3.2 What Makes a Soil Fertile?

Introduction
As long as soil fertility is measured only by the crop yields, the awareness about the soil will remain low. Soil in this context is just a medium where plants grow and a base to apply plant nutrients. Compared to this simple approach in conventional agriculture, soil fertility has a totally different meaning in organic agriculture. Improving and maintaining the fertility of the soil is the central focus in organic farming. For the organic farmer, feeding the crop means feeding the soil. Only a fertile soil can yield healthy crops and it is the most important resource of every farm. Therefore, it is very important for organic farmers to gain a thorough understanding on the various factors influencing soil fertility.

Lessons to be learnt
- *Awareness creation for the central importance of soil fertility and its management for organic agriculture.*
- *Soil fertility can be improved by organic management practices.*
- *Soil organic matter plays a central role in soil fertility.*
- *How to increase the amount of soil organic matter, and how to produce sufficient biomass.*

Motivation: What means «soil fertility»?
Note the term «Soil fertility» on a board. Ask the participants: «What does this mean for you? What comes to your mind when thinking of soil fertility?» Note down keywords of the answers on the same board. Summarize and continue.

3.2.1 How to Achieve a Fertile Soil?

What has an influence on Soil Fertility?
Farmers know that the fertility of the soil depends on many factors. For the plants to grow they need to get from the soil suitable conditions for root growth, appropriate supply of water and nutrients available for uptake by roots. If certain soil conditions are not suitable, plant growth can be inhibited. For example water logging, acidity, compaction or shortage of nutrients can tremendously decrease the yields of some crops.

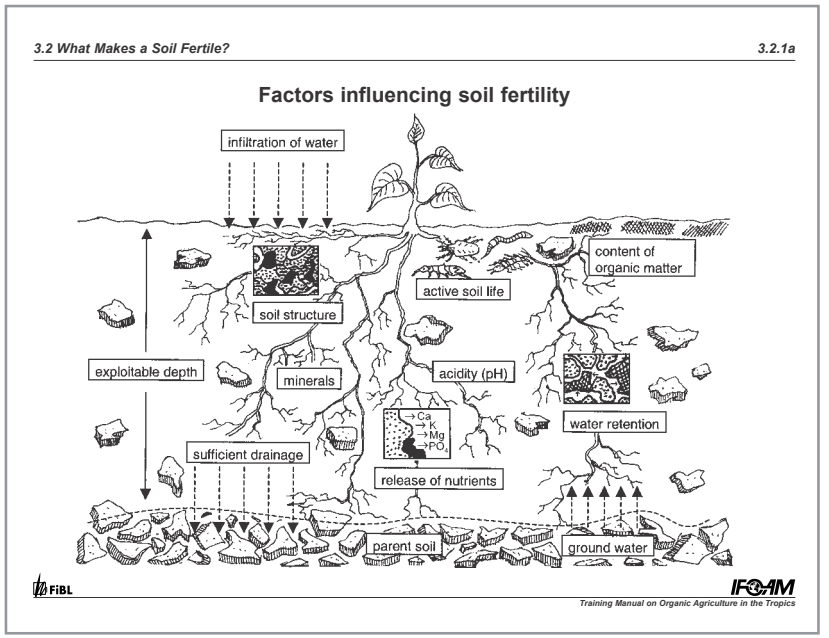
Group Work: What a plant expects from soil
For identifying the various factors which influence soil fertility, make use of the probably rich experience participants have with cultivating more or less fertile soils.

Divide the participants into groups. Each group gets some cards in two colours (about ten per colour) and some marker pens. Each group shall collect points on the following two questions (15–20 minutes):
1.) What do plants need from the soil for healthy growth? (to be noted down on cards of one colour)
2.) Which soil properties can inhibit plant growth? (to be noted down on cards of the other colour)

A member of the first group shall present the points they found by stikking the cards on a prepared paper chart (see illustration). The same way, all other groups add their cards, omitting the points which are already mentioned. The trainer comments the results and leads over to Transparency 3.2.1a.

