3 Soil Fertility

3.1 The Soil - A Living Organism

Introduction
Soil is the most important production factor for crops and at the same time is also most influenced by the farmer. Soils are very diverse and complex systems full of life. The soil itself can be viewed as a living organism, because it is a habitat for plants, animals and micro-organisms which are all interlinked with each other.

Lessons to be learnt

- *Soil is a living organism and therefore in a continuous process of transformation.*
- *Without soil organisms, soil is dead! Not all microbes are hostile, most soil microbes are very important helpers of the farmer.*
- *The relations among the elements of the soil ecosystem are complex and sensitive to disturbance.*

3.1.1 The Composition and Structure of Soils

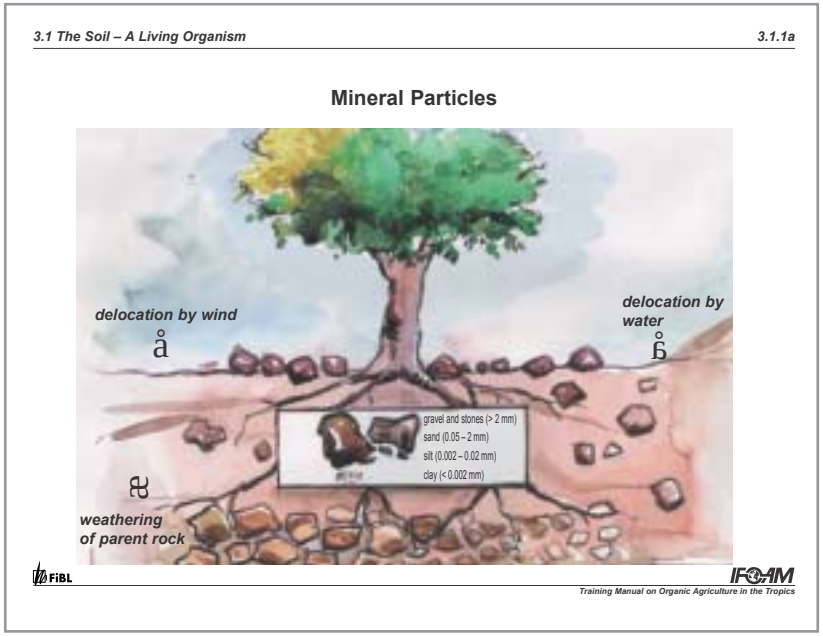
Mineral Particles
Soil consists of mineral particles, organic matter and pores. Mineral particles originate from subsoil and rock, which gets crushed to smaller and smaller pieces through physical and chemical weathering processes.

The mineral soil particles are divided into four groups according to their size:

- Gravel and stones: particles larger than 2 millimetres
- Sand: particles from 0.05 to 2 millimetres; they can be felt between the fingers
- Silt: particles from 0.002 to 0.05 millimetres
- Clay: particles smaller than 0.002 millimetres

The difference between sand, silt and clay is not visible to the naked eye. Still it is important to distinguish between them, as the properties of the soil is very much dependent on the composition of the different particle sizes. Soils having equal amounts of clay, silt and sand are ideal for agricultural use. Such a soil is called loam.

Mineral particles contain nutrients which are slowly released in the process of weathering. Plant roots and some micro-organisms can actively dissolve nutrients from mineral particles and use them for their growth. The plants need minerals to build up organic matter and for physiological processes.



Transparency 3.1.1a: The formation process of mineral particles and the classification of their sizes.

Motivation: The importance of soil
Ask the participants why the soil is of central importance to organic agriculture. Collect the statements in keywords on the board. Continue with the theory to provide a closer understanding of soil.

Soil Organic Matter
Besides mineral particles, soil contains smaller or larger quantities of organic matter or humus, resulting from the decomposition of biomass. Though in most agricultural soils of the tropics it makes only a few percent or even less than one percent of the total solid material, it is of tremendous importance for the soil fertility. Its functions are described in detail in chapter 3.2.2.

Organic matter is mainly present in the top layer of the soil, which is subject to continuous transformation processes. The active part of soil organic matter can be further decomposed by soil organisms. The resulting structures can recombine themselves to form very stable humus structures, which can remain in the soil for many years. This long term soil organic matter or humus contributes a lot to improve the soil structure.

Illustration: Soils of different sites arranged on banana leaves in a class room.

