# ORGANIC AGRICULTURE IN THE PACIFIC

Training Manual

POETCom
Pacific Organic & Ethical Trade Community

IFOAM
INTERNATIONAL FEDERATION OF ORGANIC AGRICULTURE MOVEMENTS

SPC
Secretariat of the Pacific Community

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# 2. Principles of Organic Agriculture

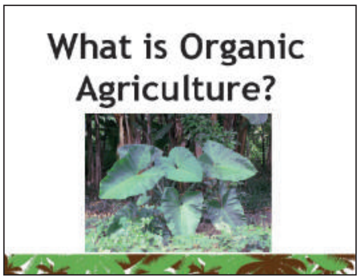
2.1 What is Organic Agriculture?

**Introduction**
There is a lot of confusion on what actually means organic agriculture. The word "organic" means "of plant or animal origin", but it also refers to the organisational aspect of an organism. Therefore, "organic agriculture" is not a very precise term. For some people it is the kind of agriculture which is based on organic manures or other natural inputs, i.e. minerals or pesticides of plant origin. In this view, emphasis is given to the renunciation of fertilizers and pesticides which are synthetic or chemical.

For others it refers to agricultural systems, which follow the principles and logics of a living organism in which all elements (soil, plants, farm animals, insects, the farmer etc.) are closely linked with each other. Organic farming therefore must be based on a thorough understanding and clever management of these interactions and processes.

Organic Agriculture is often defined by organic standards which explain what the principles are and which methods and inputs are not permitted. While standards are well suited to define a minimum common ground for the various kinds of organic agriculture, they do not provide many guidelines on how an ideal organic farming system should look like.

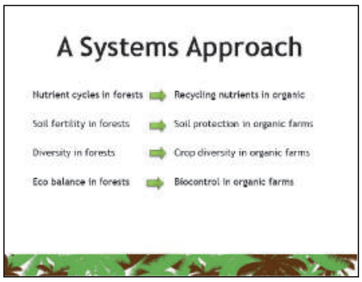
**Lessons to be learnt**
- Natural ecosystems can be a model for organic farming systems
- Understand the difference between organic agriculture and related systems
- Organic farming is not a step back to traditional methods but a modern approach
- Become familiar with the advantages, but also with the challenges of Organic Farming




**Activity**:
*Ask the participants: How would you define "Organic Agriculture"? Note down the suggestions in keywords on a board, discuss. Come back to the notes in the end of the session and check whether the participant's understanding has changed.*

### 2.1.1 Principles and Aims of Organic Agriculture

**A System Approach**
Conventional farming puts its focus on achieving maximum yields of a specific crop. It is based on a rather simple understanding: crop yields are increased by nutrient inputs and they get reduced through pests, diseases and weeds, which therefore must be combated. Organic agriculture is a holistic way of farming: besides production of goods of high quality, an important aim is the conservation of the natural resources fertile soil, clean water and rich biodiversity. The art of organic farming is to make the best use of ecological principles and processes. Organic farmers can learn a lot from studying the interactions in natural ecosystems such as forests. The following section shows how principles of a natural ecosystem can be used for designing an organic farming system.




**Activity:**
*Discuss with the participants which of the principles of natural ecosystems they can identify in traditional or organic farm ecosystems of the area. What is their significance for the farmer? Which elements could be included in order to improve the farms?*

**Nutrient cycles in forests**
Trees and other plants take up nutrients from the soil and incorporate them in their biomass (leaves, branches etc.). The nutrients go back to the soil when leaves fall or plants die. Part of the biomass is eaten by various animals (including insects), and their excrements return the nutrients to the soil. In the soil, a huge number of soil organisms are involved in the decomposition of organic material which makes nutrients available to plant roots again. The dense root system of the forest plants collects the released nutrients almost completely.

**Recycling nutrients in organic farms**
Organic nutrient management is based on biodegradable material, i.e. plant and animal residues which can be decomposed. Nutrient cycles are closed with the help of composting, mulching, green manuring, crop rotation etc. Farm animals can play an important role in the nutrient cycle: their dung is of high value and its use allows to recycle nutrients provided with the fodder. If carefully managed, losses of nutrients due to leaching, soil erosion and gasification can be reduced to the minimum. This reduces the dependency on external inputs and helps to save costs. However, nutrients exported from the farm with the sold produce need to be replaced in some way.

**Soil fertility in forests**
Soil and its fertility both together constitute the centre of the natural ecosystem. A more or less permanent soil cover prevents soil erosion and it helps to build up soil fertility. The continuous supply of organic material feeds a huge number of soil organisms and provides an ideal environment for them. As a result the soil becomes soft and capable of taking up and storing large quantities of water.

**Soil protection in organic farms**
Organic farmers give central importance to the maintenance and improvement of soil fertility. They stimulate the activity of soil organisms with organic manures and avoid harming them with chemical pesticides. Mulching and cover crops are used among other methods to prevent soil erosion.

**Diversity in forests**
Forests host a high diversity of plant varieties of different size, root systems and requirements. Animals are also part of the system. If one organism drops out, it is immediately replaced by another one which fills the gap. Thus space, light, water and nutrients are used to the optimum. The result is a very stable system.

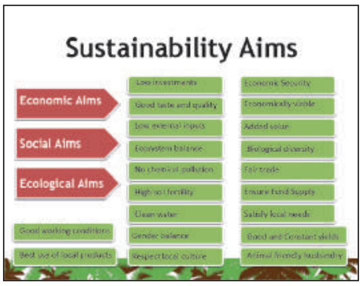
**Crop diversity in organic farms**
Organic farms grow several crops including, trees, either as mixed cropping or in rotation. Animals are an integrated part of the farm system. The diversity not only allows optimum use of the resources but also serves as an economic security in case of pest or disease attack or low market prices for certain crops.

**Eco-balance in forests**
Pests and diseases do occur in natural ecosystems, but they rarely cause a big damage. Due to the diversity it is difficult for them to spread. Plants usually can recover from an infestation on their own. And many pests are controlled by other organisms such as insects or birds.

**Bio-control in organic farms**
Organic farmers try to keep pests and diseases at a level which does not cause economical damage. The main focus is on supporting the health and resistance of the crop. Beneficial insects are promoted by offering them a habitat and food. If pests reach critical levels, natural enemies and herbal preparations are used.

**Back to nature?**
Organic farming wants to follow the laws of nature. Does it mean that organic farms must be as close to natural systems as possible? Within the organic movement one will find farmers who focus on natural farming, and others who take a purely commercial approach. The majority of organic farmers probably is somewhere in between these two extremes. Most farmers will expect to get sufficient production from the farm to make a living. For them the challenge is to follow the principles of nature to achieve a high productivity.

**Sustainability Aims**
Organic agriculture claims to be sustainable. But what does sustainability mean? In the context of agriculture, sustainability basically refers to the successful management of resources of agriculture to satisfy human needs while at the same time maintaining or enhancing the quality of the environment and conserving natural resources. Sustainability in organic farming must therefore be seen in a holistic sense, which includes ecological, economical and social aspects. Only if the three dimensions are fulfilled, an agricultural system can be called sustainable.




**Activity:**
*Draw a triangle on a board or butchers paper each corner representing one of the sustainability aims. Give cards and pens to each participant and get them to write down the aims of organic agriculture on each card and attach them to the triangle. Discuss result.*

**Ecological sustainability**
Some important aspects are:
- recycling the nutrients instead of applying external input
- no chemical pollution of soil and water
- promote biological diversity
- improve soil fertility and build up humus
- prevent soil erosion and compaction
- animal friendly husbandry
- using renewable energies

**Social Sustainability**
Some important aspects are:
- sufficient production for subsistence and income
- a safe nutrition of the family with healthy food

- good working conditions for both men and women
- building on local knowledge and traditions

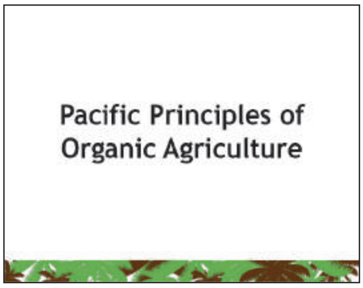
**Economic Sustainability**

Some important aspects are:

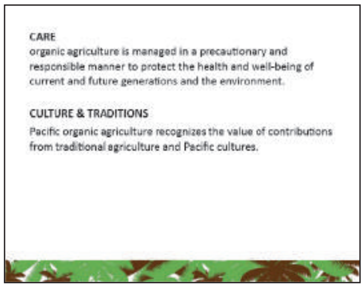
- satisfactory and reliable yields
- low costs on external inputs and investments
- crop diversification to improve income safely
- value addition through quality improvement and on-farm processing
- high efficiency to improve competitiveness

**Principles  of Organic Agriculture**

In a process of several decades, the international organic community, organised in the IFOAM movement, agreed on a common understanding on what the principles of organic agriculture are adopting the Principles Health, Ecology, Fairness and Care. The Pacific organic movement adopted the IFOAM Principles of Organic Agriculture but also felt that the recognition of the role of culture and tradition and Pacific people's connection to the land needed to be reflected when referring to organics in the Pacific Island region and so adopted a fifth Principle of Culture and Traditions.








**Activity:**

*Divide participants into 4 groups assign each group one principle: Ask the participants whether they agree with their principle what are some examples of this principle on a practical level and whether they make sense in local conditions. What needs to be done to achieve this principle in local organic farms? Share responses in whole group.*

**Pacific Principles of Organic Agriculture**

| | |
|---|---|
| **Health** | The soil, which enables the production of healthy plants and animals to enhance the lives of people and their environment, as one and indivisible. |
| **Ecology** | Organic agriculture is based on living ecological systems and cycles, works with them, emulates them and helps to sustain them. |
| **Fairness** | Organic agriculture builds on relationships that ensure fairness with regard to the common environment and life opportunities. The key role of farmers and rural communities are recognised and benefits shared equitably with them. |
| **Care** | Organic agriculture is managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment. |

| | |
|---|---|
| **Culture & traditions** | Pacific organic agriculture recognises the value of contributions from traditional agriculture and Pacific cultures. |

The principles show that organic farming is much more than the renunciation of agro- chemicals.

### 2.1.2 Distinction from other farming systems

**"Sustainable" Agriculture**
Since the negative environmental impact of chemical use in agriculture became more and more obvious, sustainability in agriculture became a widely accepted objective. Sustainable kinds of agriculture claim to be environmentally sound, resource-conserving, economically viable, socially supportive and commercially competitive. Concerning the goals, sustainable agriculture therefore has much in common with organic agriculture.
However, there is no general agreement to which extent sustainability must be achieved and which methods and inputs can be accepted. Therefore, also systems which do use chemical fertilizers, pesticides or genetically modified organisms call themselves sustainable. Integrated Pest Management (IPM) or Integrated Crop Management (ICP), for example, only avoids certain highly toxic pesticides and reduces the application of others to a certain extent.

It is not always possible to draw a clear line between different systems. There are sustainable agriculture systems which are also organic, and there are even organic farms which are not really sustainable, though they fulfil the minimum requirements of the standards.

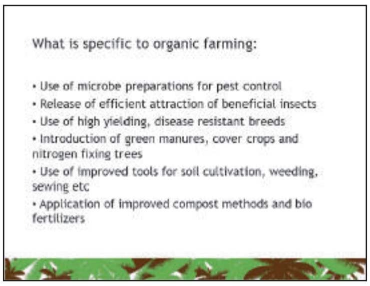

**Discuss**: *what is the difference between these systems?*

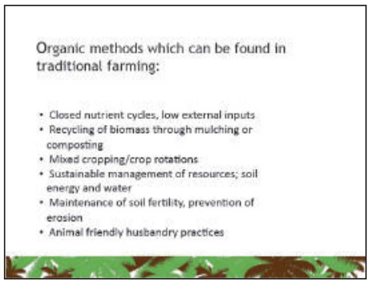
**Is Traditional Farming Organic?**
Agro-chemicals have been used in a large scale only since the 1960's. Many farming communities of the Pacific have not adopted many of these chemicals and practices and so meet the most important criteria of organic agriculture, i.e. the non-use of any chemical fertilisers, pesticides and genetically modified organisms. These agricultural systems are referred to as "Traditional Farming".

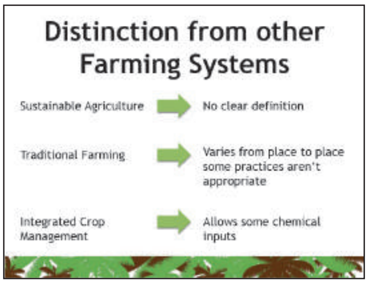
Over the last few decades, the focus in agriculture typically shifted from mainly subsistence agriculture (for own consumption) to market production (for gaining a financial income). In many countries, the density of population increased tremendously and many traditional farming systems have been unable to meet the yield expectations of the farmers. Due to reduced fallow periods, overgrazing or exploitative cultivation, many traditionally farmed areas face severe degradation. At the same time, higher yielding crop varieties have been introduced which are more prone to diseases. Organic farming tries to meet the increased needs of the growing population while not risking the long-term productivity of the farmland.

Many methods and techniques of organic agriculture have originated from various traditional farming systems all over the world. However, not all traditional systems make use of these methods, sometimes for the simple reason that they are not known in a specific region.

In addition, organic farming disposes of a range of rather modern technologies such as the use of antagonistic microbes in pest management, high yielding but disease resistant varieties or the use of highly efficient green manure plants.
Whether a certain traditional farming system can be called organic will depend on whether all the organic standards are fulfilled. For instance, some traditional systems get in conflict with the requirements of organic animal husbandry (e.g. sufficient space and free move), the necessary prevention of soil erosion, the ban to cut forests and to burn biomass (e.g. slash and burn systems).

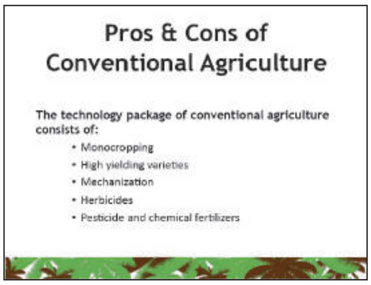



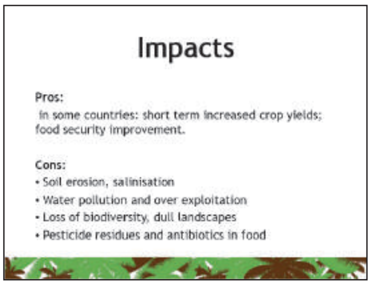

**Activity:**
*In small groups participants describe their traditional farming system in a few keywords. With the help of the checklist in Annex 8.1, each group shall discuss which of the principles and minimum requirements of organic agriculture are met in their traditional system and which are not. Which are the problems the traditional systems facing? Can the system be called "sustainable" from an ecological, economical and social point of view? Each group shall present their findings to the whole group.*

### 2.1.3 Why Organic Agriculture?

The term "conventional agriculture" is not very clear, as it depends on whether the conventions in a region are rather traditional or modern. "Conventional Agriculture" usually refers to mainstream agriculture, i.e. agriculture which includes the use of agro-chemicals, in contrast to organic agriculture.

**Conventional Agriculture can include:**
- The use of chemical fertilizers and pesticides is a technology which has spread out in most tropical countries since the 1960's
- Monocropping of high yielding varieties
- Intensive soil tillage (usually with machines)
- Use of herbicides to eliminate competing weeds
- Use of pesticides (insecticides, fungicides, molluscicides etc.) for eliminating pests and diseases
- Intensive fertilization with chemical fertilizers (N, P, K) often combined with intensive irrigation




**Activity:**
*Brain storm possible and known impacts of pesticides in local environment .*

**Success of conventional agriculture**
It must be acknowledged that with the help of the conventional agriculture technologies crop yields increased tremendously, especially in the temperate zones of Europe and North America. Several Southern countries also experienced conventional agriculture as a success story, though the yield increase usually lagged behind the North. India for example managed to become self sufficient in its cereal production, whereas formerly it was subject to severe famines quite often.

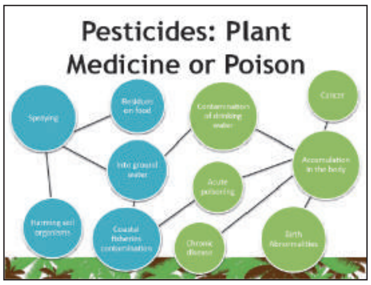
After the initial success of these practices it became evident that this kind of farming has many unwanted side effects, both on natural resources (soil, water, bio-diversity) and on human health:

- Soil: Vast areas of once fertile lands got degraded due to soil erosion, salinisation or a general loss of soil fertility.
- Water: Freshwater resources have been polluted or overexploited through intense use of agro-chemicals and excessive irrigation.
- Bio-diversity: Many wild and cultivated plant and animal species have been extinct and landscapes became dull.
- Human Health: Residues of harmful pesticides in food or drinking water endanger both farmer's and consumer's health. Further health risks from antibiotics in meat, BSE infection (mad cow disease) and genetically modified organisms (GMO).
  In addition, this kind of agriculture is based on an excessive use of external inputs and consumes a lot of energy from non-renewable resources.

**Pesticides: "Plant Medicine" or Poison?**
In some local languages, pesticides are called "medicine", having in mind their curing effect on sick or infested plants. Most chemical pesticides, however, have a range of unwanted side effects:

- Killing also non-target and beneficial insects sometimes offers ideal condition for new pests to develop.
- Many pesticides are also harmful to soil organisms, that are important to keep plants health. Therefore, the application of pesticides may call for further need for the same.
- When applying pesticides, farmers risk to get poisoned. It is estimated that worldwide, severe poisoning with agro-chemicals causes 200'000 deaths per year.
- Part of the pesticides will still remain on the products after harvesting, thus reaching consumers. They also infiltrate into the ground water, contaminating the drinking water.
- Some pesticides are very persistent and get accumulated in the body. Many of them show their effect only in the long term: they can cause chronic diseases, anomalies on newborn children, cancer etc.

Many pesticides are already banned in industrialised countries because they are too danger- ous. Still, some of them are sold to Pacific countries, where the awareness of their potential risk is still low. Some developing countries face big problems with the disposal of huge stocks of prohibited pesticides which they received from northern companies.




*Question to group– did we miss anything in our brain storming?*

**Benefits  of Organic Agriculture**

The advantages of organic farming compared to conventional agriculture can be summarised as follows:

- soil conservation and maintenance of soil fertility
- less pollution of water (groundwater, rivers, lakes)
- protection of wildlife (birds, frogs, insects etc.)
- higher biodiversity, more diverse landscape
- better treatment of farm animals
- less utilisation of non-renewable external inputs and energy
- less pesticide residues in food
- no hormones and antibiotics in animal products
- better product quality (taste, storage properties)

**Benefits  of Organic Agriculture**

**Activity:**

*Each participant writes one benefit of organic agriculture on a card and sticks it to a large sketch of a tree on the wall.*

## 2.2  The Organic Quality Control  System

**Introduction**

In order to assure the consumer that a product is produced organically, a kind of quality control is inspection, certification and accreditation. It is a rather complex field in organic agriculture, too large to be covered i overview and general understanding.