Factors influencing soil fertility

- Soil depth: the exploitable volume for plant roots.
- Availability of water: moisture retention for continuous water supply.
- Drainage: most crops can't bear water logging.
- Aeration: necessary for a healthy root growth and a high activity of soil life.
- pH (range of acidity): the soil should neither be too acidic nor too alkaline.
- Mineral composition: has an influence on the amount of nutrients released by weathering, the nutrient holding capacity and the soil structure.
- Content of organic matter: has an influence on the nutrients released by decomposition, the nutrient holding capacity, water retention, soil structure and soil life.
- Activity of soil organisms: they are crucial for nutrient availability, water retention, a good soil structure, decomposition of organic material and soil health.
- Contamination: high concentration of salt, pesticides or heavy metals can inhibit plant growth.



Transparency 3.2.1a: Sketch of the root system of a plant in the soil, showing the factors listed above

Examples: Soil fertility factors in local conditions

Select the factors which are most relevant under local conditions and explain them with the help of the transparency. Where possible, give examples from the local context.

Different plants have different requirements

Plants differ in their soil fertility and soil moisture requirements.. All soils are not suitable for all crops. Therefore, while deciding which crops to be grown on a specific plot, the soil properties should be taken into account.

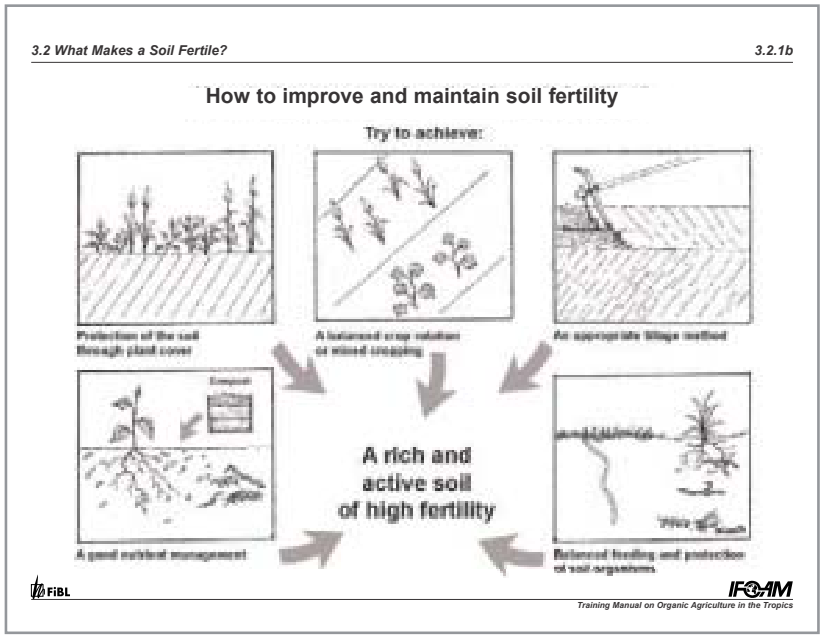
Examples: Which crops grow on which type of soil?

Give local examples for which crops need which specific type of soil, or for which soils can be used to grow which kind of crops. Ask the participants for other examples. Examples may be: pineapples can be grown on marginal, sandy soils, while bananas need rich soils; damp and heavy soils are suitable for cocoa, yams or rice, but not for growing pepper etc.

How to improve and maintain soil fertility

Farmers can improve the fertility of their soil by various management practices. It is important to achieve:

- Protection of the soil from strong sunlight and heavy rain by means of plant cover: e.g. mulching with plant residues, green manure crops or cover crops, in order to prevent soil erosion and to preserve moisture.
- A balanced crop rotation or mixed cropping: a suitable sequence of annual crops grown on a field for preventing a depletion of the soil.
- An appropriate tillage method: suitable for getting a good soil structure without causing erosion and compaction.
- A good nutrient management: application of manures and fertilizers according to the demands of the crops in their respective growth stages.
- Balanced feeding and protection of soil organisms: enhancing the activity of beneficial soil microbes and organisms like earth worms by supplying organic material.



Transparency 3.2.1b: Steps to improve soil fertility

Farm excursion: Learning on soil fertility

Visit fields with soils of different fertility. Examine the soil with the spade probe and the soil questionnaire described in chapter 3.1.1. If possible, dig out a soil profile for demonstration. Interview the farmer about the piece of land and the soil properties. What is the history of this field, how was it managed in the last years, what was its condition when the farmer was a child? How did the soil change over the years? what were the related benefits and problems for cultivation? In the case of fertile soils, ask the farmer how he/she managed to increase or maintain the fertility. In the case of poor soils, discuss with the farmer and among the participants how the soil could be improved. Which management practices would be suitable? What are the constraints?

