During 2010 - the International Year of Biodiversity - the multitude of animals and plants that live in Europe have enjoyed greater public and political interest; this has been reflected in a notable increase in related publications, initiatives and political actions. Colourful images of endangered birds and butterflies call for our attention, but what of the ‘bugs’ and bacteria that inhabit our soil; do earthworms, springtails, soil mites and microbes enjoy the same level of attention?

Their diminutive nature and underground existence keeps them out of sight and out of mind; their other-worldly appearance, their crawling, squirming, gnawing, conspire to render them unattractive; but what they lack in size and beauty, they make up for in numbers and worth. The mites, lice and bacteria that inhabit the world beneath our feet are vital for maintaining balanced ecosystems and agricultural production - quite simply, we could not live without them.

From the standpoint of functional biodiversity as well as from the purely quantitative perspective, soil organisms exceed many more popular groups of organisms. What does “soil biodiversity” mean? What do these organisms look like? Why are they so important? How do they interact with agriculture, and what can agriculture do to maintain and improve soil biodiversity and soil fertility? We want to briefly address some of these questions.

Images: 1. Ploughing. A mechanical soil treatment that can significantly impact soil biodiversity. 2. Grub (insect larvae). This is a plant-eating beetle larva, the majority of which are predators. 3. Bacteria. One gram of soil may contain as many as 1 billion bacteria cells. 4. Earthworm. You may find up to 3000 kg of earthworms per hectare of agricultural soil. 5 & 6. Soil mites. One of the most diverse and successful soil arthropod groups (a taxon closely related to spiders). 7. Springtail. In numbers, the most abundant soil insect - they feed on dead organic matter and contribute to humus formation.
Defining and describing soils

Soil is the living upper part of the Earth’s crust, a complex natural body and an integral part of the element cycles. It is the link between the atmosphere and the geological formations of the Earth’s crust. Geological raw material, climate, relief, groundwater vegetation and the influence of human beings combine and interact to create a variety of different soils, each with a distinct composition of layers. Soil layers are called ‘horizons’; common layers include the A, B and C horizons.

Figure 1. A comparison of agricultural and desert soil profiles.

Soils are the living upper part of the Earth’s crust, and an integral part of the element cycles.

Agriculture depends on soil for the supply of water and nutrients as well as for plant root fixation. Soils, through their structures and their inhabitant species, perform numerous functions including nutrient and water storage, filtering, buffering as well as breakdown and conversion of matter and gases, thus playing a central role in the protection of water and beneficial exchange of gases with the atmosphere. Moreover, soil is a biological habitat, gene pool, an element of the landscape and a cultural heritage as well as a provider of raw materials. In this context, soils are fundamental for the agricultural production of biomass in the form of food, fibre and biofuels.
Soil biodiversity

The number of organisms under a single footprint is tremendous. There are literally billions of microorganisms such as bacteria, fungi, and protozoans, and there are thousands of insects, mites, and worms. As in any successful and effective team, each member performs a specific function. However, only the cooperation of all the team members can result in a successful outcome which is, in the case of soil, the maintenance of fertility and, in addition, the diverse range of ecological services which are provided.

Microorganisms
- Decompose organic matter, may fix nitrogen, & regulate plant nutrients.

Protozoans
- Feed primarily on bacteria & are an important element of soil food chains.

Funghi
- Have often symbiotic relationships with plant roots & may decompose plant material.

Springtails
- Feed on dead organic material & therefore contribute to create humus.

Earthworms
- Contribute to the bioturbation of the soil and to the water balance. Earthworm burrows are an essential element of the soil pore system.

Insects
- May be predators of other animals, or feed on plant material and contribute herewith to the degradation of plant material.

The number of microorganisms under a footprint is tremendous. The absolute number of organisms will probably range between $10^9$ and $10^{14}$ individuals. From a quantitative perspective, the majority of biodiversity on earth is to be found in soils.

Key ecosystem services provided by soil organisms:

**Formation of humus**: Humus is the stable end product of the microbial breakdown of plant and animal (organic) residues, which is a basis for the maintenance of soil fertility.

**Carbon cycling**: Soil predominantly sources carbon in the form of CO₂ through the mineralisation of organic substances. Soils act as both a sink and source of carbon.

**Fixation of atmospheric nitrogen**: The most important natural process is the nitrogen fixation in soils by nitrogen-fixing bacteria. Many plants benefit from this nitrogen fixation, since nitrogen can be assimilated and converted to plant biomass.

**Physical properties**: The soil pore system is a network of cavities which allow gas and water exchange between the soil surface and atmosphere. Water exchange is a basic requirement for plant growth. The surface of the pore system is a living place for millions of organisms.

**Bioturbation**: Soil bioturbation means the mixing of soil particles from the surface to lower layers and vice versa. Earthworms play a most important role.
Interaction between agriculture and soil organisms

Mechanical soil treatment:
Mechanical soil treatment is one of the most important agricultural influences on soil. From the perspective of soil organisms, it may have benefits and drawbacks. On one side oxygen and biomass becomes available for degradation by soil organisms, on the other side bigger soil animals and earth worms are negatively affected.