**Lessons to be learnt**

- Organic certification aims at building trust between consumers and organic farms
- Organic standards are minimum requirements for organic production
- Organic inspection is a surveillance of the whole farming system or processing process, laboratory testing is just one tool
- PGS can be useful for developing domestic markets and raising awareness of organic

### 2.2.1 Why is Certification Needed?

**Building trust**
More and more consumers are getting interested in organic products because they are worrying about their health or are concerned about the environment. Some of them are ready to pay a somewhat higher price for agricultural products.
On the other side, more and more farmers switch over to organic agriculture for various reasons. At least some of them expect to get a better price for their products because they have to face a higher work load or lower yields, and the products are more safe and tasty.

A premium price is possible only if there is mutual trust between producers and consumers. The consumer wants to be sure that the product he buys is really organically produced. The organic farmer also needs to be protected from unfair competition of other farmers who use the term "organic" in a fraudulent way.


**Activity:**
*Break in 2 groups. Group one identifies reasons why consumers want organic products? Why are they willing to pay more for organic? Group 2 identifies why farmers want to grow organic? Why farmers expect to get paid more for organic produce?*

**Activity:**
*Discuss in whole group who we can build trust in organics:*
*1) for markets far away;*
*2) for markets in our country.*

**Organic labels and certification marks**
In order to show the buyers in the markets or shops that a product is organic, usually labels or registered and protected and can be used only by authorized producers and processors.

Authorisation is usually gained by signing a contract when a producer or processor gets certified processed according to specific organic standards.

Labels and certification marks help the consumer to recognise trustworthy organic products easily. They can get a better price compared to the one for conventional products.


**Activity:**
*Show examples of certified products vs. 'self claim' labelling; group discusses difference if any.*

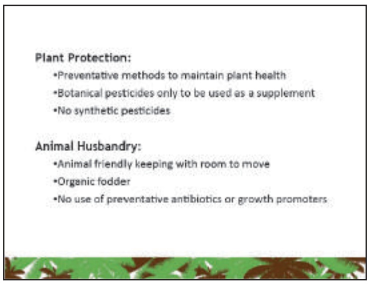
### 2.2.2 Organic Standards

What exactly does it mean if a product is labelled "organic"? The organic claim says that the product is produced according to certain requirements which are called "standards".

Organic standards do not define a quality status which can be measured in the final product (e.g. how many pesticide residues are allowed). They define the way of production (e.g. that no chemical pesticides shall be used).

**Important organic standards requirements**

There are various other organic standards on the private, national and international level. The IFOAM Norms provide a frame work for certification bodies and standard setting organizations worldwide to develop their own certification standards and cannot be used for certification on their own. Local certification standards may meet or exceed the IFOAM Norms standards but should take into account specific local conditions and provide more specific requirements. In the Pacific region we have the Pacific Organic Standard which was written to suit the farming practices and conditions of the Pacific islands.


**Activity:**

*Small groups briefly review the Pacific Organic Standard and identify any elements they were surprised to find in the POS. Share with group.*

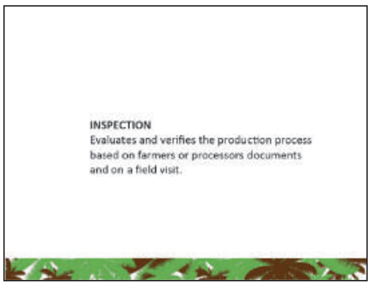
### 2.2.3 Inspection and Certification

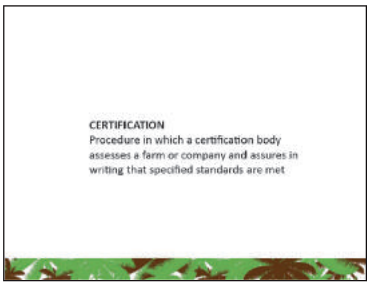
**Inspection and certification**

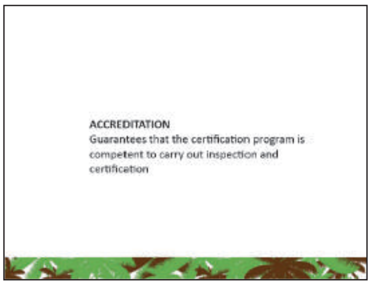
It frequently appears that there is a lot of misunderstanding on what is inspection and certification. As these terms are important in organic agriculture, they shall be explained here briefly.

**Inspection**

If an organic farmer wants his products to be certified, he has to undergo an inspection at least once a year. This can also be called an audit. The inspector evaluates the performance of the farm activities with the help of the farmer's statements and records and by viewing the fields, animals and farm buildings. He or she checks whether the statements and records are correct and plausible. In case of doubt, the inspector can take samples for laboratory testing or later conduct unannounced inspections. However, laboratory testing is only one tool for inspection in cases of suspicion of application of or contamination with prohibited substances. Chemical analyses just reveal whether a certain sample contains a specific substance at a certain moment. There is only limited scope to detect residues of chemical fertilizers and pesticides after some time, and in addition chemical analysis are expensive. It therefore cannot replace the inspection of the whole farming process.




**Activity:**
*Check participants understanding through the following questions: Who inspects in your country? Who provides certification? Who accredits your certifier?*

**Participatory Guarantee System**

Participatory Guarantee Systems (PGS) aim to provide a credible organic guarantee to consumers seeking organic produce through direct participation of farmers and consumers in the organic guarantee process. Participatory Guarantee Systems are based on recognized and publicly available standards for organic production. PGS are shaped by the very farmers and consumers that they serve and while the details of methodology and process vary, there is a consistency of core principles which can be adapted and specific to local conditions (communities, geographies, politics and markets). Participatory Guarantee Systems have transparent, systemised decision making processes and aim to share the responsibility for the organic guarantee and to verify that farmers are consistently maintaining the standards. Trust is created through open information and peer reviews. PGS involve less administration and lower costs than export focused third party certification but can only be used for local markets.
Participatory Guarantee Systems support and encourage producer groups to work together and to improve their farming practices through the sharing of knowledge and experiences.

Participatory Guarantee Systems can be used as a tool for improving local socio-economic and ecological conditions by encouraging small-scale production and product processing. In local markets they help smallholders to have their products recognized as organic and can open unique opportunities such as small holder links with the tourism and hospitality industries.

**Pacific Certification**

# 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 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 constant process of transformation
- Without soil organisms soil is dead.
- Not all microbes are hostile, most soil microbes are very important helpers of the farmer
- Each soil organism plays a role that contributes to the maintenance of soil fertility
- The relations among the elements of the soil ecosystem are complex and sensitive to disturbance


**Activity:**

Carry out a motivation exercise by asking the participants why the soil is of central importance to organic agriculture. Collect all the statements in keywords on the board, before continuing with the session to provide a closer understanding of soils.

### 3.1.1 The Composition and Structure of Soils

**Mineral Particles**

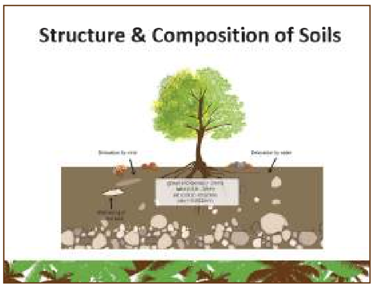
Soil consists of mineral particles, organic matter and pores. Mineral particles originate from subsoil and rock, which gets crushed to smaller and smaller pieces through physical and chemical weathering processes.

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.




**Notes**: Emphasize that soil is made up of 4 components (Mineral particles, Organic matter, Pore spaces for air and water, and Living organisms), before going through each components in detail starting with slide 2.
Go through the different sizes of soil mineral particles and how they influence the texture of the soil, and therefore the water holding capacity of soils. Explain how soil is formed through the process of weathering.

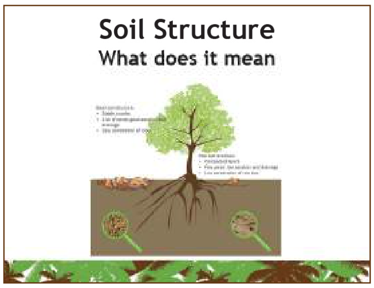
**Soil Organic Matter**
Besides mineral particles, soil contains smaller or larger quantities of organic matter or humus, resulting from the decomposition of biomass. Though in most agricultural soils of the tropics it makes only a few percent or even less than one percent of the total solid material,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


**Notes**: *Point out that SOM is the smallest fraction of the soil, about 1-3% on average, but it is critical for the fertility of the soil.*

*Explain how it is formed from the decomposition of biomass residues. In the soil the SOM can be further decomposed by microbes. This decomposable fraction is important for supplying nutrients to plants. The remaining stable fraction of the SOM, however, is important for improving soil structure by binding soil particles together into aggregates.*

**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.




**Notes:** *Emphasize that it is the structure that enables the 3rd component - pore spaces for air and water- of soils to exist. Go through how soil structure is formed from soil particles and its important functions for aeration, water infiltration and storage, and root growth. Highlight the role of SOM in soil structure formation. Also highlight management practices that can destroy the structure of the soil.*

**Activity:**
*Carry out a Slaking Test in petri dishes to demonstrate that soils with a good structure have stable soil aggregates. Do this by placing one aggregate in petri dish full of water. Observe the length of time it takes to slake off or disintegrate. Relatively stable aggregates will not disintegrate or will take longer before disintegrating.*

**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. 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.

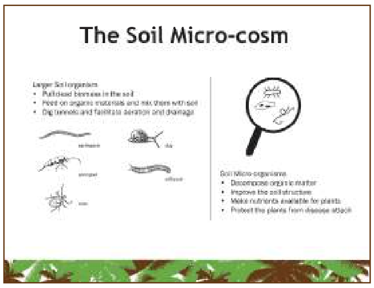
### 3.1.2 The Soil-Microcosm

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




**Notes**: *This slide can be presented as an introduction to soil living organisms.*

*Activity: Before presenting this slide carry out an Experience sharing exercise by asking participants what they know about soil organisms? Did they come across situations where soil organisms played an important role? Are farmers aware of the importance of soil organisms?*

*Emphasize the two groups of soil organisms, and give examples.*

**Soil Organisms: adversaries or friends?**
Many farmers consider all micro-organisms only as pests and think: "How can we kill them"? Actually 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 the soil is crucial for their development.



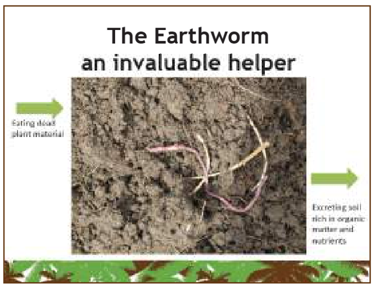
**Notes**: *Emphasize that soil is a living entity because of the living things inside the soil (if no living organisms then it should just be called sediments). Also indicate the abundance of soil organisms,*

*especially micro-organisms, which can be 1-7 million per gram of soil (one teaspoon). Indicate the diversity of soil organisms, 147,800 species already but could be up to 1.8 million species.*
*Describe their roles in nutrient cycling and improving soil structure as presented in the table below:*

| Large Soil Organisms | Micro Organisms |
|---|---|
| burrowing and tunneling give soil aeration and easy movements of plant roots | Decompose organic residues or biomass and builds up humus or soil organic matter |
| Channeling helps mingle organic matter with soil particles and helps build soil structure | Recycle/transform nutrients into plant available or usable forms |
| Act as vector or fungal propagules that colonize and decompose organic residues in deeper soil layers (eg earthworms) | Helps release nutrients from mineral particles |
| Concentrate nutrients in excrements called casts | Produce glue like substances that bind soil particles together into aggregates |
| | Control pests/organisms affecting the root of crops |

**The earthworm – an invaluable helper**
Most farmers are well aware that the presence of earthworms is a sign for a fertile soil. Indeed, crucial functions. For example they accelerate the decomposition of biomass by removing dead plan 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 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 earth- worms in the soil, as does the use of pesticides.




**Notes**: *Highlight the roles of earthworms in decomposition (shredding and chewing litter, and as vector for fungal propagules), concentrating nutrients in casts, and in the formation of soil structure, especially their role as soil engineers.*

**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.

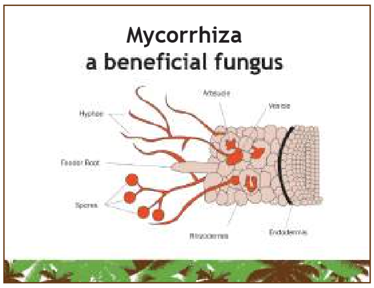
Mycorrhizae have several functions, which are of high interest for the farmer:

- 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.




**Notes:** *Describe the association between the fungi and roots of plants. Further explain the benefits of having the mycorrizhal association, especially in relation to organic agriculture. Also discuss the management practices that can encourage or inhibit the presence or growth of mycorrizha.*

**Group Work: Studying Soil Samples**

Collect a variety of soil samples from different sites, of different colours, under different cultivation practices, from slopes or flat land, forets, top soil, deep soil, soil rich and poor in organic matter. Keep samples (100gms) in plastic bags so they don't dry out. Write description of site on each bag.

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 (a in Annex 8.2), 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.

**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 sol organisms and the presence of soil crumbs.

**Extracting larger soil organisms**

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 this way.

**Activity :**

*Determining the presence of soil micro-organisms using Calcium Hydroxide CO2 tests for microbial respiration.*

*Materials:*

i. *Soil (and teaspoon to measure)*
ii. *Shallow jar with lid (eg a clear peanut butter bottle)*
iii. *Cup (about 100ml)*
iv. *Rainwater*
v. *Two small medicine delivery cups as vials*
vi. *One teaspoon of calcium hydroxide (borrowed from nearby science lab)*
vii. *Drinking straws*

**Procedures:**

- *Before the Training Session, prepare the calcium hydroxide solution by dissolving one teaspoon of calcium hydroxide into a cup of rainwater. Pour about 10ml into each of the two plastic medicine vials.*
- *Place two teaspoons of soil into the base of the jar and then place the vial of calcium hydroxide solution beside the soil and close the jar tightly then let jar stand somewhere safe overnight.*
- *Observe the clear calcium hydroxide solution turning cloudy due to the respiration (breathing) of the soil micro-organisms.*
- *Let participants prepare another vial of calcium hydroxide solution and get them to breathe out through their mouth (using a straw) into the vial of clear calcium hydroxide solution. A cloudy solution will appear as test for CO2 which is the product of breathing from living things.*
- *Emphasize that CO2 can only be released from the soil sample if there are living things in there.*

**Activity:**

*Assessing the biological status of a farm*

*Materials:*

*i. Spade*
*ii. Clean white sheet or plastic*
*iii. Record sheet of paper*
*iv. Pencil and rubber*
*v. Map of the farm*

**Procedures:**

- *Get the map and identify 10 sampling points evenly distributed throughout the farm.*
- *At each sampling point dig a 30cmX30cmX30cm unit of soil using the spade.*
- *Put this unit of soil on the white clean sheet and break it out using hand to look for any visible soil organisms.*
- *Note the various species and the numbers and their abundance and record them on a table such as below*
- *For each species, sum the total species count and calculate the average count per sample point.*

| Species | Samples | | | | | | | | | | Total | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | |
| Earthworms | | | | | | | | | | | | |
| Millipedes | | | | | | | | | | | | |
| Centipedes | | | | | | | | | | | | |
| Others | | | | | | | | | | | | |

## 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.

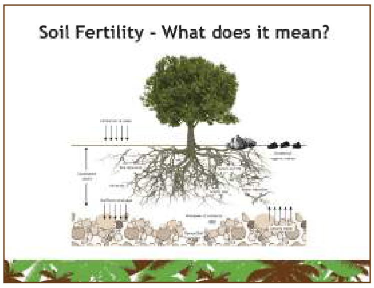
**Lessons to be learnt:**

- 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

### 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.




**Activity:**

*This is for a motivation exercise. When putting up this slide, ask the participants the following questions:*
*What does "soil fertility" mean to you?*
*What comes to your mind when you think of soil fertility?*
*Note the keywords of their answers on a board and summarize, emphasizing:*

- *The distinction between conventional agriculture and organic agriculture concept regarding soil fertility.*
- *That feeding the soil means feeding the plant, and that only a fertile soil can yield healthy crops which can withstand pests and diseases and produce higher yields*
- *That a thorough understanding of factors influencing soil fertility is important for organic farmers.*

**Factors influencing soil fertility**

| | |
|---|---|
| Soil depth: | the exploitable volume for plant roots |
| **Availability of water:** | moisture retention for continuous water supply |
| **Aeration:** | necessary for a healthy root growth and a high activity of soil life |
| **pH(range of acidity):** | the soil should be neither 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. |

**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.

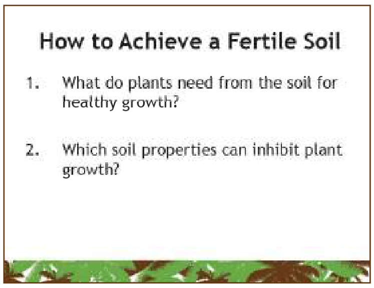
**How to improve and maintain soil fertility**
Farmers can improve the fertility of their soil by various management practices. It is important to achieve:

- 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

## 3.3 Improving Soil Fertility

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. 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). 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.




**Notes:** *Explain the factors presented in slide and then:*
*(a) Select, with the assistance of participants, the most relevant factors under local conditions.*
*(b) Ask participants to identify suitable crops for particular soil type, eg. Sandy, damp, heavy soils.*
*(c) Emphasize that plants differ in their soil fertility and soil moisture requirements.*

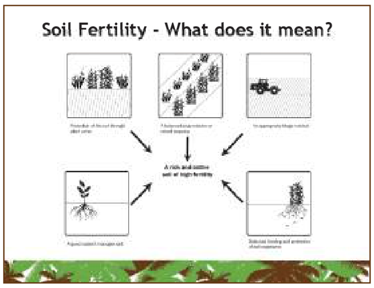
**How to improve the soil structure**
A good soil structure is important for easy penetration of plant roots, good aeration, sufficient infiltration, active soil life and many other functions. Some soils are generally of a poor structure because of their mineral composition (e.g. high clay content). 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.

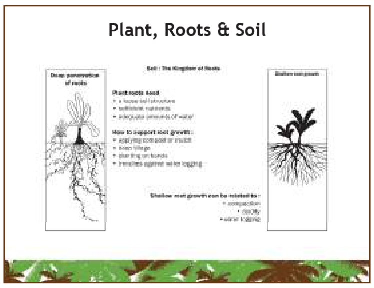
**Activities that improve soil structure:**

- 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




**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

### 3.3.2 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.

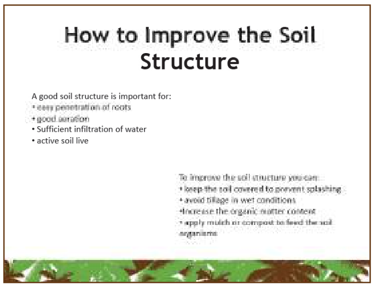
**The formation of soil organic matter**
Plants are built up from water, air and nutrients. When plant material is decomposed with the help of animals, soil organisms and microbes, the components are released again as nutrients or gases, and are available for new plant growth. In the process of decomposition, 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.