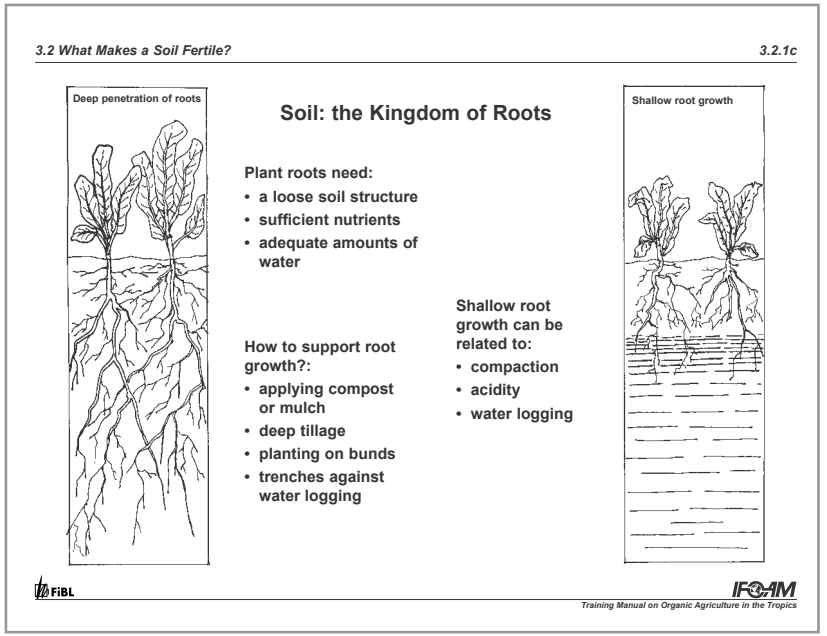
Alternatively, if time is short, personal experience of the participants can be discussed without visiting fields.

Soil: the kingdom of roots

Plant roots will grow only where they find suitable conditions, i.e. a loose soil structure, sufficient nutrients and adequate amount of water. But shallow root growth can also be related to harmful effects in the deeper soil layers such as acidity, low content of nutrients or water logging.

Where shallow soils are farmed, crop roots find only limited space to grow. If the sub soil is compact but tillable, deep ploughing or double digging can help crop roots to grow more deeply (see chapter 3.3). To stabilise the structure and to incorporate nutrients into the deeper layers of the soil, it is important to incorporate organic material (ideally compost) into the soil.

Most crops can't bear water logging in the root zone (exceptions are e.g. rice, sugar cane or tarot). A good soil structure with many tubular channels dug by earth worms will help water to infiltrate into deeper layers of the soil. In areas where the ground water table is high, planting on elevated bunds and digging trenches can be a solution. However, care must be taken that soil is not more prone to erosion.



Transparency 3.2.1c: What crop roots need for their growth, what can harm them and how to promote root growth

How to improve the soil structure?

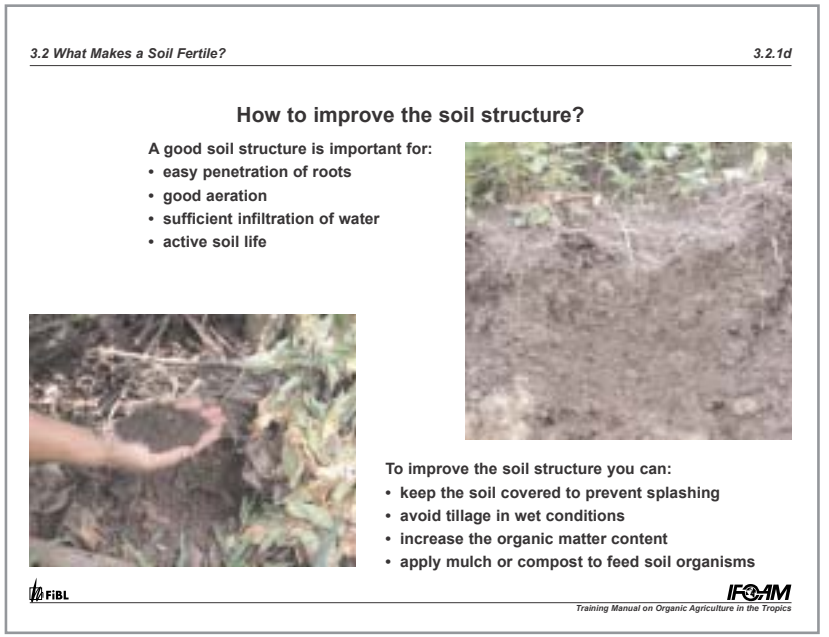
A good soil structure is important for easy penetration of plant roots, good aeration, sufficient infiltration, active soil life and many other functions. Some soils are generally of a poor structure because of their mineral composition (e.g. high clay content). What is most important for improving the soil structure is to increase the content of organic matter. It sticks soil particles together and helps to support the work of soil organisms by providing food and shelter.