Group work: Studying soil samples
Collect a variety of soil samples from different sites, of different colours, under different cultivation practices, from slopes or plain fields, forest soil, top soil or deep soil, rich or poor in soil organic matter. Keep the samples (some hundred grams) in plastic bags in order to preserve the moisture. Write the description of the site on each bag. Even better is to ask the participants to bring some samples

from each one's place. Or collect the soil samples together with the participants from the nearby surrounding.
Exhibit the soil samples in the class room by placing them in small heaps on a table, indicating the site and soil type. If banana leaves are used, the origin and type of each sample can be written on the bottom side of the leaf. This will stimulate the participants to first guess which type of soil they see and then check by lifting the respective leaf section.
Ask the participants to form groups of two or three and each group to select one soil sample. With the help of the soil assessment questionnaire in Annex 8.1, the groups shall analyse the composition, structure, colour, smell etc. of their soil sample and discuss its properties and fertility. When finished, gather all groups around the exhibits and take some of the soil samples for discussion: "Who can tell us something about this soil? Which types of crop could one grow on that soil? Would you buy a piece of land with such a soil? How could the fertility of such a soil be improved?"
This simple demonstration may help to revaluate soil by putting it in the focus centre in the classroom. It is important to develop a feeling for the properties of soil - see it, touch it, smell it! Probably, there is a lot of local knowledge on the prevailing soils and their properties. Therefore, encourage the participants to share their knowledge and experience.

Soil structure – What does it mean?
Besides mineral particles and soil organic matter, soils also consist of minute pores (tiny hollows) filled with air or water. The spatial arrangement of particles and pores is summarized as "soil structure". Small pores are good in preserving moisture while the larger ones allow a fast infiltration of rain or irrigation water, but also help to drain the soil and ensure aeration.

In soils of good structure, mineral particles and soil organic matter form stable crumbles (aggregates). Organic matter works as a kind of glue, sticking together soil particles. This process is supported by soil organisms such as earth worms, bacteria and fungus. Thus the soil structure can be improved by supplying organic matter to the soil. But it can also be ruined by wrong management e.g. tilling the soil in wet conditions causes compaction.

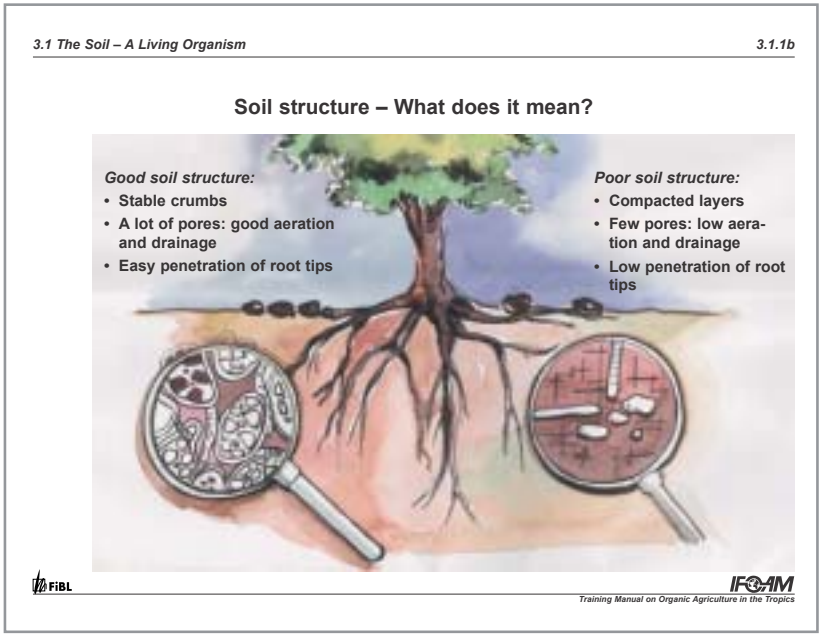
Demonstration: Spade Examination
The spade examination is a simple method to assess the fertility of a soil considering its structure and visible properties. With the help of a flat garden spade, a block of soil is carefully cut out from a plot, avoiding compaction or deformation as far as possible. For this, the spade is pushed vertically into the soil and a ditch is dug in front of the spade. The profile is cut out by cutting the edges and pushing the spade about 15 cm behind the ditch.
Now you can observe the different layers of soil horizons, the distribution of humus, the number of pores or the degree of compaction, the density and depth of roots, signs of earth worms and other soil organisms and the presence of soil crumbs.

Soil Testing

Most people have strong trust in any scientific work. Therefore, when it comes to soil fertility, farmers might also think of getting their soil analysed in a laboratory. Though chemical soil testing may yield valuable information to specific questions, farmers should not expect too much of it.