Notes: The decomposition of organic materials can be accelerated by making compost




Notes: *Before presenting Slide the trainer can ask participants how they can improve their soil fertility. Ask some participants to share their personal experiences about the fertility of their farm soil. Use the following questions as a guide:*

*(a) What is the history of his/her farm*

*(b) How was it managed in the last years*

*(c) What was its condition when the farmer was a child, and how did it change over the years?*

*(d) What was the related benefits and problems for cultivation*

*(e) How does he/she manage to increase or maintain soil fertility in the farm?*

*(f) Which management practices would be suitable?*

*(g) What are the constraints to improving soil fertility?*

*Alternatively a farm visit could be carried out to assess the fertility of the soil and/or interview the farmer.*


**Notes.** *Before presenting this slide it would be good to show participants how roots grow out in a soil profile or at least a photo of this. Ask participants to discuss the soil conditions which encourage and discourage plant roots to grow. Ask participants how they can assist plant roots to grow*

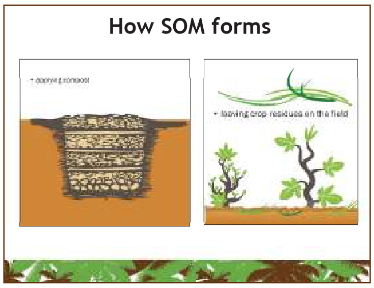
*Present the slide as a summary and emphasize how the growth of roots is important in extracting water and nutrients from the soil for the plant to grow.*

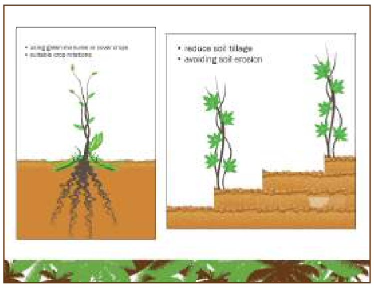
**Why organic matter is so important**

- 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.

**Why organic  matter is so important**


**Notes:** *Ask participants which of the two profiles or samples they would like to have in their farm, and why.*



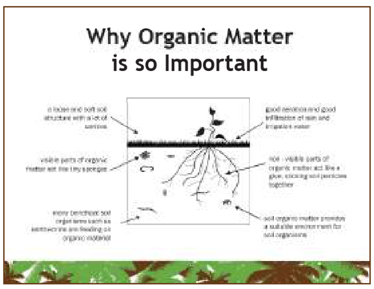


**Activity**
**Discuss** the factors that affect the rate of decomposition of organic residues through brainstorming/personal experiences.
The above slide could be replaced with samples of composts at different weeks of decomposition

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.

**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).

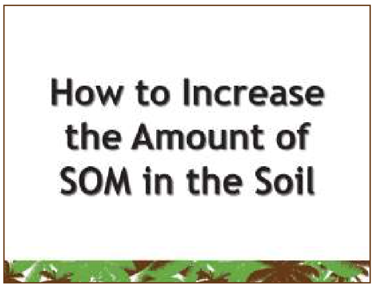


Activities that increase the level of soil organic matter:

- 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 con tribute 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.

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 de- composed 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.

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







**Notes:** *The slide could be used as summary to ensure all points are covered by a prior discussion with participants on 'What methods can help to increase the content of humus or SOM in the soil?' Note down the suggestions and ask if others agree or disagree.*

*Discuss with participants which of the suggested methods can be easily applied to local conditions. What experiences did participants make of these methods?*

*Point out that shortage of biomass could be a limiting factor to apply residues to the soil.*
*Alternatively this slide could be replaced by actual photos of the management practices.*

**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.

**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.


**Notes:** *Go through the practices on how to increase biomass on farm as presented in the slide. Emphasize the advantage of growing legumes as biomass trees on the farm*
*As an experience sharing exercise ask participants if they know of examples where the production of organic materials was successfully increased. Ask them how the production of biomass could be increased in their local situations.*

## 3.4 Soil Cultivation and Tillage

**Introduction**
Soil cultivation includes all mechanical measures to loosen, turn or mix the soil, such as ploughing, tilling, digging, hoeing, harrowing etc. Careful soil cultivation can improve the soil's capacity to retain water, its aeration, capacity of infiltration, warming up, evaporation etc. But soil cultivation can also harm the soil fertility as it accelerates erosion and the decomposition of humus. There is not one right way to cultivate the soil, but a range of options. Depending on the cropping system and the soil type, appropriate soil cultivation patterns must be developed.

**Lessons to be learnt:**
By the end of this session the participants should learn that:
- Soil cultivation can have a positive or negative impact on soil fertility
- Frequent tillage can lead to decrease of soil organic matter, nutrient losses and soil erosion
- Soil cultivation should aim on a minimum disturbance of the soil life

### 3.4.1 Aims of soil cultivation- Creating good growing conditions for plants

There are many reasons for cultivating the soil. The most important ones are to:
- Loosen the soil to facilitate the penetration of plant roots
- Improve the aeration (nitrogen and oxygen from the air)
- Encourage the activity of the soil organisms
- Increase infiltration of water
- Reduce evaporation
- Destroy or control weeds and soil pests
- Incorporate crop residues and manures into the soil
- Prepare the site for seeds and seedlings
- Repair soil compaction caused by previous activities

**Minimum disturbance**
Any soil cultivation activity has a more or less destructive impact on soil structure. In tropical soils, regular tillage accelerates the decomposition of organic matter which can lead to nutrient losses. The mixing of soil layers can severely harm certain soil organisms. Soil after tillage is very prone to soil erosion if left uncovered before the onset of heavy rains.

Zero-tillage systems on the other side help to build up a natural soil structure with a crumbly top soil rich in organic matter and full of soil organisms. Nutrient losses are reduced to a minimum as there is no sudden decomposition of organic matter and nutrients are caught by a dense network of plant roots. Soil erosion won't be a problem as long as there is a permanent plant cover or sufficient input of organic material. Last but not least, farmers can save a lot of labour.

Thus, each organic farmer will have to assess the soil cultivation practice which is most suitable for his conditions. Zero-tillage can be used only in few crops, mainly perennials. To minimize the negative impacts of soil cultivation while benefiting from its advantages, the organic farmer should aim on reducing the number of interventions to the minimum and choose methods that conserve the natural qualities of the soil.

**Soil compaction**
If soils are cultivated in wet conditions or burdened with heavy machinery, there is a risk of soil compaction which results in suppressed root growth, reduced aeration and water logging.

Where soil compaction is a potential problem, farmers should be aware of the following aspects:

- The risk of soil compaction is highest when the soil structure is disturbed in wet conditions
- Do not drive vehicles on your land soon after rains
- Ploughing of wet soils can lead to a smearing of the plough sole
- Soils rich in sand are less prone to soil compaction than soils rich in clay
- High content of soil organic matter reduce the risk of soil compaction
- It is very difficult to restore a good soil structure once soil compaction took place
- Deep tillage in dry conditions and the cultivation of deep rooted plants can help to repair soil compaction

### 3.4.2 Methods to cultivate the soil

**Types of soil cultivation**

Depending on the aim of the soil cultivation, different cultivation practices are implemented during different stages of the cropping cycle: after harvesting, before sowing or planting or while the crop stands.


**Post-harvest**

In order to accelerate decomposition, the residues of the previous crop are incorporated into the soil before preparing the seedbed for the next crop. Crop residues, green manure crops and farmyard manure should be worked only into the topsoil layer (15 to 20 cm), as decomposition in deeper soil layers is incomplete, producing growth inhibiting substances which can harm the next crop.

**Primary tillage**

In annual crops or new plantations, primary tillage is usually done with a plough or a similar instrument. As a principle, soil cultivation should achieve a flat turning of the top soil and a loosening of the medium deep soil. Deep turning soil cultivation mixes the soil layers, harms soil organisms and disturbs the natural structure of the soil.

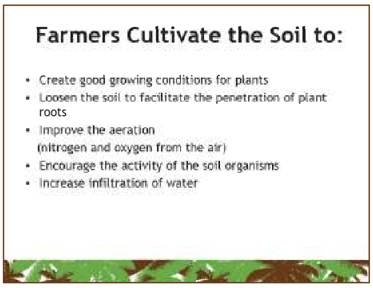
**Seedbed preparation**

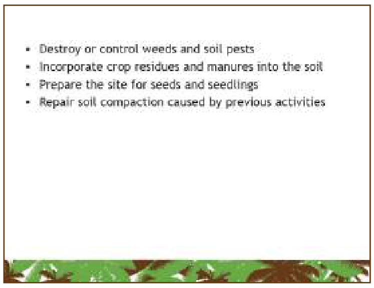
Before sowing or planting, secondary soil cultivation is done to crush and smoothen the ploughed surface. Seedbed preparation has the purpose to provide enough loose soil of appropriate clod size. If weed pressure is high, seedbeds can be prepared early thus allowing weed seeds to germinate before the crop is sown. Shallow soil cultivation after some days is sufficient to eliminate the young weed seedlings. Where water logging is a problem, seed beds can be established as mounds or ridges.

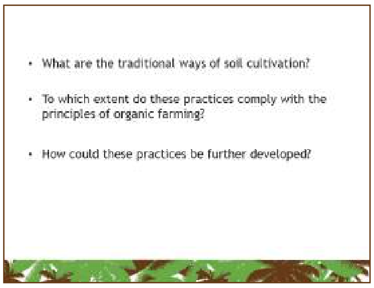
**In-between the crop**

Once the crop is established, shallow soil cultivation e.g. by hoeing helps to suppress weeds. It also enhances the aeration of the soil and at the same time reduces the evaporation of soil moisture from the deeper soil layers. When crops are temporarily lacking nutrients, shallow soil cultivation can stimulate the decomposition of organic matter thus making nutrients available.

**Why do farmers cultivate the soil? (Note participants' answers on the board)**



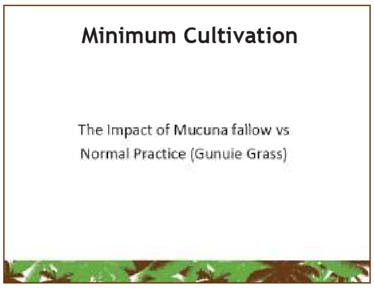



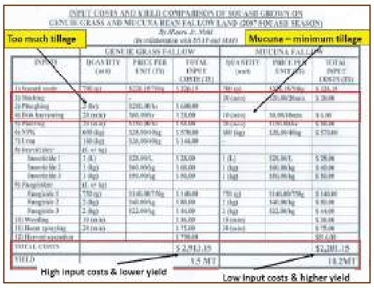

### 3.4.3 Appropriate Tools for Soil Cultivation

The tools for soil cultivation can be grouped in four types:

- Tools for primary cultivation: pole plough, mouldboard plough, digging fork, spade
- Tools for secondary cultivation: cultivators, harrows, rakes
- Tools for inter-row cultivation: inter-row cultivators, hoes
- Tools for land forming: ridgers, hoes

Tools should be chosen considering the soil cultivation purpose, the soil type, the crop and the available power source. Therefore, it is difficult to make general recommendations.



**Activities**

**Discussion:** *Why to cultivate the soil?*
*Ask participants for reasons why farmers cultivate the soil. Note them down at the board.*

**Discussion:** *What are the negative impacts of soil cultivation?*
*Ask participants and note their answers at the board.*

**Activity 3**
**Discussion:**
*1. What are the traditional ways of soil cultivation? Note them down at the board.*
*2. To which extent do these practices comply with the principles of organic farming? How could they be further developed? (Note also the issue of burning which is a popular traditional cultivation practice and discuss how the Pacific Organic Standards deals with burning.)*

### 3.5 Soil Erosion: A Major Threat

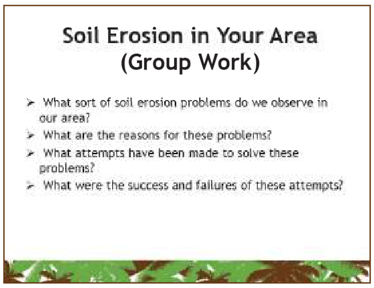
**Introduction**
Soil erosion is one of the most serious and irreversible threats to soil fertility. It carries away the most fertile parts of the soil: the top soil and the finer clay fractions which are rich in humus and nutrients. Even low erosion rates which are almost invisible can over the years have a severe impact on soils. It is therefore of vital importance to protect the soil from erosion. Especially organic farming fully depends on the maintenance of the natural fertility of the soil. Therefore, this manual allots a full chapter to this topic. In areas, where soil erosion does not occur, or farmers are already familiar with how to prevent soil erosion, this topic may be dropped in training courses.

Many tropical countries have distinctly dry and wet seasons. During the dry season, ground vegetation usually gets scarce and thin, leaving the soil uncovered. As a result, when the rains arrive, large amount of valuable topsoil can be washed away, leaving the land uneven with gullies and with soil of low fertility. Not only steep slopes but plain fields are also prone to soil erosion, and can be severely affected. Besides rain, excessive irrigation can also cause soil erosion.

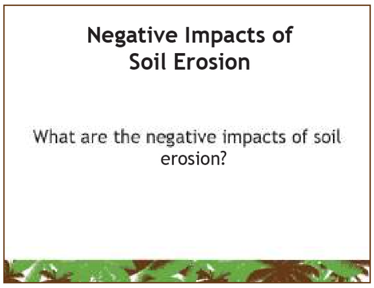

#### 3.5.1 How to Approach Soil Erosion

**Signs for soil erosion**
How can we identify whether a field is affected by soil erosion? There are some indicators:
- Deep gullies show severe and obvious soil erosion
- Small grooves at the soil surface indicate significant losses of soil
- A compact soil crust after a heavy rain is an indicator of probable soil erosion
- Accumulation of fine soil material in trenches and depressions is an evidence of soil erosion in the immediate neighbourhood
- Brown colour of the drainage water or streamlets during and after heavy rains is a reliable indicator of soil erosion in the watershed
- Farmers say: “The stones are growing out of the soil!”
- Roots of trees are partially exposed

**Lessons to be learnt:**
- Awareness creation on the serious impact of soil-erosion: it takes away the most fertile part of the soil
- There are several strategies for reducing the eroding impact of rain
- Learning practical methods to reduce soil erosion




*Each group shall present the main points of their discussion. Note down the most important aspects on a paper chart or on cards.*




**Discussion:**
*What are the negative impacts of soil erosion?*
*(Note participants' answers on the board)*

**How to prevent soil erosion?**
There are three general strategies for preventing soil erosion:
- Reducing the erosive power of the rain drops by keeping the soil covered (with vegetation or mulch)
- Improving the infiltration of the rain water into the soil
- Reducing the speed of the water flowing down the slopes with the help of constructions

On sites that are highly prone to erosion, these three strategies ideally should be combined.


### 3.5.2 Plant Cover

**What to Learn from Natural Forests**
In natural forests, several mechanisms ensure that no erosion of the scarce and valuable top soil occurs. Several layers of dense canopy break the speed of the rain drops falling on the ground. Large drops formed on leaves of the tree-tops are caught by the canopy of shrubs and ground vegetation. The water drops reach the soil at less speed and thus have a lesser smashing effect on soil crumbles. The ground is directly covered with living plants like ferns, mosses or seedlings, and with a mixture of rotten plant materials (leaves, bark, twigs, branches etc.). The top soil is intensively penetrated by roots, fungus and algae and is rich in humus. A large number of soil organisms such as earthworms maintain a loose and stable structure where rainwater can infiltrate easily.

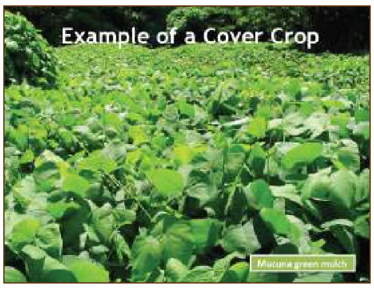
**Dense vegetation protecting the soil**
In perennial plantations such as orchards, dense vegetation can be achieved by growing legumes, grass or creepers between the trees. In new tree plantations, fodder grass and arable crops (such as tubers, pineapple, beans etc.) can be grown until the trees develop a dense canopy. Not only crops but also grass and weeds can provide the protecting cover. If possible, weeding should be avoided before and during the rainy season, as weeds help to protect the soil. If it is necessary to cut the weeds because the competition with the crops is too strong, the cut weeds should be kept on the spot as a protecting mulch layer.

Mulching means covering the soil with cut plant material of any kind. Owing to its multiple functions, mulch is very effective in protecting the soil from erosion. Even a few leaves or stalks will reduce the erosive power of rain drastically.

**Cover crops**
Every plant which covers the soil and improves soil fertility can be a cover crop. It could be a leguminous plant with other beneficial effects, or it could be a weed characterised by its rapid growth and enormous production of biomass. The most important property of cover crops is their fast growth and the capacity of maintaining the soil permanently covered.

The following characteristics make an ideal cover crop:
- The seeds are cheap, easy to get, to harvest, to store and to propagate
- Be of rapid rate of growth and be able to cover the soil in short time
- Be resistant against pests and diseases
- Produce large amounts of organic matter and dry material
- Fix nitrogen from the air and provide it to the soil
- Have a de-compacting root system and regenerate degraded soils
- Easy to sow and to manage as single crop or associated with other crops
- Can be used as fodder, grains as food grains

Example: Cowpea as a cover crop
Cowpea (Vigna unguiculata, French: Niébé) is an important grain legume throughout the tropics and subtropics. It has some properties which make it an ideal cover crop:
- It is drought tolerant and can grow with very little water
- It can fix nitrogen and grows even in very poor soils
- It is shade-tolerant and therefore compatible as an intercrop
- It yields eatable grains and can be used as an animal fodder rich in protein
- It is quite resistant to pest attack




**Designing Cropping Systems**
Cropping systems should be designed in such a way that the soil is almost permanently covered with plant canopy. In arable crops, careful timing of sowing and planting can help to avoid uncovered soil being washed away during the rainy season. After the main crops are harvested,

a green manure crop may be sown. On slopes, crops should be grown in lines across the slopes (along contour lines) rather than vertically. This can contribute enormously to reduce the speed of surface water.

In crops which take some time to develop a protecting canopy, intercropping of fast growing species such as beans or clover can help to protect the soil in the initial stage of the main crop.

