete or asphalt ?
If we "forgot" to enrich it with organic matter ?
If soil micro-organisms disappeared as a consequence of severe soil pollution ?

Maintaining the carbon and nitrogen cycles

Compost, an everyday material for gardeners, is created through the decomposition of organic matter by organisms (worms, insects, bacteria, etc.). To fulfil its role effectively, compost must be balanced and contain both nitrogen matter ("wet" waste, peelings, wet dead leaves, grass cuttings, etc.) and carbon matter (straw, crushed wood, dried leaves, etc.).

One method of making up for nitrogen deficiencies in soil is to grow **green fertiliser** (legumes, such as clover, alfalfa, peas, etc.) from time to time and then bury this growth at the end of its cycle. The benefits of this traditional agricultural practice are being recognised once again.

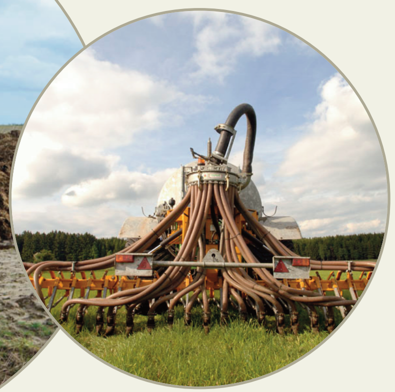
Let's not confuse organic matter with fertiliser!

Organic *soil amendments* (compost, manure, etc.) or inorganic equivalents (lime) improve soil's structure (essential for its fertility and to protect against deterioration from erosion) by acting on its physical, chemical or biological properties. On the other hand, *fertilisers*, whether inorganic (nitrogen, phosphate, etc.) or organic (liquid manure, slurry, etc.), nourish plants directly, at varying speeds and with no other improving effect.

Let's take a closer look...

If we scratch soil down to 15 or 20 cm, we find

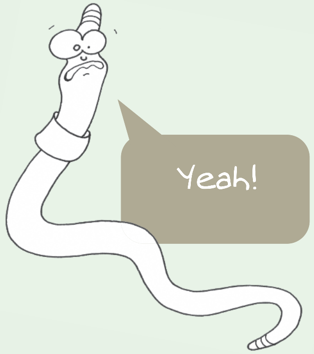
- "Earth": the colour, structure, humidity and other characteristics vary between different types of soil, and even within the same type depending on the depth. Earth consists of organic matter (recently dead, broken down into small fragments, decomposing or decomposed), nutrients (invisible) and mineral particles (sand, silt and clay) resulting from weathering of the bedrock.
- Stones (of different sizes)
- Earth**worms** and other animals (or signs of life such as burrows, tunnels and so on)
- Plant roots
- Fungi (white filaments, very close to the surface)
- Gaps filled with air or water
- …



Earthworms, soil superstars

The tunnels created by earthworms help to aerate and stir oil, as well as promoting circulation of water.

Earthworms digest and distribute precious organic matter. Their sticky excrement increases soil's cohesion. They create habitat for the other soil organisms. They help to make soil more fertile. To allow them to carry out these functions, we need to provide them with regular inputs of organic matter, avoid pesticides and choose non-harmful products, etc.



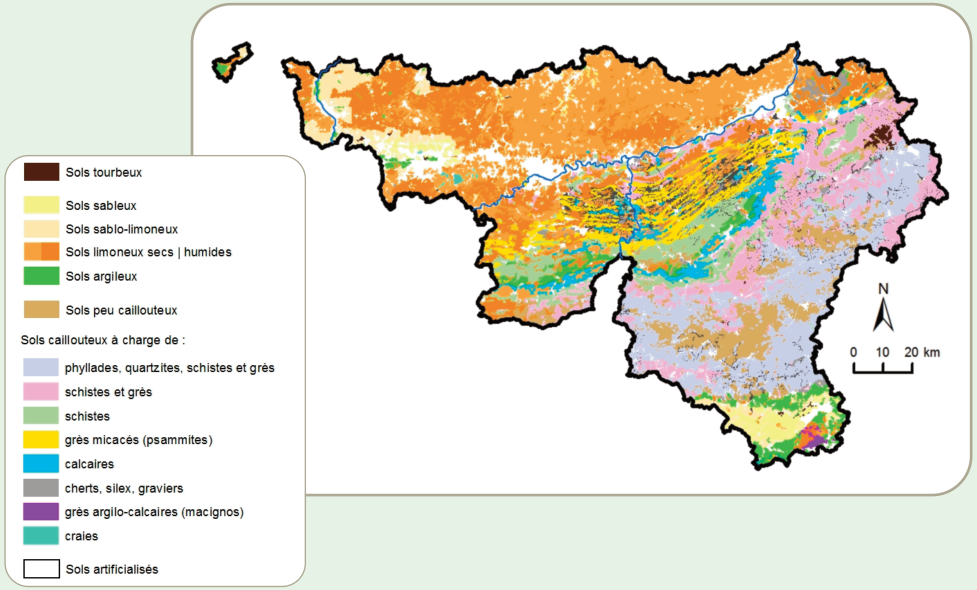
Roots need air, water, nutrients and soil that is loose enough to allow them to develop properly. Conversely, soil criss-crossed by lots of roots will be more stable and richer in different micro-organisms.