For example there are some inherent problems related to analysing nutrient contents: For the plant, the total content of a certain nutrient in a sample is not always relevant, as the nutrient may be absorbed to minerals so strong that it is not available to the plant roots (e.g. Phosphorus, see chapter 4.1.3). Therefore, some tests treat the sample with solvents in order to simulate the fraction of the nutrient available to plants. This might be a realistic simulation for conventional farming. In organically managed soils, however, the higher activity of soil organisms can result in a better availability of the nutrient, thus the result of the test is not fully appropriate. The content of other nutrients such as nitrogen is extremely fluctuating within few days, so that it highly depends on the point of time when the sample is taken. Still, chemical soil analysis can be useful in some cases, e.g. to analyse the level of acidity of the soil (pH) or to detect deficiency of nutrients such as Potassium (K) or Zinc (Zn). Organic farmers might be especially interested in knowing and monitoring the content of soil organic matter.

Chemical soil analysis on pesticide residues is highly complicated as one must know which pesticide to look for, and they are very costly. Physical testing, e.g. related to water retention capacity or soil structure can yield interesting information, but samples must be taken very carefully. Biological analysis, e.g. of the activity of soil organisms, must be done in specially equipped laboratories and is rather costly. Altogether, the use of soil analysis on the farm level is limited due to the scientific methods, the availability of suitable laboratories and the costs involved. If soil tests are used, make sure that the relevant aspects are investigated and that the results of the test are critically discussed.



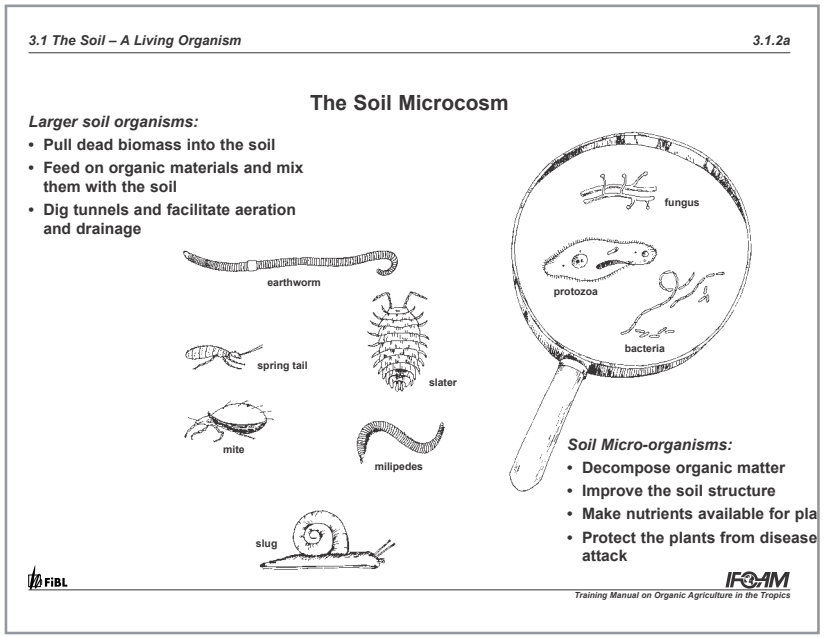
Transparency 3.1.1b: Scheme of soil structure showing the main components of soil: mineral particles, soil organic matter, water and air. Left an example of a good soil structure, right of a poor one.

3.1.2 The Soil-Microcosm

A teaspoon of active soil is the habitat of millions of soil organisms! Some are of animal origin, some are of plant origin. The organisms vary greatly in size. Some are visible with the naked eyes such as earthworms, mites, spring-tails or termites. Most of them, however, are so small that they can only be seen with a microscope, therefore called micro-organisms. The most important micro-organisms are bacteria, fungus and protozoa. Micro-organisms are the key elements to the quality and fertility of soils, but for us humans they do their work invisibly. The greater the variety of species and the higher their number, the greater is the natural fertility of the soil.

Some larger soil organisms:
- earthworms
- spiders
- slugs and snails
- beatles
- spring tails
- mites
- millipedes
- slaters

Some soil micro-organisms:
- bacteria
- algae
- fungus
- protozoa
- actinomycetes



Transparency 3.1.2a: Some soil organisms.

Demonstration: Discovering the micro-cosmos
Prepare before the training: Fill a handful of moist top soil rich in organic matter (or compost) in a half cut water bottle (or kitchen sieve) as shown in the illustration. Fill a shallow vessel with a mixture of water and alcohol. Place the bottle in a paper cylinder or similar structure above the vessel and fix a strong lamp above the whole structure. Make sure the lower part of the construction is kept dark inside.