Possible measures to ensure a permanent plant cover may have focus on:
- Timing of soil cultivation
- Timing of planting or sowing
- Producing seedlings and transplanting them
- Mixed cultivation
- Intercropping
- Cover crops
- Mulching
- Timing of weeding
- Sowing of a green manure crop in the off-season

The following aspects must also be taken into account:
- Expected effect on yields
- Availability of suitable species
- Costs of seeds
- Availability of water
- Availability of labour
- Additional use of side-crops
- Reduction of the risk
- Food security

### 3.5.3 Constructions against Soil Erosion

Cultivated slopes are extremely prone to soil erosion. In order to reduce the speed of water flowing down during heavy rains, constructions along contour lines are useful. Contour lines are imaginative horizontal lines across a slope.

Constructions against soil erosion aim at reducing the slope and consequently the speed of surface water. In addition, they catch and accumulate the soil eroded from above. To be effective, all constructions against soil erosion (bunds, stone walls, living barriers, trenches, terraces) must be arranged along the contour lines of a field.

**Identifying Contour Lines**
A simple way to identify contour lines on a slope is to use the "A-frame". The A-frame is a simple tool made from three poles, some rope, a stone and a supply of stakes.

**How to build and use an A-frame**

1. Fix three poles of about 2.5 meters long each in a position forming an even “A”. If rope is not sufficient to tie the ends, use nails.
2. Tie one end of a piece of cord to the top of the A and fix a stone tied to the other end so that the stone is at some distance from both the ground and the crossbar.
3. Put the A-frame upright and mark the position of both legs. Then, mark the point where the string passes the crossbar of the “A”.
4. Turn the A-frame so that the placement of the legs is reversed. Again mark the point where the string passes the crossbar. If the two marks are not at the same point, mark a third point with a knife exactly halfway between the first two.
5. Drive the first stake at the edge at the top of the field. Place one leg of the A-frame above and touching the stake. Place the other leg in such a position that the string passes the level position point on the crossbar.
6. Drive another stake into the ground just below the second leg. Move the A-frame and continue in the same way across the field.
7. The next contour line is placed 3 to 6 meters below the first line, depending on the slope of the site. The steeper it is, the closer the lines should be.

**Some constructions against soil erosion**

**Wooden barriers and stone walls**

Simple barriers can be constructed using tree trunks and branches. They accumulate eroded soil behind them, thus preventing it from being washed away.

The construction of stone walls needs more time, but they last longer and the maintenance work is rather less. They are suitable on steep slopes and in areas where plenty of stones are available.

**Bunds and trenches**

Earth or mud bunds are comparatively easy to build, but need more efforts for maintaining them. In addition, fodder grass, hedges, pineapple or other crops can be planted on them.

The bunds can be combined with contour trenches. They help to keep back eroded soil and increase the infiltration of water.

**Living Barriers**

Constructions alone will not be sufficient to prevent soil erosion unless they are combined with plants. Plant roots help to enforce the walls, dikes and trenches, thus preserving them from destruction by heavy rains.

- If constructions are planted on with fodder grass, hedges, pineapple or other suitable crops, they are no longer a loss of space for the farmer and therefore they provide double use.
- When hedges are grown very densely along contour lines, they themselves can become a living barrier without any construction work. On light slopes, they can contribute to terracing and levelling the site over the years, as eroded soil gets accumulated at the hedges.

**Maintenance**

To be effective careful maintenance of the constructions is important. Walls and dikes should be repaired if damaged. Trenches should be cleaned from time to time, especially after heavy rains. The accumulated soil is of good fertility and should be returned to the fields. Newly planted trees, hedges and grass saplings should be irrigated initially, weeded appropriately and the soil around them loosened from time to time.

After heavy rains, the colour of streams and rivulets from an area is a good indicator for the degree of soil erosion at the site and therefore for the effectiveness of the measures.

## 3.6 Water Conservation

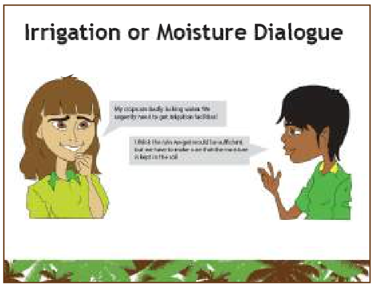
**Introduction**

Scarcity of water for agriculture is a common phenomenon in tropical countries. In some regions it is almost impossible to grow crops without irrigation. Even in areas with large amounts of rainfall in the rainy season, crops may get short of water during dry periods.

Organic farming aims at optimising the use of on-farm resources and at a sustainable use of natural resources. Active water retention, water harvesting and storing of water, therefore, are important topics especially for organic farmers. There are very useful technical publications describing the details of building structures for water harvesting or storing water.

**Lessons to be learnt:**

- The importance of a sustainable use of water which is a very valuable and scarce resource
- The need to preserve moisture in the soil
- Methods for harvesting and storing water
- Understanding the potential and constraints of irrigation in organic farming




**Notes:** *Emphasize that the focus of organic farming is to conserve water, not bringing in more water to the soil (cf. conventional agriculture). Organic agriculture focuses on first improving the retention and infiltration of water into the soil.*

### 3.6.1 Keeping the Water in the Soil

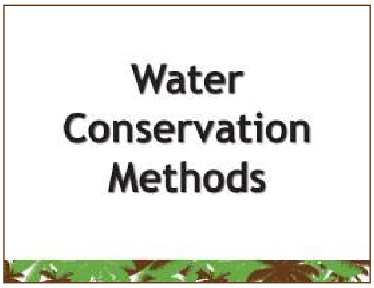
In conventional agriculture, the first idea to overcome shortage of water usually is to install irrigation facilities. Organic farmers know that it is more important to first improve the water retention and the infiltration of water into the soil.

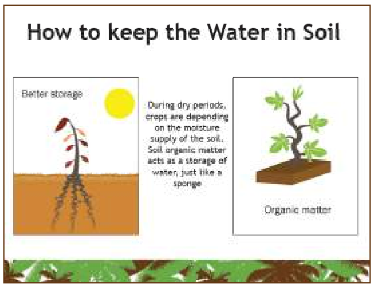
During dry periods, some soils are more and some are less in a position to supply crops with water. The ability of a soil to absorb and store water largely depends on the soil composition and on the content of organic matter. Soils rich in clay can store up to three times more water than sandy soils.
Soil organic matter acts as a storage of water, just like a sponge. Therefore, soils rich in organic matter will preserve their moisture for a longer time. For increasing the content of organic matter, the application of organic manures, compost, mulch or green manure can be used.

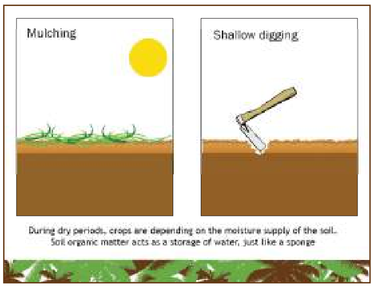
A thin layer of mulch can considerably reduce the evaporation of water from the soil. It shades the soil from direct sunlight and prevents the soil from getting too warm.

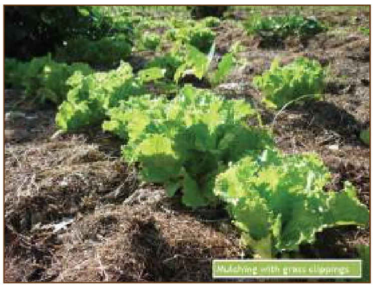
Shallow digging of the dry top soil can help to reduce the drying up of the soil layers beneath (it breaks the capillary vessels). A better retention of water within the soil saves costs on irrigation.

Attention: A green manure or cover crop is not always a suitable way of reducing evaporation from the soil. While a plant cover provides shade and thus reduces sunshine directly reaching the soil, they are themselves evaporating water through their leaves even more efficiently than mere soil. When soil moisture gets scarce, plants competing for water with the main crop can be pruned or cut down, thus serving as mulch.






**Notes**: *Go through the methods of conserving water especially mulching and addition of organic matter. Emphasize that SOM acts like a sponge which holds on to water, and that mulches regulates the temperature of the soil and therefore evaporation. Green cover cropping can also increase the infiltration of water. Point out that soil water storage is also dependent on the soil texture or composition of soil mineral particles, eg. Sandy vs Clayey soils.*

**Activity:**

*Carryout an experience sharing exercise on water scarcity. Ask participants which crops and at which period of time do they face major water shortage problems in their area. Which methods discussed is relevant for retaining moisture within the soil for the dry period in their area? Are there any traditional methods to conserve soil water?*

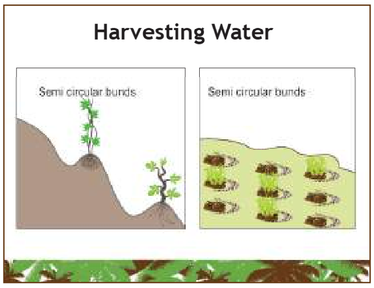
### 3.6.2 Harvesting Water

**Increasing the infiltration**

During strong rains, only a part of the water infiltrates into the soil. A considerable part flows away as surface runoff, thus being lost for the crop. In order to get as much of the available rainwater into the soil, the infiltration of rainwater needs to be increased.

Most important for achieving a high infiltration is to maintain a topsoil with a good soil structure containing many cavities and pores, e.g. from earthworms. Cover crops and mulch application are suitable to create such a favourable top soil structure. Further, they help to slow down the flow of water, thus allowing more time for the infiltration.

On slopes, the infiltration of rainwater can additionally be encouraged through trenches dug along contour lines. Surface runoff is caught in the trench where it can slowly infiltrate into the soil. Semi-circular bunds, e.g. around tree crops, have a similar effect. They collect water, which is flowing down the slope and encourage its infiltration near the root zone of the crop. On level fields, plant pits can be used. The effect of these "water traps" can be increased if a layer of mulch is also integrated.


**Notes:** *Emphasize that slides show additional methods to encourage infiltration of rain water – they are more effective when integrated with a layer of mulch. The most important method to increase infiltration of water is to maintain a topsoil with a good soil structure, and containing many cavities and pores from soil organism activities. Cover crops and mulch not only contribute to good soil structure, they also slow down the flow of water, allowing more time for infiltration to take place.*

Carry out an Experience Sharing exercise on water harvesting. Ask participants which methods they know use rainwater more efficiently? What are their experiences with water harvesting? Which approach might be suitable for their area?

**Water Storage**

Excess water in the rainy season may be made use of during dry periods. There are many possibilities of storing rainwater for irrigation, but most of them are labour intensive or costly.

Storing water in ponds has the advantage that fish may be grown, but water is likely to be lost through infiltration and evaporation. The construction of water tanks may avoid these losses, but needs appropriate construction materials. To decide whether or not to build water storage infrastructure, the benefits should be weighed against the costs, including the loss of arable land.

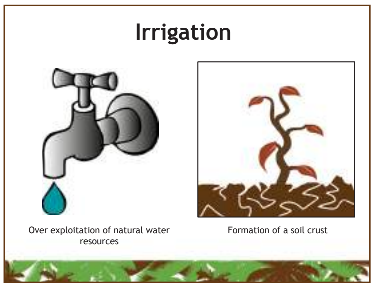
### 3.6.3 Irrigation

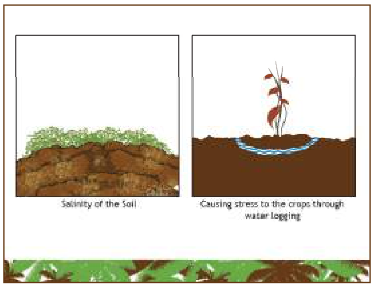
**Potential Harms of Irrigation**

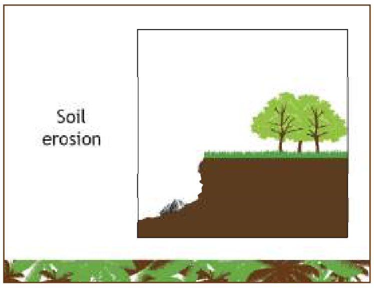
Even in organic agriculture, large areas of land nowadays are under irrigation. While the opportunity for irrigation may help farmers to improve their income and livelihood, there are also some potential negative impacts of irrigated agriculture, which should be considered:

- When the amount of water extracted from a lake, river or groundwater table exceeds its replenishment, depletion of the water resource can be the result, with its well known impact on the eco-system.

- Excessive irrigation in dry or semi-arid areas can cause salinity of the soil, which in the worst case can make the soil unsuitable for agriculture.
- Intense irrigation can cause soil erosion.
- Irrigation by sprinkling or flooding can harm the structure of the topsoil. The crumb structure of the soil may get destroyed and soil particles may accumulate in the pores, resulting in the formation of a hard crust. This will reduce the aeration of the soil and harm the soil organisms.
- Improper irrigation may cause stress to the crops, making them more vulnerable to pests and diseases. Most dry land crops are affected by water logging even if it is of short duration. Application of irrigation water during the hot period of the day can cause a shock to plants.




**Notes**: *This slide can be presented as a discussion or experience sharing exercise by participants*

### What the Pacific Organic Standard Says about Water

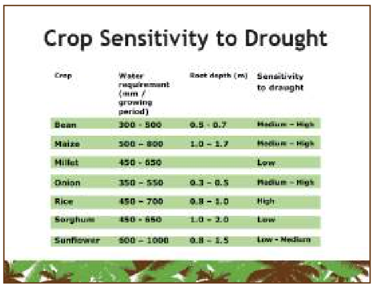
Many islands have very limited water resources, often located as a thin lens under the island. Harvesting of rainwater is an important source of water, though not always a reliable one. Traditions evolved to protect these water resources from overuse and contamination. However, on many islands there is increasing pressure on water resources as a result of higher population, intensification of production, and events such as sea level rise.

The approach of this standard to soil and water conservation is to use traditional practices alongside organic farming methods to conserve and build up soil, maintain water quality and ensure water is efficiently and responsibly used. This approach will help ensure the protection of soil resources, and water quality and quantity at the catchment level. It will also contribute to the protection of sensitive downstream coastal aquatic ecosystems, such as mangroves and coral reefs.

### Crop Selection

The major factors that determine the necessity of irrigation are the selection of crops and an appropriate cropping system. Obviously, not all crops (and not even all varieties of the same crop) require the same amount of water, and not all need water over the same period of time. Some crops are very resistant to drought while others are highly susceptible. Deep rooting crops can extract water from deeper layers of soil and hence they are less sensitive to temporary droughts.

With the help of irrigation, many crops can nowadays be grown outside their typical agro- climatic region. This may cause not only the above mentioned negative impacts, but also some advantages. It may make it possible to cultivate land which would otherwise be unsuitable for agriculture without irrigation. Or the cultivation of sensitive crops can be shifted into areas with less pest or disease pressure.



Crop Sensitivity to Drought

| Crop | Water requirement (mm / growing period) | Root depth (m) | Sensitivity to drought |
|---|---|---|---|
| Bean | 300 - 500 | 0.5 - 0.7 | Medium – High |
| Maize | 500 – 800 | 1.0 – 1.7 | Medium – High |
| Millet | 450 - 650 | | Low |
| Onion | 350 – 550 | 0.3 – 0.5 | Medium – High |
| Rice | 450 – 700 | 0.8 – 1.0 | High |
| Sorghum | 450 - 650 | 1.0 – 2.0 | Low |
| Sunflower | 600 – 1000 | 0.8 – 1.5 | Low - Medium |

**Notes:** *Emphasize that different crops species (and varieties) have different water requirements and therefore we can select for crops that require less water or drought resistant. Crops that are deep rooting can also resist short term droughts.*

*Activity: Discuss in groups the following questions.*

- *Which crops can be grown in the local area under rainfed conditions?*
- *Which crops need irrigation for growth?*
- *What might be appropriate and sustainable irrigation systems in the local conditions?*

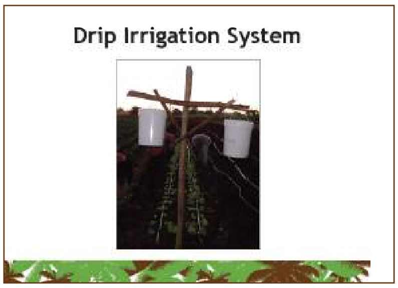
*Each group shall note down the most important findings on cards (maximum 5 cards per question). Each group shall then present their findings with the help of the cards. Points which are already presented by a previous group can be dropped in the presentation. Summarize and conclude.*

**Drip Irrigation Systems**

There are irrigation systems of higher or lower efficiency and with more or less negative impact. If irrigation is necessary, organic farmers should carefully select a system, which is does not overexploit the water source, does not harm the soil and has no negative impact on plant health.

One promising option are drip irrigation systems. From a central tank, water is distributed through thin perforated pipes directly to the single crop plants. There is a continuous but very light flow of water, thus allowing sufficient time to infiltrate in the root zone of the crops. In this way, a minimum of water is lost and the soil is not negatively affected.

The establishment of drip irrigation systems can be quite costly. However, some farmers have developed low cost drip irrigation systems from locally available materials. Whatever irrigation system the farmer chooses, he will reach higher efficiency if it is combined with accompanying measures for improving the soil structure and the water retention of the soil, as described above.




**Notes**: *Emphasize the advantages of drip irrigation as minimum water wastage and leaching of soil nutrients, even distribution of water, greater soil water infiltration and no or less soil erosion Also emphasize that regardless of the irrigation, a higher efficiency in water conservation can only be achieved if combined with measures to improve soil structure and water retention.*

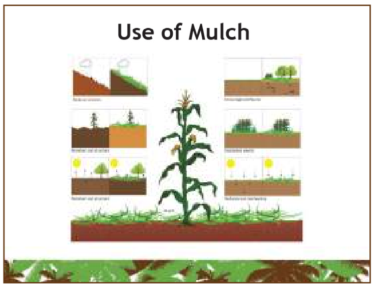
## 3.7 Mulching

**Introduction**
Mulching is the process of covering the topsoil with plant material such as leaves, grass, twigs, crop residues, straw etc. A mulch cover enhances the activity of soil organisms such as earthworms. They help to create a soil structure with plenty of smaller and larger pores through which rainwater can easily infiltrate into the soil, thus reducing surface runoff. As the mulch material decomposes, it increases the content of organic matter in the soil. Soil organic matter helps to create a good soil with stable crumb structure. Thus the soil particles will not be easily carried away by water. Therefore, mulching plays a crucial role in preventing soil erosion.

In some places, materials such as plastic sheets or even stones are used for covering the soil. Here, the term 'mulching' refers only to the use of organic, degradable plant materials.

### 3.6.1 Why to use mulch?

**What is the use of mulching?**
- Protecting the soil from wind and water erosion: soil particles can not be washed or blown away.
- Improving the infiltration of rain and irrigation water by maintaining a good soil structure: no crust is formed, the pores are kept open
- Keeping the soil moist by reducing evaporation: plants need less irrigation or can use the available rain more efficiently in dry areas or seasons
- Feeding and protecting soil organisms: organic mulch material is an excellent food for soil organisms and provides suitable conditions for their growth
- Suppressing weed growth: with a sufficient mulch layer, weeds will find it difficult to grow through it
- Preventing the soil from heating up too much: mulch provides shade to the soil and the retained moisture keeps it cool
- Providing nutrients to the crops: while decomposing, organic mulch material continuously releases its nutrients, thus fertilizing the soil
- Increasing the content of soil organic matter: part of the mulch material will be transformed to humus




**Notes:** Go through all the functions of mulch on the slide and explain them. A group discussion or Q&A exercise can also be useful before presenting Slide.