Activities that improve soil structure:

- Apply organic matter as manure, compost, mulch etc.
- Encourage the activity of soil organisms.
- protect the soil surface with mulch or plant cover.

Activities that harm the soil structure:

- Cultivating the soil in wet conditions can cause soil compaction.
- Frequent soil cultivation reduces the content of soil organic matter.
- Intensive mechanical cultivation like rotary tilling destroys the soil crumbs.



Transparency 3.2.1d: Benefits of a good soil structure and how to achieve it.

Experience sharing: Improving soil structure

Ask the participants to share their experience with improving soil structure. What did they try, what did they observe?

3.2.2 The Importance of Soil Organic Matter

The content of organic matter in the soil is one of the most important factors for soil fertility. It has many functions which are crucial for the farmer's success. Understanding the different functions of organic matter can help to make the right decisions in soil management.

The formation of soil organic matter
Plants are built up from water, air and nutrients. When plant material is decomposed with the help of animals, soil organisms and microbes, the components are released again as nutrients or gases, and are available for new plant growth. In the process of decomposition, a part of the material gets decomposed only to a certain extend. These half rotten components join together to build up dark brown or black "soil organic matter". A part of this organic matter contains still visible structures of leaves, fibres, wood etc., while most of it is shapeless and intimately mingled with the soil.

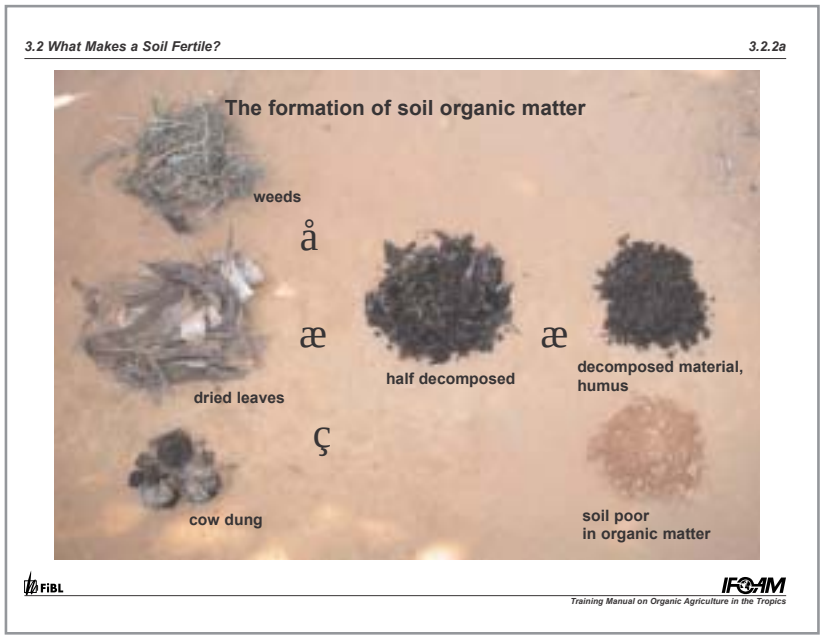
Main actors in the decomposition of plant material are the bigger and smaller organisms living on top of the soil or in the soil. Cutting, chewing, eating and pulling the organic material into the soil, they prepare the food for the next to come, the micro-organisms.