Soil formation

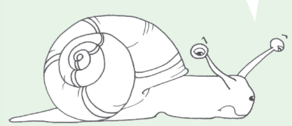
Soil has been formed over thousands of years. A hard, soft or loose rock (shale, sandstone, limestone, sand, etc.) disintegrates and alters as a result of the effects of rain, heat, frost and other factors. This marks the start of a long physical-chemical process. Plants grow and decompose. This intrinsically linked mixture can already be regarded as soil. Over time, it becomes deeper and the migration of some of its components results in the formation of horizons (layers of soil more or less parallel to the surface), with distinct properties.

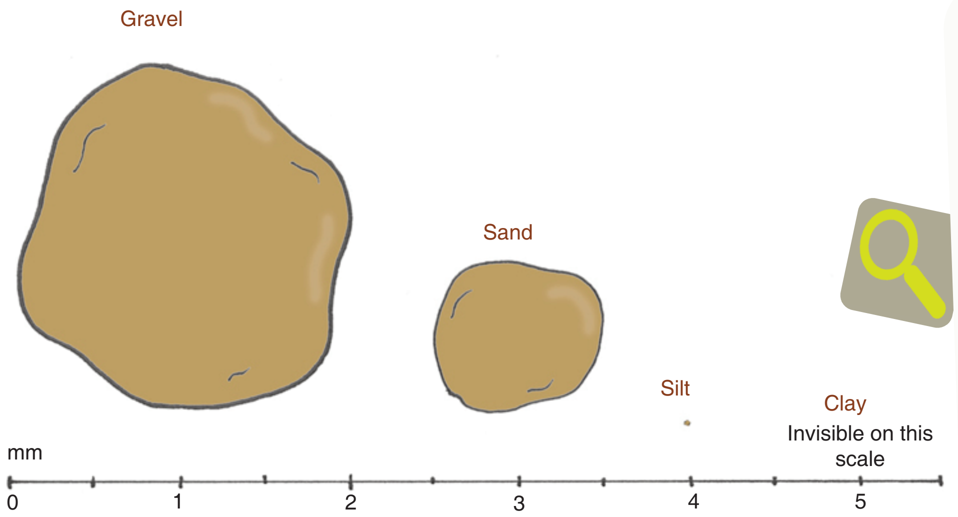
Each individual soil is unique

Soil is shaped by continuous and subtle interactions: its composition and properties depend on the source rock, the climate, local vegetation, the relief of the land, weather, etc. These factors combine to create an amazing variety of soil. For example, a detailed map of Belgian soil lists at least a thousand different soils, with no fewer than 10,000 variants. Around the world, the official classification identifies thirty-two main types of soil ("reference groups"). For comparison, Europe has twenty-two and Wallonia around fifteen.



"You need patience...
A two-centimetre layer of loose and fertile soil can take more than five hundred years to form!





Let's take a closer look...

Feel soil: texture

A lump of earth rolled between your fingers can

1. be malleable, quite sticky, change shape as you apply pressure. A bit like "clay" or "potter's clay": this soil has a clay texture. Clay consists of extremely small and fine particles (no more than two microns* in size). This type of soil is very compact and holds a lot of water. In summer, it can quickly become dry and hard.

2. stay relatively malleable, while being more prone to break into lumps of different sizes: this soil has a silt texture. Silt is made up of larger particles than clay (between 2 and 50 microns). Silt and sand-silt soil, the predominant types in the area north of the Sambre and Meuse rivers in Wallonia, are good arable soils;

3. crumble and trickle between your fingers: this soil has a sandy texture. Sand consists of coarser particles (between 50 microns and 2 millimetres**). It does not hold water and dries out quickly.