**Selection of mulch materials**
The kind of material used for mulching will greatly influence its effect. Material which easily decomposes will protect the soil only for a rather short time but will provide nutrients to the crops while decomposing. Hardy materials will decompose more slowly and therefore cover the soil for a longer time. If the decomposition of the mulch material should be accelerated, organic manures such as animal dung may be spread on top of the mulch, thus increasing the nitrogen content.

Where soil erosion is a problem, slowly decomposing mulch material (low nitrogen content, high C/N) will provide a long-term protection compared to quickly decomposing material.

Sources of mulching material can be the following:
- Weeds or cover crops
- Crop residues
- Grass
- Pruning material from trees
- Cuttings from hedges
- Wastes from agricultural processing or from forestry

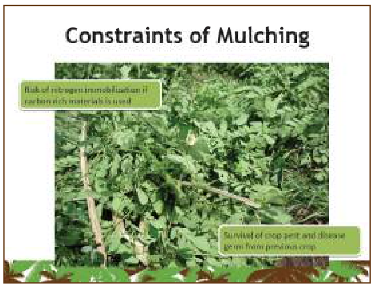
A list of different mulching materials, their nitrogen content and their C/N ration is given in chapter 4 (Composting).


**Notes:** *Emphasize that the kind of mulch material greatly influences its effect. Fast decomposing materials have short residence time, and are more important as a nutrient source, while slow decomposing ones will last longer and are more appropriate for erosion control and moisture/ temperature regulation.*
*Carry out a group work on the use of mulch in local cropping systems. Discuss the following questions and note down the main points:*

- *Which materials are available in the region suitable for mulching?*
- *Which problems in which crops might be overcome with mulching?*
- *Select an example of a crop. When would be the point of time in the cropping cycle ideal for applying mulch?*
- *What problems might occur when using mulch in this crop and how to overcome them?*
- *Present the results of the group discussion and try to pick out common aspects and conclusions.*

### 3.7.2 Constraints of Mulching

While mulching has a lot of advantages, it can also cause problems in specific situations:
- Some organisms can proliferate too much in the moist and protected conditions of the mulch layer. Slugs and snails can multiply very quickly under a mulch layer. Ants or termites which may cause damage to the crops also may find ideal conditions for living.
- When crop residues are used for mulching, in some cases there is an increased risk of sustaining pests and diseases. Damaging organisms such as stem borers may survive in the stalks of crops like cotton, corn or sugar cane. Plant material infected with viral or fungal diseases should not be used if there is a risk that the disease might spread to the next crop. Crop rotation is very important to overcome these risks.
- When carbon rich materials such as straw or stalks are used for mulching, nitrogen from the soil may be used by microorganisms for decomposing the material. Thus, nitrogen may be temporary not available for plant growth
- The major constraint for mulching usually is the availability of organic material. Its production or collection usually involves labour and may compete with the production of crops.

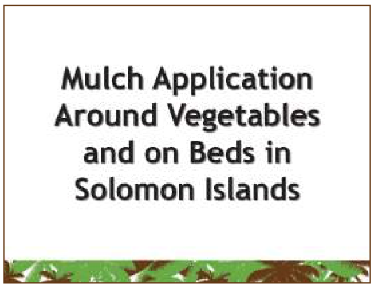



**Notes:** *Go through the various potential problems and explain them. Can be an experience sharing exercise.*

### 3.7.3 Application of mulch

If possible, the mulch should be applied before or at the onset of the rainy season, as then the soil is most vulnerable. If the layer of mulch is not too thick, seeds or seedlings can be directly sown or planted in between the mulching material. On vegetable plots it is best to apply mulch only after the young plants have become somewhat hardier, as they may be harmed by the products of decomposition from fresh mulch material.

If mulch is applied prior to sowing or planting, the mulch layer should not be too thick in order to allow seedlings to penetrate it. Mulch can also be applied in established crops, best directly after digging the soil. It can be applied between the rows, directly around single plants (especially for tree crops) or evenly spread on the field.




**Notes:** *Emphasize appropriate timing of application - just after rain and for vegetables only apply after seedlings have become established. Do not plant seedlings onto fresh mulch. Mulch can be applied around established crops or evenly spread in the field or on the bed.*

# 4 Plant Nutrition

## 4.1 Balanced Nutrition

**Introduction**

The approach to plant nutrition in organic agriculture is fundamentally different from the practices of conventional agriculture. While conventional agriculture aims at providing direct nutrition to the plants by using mostly easily soluble mineral fertilizers, organic farming feeds the plants indirectly by feeding the soil organisms with organic matter.

**Lessons to be learnt:**

- Chemical fertilisation bears many risks and offers many long term disadvantages.
- Plant nutrition, in organic farming, is based on organic fertilisation. Nutrient supply is ensured by sound management of the organic matter in the soil.
- Large quantities of unused organic material can be found on many farms. This material could be used for mulching or composting.
- The best use of the nutrients is made, when they are systematically recycled, with losses being minimised and inputs being optimised.

### 4.1.1 Plant Nutrition and Plant Health

Synthetic or mineral fertilizers –advantages and disadvantages

The use of mineral fertilizers can lead to an impressive increase in yields. Mineral fertilizers offer large amounts of nutrients to the plants in an easily available form. This fact makes the use of nitrogen fertilizers especially tempting. But, they also have their limitations. About half of the applied nitrogen fertilizer usually gets lost through runoff, leaching, and volatilisation. Under unfavourable conditions (strong rainfalls, long dry periods, eroded soils or soils with a low level of organic matter) efficiency of nitrogen fertilizers may be even lower. As a result of runoff and leaching, for example, ground and drinking water may become polluted. Besides being economically and ecologically questionable, mineral fertilizers can also have a negative impact on plant health.


**Activity:**

*Review of level of knowledge of trainees by having the trainees share their experiences on the use of chemical and organic fertilizers. Collate positive and negative experiences.*

**Plant nutrition and plant health are closely linked**

Chemical fertilisation has the following negative impact on soil and plant health:

- Oversupply of nitrogen leads to a softening of the plants' tissues resulting in plants which are more sensitive to diseases and pests.
- It reduces the colonisation of plant roots with the beneficial root fungus mycorrhiza.
- High nitrogen fertilisation stops symbiotic nitrogen fixation by rhizobia.
- The exclusive use of NPK-fertilizers leads to a depletion of micro-nutrients in the soil as these are not replaced by these fertilizers. This results in a decline of yields and a reduction in plant and also animal health.

- Decomposition of soil organic matter is enhanced which leads to a degradation of the soil structure and a higher vulnerability to drought.

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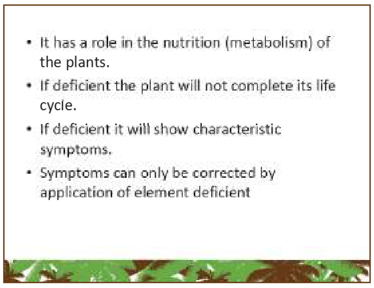
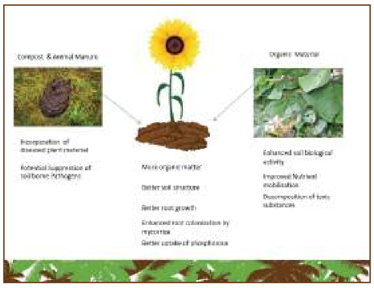
Organic fertilisation feeds the soil with organic matter, which has the following positive effects:

- The supply of nutrients is more balanced which helps to keep plants healthy
- Soil biological activity is enhanced which improves nutrient mobilisation from organic and mineral sources and the decomposition of toxic substances.
- Mycorrhizal colonisation is enhanced which improves the supply of phosphorus.
- Compost has the potential to suppress soil borne pathogens when applied to the soil.
- Due to better soil structure root growth is enhanced.
- Humus improves the exchange capacity for nutrients and avoids soil acidity.




### 4.1.2 Nutrient Supply by Managing Soil Organic Matter

Plant nutrition in organic farming focuses on sound management of the soil organic matter, which is the main nutrient pool for the plants (beside nitrogen from symbiotic fixation).
The organic farmer uses three approaches to ensure a continuous nutrient supply from soil organic matter:

- Varying the input of organic material: The amount and the quality of organic matter, which is supplied to the soil, influences the content of organic matter in the soil. A regular supply of organic matter provides the best conditions for a balanced plant nutrition. Estimates say that in humid tropical climates 8.5 tonnes, in subhumid climate 4 tonnes, and in semiarid 2 t of biomass is needed per hectare and per year to maintain soil carbon levels of 2, 1 and 0.5 % respectively.
- Suitable crop rotation: The crops being grown determine the amount of nutrients the soil needs in order to maintain its fertility. The farmer arranges the rotation in such a way that demand and supply of nutrients (e.g. nitrogen from legumes, nutrients from a green manure crop) fit in the best possible way.
- Influencing nutrient mobilisation: Soil cultivation improves aeration of the soil and enhances the activity of soil micro-organisms.

The farmer can influence the nutrient release from humus by cultivating the soil at the appropriate time, to the appropriate depth, and with the appropriate intensity and frequency. The activity of soil micro-organisms is very important for ensuring a sufficient nutrient supply to the plant. If the micro-organisms find suitable conditions for their growth, they can be very efficient in dissolving nutrients and making them available to plants. Therefore, in organic agriculture it is important to encourage plant health through creating a biologically active soil. Even if soil tests find low rates of available nutrient contents, organically managed soils may still be in a position to provide sufficient nutrients to the plants.


**Activity**

*Motivation: How do you ensure continuous nutrient supply?*

*Ask the participants: How do you ensure the nutrient supply for your crops? Write keywords on cards and fix them onto the board. Come back to the answers at a later stage.*

**Discussion**: *How can organic matter for plant nutrition be managed?*

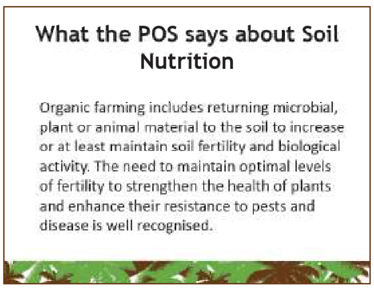
*Use a typical crop rotation from your area. Discuss with the participants how nutrient may be supplied by managing organic matter.*

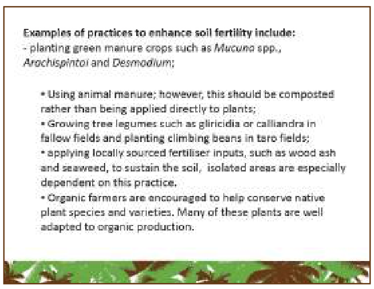
**What does the Pacific Organic Standard say on plant nutrition?**

The Pacific Organic Standard defines how plant nutrition should be approached in organic agriculture and which materials are allowed, which are allowed with restrictions and which are prohibited. Organic farming includes returning microbial, plant or animal material to the soil to increase or at least maintain soil fertility and biological activity. The need to maintain optimal levels of fertility to strengthen the health of plants and enhance their resistance to pests and disease is well recognised.

Examples of practices to enhance soil fertility include:

- planting green manure crops such as Mucuna spp., Arachis pintoi and Desmodium;
- using animal manure; however, this should be composted rather than being applied directly to plants;
- growing tree legumes such as gliricidia or calliandra in fallow fields and planting climbing beans in taro fields;
- applying locally sourced fertiliser inputs, such as wood ash and seaweed, to sustain the soil – isolated areas are especially dependent on this practice.
- Organic farmers are encouraged to help conserve native plant species and varieties. Many of these plants are well adapted to organic production.




**Motivation:** *Which nutrients do you know?*

*Ask the participants to name the nutrients plants need in order to grow normally. Ask them which functions the different nutrients have and what the symptoms of their deficiencies look like.*

**The Pacific Organic Standard main standards on Plant Nutrition:**
4 25

- Material of microbial, plant or animal origin shall form the basis of the fertility programme.
- Nutrients and fertility products shall be applied in a way that protects the soil, water and biodiversity. Brought-in manures shall be composted and only applied at rates that do not cause negative environmental impacts.
- Manures containing human excrement (faeces and urine) are prohibited for use on crops for human consumption.
- Mineral fertilisers shall only be used in a programme to address long-term soil fertility needs together with other techniques such as addition of organic matter, green manures, rotations and nitrogenfixing plants, e.g. legumes.
- Fertilisers of mineral origin shall be applied in the form in which they naturally exist and are extracted. They shall not be rendered more soluble by chemical treatment, other than the addition of water.

### 4.1.3 The Main Plant Nutrients and how to Ensure their Supply

**Macro- and micro-nutrients**
Plants require a number of nutrients for healthy growth. The nutrients are generally grouped into macro-nutrients which are required in considerable amounts (such as nitrogen, phosphorus, potassium, calcium etc.) and micro-nutrients required only in tiny amounts, but which are nevertheless important (such as zinc, manganese, iron etc.). Organic manures usually contain all required nutrients in sufficient amounts and in a balanced composition. Therefore, deficiency of single nutrients can in most cases be avoided by applying compost, animal manure and other organic sources.

**Nitrogen**
One of the most important nutrients limiting plant growth is the element nitrogen (chemical sign: N). Nitrogen is needed to build chlorophyll, which gives the leaves their green colour and enables the plants to gain energy for nutrient uptake and growth. It is also a component of amino acids, a building block of proteins. Nitrogen can be easily lost from the soil through leaching (washed out) or volatilisation (it "evaporates"), if not bound to organic matter.

An important source of nitrogen is the fixation of the element from the air through microbes (rhizobia) associated with certain plant species (especially legumes). Because of their potential to supply nitrogen for other crops, legumes play an important role in organic farming, be it in the form of pulses, cover crops, green manures, hedges or trees.

To attain its highest level of nitrogen fixing ability, the legume crop needs good growing conditions.

**How can a sufficient supply of nitrogen be ensured?**

- Hoeing improves aeration of the soil and encourages the activity of the soil micro-organisms. The result is a mobilisation of nitrogen from the organic matter.
- Irrigation restores microbial activity in dry soils.
- The incorporation of easily decomposable organic material into the soil can cause a large amount of bound nitrogen to be released into the soil.

**Phosphorus**
Phosphorus plays an essential role in the metabolism of plants in all the processes where transport of energy occurs.

Phosphorus improves root growth, and encourages flowering and ripening of the seeds. It is also essential in livestock nutrition for bone growth and for the metabolism. Deficiency in phosphorus hinders plant growth resulting in poor root growth and delay in flowering and ripening. Plants appear stiff, and their older leaves first take on a dark green colour, and then a reddish one before dying Most chemical soils are poor in phosphates. Phosphates available to the plant usually are bound onto soil organic matter or are incorporated into soil micro-organisms, while the soil solution contains only small amounts of phosphorus. Once phosphate is adsorbed onto soil particles, only very small quantities can be dissolved, becoming available for plants. The colonisation of plant roots with mycorrhiza, however, can improve the phosphorus uptake of plants .

**How can the availability of phosphorus be improved?**

- The mobility of phosphorus is best at a soil pH of 6.0 to 6.5.
- Rock phosphate is ideally given in addition to elementary sulphur and the bacteria Thiobacillus. It is best mixed into compost or animal manure to avoid being fixated by mineral particles and thus becoming almost unavailable to plants.
- Encourage root growth and thus improve phosphorus uptake. Root growth is enhanced by raising the level of soil organic matter by, for example, covering the soil with mulch (in dry climate).
- Grow deep rooting plants
- Humidity in the soil is essential in order to make phosphorus available to plants.
- Preferably grow legumes that are adapted to the local conditions.
- Improve the growing conditions for mycorrhiza.

**Potassium**

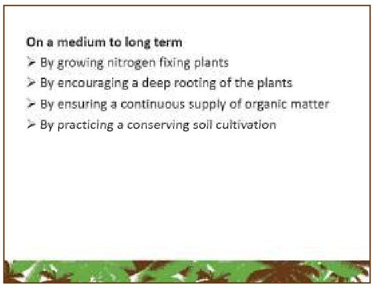
Potassium is necessary for the synthesis of amino acids and is involved in the process of photosynthesis and in the plants ability to develop resistance to diseases. Good supply of potassium during growth also improves the storing capacity of what? Plants ideally contain potassium and nitrogen in a 1:1 ratio. Potassium is also essential to animals. It is usually supplied in sufficient amounts by the fodder plants.

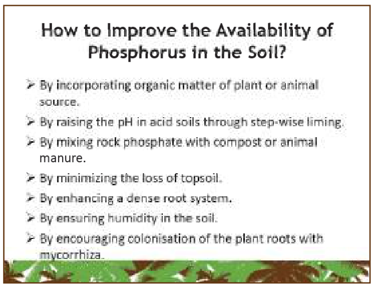
The majority of potassium in the soil is incorporated in mineral particles and thus not readily available. Some potassium is adsorbed onto the surface of mineral particles and is more easily available to the plants. Clay and silt soils are rich in potassium.

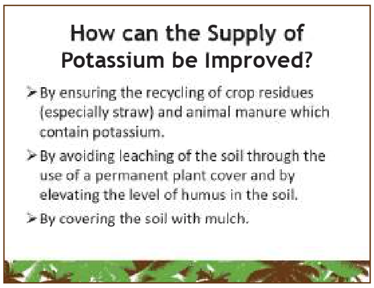
As potassium is needed most in new tissues and is highly mobile in plants, deficiency results in a premature death of older plant parts first. Soils low in nitrogen and potassium result in stunted plants with small leaves and small and few fruits. In general, potassium supply can be satisfied through weathering of the mineral underground. The need for potassium is strongly linked to the type of crops being cultivated. Tuber crops are especially sensitive to insufficient supply of potassium.

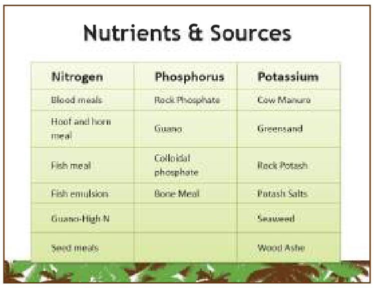
**How can the supply of potassium be improved?**

- By ensuring the recycling of crop residues (especially straw) and animal manure which contain potassium.
- By avoiding leaching of the soil through the use of a permanent plant cover and by elevating the level of humus in the soil.
- By covering the soil with mulch.