Not all material of plant or animal origin will decompose in the same speed:

- The more nutritious the material is, the faster and the more completely will it be eaten up by soil organisms and microbes. Such fast decaying materials are for example fresh young leaves, animal dung or nitrogen fixing plants.
- The hardier the material is and the fewer nutrients it contains, the longer will it take to decompose. Old plants and plant materials which are fibrous or rich in woody components need more time to decompose.
- The speed of decomposition also depends on the soil humidity and on the temperature. Soil life is most active under warm and moist conditions, thus conducive to decomposing organic material very fast.
- When decomposition is fast and complete, a lot of nutrients are released but less humus is built up. Slow decomposition due to hardy material or cold climate will cause more humus to accumulate in the soil.

Note: The decomposition of organic materials can be accelerated by making compost (see chapter 4.4).

Motivation
Present samples of two soils of obviously different content of organic matter. Ask the participants: "Which of the two soils would you prefer to have on your field? Why?"

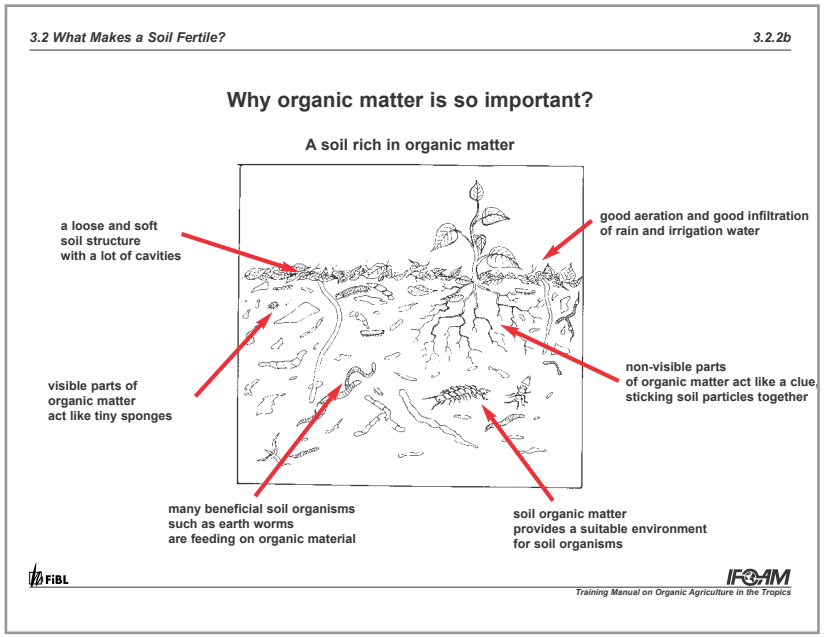


Transparency 3.2.2a: Photo of different plant material and organic matter in different stages of decomposition, finally as dark soil, as compared to soil with low organic matter content

Demonstration: Studying soil organisms
In order to show the involvement of soil organisms in the decomposition of organic material, the method for extracting visible soil organisms described in chapter 3.1.2 can be applied on a handful of litter or fresh compost.

Why organic matter is so important?

- Soil organic matter helps to build up a loose and soft soil structure with a lot of cavities (pores). This leads to better aeration, better infiltration of rain or irrigation water and an easier penetration of roots.
- The visible parts of organic matter act like tiny sponges which can hold water up to five times their own weight. Therefore in dry periods more water is available for the plants for a longer time. This is especially important in sandy soils.
- The non-visible parts of organic matter act like a glue, sticking soil particles together thus forming stable crumbs. Such aggregates improve the soil structure, especially in clay and sandy soils.
- Beneficial micro-organisms and other soil organisms such as earthworms also feed on organic material thus decomposing it. As these organisms require sufficient humidity and aeration, soil organic matter provides a suitable environment for them.
- Organic matter has a great capacity to retain nutrients and release them continuously. It thereby increases the capacity of the soil to supply the plants with nutrients and reduces nutrient losses by leaching. This is especially important in sandy soils as they naturally retain very few nutrients.
- Organic matter also prevents soils from becoming too acidic.