*a micron is equal to one thousandth of a millimetre

** above two millimetres, we talk about gravel, stones or boulders.

Soil's texture is determined by the proportion of clay, silt and sand that it contains. The majority of soil consists of a mixture dominated by one of these elements: for example, sand-silt, clay-silt texture, etc.

Above the source rock, soil is organised into layers called "horizons".

These layers are not identical. They have different compositions and properties. The layers containing the most organic matter (the most fertile) are located within the first 20 to 40 centimetres from the surface, depending on the type of soil. This explains why very deep ploughing disturbs horizons formed over hundreds of years and brings less fertile or more clayish layers to the surface.

Let's take a closer look...

Soil structure

Squeezing a clod of earth in your hand can cause it to break up:

1. into large compact blocks, with defined corners.
This soil is hard and compacted. Water cannot escape easily and it has almost no air-filled gaps. Roots (and most earthworms) find it difficult to penetrate this soil.

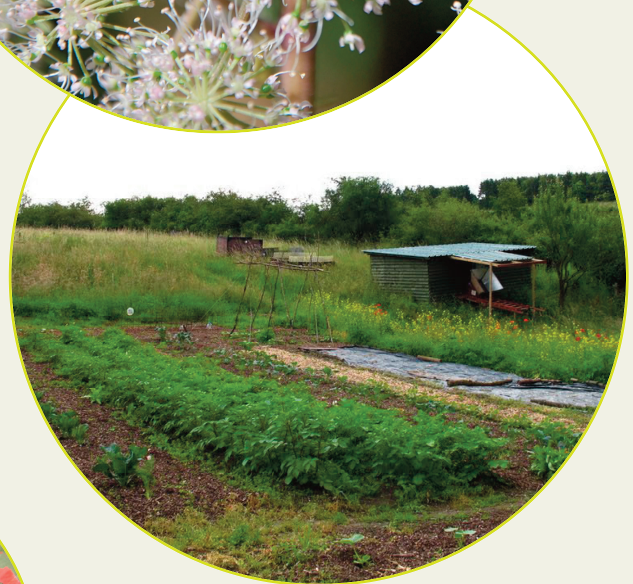
2. into lumps (called "aggregates") with rounded or uneven edges.
Water and air can flow easily between these lumps. Roots and earthworms can penetrate this soil without difficulty. It contains a lot of life, and consequently organic matter and humus. This is the best type of soil for agriculture.

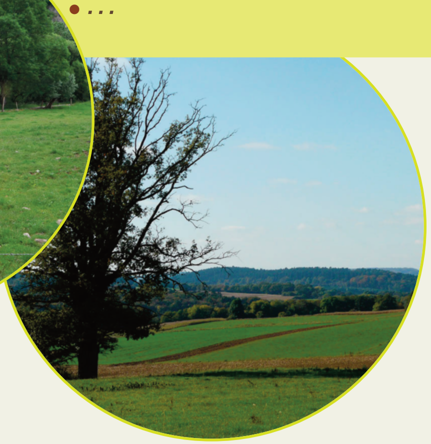
3. into particles, like sand.
Water and nutrients are carried to deeper levels of soil.

Free services

Soil provides a whole range of services.

- It feeds the world (crops, livestock).
- It supports and nourishes plants.
- It absorbs water and reduces the scale of flooding.
- It stores water for plants and supports their photosynthesis.
- It filters rain water and supplies groundwater bodies.
- It stores CO_2 and, as a result, delays the contribution made by this gas to the greenhouse effect.
- It provides a home for billions of organisms.
- It is a source of raw materials (coal, vegetable mould, metals, sand, clay, etc.).
- It helps to create landscapes.
- It supports buildings and human activities.
- It can help to preserve our history (archaeology)
- …





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When the magic is jeopardised...