Nutrients & Sources

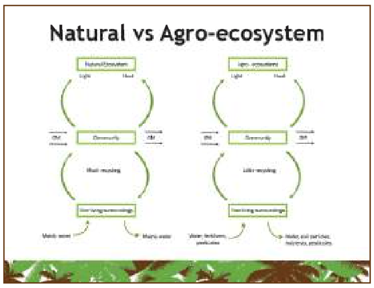
| Nitrogen | Phosphorus | Potassium |
|---|---|---|
| Blood meals | Rock Phosphate | Cow Manure |
| Hoof and horn meal | Guano | Greensand |
| Fish meal | Colloidal phosphate | Rock Potash |
| Fish emulsion | Bone Meal | Potash Salts |
| Guano-High N | | Seaweed |
| Seed meals | | Wood Ashe |

**Group work:** *What can organic nutrient management look like?*
*Ask the participants to discuss in groups how nutrient supply in locally grown crops can be ensured. Select 3 or 4 crops with different needs (high and low, general and special, short and long term) and ask the groups to develop strategies for ensuring nutrient supply for these crops. Discuss the results in the plenum.*

### 4.1.4 Nutrient Cycles – Optimising Nutrient Management in the Farm

**Nutrient recycling in nature**

In nature, nutrient recycling results from the close link of above ground and underground life. Plants generally build more biomass in the roots than in the plant parts above ground. Roots are rapidly and constantly decomposed and are an important source of food for the soil organisms. Through their work and the nutrient release that follows their death, the soil organisms are recycled into food for new plant growth. When the plants die, the recycled plant matter is again recycled and feeds the soil organisms, thus closing the cycle and slowly improving soil fertility.




**Motivation:** *How does nature manage nutrients?*
*Discuss with the participants: How do the plants in natural ecosystems manage to grow so well? Where do they take the nutrients from? Draw the elements of the natural ecosystem and nutrient flows on the board as the answers come from the participants.*

**Group work:** *How can nutrient recycling be improved?*
*Discuss the following questions with the participants or in groups: What are the differences in nutrient cycling in the farm as compared to nature? Draw nutrient flows on the board for natural and farm systems, or ask participants to do so. Compare the two systems. Ask the participant: How can we optimise nutrient cycling in our farms?*

**Nutrient recycling on the farm**

In contrast to nature, in agriculture, the farmer fertilises the fields to harvest more products. If a farmer does not want to depend on external inputs to a great extent, he must achieve a more efficient use of nutrients, i.e. practice a better nutrient management in the farm. This results in the idea that nutrients should be made available from within the farm organism. This idea leads to the concept of closed nutrient cycles.

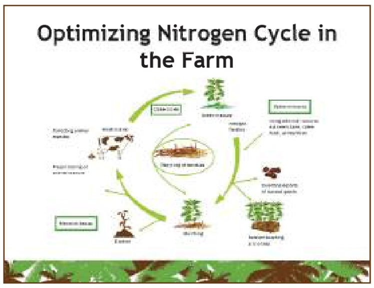
**How to optimise nutrient management in the farm**

There are three principles of how to optimise nutrient management in the farm.

**Principle 1: Minimise losses**

- High losses of nutrients result from leaching which is due to a low exchange capacity of the soil. Leaching of nutrients can be reduced by raising the content of soil organic matter.
- If dung or compost is kept in water-logged conditions or is exposed to the sun, high losses of nitrogen may occur. Washout of soluble nutrients from stored dung and compost can be prevented by proper sheltering and storage. Dung or compost are often stored in pits where water collects during the rainy season. Nitrogen gets lost through leaching (if the bottom of the pit is permeable) or through volatilisation (if the water gets logged in the pit).
- Soil erosion robs the soil of its most fertile part: the top soil, which contains the majority of nutrients and organic material. This can be prevented by maintaining a dense plant cover and with constructions such as terracing.
- Avoid burning of biomass.
- To prevent losses of nitrogen fixed by leguminous plants, practice mixed cropping or crop rotation with species of high nitrogen demand.
- Nutrient release from soil organic matter when there are no plants present or able to take it up, leads to considerable nutrient losses.
- Nitrogen is easily lost by volatilisation (in the form of ammonium). The highest losses occur during the first two hours after manure is applied to the field. Therefore, farmyard manure should be applied in the evening as cool night temperatures and the higher humidity reduce the losses. Farm yard manure and slurry should be brought out in quantities which the plants can take up in a short time. It should be worked into the top soil soon after application.

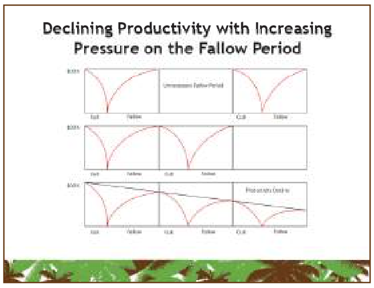
However, export of nutrients with market goods and losses through leaching and volatilisation and erosion cannot be avoided completely.




**Group work:**

*How much money can we save by minimising losses?*

*Ask the participants to discuss in groups how much money can be saved on manures by minimising the nitrogen losses?*
*Collect the answers in the plenum.*



**Principle 2: Closed nutrient cycles**

- Maximise recycling of plant residues, by-products, dung and farm wastes. Every leaf, every twig, every husk, every peel, every root, every excrement are valuable sources of various nutrients and should be returned to the crops.
- Deep-rooting trees and shrubs planted in spare corners collect leached nutrients and can supply a great deal of mulch material, if intense pruning is done.
- Compost can be made out of almost any organic material from the farm. It is not only a means of recycling nutrients but also increases the "exchange capacity" (that is, the capacity to store nutrients) of the soil.
- Mulching is a simple way of recycling nutrients. It helps to keep moisture in the soil and feeds soil organisms.
- Ashes of stoves are a highly concentrated mixture of nutrients like potassium, calcium, and magnesium and may be applied to fields or mixed into the compost.
- Different plants have different requirements for nutrients; mixed cropping and crop rotations help to optimise the use of nutrients in the soil.

Recycled or saved nutrients also mean saved money!

**Principle 3: Optimise inputs**

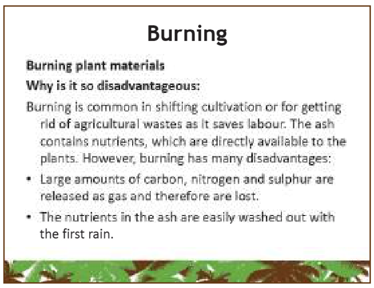
- Introduce external organic "wastes", if available. Several cheap organic wastes like coffee husks, sugarcane trash, rice husks, cotton stalks etc. may be available in the region and could be used to prepare compost.
- Minerals like rock phosphate or dolomite help to supply scarce nutrients, and are less prone to leaching and less harmful to the soil than concentrates.
- Nitrogen fixing plants provide free-of-cost nitrogen. They can be planted as cover crops, food grains, hedges or trees, and also provide firewood, mulch and fodder.

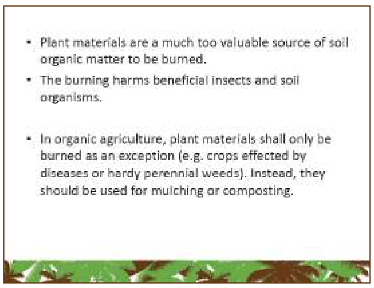
**Burning plant materials – why is it so disadvantageous?**

Burning is common in shifting cultivation or for getting rid of agricultural wastes as it saves labour. The ash contains nutrients, which are directly available to the plants. However, burning has many disadvantages:

- Large amounts of carbon, nitrogen and sulphur are released as gas and therefore are lost.
- The nutrients in the ash are easily washed out with the first rain.
- Plant materials are a much too valuable source of soil organic matter to be burned.
- The burning harms beneficial insects and soil organisms.

In organic agriculture, plant materials shall only be burned as an exception (e.g. crops effected by diseases or hardy perennial weeds). Instead, they should be used for mulching or composting.




**Field walk:** *Where are nutrients being lost?*
*Invite the participants for a walk, on a transect, through a farm. Find, together with them, answers to the following questions (examples are given a field work in a PICT):*

- Where are nutrients being lost? (e.g. unused pig dung due to social inhibitions as pigs are considered "dirty", dung heaps without shelter, leaching of nutrients from compost heaps, crops with soil erosion, etc.)
- Which sources of nutrients can be found? (e.g. coffee husks, coconut husks, twigs, leaves, grass, nitrogen fixing hedges, legumes as cover crops, mud from a dry pond, ashes from stoves, kitchen wastes etc.)
- How can nutrients be recycled? (e.g. kitchen waste compost, compost of collected organic materials and dung, ash from wood burning stoves mixed into the compost, mulching with twigs of trees or other organic material, mixed cropping and crop rotations, etc.).

## 4.2 Associating Crops and Crop Rotation

**Introduction**
In many traditional agricultural systems a diversity of crops in time or space can be found. There are different reasons, why farmers do rotate or associate crops. To many farmers though the underlining connection is not known and thus these practices potential not exploited.

**Lessons learnt:**
- Different species have different nutrient needs and occupy different areas in the soil with their roots.
- Associating crops offers many benefits compared to mono-cropping, and there are several possibilities to associate crops.
- The appropriate rotation of crops is an essential part of preventing soil borne pests and diseases from damaging plants, controlling weeds and optimizing nutrient management.

### 4.2.1 Crop Diversity for Nutrient Management

**Different plant species have different root systems**
Some plants generally grow deep reaching tap roots while others have rather flat root systems. Besides forming their typical root systems, they also respond to the characteristics of the soil. Depending on where water is available in the soil, where nutrients are released from organic matter or fertilizers, whether stones or compressed soil layers hinder root growth, the roots will show a different pattern typical of the respective condition. The way the plant roots occupy the soil can also be influenced by the farmer to a certain extent (e.g. through a specific association of species, through cultural practices such as tilling, ridging and mounding).

To be able to decide which plants are best grown in association with each other and which sequence of crops is the most appropriate, it is necessary to know how different crops explore the soil with their roots.

**Different needs of different crops**
Different plant species, or even varieties, have different needs.
The following basic needs can be distinguished: Need for nutrients, for water, for light, for temperature and for air. Different plants require different total amounts of nutrients to produce a good yield. Nutrient demands may also change from one stage of development to the next. Some species have an especially high demand for specific nutrients. While some plants like full sunlight, others prefer half-light and again others grow best in the shade. Some plants are nearly indifferent to light conditions, though all plants need light. If light conditions are not ideal, the plant will be stressed and will not grow properly. The plant's need for light is in many cases linked to plant nutrition.

*Plants growing in poor soils prefer to be shaded more than plants growing under ideal soil conditions.*

General conclusions for associating crops:

- Root competition should be minimal (especially during the phase with the highest demand of nutrients).
- The roots should occupy the soil volume in the best possible way.

Specific conclusions for mixed cropping:

- Crops with strong rooting should be associated or alternated with crops with a weak root growth.
- Plant distances should be such that nutrient competition between plants can be minimized.
- Crops with deep rooting are best grown together with species with shallow root growth.
- Perennial plants can be well associated with seasonal plants.
- Leguminous crops may be grown in association with crops or before crops which have a high demand for nitrogen.
- Species grown in association should have different growth habits and different needs for light.
- In associated crops, the periods of most active nutrient uptake should not coincide.


**Demonstration:** *Which crops have which root systems?*
*Ask the participants to draw the root systems of some locally grown crops on a sheet of paper or on a board. If possible, dig out some crops with the entire root system and expose them in the classroom.*

To show how different species root if grown in association, a profile (a vertical section) can be dug out. Discuss with the participants what consequences different rooting has on plant nutrition and plant growth and what possibilities the farmer has to make the best use of it. Besides knowing the shape of the root system of the different crops, it is also important to know through which parts of the roots the plants absorb water and nutrients, where the roots grow, and which factors may influence depth, intensity, and width of root growth.

Exercise: What are the needs of plants?
Discuss with the participants, which basic needs the plants have and write these needs on the board. Ask the participants to form small groups and to characterise the locally grown crops. What specific needs do these crops have? Try to draw some general conclusions for mixed cropping and crop rotation.

### 4.2.2 Associating Crops

Associating crops is defined as the growing of two or more crops in the same field at the same time. If suitable crops are combined, mixed cultivation can lead to a higher total yield per area.

This is basically due to the more efficient use of space (over and under ground) and because of beneficial interactions between the mixed crops.

Further benefits of associating crops:

- Diversification: a greater diversity of crops can be grown in the fields. This helps the farmer to not become dependent on only one crop, and ideally to achieve a continuous supply of products from the field.
- Reduction of pest and disease attack: The deterring or attracting effects of some plant species helps to prevent pest attack on other crops. The diversity increases disease resistance and makes it more difficult for pests and germs to find a certain species.
- Improving soil fertility management: Mixed cropping with legumes, like beans, improves nitrogen supply of the non-legumes in a later term.
- Weed control: Ideally, associated crops cover the soil faster and grow more densely and thus suppress weeds more efficiently.

There are different possibilities to associate crops:

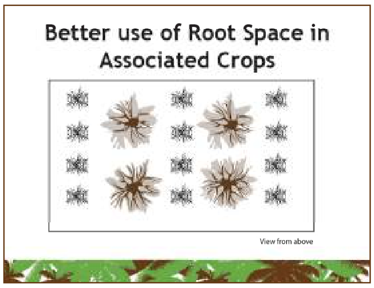
- Mixed cropping: Two or more crops are sown at the same time sharing the same space, or they are sown at the same time in neighbouring rows. One crop may also be sown as a border crop.
- Cropping in lines: Two or more crops are sown at the same time in neighbouring lines with wide spacing.
- Graduate cropping: A second crop is being sown before the harvest of the first one.
- Combined cultivation of trees and annual crops.

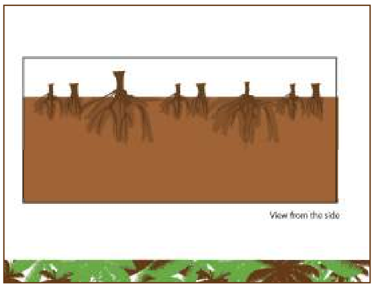
According to farmers' experience, there are 3 types of interactions in associated crops:

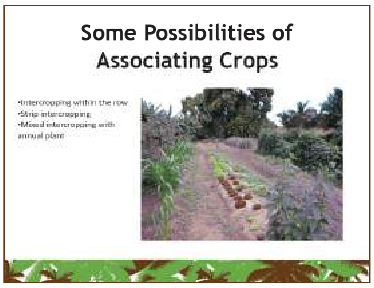
- Positive interaction: when the crops mutually promote the development of the other. Examples: radish with chard, potato with green beans.
- Negative interaction: when the combination mutually hinders the development of the other plants, resulting in deficient growth or pest and disease attack. Examples: lettuce with parsley, leeks or cabbage.
- Neutral interaction: indifferent reaction between the vegetable crops: Examples: lettuce with carrot, carrot with cabbages, tomato with green beans.

Examples of associating crops:

- According to the edible parts of the plants: leafy vegetables are combined with root vegetables. For example: lettuce with carrot
- According to the plant families: legumes (nitrogen fixers), with cabbages or solanaceas, (high nitrogen users).
- According to the crop duration: vegetables of rapid growth with others of slower growth. For example: radish with cabbage or pumpkin with lettuce or beets.



### 4.2.3 Crop Rotation

**Problems of mono-cropping**
If the same crop is grown for several consecutive years on the same land, usually yields will decline (or more fertilizer will be needed to reach the same yield) and health problems will arise in the crop or field. The extraction of a specific combination of nutrients leads to an impoverishment of the soil. Soil borne crop specific diseases and pests may develop, as well. Weeds, which are well adapted to the conditions offered by the crop (e.g. good light conditions, typical soil cultivation), may spread and require increased efforts to be controlled.

**Benefits of crop rotation**
When different crops are grown in sequence in the same field, each crop uses the soil in its own particular way and thus reduces the risk of nutrient depletion. A well-balanced alternation of crop species also prevents the development of soil-borne diseases. Therefore, cultivation pauses must be respected for the same crop and among crops of the same plant family.

To avoid the development of persistent weeds, plants with a slow youth growth should be grown after crops with a good weed suppression. A change between deep and flat rooting crops and between crops building high stalks and species producing a great leaf mass which covers the soil quickly also helps to suppress the weeds.

Crop rotation is also an important instrument to maintain soil organic matter. Ideally, crop rotation should maintain, or even raise, the content of soil organic matter.

Lessons to be learnt:
- In organic farming, organic manures play an important role in plant nutrition.
- The use of farmyard manure is often neglected. Storage and application of farmyard manure can in many cases be improved.
- The use of mineral fertilizers is restricted in organic agriculture.

**Motivation:** *What nutrient sources are being used?*
*Ask the participants, which organic manures are locally used. What other sources may be available? Which are underexploited? Why? Discuss the advantages and disadvantages of the different sources.*




**Brainstorm:** *Experiences with organic and chemical fertilizers*
*Ask participants to discuss why they made their choices to use inorganic fertilizer or organic fertilizer.*

### 4.3.2 Appropriate Treatment of Farmyard Manure

Depending on whether animals are kept in stables or not (part or full time), farmyard manure consists of animal excreta and bedding material (usually straw or grass). In many places, farmyard manure is dried and burned for cooking or is just not recognised as a source of nutrients and organic matter. By drying or burning farmyard manure, large quantities of organic matter and nutrients are lost from agricultural systems.
Farmyard manure is an extremely valuable organic manure. Some characteristics and effects of farmyard manure:

- It contains large amounts of nutrients.
- Only part of the nitrogen content of manure is directly available to plants, while the remaining
- part is released as the manure decomposes. The nitrogen in animal urine is available in the short term.
- When dung and urine are mixed, they form a well-balanced source of nutrients for plants.
- The availability of phosphorus and potassium from farmyard manure is similar to that from chemical fertilizers. Chicken manure is rich in phosphorus.
- Organic manures contribute to the build up of soil organic matter and thus improve soil fertility.

**How to store farmyard manure**
Farmyard manure should ideally be collected and stored for a while so as to obtain a manure of high quality. The best result is achieved if the farmyard manure is composted. Manure stored under anaerobic conditions (e.g. in water logged pits) is of inferior quality.

Collection of farmyard manure is easiest if the animals are kept in stables. For storage, the manure should be mixed with dry plant material (straw, grass, crop residues, leaves etc.) to absorb the liquid. Straw that has been cut or mashed by spreading it out on a roadside can absorb more water than long straw.

Usually, the manure is stored next to the stable, either in heaps or in pits. It can also be stored within the stable as a bedding, provided it is covered with fresh bedding material.

In any case, the farmyard manure should be protected from sun, wind and rain. Water logging as well as drying out should be avoided, so as to avoid nutrient losses. The storage site should be impermeable and have a slight slope. Ideally, a trench collects the liquid from the manure heap and the urine from the stable. A dam around the heap prevents uncontrolled in and outflow of urine and water.

Storing manure in pits is particularly suitable for dry areas and dry seasons. Storage in pits reduces the risk of drying out and the need to water the pile. However, there is greater risk of waterlogging and more effort is required as the pit needs to be dug out. For this method a 90 cm deep pit is dug with a slight slope at the bottom. The bottom is compressed and then first covered with straw. The pit is filled with layers about 30 cm thick and each layer compressed and covered with a thin layer of earth. The pit is filled up until it stands about 30 cm above ground and then covered with 10 cm of soil.