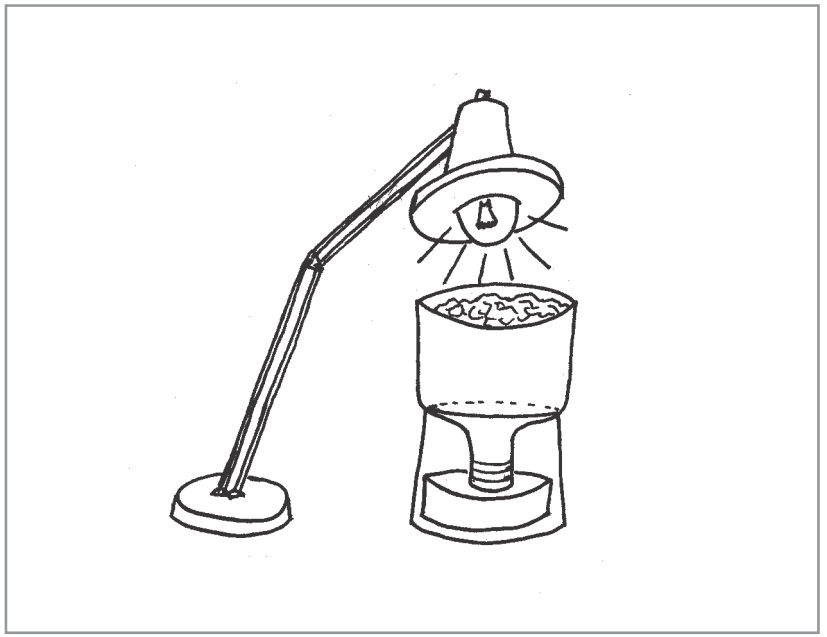


Illustration: Extracting larger soil organisms from a soil sample.

The light and heat will slowly make the soil organisms move downwards where they finally drop into the vessel and get killed by the alcohol. The thus caught tiny insects, spiders, worms etc. can be studied during the training with a magnifying glass or binoculars. Make the participants aware that these soil organisms are the most valuable free of cost helpers of the organic farmer. Also point out that the vast majority of soil organisms are too small to be discovered in this way.

Soil Organisms: adversaries or friends?
Many farmers consider all micro-organisms only as pests and think: "How can we kill them"? Actually, while few micro-organisms in the soil can harm crops, the majority is of great use and importance for soil fertility. Soil organisms are important because they:

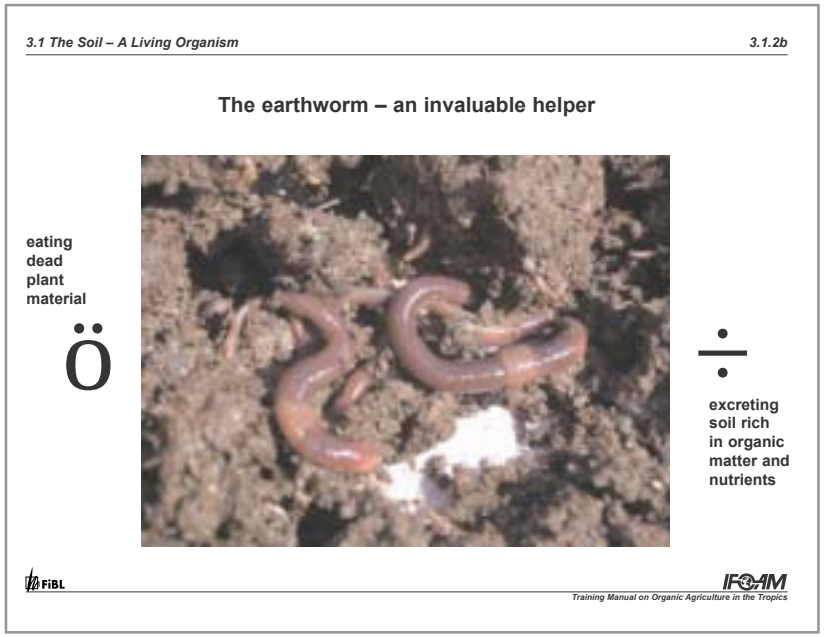
- help to decompose organic material and build up humus
- mingle organic matter with soil particles and thus help to build stable crumbs
- dig tunnels, which encourages deep rooting of plants and good aeration of the soil
- help to release nutrients from mineral particles
- control pest and disease organisms affecting the roots of crops

Most soil organisms are very sensitive to changes in soil moisture and temperature. As the plant roots and the soil organisms consume air, a good air circulation within the soil is crucial for their development. Soil organism activity is generally low when soils are dry, very wet or too hot. Activity is highest in warm, moist soils when food (i.e. biomass) is available.