Transparency 3.2.2b: Overview on the functions of soil organic matter

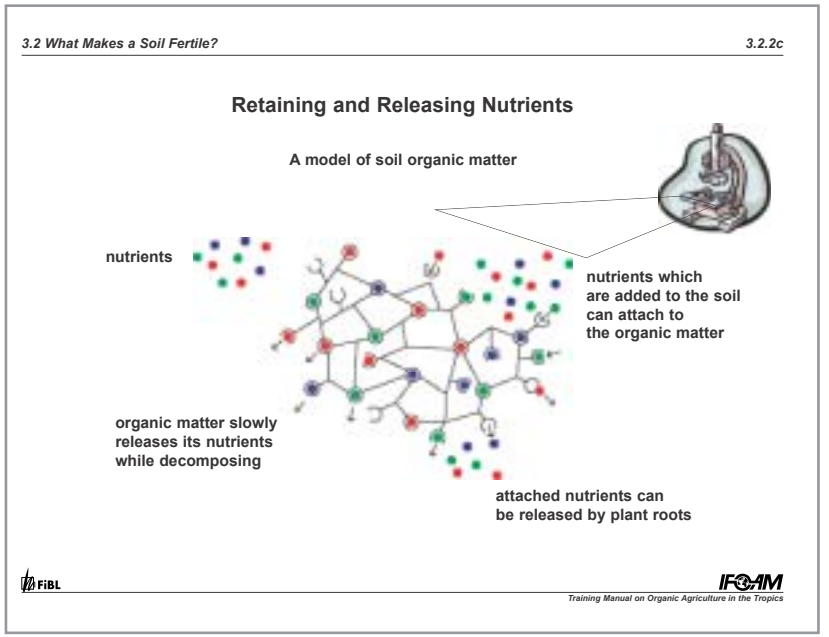
Discussion: Local relevance of soil organic matter

Discuss with the participants: Which of the above properties are most relevant in local conditions. Which problems might be reduced if more organic matter is found in the soil?

Organic matter retains and releases nutrients

As organic matter consists of decomposing biomass, it provides a well balanced mixture of all nutrients which plants require for their growth. While decomposing, it acts as a slow-release source of nutrients to the crops.

Organic matter acts as an exchanger or absorption agent for nutrients added to the soil. In acidic, highly weathered soils organic matter is responsible for almost the entire nutrient exchange capacity (CEC) of the soil. Nutrients are bound reversibly to the humus and can be constantly released by the activity of plant roots and microorganisms. This helps to reduce nutrient losses through leaching.



Transparency 3.2.2c: Sketch of symbolic structure of humus, containing nutrients (coloured spots) within the network. The semicircles symbolise sites where added nutrients can get bound, but also released.

Example: How to explain the concept of exchange capacity

The concept of exchange capacity may be rather difficult to understand, but it is very important in organic farming. Think of a story which helps you to explain the concept to the participants.

One example: «If we compare crops with small kids, nutrients are like sweets. Imagine to throw a bag of sweets over a kid sitting on a chair. The kid will catch some of the sweets and enjoy them, but most of them will fall on the ground The same would happen to fertilizers applied to a crop: some is getting utilizedby the crop, but most will be lost through leaching. In our picture, organic matter can be compared with a friendly mother who picks up the sweets and gives them one by one to the kid. Some of the sweets she will store in her pockets to save them for the next days. In the same way, organic matter will catch nutrients and

release them slowly when the plants demand them. – Soil without organic matter is like a motherless child!»

How to increase the amount of organic matter in the soil?

Organic matter permanently undergoes a process of decomposition. In order to maintain or increase the content of soil organic matter, organic material must be applied again and again. The speed of decomposition depends on the climate (in warm and damp conditions, the organic matter is broken down much faster than in cold or dry conditions) and on how green the material is (C/N-ratio).

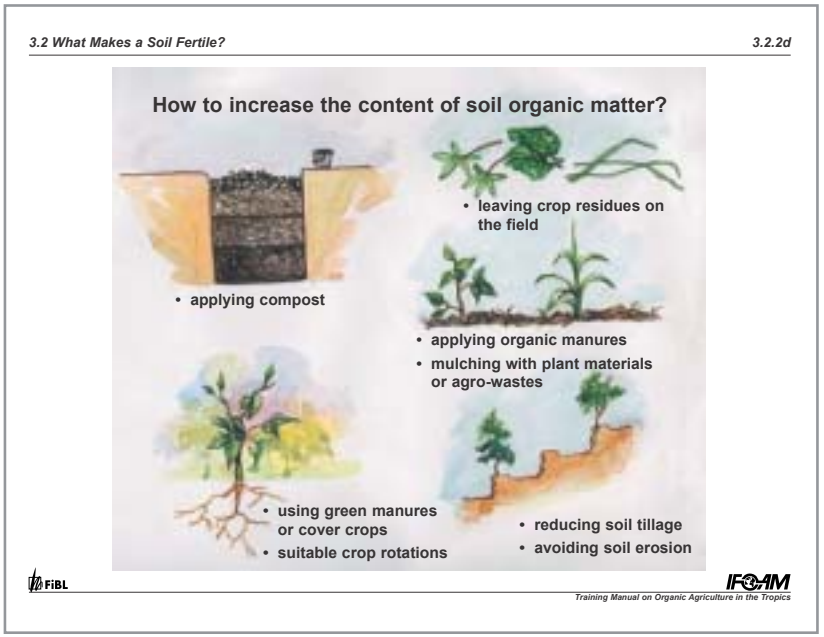
Activities that increase the level of soil organic matter:

- leaving crop residues on the field, instead of burning or wasting them, as they are the major source of biomass
- applying compost: this is very effective, as part of the organic matter in compost is already stabilised and will remain in the soil for a longer time than fresh plant material
- applying organic manures: as they contain organic material, they help to increase the content of organic matter; at the same time, they can speed up decomposition as they are rich in nitrogen and thus stimulate soil organisms
- mulching with plant materials or agro-wastes: especially applying hardy material (rich in fibres or wood) will increase the organic matter content, as it will remain in the soil for a long time; in addition, it helps to reduce erosion
- using green manures or cover crops: green manures grown on the same field will contribute biomass both from the leaves and roots; material grown on another site contributes only the leaves; the younger the plant material is, the faster will it decompose, thus releasing the nutrients faster but adding less to the built up of soil organic matter
- Suitable crop rotation: including crops in the rotation which build up soil organic matter (e.g. pastures); especially perennials and crops with a dense root system (e.g. pastures) are very beneficial
- reducing soil tillage: each tillage will speed up the decomposition of organic material, as it aerates the soil and stimulates soil organisms
- avoiding soil erosion: all methods listed before will be in vain unless soils are prevented from erosion; it carries away those parts of the soil which contain most humus and are most fertile

Details for all these approaches can be found in the respective chapters.

Motivation: Increasing organic matter contents

1. *Ask the participants: «Which methods can help to increase the content of humus in the soil?»*
2. *Note down the suggestions on a board, discuss them with the participants.*
3. *Check the completeness of the notes with the following transparency, providing some further explanations as given below*



Transparency 3.2.2d: How to increase the content of soil organic matter?

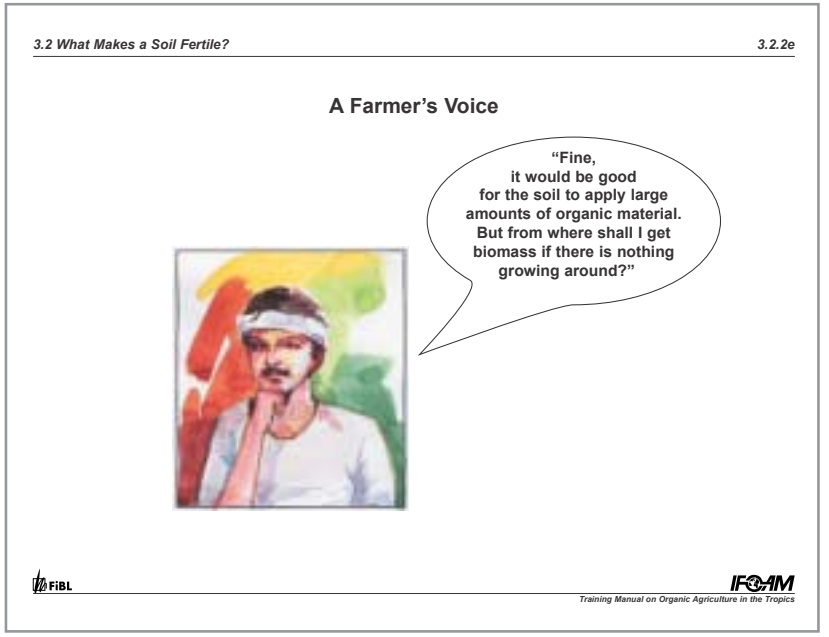
The amount of organic matter in the soil is largely determined by the amount of biomass added in the form of plant residues from crops, cover crops and weeds and, if available, animal manure. It is though rather the quality of the biomass than the quantity, which leads to an increase of the level of soil organic matter. Green organic matter, which can easily be decomposed by soil-organisms, encourages the build-up of a large population of organisms and thus improves availability of nutrients in the soil, but also leads to an accumulation of stable organic matter.