Humidity in the manure heap must be controlled. To avoid nutrient losses, it should neither be too wet nor too dry.

- If white fungus appears (threads and white spots), the manure is too dry and should be dampened with water or urine.

- A yellow-green colour and/or bad smell are signs that the manure is too wet and not sufficiently aerated.
- If the manure shows a brown to black colour throughout the heap, the conditions are ideal.


**Demonstration:** Look at the manure
If available, bring samples of manure to the classroom and let the participants inspect the quality of the samples. If possible, visit a local farmer, who practices appropriate treatment of manure. With the farmer and the group discuss the advantages, constraints, potential and possible alternatives for farmyard manure.

**Biogas Slurry**
Biogas production makes use of the potential of farmyard slurry to produce methane gas which is a cheap and environmentally sound source of energy. Biogas production is carried out in methane digesters, which exclude oxygen and allow aerobic fermentation. The liquid waste can then be added to the compost or applied directly to the crops.

Through the process part of the carbon is transformed to biogas and therefore lost as organic matter. However, the installation of a biogas system can be costly and management can be rather labour intensive.

### 4.3.3 Commercial Organic Manures

Where nutrient recycling is practiced systematically, few organic manures from outside are needed. They should be used as a supplement to nutrient recycling and not as an alternative to it. There are a number of valuable sources of nutrients and organic matter that can be used, especially if they are available at low costs. Commercial organic manures are mostly by-products from agro-processing or food industry waste. Commercial manures should be carefully selected depending on their nutrient and toxic substance contents and their price.

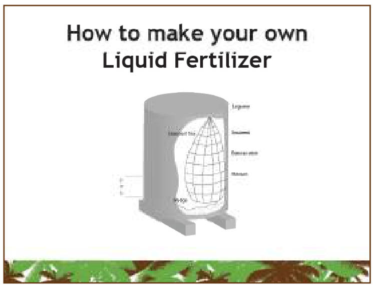
These manures are best mixed with other organic material from the farm (including farmyard manure) and composted, or used for biogas production so as to become a balanced fertiliser before being applied to the fields.

The use of costly fertilizers may in general only be justified for crops with a high and safe revenue.

### 4.3.4 Liquid Organic Manures

The plant can absorb nutrients about 20 times faster through the leaves than if they are applied through the soil. Therefore, liquid manures are helpful to overcome temporary nutrient shortages. In organic farming they are mainly used to stimulate growth during the growing season, nutrient uptake through the roots is hindered.

Liquid manure is made from farmyard manure or plant material (plant teas or slurries). Nutrient rich material is soaked in water for several days or weeks to undergo fermentation. Frequent stirring encourages microbial activity. The resulting liquid can either be used as a foliar fertilizer or be applied to the soil.




**Experience sharing:**
Ask the participants if they produce and apply liquid manures. Invite them to explain the procedure and to share their experience. You can also demonstrate how to prepare liquid manure using a local formula.

### 4.3.5 Mineral Fertilizers

The mineral fertilizers, which are allowed in organic agriculture, are based on ground natural rock. As mentioned in chapter 4.1, they may only be used as a supplement to organic manures. If they contain easily soluble nutrients, they can disturb soil life and result in an unbalanced plant nutrition. In some cases, mineral fertilizers are ecologically questionable as their collection and transport is energy consuming and in some cases natural habitats are being destroyed.

Group work: Which mineral fertilizers are allowed?
Ask the participants to name the mineral fertilizers, which are used in the region and note them on the board. Distribute copies of the Appendix 1 of the IFOAM Basic Standards and ask the participants to find out which of these fertilizers are allowed in organic agriculture and which are not. Discuss why certain fertilizers are not allowed, and why others are restricted.

Try to allocate all the allowed mineral fertilizers according to their effect on plant nutrition to one of the following groups: nitrogen rich fertilizers, phosphorus rich fertilizers, potassium rich fertilizers, fertilizers containing multiple nutrients, fertilizers with liming effect, fertilizers rich in micronutrients.

### 4.3.6 Microbial Fertilizers

Some people and companies recommend the application of microorganisms to the soil to enhance decomposition processes and control diseases. The microorganisms are usually sold as ready-to-use products for fertilization and plant protection.

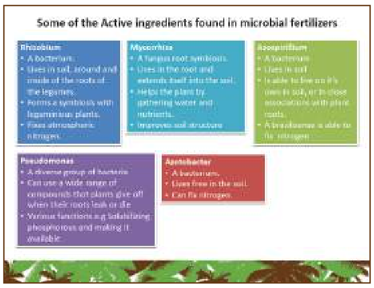
These microbial fertilizers mostly consist of organic material and some source of sugar or starch, which are fermented together with specific species of microorganisms. The products are living organisms and need to be applied cautiously. They should not be used when expired, since the organisms may be dead.

Although some research has been done on the use of microorganisms and positive effects may be proven, there is still little experience with such products.

To find out the effect of a certain product, it is recommended to test them in small scale and compare with an untreated plot. Remember though: microbial fertilizers cannot substitute an appropriate humus management in the farm. Most of the bacteria and fungi present in the purchased products are generally present in soil. Microbial inocula, therefore, enhance the presence of the specified organisms.

Some microbes add nutrients to the soil through mineralisation. Others add nitrogen by fixing it from the atmosphere. These include Rhizobium and Azotobacter. Other microbes, such as Mycorrhizal fungi, help to supply plants with phosphorus.

Azospirillum and Azotobacter are bacteria that can fix nitrogen. Pseudomonas species are a diverse group of bacteria that can use a wide range of compounds that plants give off when their roots leak or die. They are able to solubilize phosphorus and may help to suppress soil borne plant diseases. Some farmers make their own microbial fertilizers such as 'Bocashi" to save on costs.




**How to make Bocashi :**

1. Place the ingredients layer by layer repeatedly, starting with straw materials, then soil, then dung, charcoal, bran, lime.
2. Dissolve the molasses in water and mix it with the organic matter.
3. Spread the material evenly so that the heap is level and about 50 cm in height and cover it with bags to keep it warm during the fermentation process.
4. Only use water during preparation. Once the correct consistency is achieved, additional water is not required.
5. During fermentation (about two weeks) the heap releases heat (however it shouldn't burn the hand when touched)
6. During the first two weeks the heap needs to be turned once per day (in cold regions) and twice per day (in warm regions).
   It takes about 14 days for the mixture to ferment and to turn into Bocashi. But it is better to let it rest for one month before using.


Experience sharing: Effects of microbial fertilizers?
It may be interesting to hear about experiences farmers have had with microbial fertilizers -– be it commercial or self-made products. Invite a farmer or another expert to describe the preparation and application of microbial fertilizers. If possible go and visit fields where such fertilizers were used.

## 4.4 Composting

**Introduction**

Composting is the process of transforming organic material of plant or animal origin into humus in heaps or pits. Compared with uncontrolled decomposition of organic material, decomposition in the composting process occurs at a faster rate, reaches higher temperatures and results in a product of higher quality.

**Lessons to be learnt**

- Composting crop residues and animal wastes improves their value.
- To receive a compost of good quality the heap must be set up carefully and the composting process regularly checked.
- To be free of weed seeds and pathogens the compost must go through a period of high temperature

### 4.4.1 The Phases of the Composting Process

Within the process of composting 3 main phases can be distinguished: the heating phase, the cooling phase and the maturing phase. However, these phases can not be clearly separated from one another.

The heating phase:

- Within 3 days of setting up the compost heap, the temperature in the heap rises to 60 to 70 °C and usually stays at this level for 2–3 weeks. Most of the decomposition occurs during the heating phase.
- In this phase, it is mainly bacteria which are active. The high temperature is a result of energy released during conversion of easily decomposable material by the bacteria. The warm temperature is a typical and important part of the composting process. The heat destroys diseases pests, weed roots and seeds.
- During this first phase of the composting process the bacteria have a very high oxygen demand due to the rapid development of their population. High temperatures in the heap signal that there is an adequate supply of oxygen for the bacteria. If there is not enough air in the heap, bacterial development will be hindered and the compost will develop an unpleasant odour.
- Humidity is also essential to the composting process as bacteria require humid conditions for their work. The need for water is greatest during the heating phase because of high biological activity and strong evaporation occurring during this phase.
- As the heat increases, the pH of the compost heap rises (i.e. acidity decreases).

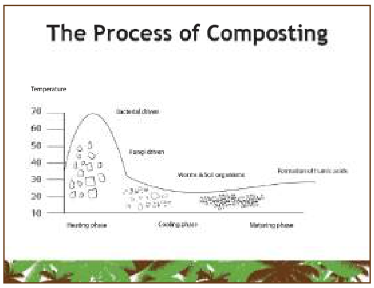
The cooling phase:

- Once the material which is easily digested by the bacteria has been converted, the temperature in the compost heap declines slowly and will remain at 25–45 °C.
- With the decline in temperature, fungi settle and start the decomposition of straw, fibres and wooden material. As this decomposition process is slower, the temperature of the heap does not rise.
- As the temperature drops, the pH of the composting material declines (i.e. acidity increases).

The maturing phase:

- During the maturing phase nutrients are mineralised and humic acids and antibiotics are built up.
- Red compost worms and other soil organisms start to inhabit the heap during this phase.
- At the end of this phase the compost has lost about half of its original volume, has the colour of dark, fertile soil and is ready to use.
- The longer it is stored from now on, the more it looses its quality as a fertilizer, while its capacity to improve soil structure increases.
- In the maturing phase, the compost needs much less water than in the heating phase.

**Motivation:** What does composting mean?
Ask the participants to describe the composting process. Discuss with them the difference between compositing and natural decomposition.




**Demonstration:**
*Compost making and sample from different stages*
*If available, bring compost samples of different maturation status to the classroom and display them (e.g. on a banana leaf). The advantage of fresh samples is that their smell and texture can also be experienced. Ask the participants to describe the samples of composting material. What does the material look like? What has happened to it? To which phase does it belong?*

### 4.4.2 Why to Make Compost?

There are a number of reasons for investing time and effort making good compost.

**Advantages of Compost**
During the composting process, some organic material is transformed into humic substances, which are relatively resistant to microbial decomposition. Composting thus helps to maintain or increase soil organic matter content. The other components of compost provide nutrients and micro-nutrients in the right proportion (as compost is built from plant materials) for plants to utilise. Compost has both a long and short term effect on plant nutrition as nutrients are permanently released. Due to its neutral pH, compost improves the availability of nutrients in acid soils. When mixed with soil, compost can suppress soil borne disease pathogens. Mature compost is good for plants and does not impede plant roots and micro-organisms in the soil as do substances released during a rotting process.

Composting certainly has many advantages. However, there are some aspects farmers should take into consideration before starting compost production. During the decomposition process some organic matter and nutrients will be lost. Also compost production is labour intensive and demands regular attention.


**Motivation:** *When is it worth the effort to make compost?*
*Ask the participants when it is worth making compost from organic material and when mulching is more appropriate? What is the general local practice (composting or mulching, composting only of selected material, in a specific season, for certain crops etc.)?*

**Motivation.** *How to proceed to make a good compost?*
*Ask the participants what should be considered when planning a compost heap and what should be done in order to make a good compost. Conclude with the transparency.*

### 4.4.3 How to Make Good Compost

**Different systems and methods**
Compost systems can be divided into «continuously» and «batchfed» systems:

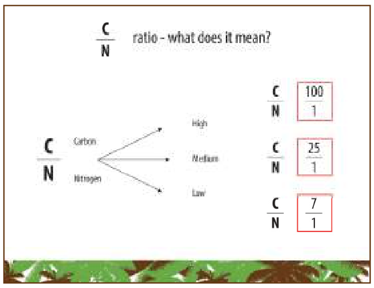
- Continuously fed systems: These systems do not heat up during the composting process. They are handy if there is a continuous supply of wastes (e.g. kitchen waste). However, they lack the advantages of the heating phase.

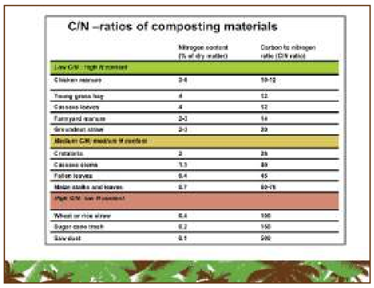
- Batch fed systems (all material is composted at once): These systems lead to a hot composting process. They offer the advantages of reduced nutrient loss death of weed seeds and diseases as a result of the high temperature of composting, the process is fast (within a few weeks) and it results in a compost of superior quality.

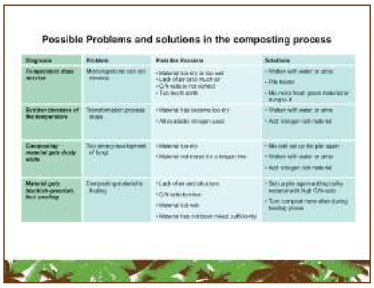
If little water is available, composting in pits may be more appropriate since humidity is conserved better in pits than in heaps.

Example: «Bangalore-method» and «Indore-method»
The two composting methods described below were developed in India, but are widespread in other countries, too.

- «Bangalore–method»: The composting materials are mixed with urine, slurry or dung. The heap, once set up, is plastered with a layer of mud and is not turned. Due to the mud layer, the composting process becomes semi-anaerobic after a few weeks. The method is simple to use, needs little labour and water. It has less nutrient losses than the «Indore–method», but may not destroy all diseases and needs more time to reach maturity.
  In dry areas, the «Bangalore–pit-method» is most appropriate. Here the heap stands with more than half of its height in the ground. To prevent drying out it is best shaded with a roof.
- «Indore–method»: In this method, the heap is turned twice. It is therefore labour intensive also needs more water than the «Bangalore-method», but has a shorter production period. The rapid conversion of the composting material due to the high temperature in the heating period may lead to considerable losses of carbon and nitrogen.


**Practical exercise:** *Setting up a compost heap*
*If possible go to a farm or a field and set up a compost heap together with the participants. Ask the participants to comment on their work. When finished, discuss the possible mistakes in the different phases. If possible come back to the compost heap in the following days and observe the progress.*

**What to consider when planning a compost heap?**

- Location: The compost is ideally located near the source of the composting material and the fields to which the compost will be applied. The site should be shady and near a water source. Water logged sites should be avoided. The compost heap should not be placed too close to houses as the heap may attract rats, snakes and termites etc., and sometimes a bad odour can not be avoided

- Composting materials: A compost heap should be set up when a lot of plant material is available. If the farm does not supply enough plant material, it may be collected from outside sources.
- Timing: It is easier to produce a good compost during the wet season as the rain saves on labour for watering.
- Size: The compost heap should reach a size of at least 1 m3 to allow for the correct composting process and so as to allow sufficient aeration should not be more than 2.5 m wide and 1.5 m high.
- Method: The chosen method should be appropriate to the climatic conditions.

**Selecting the primary materials**

The composition of the composting material is of major importance. The C/N-ratio and the structure of the material have a major influence on the composting process. Material which is rich in nitrogen (low C/N-ratio) does not usually contribute to a good structure and thus does not allow for good aeration if composted separately. Material which has a good structure usually has a low nitrogen content (high C/N-ratio) and does not offer enough nitrogen for the bacteria to feed on. Mixing different materials thus helps to achieve a balanced nutrient composition and a structure which allows for good aeration.

Which material, size and mixture? Material suitable for composting:

- Plant material: a balanced mixture of N-rich and C-rich material.
- Animal dung: cow, pig (rich in K and P), poultry (very rich in P), goat, horse etc.
- Wood ash: contains K, Na, Ca, Mg etc.
- Rock phosphate: the phosphorus binds to the organic material and is thus less fixed to soil minerals. It is therefore better applied to the compost heap than directly to the soil.
- Small quantities of soil, especially soil rich in clay, or ground rock improve the composting process and the quality of the compost. They are mixed with the other material or used to cover the heap to reduce nutrient losses.

Material not suitable for composting:

- Plant material affected by diseases like rust or virus.
- Persistent perennial weeds unless first dried in the sun.
- Materials of unnatural origin such as metal or plastic.
- Material with hard prickles or thorns.
  The finer the material, the greater its surface and the easier it can be digested by bacteria. An ideal length of the material is 2 to 5 cm. If some of the material is smaller (e.g. short grass, kitchen waste, ash), it must be mixed with more bulky material to ensure a good aeration of the heap.

To allow an ideal composting process, the mixture should consist of approximately:

- One third bulky material with a rich structure (chopped branches and tree bark, bulky material separated from previous composts)
- One third medium to fine material with a high C/N-ratio (straw, leaves, crop residues etc.)
- One third fine material with a low C/N-ratio (household wastes, animal manure etc.)
- to 10 % soil.

**Setting up a compost heap**

- Prepare the composting material properly: Chop coarse woody material to increase its surface area and encourage decomposition by fungi and bacteria.
- If dry, soak the composting material before mixing it.

- At the bottom of the heap, put twigs and branches to allow for good drainage of excess water.
- Pile up coarse carbon rich and nitrogen rich material in alternating layers.
- Manure or old compost applied to each layer enhances the composting process.
- Thin earth layers between the compost help to prevent nitrogen loss.
- A 10 cm thick cover of straw or leaves in the initial stage, and an impermeable cover (sacks, plastic sheet etc.) in the final stage prevent potassium and nitrogen being was- hed out of the heap. In dry climates, cover the heap with a 15 cm thick layer of mud.
- If the heap is not moist enough, from time to time pour water or liquid manure over the compost.
  Turning the compost
  Two to three weeks after building up the compost heap, it will have decreased to about half its original size. This is the right time to turn it. Turning the compost helps to accelerate the process, but it is not essential.

Turning has a number of advantages:
- It improves aeration and encourages the process of composting.
- It ensures that material from the outside of the heap can decompose properly by being put into the centre.
- It allows the quality of the composting process to be checked and for any non ideal conditions to be improved.

**Vermi-Composting**
Earthworms are highly efficient in transforming dead biomass such as leaves into excellent humus. They usually become very active in a compost heap after the heating phase. Vermi-Composting is mainly based on the activity of worms and does not go through a heating phase at all. As worms transform biomass into excrement within a short period of time, the process can be faster than ordinary composting. The excrement of worms is stable crumbles of soil closely bound to organic matter. They have high nutrient levels and good water retention. In addition, the excrement has a growth promoting effect on plants. Some experienced farmers use «vermi-wash», the liquid collected from the compost heap after sprinkling, as a leaf fertilizer and plant tonic. This can even help plants to get rid of pests (e.g.aphids) and diseases. Worms are very sensitive to fluctuations in moisture and temperature. They need a continuous supply of «food», i.e. compost material. They are also attacked by ants and termites. Therefore, a solid base is needed which protects the worms from predators. To remove the compost, let the top of the heap dry out so that the worms move to the deeper layers. Though vermi-compost is definitely a very good manure, it requires more investments (tank and worms), labour and permanent care when compared with ordinary composting methods.