Experience sharing: Talking about microbes
What do the participants know about soil organisms? Did they come along situations where soil organisms played an important role? Are farmers aware of the importance of soil organisms?

The earthworm – an invaluable helper
Most farmers are well aware that the presence of earthworms is a sign for a fertile soil. Indeed, earthworms are very important for soil fertility as they fulfil several crucial functions. For example they accelerate the decomposition of biomass by removing dead plant material from the soil surface. During the digestion of organic material, they mix organic and mineral soil particles and build stable crumbs, which help improve the soil structure. Their excrements contain 5x more nitrogen, 7x more phosphate, 11x more potash and 2x more magnesia and calcium than normal earth. Last but not the least, their tunnels promote infiltration and drainage of rainwater and thus prevent soil erosion and water logging.

Earthworms need sufficient supply of biomass, moderate temperature and sufficient humidity. That's why they are very fond of mulching. Frequent tillage decreases the number of earthworms in the soil, as does the use of pesticides.



Transparency 3.1.2b: An earthworm in a rich organic soil and its functions.

Mycorrhiza – a beneficial fungus

A major part of the soil microbial biomass is composed of fungi. Important representatives of the soil fungi are the "mycorrhizae" that live in association (symbiosis) with plant roots. Both the plant and the fungus profit from the association: the plant gets nutrients collected by the fungus and the fungus receives assimilates ("food") from the plant in exchange. Mycorrhizae are present in all types of soils, but not all crops can get into a symbiosis with the fungus.

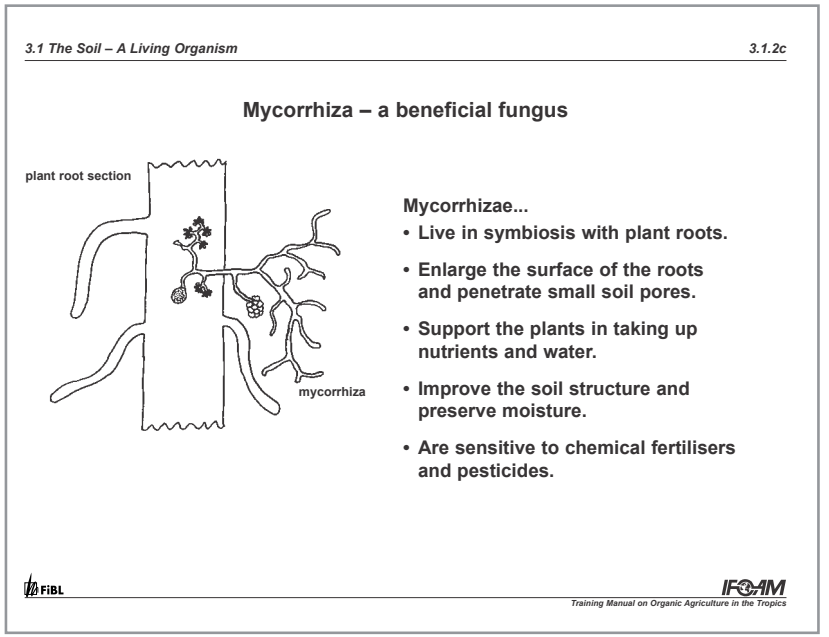
Mycorrhizae have several functions, which are of high interest for the farmer:

- They enlarge the rooting zone of plants and can enter into small soil pores
- They dissolve nutrients such as phosphorus from mineral particles and carry them to the plant
- They make soil aggregates more stable thus improving the soil structure
- They preserve moisture and improve the water supply to the plants

Mycorrhiza formation depends on the soil conditions, the crops that are grown and the management practices:

- Soil tillage and burning of biomass drastically harm the mycorrhizae
- High nutrient levels (especially phosphorus) and chemical pesticides suppress the symbiosis
- Mixed cropping, crop rotation and the cultivation of perennial plants encourage mycorrhiza
- Practice mulching to stabilize soil temperature and moisture

Among the naturally occurring species of mycorrhizae, not all show the same efficiency to take up phosphorus from the soil. That is why artificial inoculation of specific mycorrhiza varieties can improve their use. Inoculation, however does not reduce the importance of offering appropriate living conditions for these organisms.



Transparency 3.1.2c: Mycorrhiza penetrating a root tip.

Recommended Reading

- *«Soil Fertility Management», Agromisa Agrodok-series No.2*
- *«Agriculture in African Rural Communities», Dupriez, H., De Leener, P.*