Shortage of decomposable material

Organic farming frequently is short of organic material, as one almost can't get enough of this valuable input. The production of biomass which can be used for applying to the soil sometimes competes with the production of crops for food or sale. Therefore, it is very important to find ways of combining the production of biomass with the production of crops. Use of cover crops or green manures, crop rotation with green manures in the off season or growing hedges on unproductive sites may be suitable options. It is very important to recycle the crop residues and processing wastes.

Discussion: Feasibility of the methods

Discuss with the participants which of the suggested methods can be used in local conditions. Which experience did participants make with these methods?



Transparency 3.2.2e: illustration of a sketch of a farmer asking the question

Farmer's Voice

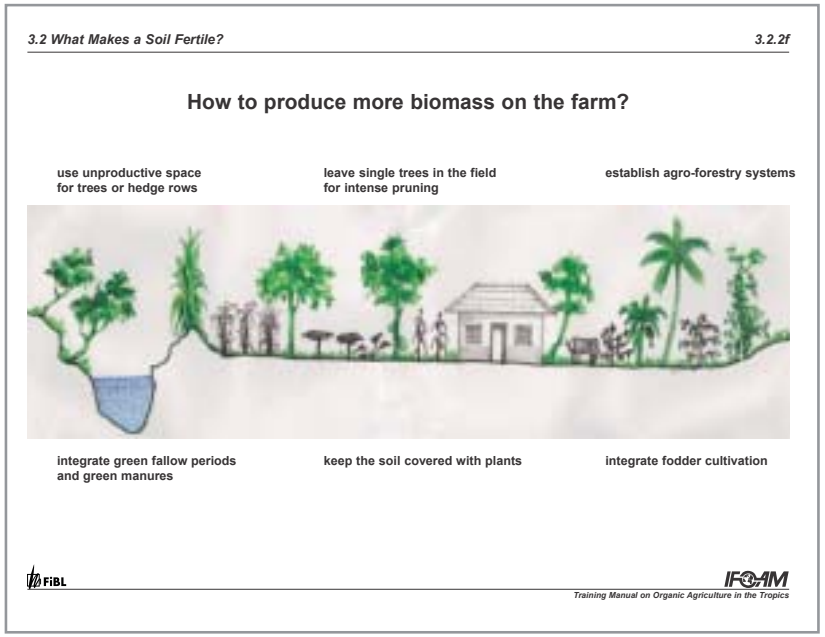
Farmers may react: "Fine, it would be good for the soil to apply good quantities of organic material. But from where shall I get biomass if there is nothing growing around?"
Discuss the statement with the participants. What to tell this farmer?

How to produce more biomass on the farm?

Integrate green fallow periods with green manures in the crop rotation

- Aim at having the soil covered with plants the whole year round, wherever possible
- Integrate fodder cultivation in the farm where possible (grass, fodder hedges)
- Use unproductive space (e.g. along paths, field borders, steep slopes etc.) for planting trees or hedge rows
- Establish agro-forestry systems, where appropriate.
- Leave single trees standing in the field (e.g. nitrogen fixing trees), manage them with intense pruning.
- Let cattle graze or spend some nights on harvested fields (it can also be the neighbour's cattle) in order to profit from their droppings.

Still, in some areas vegetation is very scarce and the soil is too poor to produce even a green manure crop. In such conditions, it might be necessary to first increase the fertility of the soil by bringing in organic manures from outside.



Transparency 3.2.2f: The black drawings show a conventional farm. Ideas of how to produce more biomass within the farm are drawn in green colour.

Experience sharing: Producing more biomass

Ask the participants whether they know of examples where the production of organic material was successfully increased. How did it work? How could the production of biomass be increased in local conditions?

Recommended Readings

- *«Manual de Agricultura Ecologica» (Spanish), Kolmans, E., Vasquez, D.*
- *«Soil Fertility Management», World Neighbours*
- *«Soil Fertility Management», Agromisa Agrodok-series No.2*