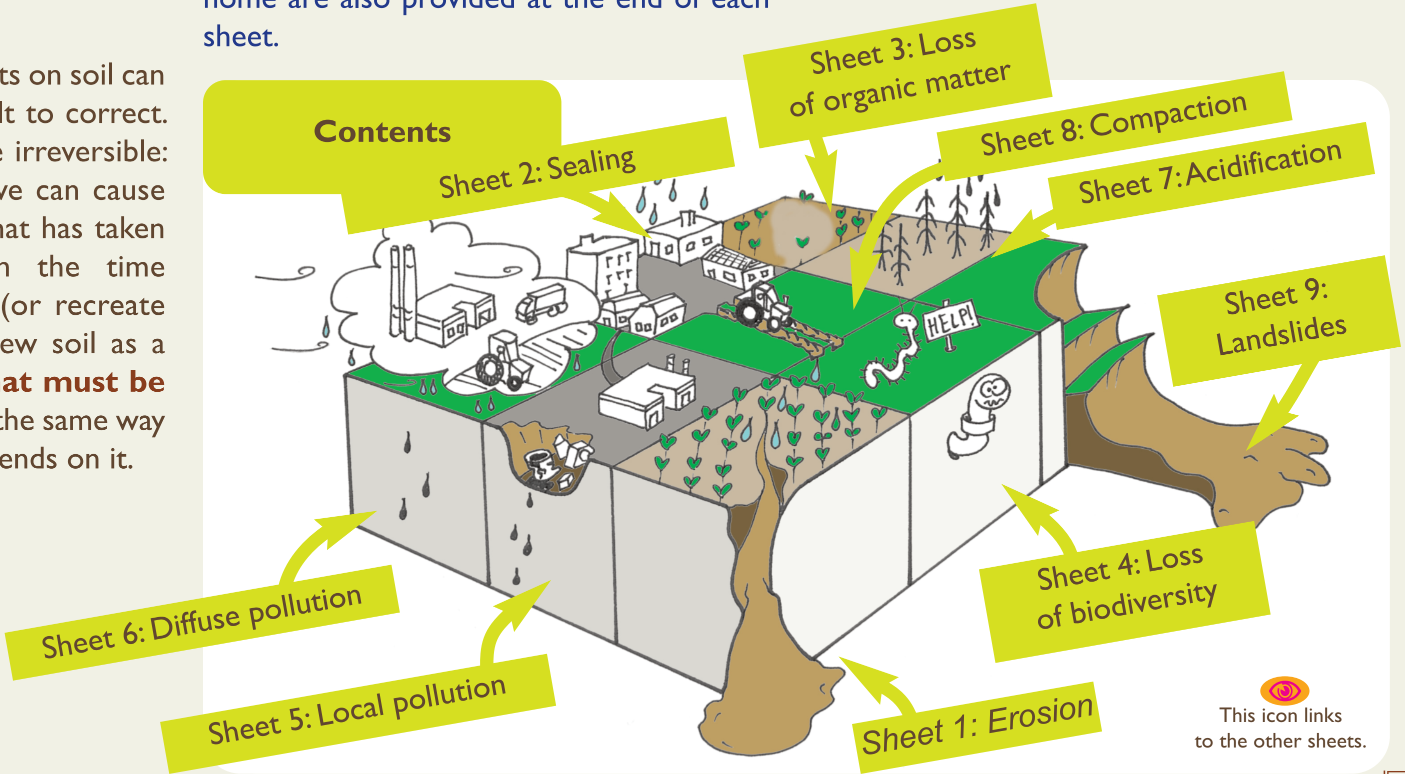
Soil evolves slowly, as a result of natural processes. However, certain **human activities** can **trigger or accelerate this evolution, with negative consequences**. In many cases, these activities are carried out without sufficient consideration for the factors which determine soil's balance: sealing with impermeable materials, various types of pollution, very aggressive agricultural or silvicultural methods, etc.

In such cases, the negative effects on soil can often be very rapid and difficult to correct. The deterioration can even be irreversible: in less than one generation, we can cause irremediable damage to soil that has taken centuries to develop. Given the time required to create good soil (or recreate deteriorated soil), we now view soil as a **non-renewable resource that must be managed and protected**, in the same way as water or air. Our future depends on it.

"Soil deterioration in Wallonia" sheets
In connection with the European soil protection strategy (2006), the Service Public de Wallonie (DGO 3) provides information intended to give citizens a better understanding of soil systems and the pressures soil is subjected to, with particular emphasis on the situation in Wallonia. Some examples of actions that can be taken at home are also provided at the end of each sheet.

This tool consists of nine sheets describing deteriorations observed in soil in Wallonia. It is aimed at a non-expert readership and interested citizens. More specialist works intended for experts are listed in the "Bibliography, links and useful addresses" section at the end of each sheet.

Contents



This icon links to the other sheets.