Use of fertilisers:
The effect of fertilisation on soil organisms can be either direct through facilitation (increased food resources) or inhibition through direct damages. Indirect effects occur through more food resources (increase in plant productivity). Due to this complexity it is not surprising that different groups of soil organisms can respond completely differently to treatments with organic or inorganic fertilisers.

Use of plant protection products:
Plant protection products are an essential tool for agriculture to control pests, plant diseases and weeds and thereby to safeguard agricultural production. Due to their mode of function, plant protection products are biologically active. Since soil organisms may be exposed to these compounds after an application, a comprehensive body of legislation is established in the context of the registration of plant protection products.

Based on these regulations, it is ensured that plant protection products when applied properly do not have an unacceptable effect on soil organisms. Tests and risk assessments are based on scientific principles. Herewith, a “risk” can be quantified and, if needed, managed by targeted risk management measures.

Mechanical soil treatments have a severe influence on soil biodiversity whereas the registration of plant protection products ensures that they can be part of sustainable agriculture practices and safeguard soil biodiversity.

Erosion:
In agricultural environments, erosion takes away productivity - from the perspective of soil organisms, it takes away their habitat. It can take only a few hours to destroy a soil completely, whereas 200-300 years are needed to build up new soil. Soil erosion is the most important problem for soil conservation. Globally, each year an area of fertile soil equivalent to the size of Ukraine (600,000km²) is being lost through wind and water erosion.

Soil erosion is a global problem, and one of the major threats to soils and European agriculture.

Soil Compaction:
The underlying cause of soil compaction is the inability of soil to withstand the external physical pressures applied to it. Soil compaction can lead to loss of soil structural aggregates, decrease in soil volume, increase in bulk density, decrease in porosity and reduction of the water-holding capacity. Heavy machines especially on wet soils as well as livestock, particularly pastoral systems with grazing animals, can lead to soil compaction and loss of fertility of soils.
Contribution of agriculture to protect soil biodiversity

General Principles:

The existence of a rich soil biodiversity and its ability to provide ‘ecological services’ should not be taken for granted. A variety of farming practices have been developed and implemented which clearly protect soils as complex natural bodies and safeguard soil organisms.

Plant Cover Supports Soil Protection:

Vegetation cover over the soil surface and the penetration of soil by plant roots has many implications. Plant roots stabilise the soil structure, maintain the availability of oxygen and organic food sources for soil organisms and protect the soil against desiccation. Therefore mixed and intercropping systems increase soil biodiversity.

Mulching:

The protective cover of plant residues that are placed on soils is called mulch. The main purpose of mulching includes reduction of weed pressure, conservation of soil moisture, moderation of soil temperature and protection against erosion. Mulching favors certain ecotypes of earthworms.

Conservation tillage / no-tillage:

Reduced tillage and in particular no-tillage increase the soil organic matter content, improve the soil structure and its water holding capacity. An adequate, location specific-mechanical soil treatment can minimize negative effects on soil organisms and can become a key factor in the control of soil erosion (e.g. Not ploughing in the direction of a slope).

Adequate crop rotation:

A rotation of different crops provides different foodstuffs to soil organisms, thus increasing soil’s biodiversity. Intercropping with annual or biannual legumes which fix nitrogen increases the amount of nitrogen available to plants and soil organisms.

Farming practices can include a range of management techniques that manage soils sustainability and promote soil biodiversity.

Appropriate use of fertilisers and pesticides:

An adequate supply of nutrients can be beneficial to soil organisms because it stimulates plant production and the availability of nutrients in the water of the pore system in which soil organisms live. The application of pesticides according to the label instructions is an element of good sustainable agriculture. Unacceptable side-effects on soil organisms can thus be prevented.

Landscape structure:

Boundary ridges or hedgerows around arable fields and marginal borders around water bodies provide relatively undisturbed habitats for soil organisms. Therefore ‘buffer strips’ alongside cropping fields, surface waters, field margins or ‘beetle banks’ increase the number and variety of species such as insects, earthworm and plants.
Conclusions

Soil biodiversity, which is the multitude of organisms living under our feet, has many important characteristics and functions. Soil organisms show a fascinating diversity of body shapes, ways of living, and ecological interactions. Soil biodiversity is a key parameter for maintaining the fertility and productivity of the soils - thereby safeguarding food production.

The need for increased agricultural production, or the requirements to manage climate change, present challenges to mankind. Soil is a limited and increasingly finite resource, which is likely to come under increasing pressure from human activities, including agriculture.

The complex ecological interactions between soil organisms and agriculture are not yet fully understood - there is a need for continued research. However, there are many tools and management techniques already available for the sustainable management of soil, although uptake of these tools and techniques could be improved.

As is so often the case with issues of this complexity, solutions can be elusive, and stakeholder agreement hard to come by. However, all can agree that soil is of paramount importance and therefore strategies for it’s protection should be found. Soil requires protection and careful management by farmers, the public and policy-makers - this is essential if we are to conserve the medium that supports our life, and helps us grow our future.

Further reading

The full 52 page unabridged version of this report will be available at www.ecpa.eu from November 2010.

For more information: www.ecpa.eu

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