**Application of compost**
There is no one definite stage of maturity. Compost ripens in an endless process. Compost can be used as soon as the original composting material is not recognisable anymore. The compost has then turned into a dark brown or blackish colour and has a pleasant smell.

Compost is a scarce and valuable manure for most organic farmers. Usually it is not possible to produce sufficient amounts for fertilising all fields. Therefore, farmers should think carefully about where compost application would be most beneficial. High efficiency is achieved in nurseries and when planting seedlings or saplings.

## 4.5 Green Manures

**Introduction**

Green manures, cover crops and mulching are related to each other and the difference between them can not be clearly distinguished. With mulching and cover crops emphasis is on protecting the soil, the main aim of green manures is to provide nutrients to subsequent crops and to increase soil fertility through addition of organic matter.

- Green manures can be an important source of organic matter and nutrients for soil and crops.
- Plant species for green manuring must be well chosen.
- Appropriate timing of green manuring in the rotation is important.

**Motivation:** *what do you know about green manuring?*
*Ask the participants whether they can explain what green manuring is and how it works.*



**Group work**: *What to expect from a green manure plant?*
*Depending on the participants' knowledge of green manuring ask them to discuss in groups, what they expect from green manure plants. Ask them to present their expectations on cards and arrange the cards by topic (nutrient supply, soil protection, fodder, soil fertility etc.). If necessary give the topics in advance.*

### 4.5.1 What is Green Manuring?

Green manures are plants grown to accumulate nutrients for the main crop. When they have built up maximum biomass, they are worked into the surface soil. As they are usually cut before flowering, growing a green manure is thus different from growing a legume crop in the rotation. Once worked into the soil the fresh plant material releases nutrients quickly and will be fully decomposed within a short period of time. Old or coarse material (e.g. straw, twigs) will decompose at a slower rate than fine material and will therefore contribute more to the build up of soil organic matter than to fertilizing the crop.

An alternative to sowing a green manure crop in the field is to collect fresh plant material from elsewhere and work it into the soil. For example, trees and/or shrubs growing alongside crops in an agro-forestry system may provide a large quantities of green material which can be used as green manure or for mulching.

### 4.5.2 Potential and Constraints of Green Manures

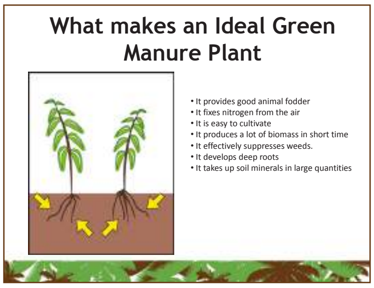
**Green manures have a number of benefits:**

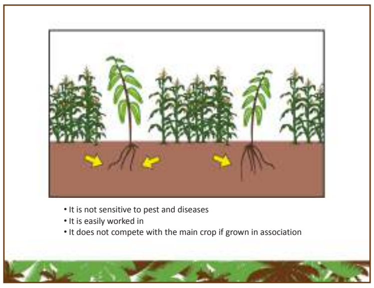
They penetrate the soil with their roots, make it more friable and bind nutrients, which would otherwise be washed away.
They suppress weeds and protect the soil from erosion and direct sunlight.

If legume plants are used, nitrogen is fixed from the air into the soil.
Some green manures can be used as fodder plants or even to provide food for human consumption (e.g. beans and peas).
By decomposing, green manures release all kinds of nutrients in the correct mixture for the main crops to utilise thus improving their yield.
The incorporated plant material encourages the activity of soil organisms, and builds up organic matter in the soil. This improves soil structure and water holding capacity.

Green manuring is thus an inexpensive way to improve soil fertility and the nutrition of the main crops grown.

The following aspects must be considered before growing green manures:
Labour is required for tillage, sowing, cutting and incorporation of plants into the soil, and is most intensive where the amount of helpful equipment available is small.
If green manures are intercropped with the main crops, they compete for nutrients, water and light.
When old or coarse plant material is incorporated into the soil, nitrogen may be temporarily immobilised and therefore unavailable for plant growth.
If food and space are in short supply it may be more appropriate to grow a food crop rather than a green manure and recycle the crop residues, or to intercrop a green manure crop with the main crop.
The benefits of green manures occur over the long term and are not always visible immediately.




### 4.5.3 Nitrogen Fixing Plants

**The Process of Nitrogen Fixation**
Air is the only primary source of nitrogen (secondary sources are rainwater, organic matter and animal manures). Air consists mainly of nitrogen (78 %) and thus offers potentially endless amounts of this valuable plant nutrient. However, in most cases nitrogen is the limiting plant nutrient as plants are unable to take up nitrogen (N2) directly from the air, instead needing it in a modified form.

Some plants, especially those of the legume family, but also some from the mimosa family, are capable of fixing nitrogen from the air with their roots to use as a nutrient. Legumes do this by living in association (symbiosis) with bacteria called rhizobium, which are hosted in visible nodules growing on the roots. These bacteria take up nitrogen from the air, transform it and make it available for the host plant. The process of nitrogen fixation is very energy consuming, whether it is done synthetically (production of chemical fertilizer) or biologically. Bacteria take the necessary energy from the plant roots (sugars, the products of photosynthesis). The blue-green algae, e.g. “azolla” growing in rice fields, produce the energy through their own photosynthesis.

The species of rhizobia that occur naturally live in symbiosis with specific host plants or host plant groups (this is an important difference to the mycorrhizae).

The partnership between plant and rhizobia is usually very specific. For this reason it may be necessary to introduce (inoculate) the bacteria the first time legume plants are grown in a field. The better the nutrient and water supply, soil qualities including soil acidity, temperature and light for the plant, the better the legume can supply the bacteria with energy and satisfy its own nitrogen needs.

**Nitrogen  Fixing Trees**

Among nitrogen fixing plants two main groups can be distinguished: the annual species and the perennial species of nitrogen fixing trees and shrubs. In 'alley cropping', perennial shrubs are grown in rows between the main crop.


**Demonstration:** *Study nitrogen fixing legumes*
*Carefully dig out a legume plant, for example a bean or pea. Check the roots for the presence of nodules. Cut some nodules: if they are reddish, they are presently fixing nitrogen.*

**The benefits of nitrogen fixing trees**

Fertilization and soil fertility: The leaves and twigs of nitrogen fixing trees are rich in nitrogen and other plant nutrients and are a valuable free source of fertilizer. With their roots they directly increase the nitrogen content of the soil and build up soil organic matter. When a field is exhausted of its nutrients as a result of intensive cultivation, nitrogen fixing shrubs or trees can be planted to increase nutrient levels and hasten the return of infertility.
Wood and timber: Some luxury timbers are provided by nitrogen fixing trees. Fast-growing nitrogen fixing trees also produce excellent fuelwood and charcoal.
Fodder and food: The highly nutritious and digestible leaves of some nitrogen fixing trees make them excellent feed for animals. The deeply penetrating roots can reach retreating moisture and provide fresh feed even during dry seasons. Several species of nitrogen fixing trees produce food for humans (e.g. carob, drumstick and tamarind).
Protection and support: Nitrogen fixing trees can be grown as living fences and hedges to protect crops from wildlife, domestic animals, and people. Trees with dense canopies can be grown as a windbreak. In hot climates, nitrogen fixing trees may be grown to provide shade, which is an important added benefit of crops such as cacao or coffee. Nitrogen fixing trees can also provide support for climbing crops such as yams, vanilla and black pepper.


**Group work:** *Develop a decision tree for choosing green manures. Suggest that the participants develop a decision tree for the integration of green manures under local conditions. Explain the idea of a decision tree (questions, which follow each other, going on from possible answers of the previous one – building a tree and easening decision making). Do this exercise in groups and present the results in the discussion.*

**Field test:** *Which plants might be worth testing?*
*Conduct small trials with green manure plants in the farm and share the results*

### 4.5.4 How to Use Green Manures

**Sowing the green manure**

- If grown within a crop rotation, the time of sowing must be chosen such that the green manure can be cut down and worked into the soil before the next crop is sown.
- Green manures need water for germination and growth, too!
- The ideal seed density must be tested for each individual situation. It depends on the species chosen.
- In general no additional fertilization is necessary. If legumes are grown in a field for the first time, inoculation of the seeds with the specific rhizobia may be necessary to profit from nitrogen fixation of the legume.
- If undersown, the green manure is sown at the same time as the main crop. If it grows faster than the main crop and competition is too high, it can also be sown later when the crop has established. Later sowing may be combined with a weeding passage.

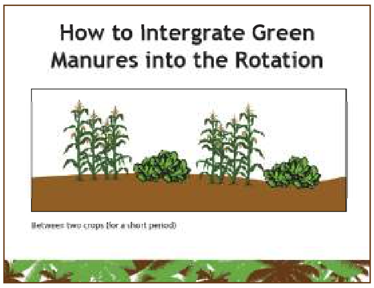
**Working the green manure into the soil**

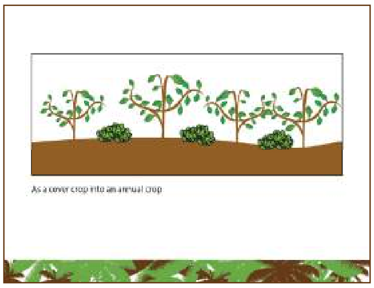
- Timing: The time gap between digging in the green manure and planting the next crop should not be longer than 2 to 3 weeks so as to prevent nutrient losses from the decomposing green manure.
- Crushing: Green manures are worked in most easily when the plants are still young and fresh. If the green manure plants are tall or contain bulky and hard plant parts, it is preferable to chop the plants into pieces to allow easier decomposition. The older the plants, the longer decomposition will take. The best time to dig in green manure plants is just before flowering.
- Depth of incorporation: Green manures should not be ploughed deeply into the soil. Instead they should only be worked in to the surface soil (in heavy soils only 5 to 15 cm deep, in light soils 10 to maximum 20 cm deep). In warm and humid climates the material can also be left on the soil surface as a mulch layer.

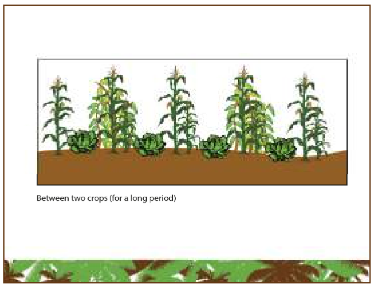
**How to choose the right species?**

There is a large variety of plants, especially legumes that can be used as green manure crops. It is important that appropriate species are chosen. Most importantly they should be adapted to the local growing conditions, especially rainfall and soil, fit into the crop rotation and not pose a risk of transmitting diseases and pests to other crops.

Further aspects that may be helpful for planning green manuring: Can the green manure be undersown into the main crop?
Is there a period in the year when the green manure does not compete with a crop? Is there sufficient water for growing both green manure and main crops?
Are there suitable species, which are fast growing and deep rooting without spreading too quickly and thus becoming a weed?
Can they be grown without too much labour? (sowing with minimum tillage, possibility of leaving it as a mulch)?



# 5 Pest, Disease And Weed Management

## 5.1 Organic Pest & Disease Management

**Introduction**

Pest and disease management consists of a range of activities that support each other. Most management practices are long-term activities that aim at preventing pests and diseases from affecting a crop. Management focuses on keeping existing pest populations and diseases low. Control on the other hand is a short-term activity and focuses on killing pest and disease. The general approach in organic agriculture to deal with the causes of a problem rather than treating the symptoms also applies for pest and diseases. Therefore, management is of a much higher priority than control.


**Lessons learnt:**

- Know the different kind of pests, diseases, useful insect and weeds.
- Know that healthy plants are more able to cope with pests and diseases.
- Know that management practices are the most effective prevention of pest and disease problems.
- Learn and demonstrate management practices to prevent pests, diseases and weeds problems.
- Learn and demonstrate curative measures to control pests, diseases and weeds.

### 5.1.1 Plant Health

**Factors influencing plant health**

A healthy plant is less vulnerable to pest and disease infestation. Therefore, a major aim for the organic farmer is to create conditions which keep a plant healthy. The interaction between living organisms and their environment is crucial for a plant's health. In favourable conditions, the plants own protection mechanisms to fight infections are sufficient. This is why a well managed ecosystem can be a successful way of reducing the level of pest or disease population. Certain crop varieties have more effective mechanisms than others and therefore have a lower infection risk.

The health condition of a plant depends to a large extend on the fertility of the soil. When nutrition is well balanced, the plant becomes stronger and is therefore less vulnerable to infection. Climatic conditions, such as suitable temperatures and sufficient water supply, are further factors which are crucial for a healthy plant. If one of these conditions is not suitable, the plant can become stressed. Stress weakens the defence mechanisms of plants and makes them easy targets for pests and diseases. One of the most important points for an organic farmer is therefore to grow healthy plants. This avoids many pest and disease problems.

**The immune system of plants**

Plants have their own mechanisms to protect themselves against pests and diseases which can be seen as their immune system. Pests and diseases do not randomly attack plants, but only those which are not able to fight them. Some plants have the ability to prevent or restrict infection by one or several disease or pests. This is called resistance. The cultivation of resistant varieties is an important preventive measure in organic farming to reduce the damages caused by pests and diseases.

Many factors are influencing the resistance mechanisms of a plant. Some of them have genetic origins, others are supported by environmental factors. Some plants are resistant against a wide range of pest and disease, others can only fight one specific insect or pathogen. Some plants are resistant over their whole vegetation period, others only in certain life stages.

**Defence mechanisms**

The different defence mechanisms of plants, which make them resistant against certain pest and disease can be classified as followed:

1) Non-preference: These are factors which either deter pests or lack the stimulation to attract them. Such mechanisms include:

- a colour which doesn't attract a certain pest,
- lack of certain nutritional factors essential for the pest or disease, an unattractive growth form which doesn't offer shelter, etc.,
- long or sticky hairs on the leaves which hinder insects' ability to walk or feed on a plant,
- a strong smell of aromatic oils which keeps pests away,
- leaves covered with wax which can not be penetrated easily.

2) Active Defence: The plant is resistant by preventing, harming, or even destroying the attacking pest. It requires that the plant has contact with the pest or disease. Such mechanisms include:

- substances in the leaves which inhibit essential steps in the pest's or disease's metabolism,
- toxic substances in the leaves which harm the pest or disease feeding on it,
- hairs excreting sticky substances which hinder pests' movements.

3) Tolerance: Instead of fighting pests in either of the previously mentioned ways, tolerant plants reproduce leaves fast enough to recover from the attack without being much affected in their growth and yield production.

**Resistant Varieties**

The selection of particularly resistant varieties requires good observation of the infection process and period of the plant in accordance with the environmental conditions. Once resistant varieties are identified, their multiplication is needed.

**Example: Yam anthracnose resistance**

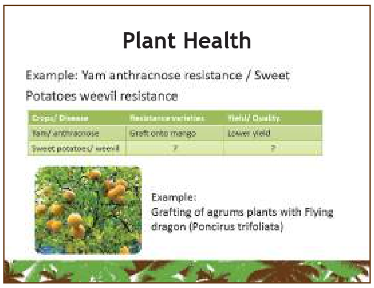
The anthracnose fungus is responsible for important yield loses due to its consequences on the photosynthesis activity. This disease is widely spread on the warm rainy regions which are on the same time, the most suitable for most roots crops production. Farmers in different Pacific islands can manage this disease by using yam varieties resistant to anthracnose and by distance with host plants like mango tree.

**Example: Grafting**

For perennial plants, grafting is a promising technique for obtaining resistant plants. It combines a shoot of a high yielding crop with a rootstock of a variety which is resistant to soil borne diseases, but, however, would not grow desired yields.

**Example: Grafting of citrus tree coffee plants**
Most of the citrus varieties (orange, limes, ...), may be grafted onto flying dragon (Poncirus trifoliata) rootstock to prevent some disease . Citrus grafted onto rootstocks of flying dragon are stronger and more resistant to various disease.

**Example: Compensatory growth**
An experiment to simulate defoliation to cabbage plants by leaf feeders (which includes the notorious diamondback moth) was done as part of a study programme in Hyderabad, India. Defoliation treatments of 0 (control), 10, 20 and 50% were conducted 1 and 3 weeks after planting. Within 2 weeks, observations on the number of leaves and plant height showed that the defoliation had no obvious effects. Trainees learnt that crops could compensate up to 50 % foliage loss in 2 weeks time and became convinced that one doesn't necessarily need to panic when caterpillars appear on crops.




**Activity/ discussion points**

- *Ask the participants on the Yam and sweet potatoes resistant varieties, they know.*
- *Ask the participants if they know of other crop varieties which have regular pest or diseases problems and others which are not effected? Which varieties would be most suitable for organic farming, considering both resistance and yields?*


**Activity/ discussion points**

- *Ask the farmers on their ideas about What does it mean a healthy plant ? and What make a plant healthy ?*
- *List their answers on a board*

### 5.1.2 Preventive Measures

Knowledge about plant health and pest and disease ecology helps the farmer to choose effective preventive crop protection measures. As many factors influence the development of pest and disease, it's crucial to intervene at the most sensitive points. This can be accomplished through the right timing of management practises, a suitable combination of different methods, or the choice of a selective method.

Some important preventive crop protection measures are the following ones:

1) **Selection of adapted and resistant varieties**

a. Choose varieties which are well adapted to the local environmental conditions (temperature, nutrient supply, pests and disease pressure), as it allows them to grow healthy and makes them stronger against infections of pests and diseases.

2) **Selection of clean seed and planting material:**

a. Use safe seeds which have been inspected for pathogens and weeds at all stages of production.
b. Use planting material from safe sources.

3) **Use of suitable cropping systems:**

a. Mixed cropping systems: can limit pest and disease pressure as the pest has less host plants to feed on and more beneficial insect life in a diverse system.
b. Crop rotation: reduces the chances of soil born diseases and increases soil fertility.
c. Green manuring and cover crops: increases the biological activity in the soil and can enhance the presence of beneficial organisms (but also of pests; therefore a careful selection of the proper species is needed!).

4) **Use of balanced nutrient management :**

a. Moderate fertilization: steady growth makes a plant less vulnerable to infection. Too much fertilization may result in salt damage to roots, opening the way for secondary infections.
b. Balanced Potassium supply contributes to the prevention of fungi and bacterial infections

**5) Input of organic matter:**

a. Increases micro-organism density and activity in the soil, thus decreasing population densities of pathogenic and soil borne fungi.
b. Stabilises soil structure and thus improves aeration and infiltration of water.
c. Supplies substances which strengthen the plant's own protection mechanisms.

6) **Application of suitable soil cultivation methods :**

a. Facilitates the decomposition of infected plant parts.
b. Regulates weeds which serve as hosts for pests and diseases.
c. Protects the micro-organisms which regulate soil borne diseases.

7) **Use of good water management**:

a. No water logging: causes stress to the plant, which encourages pathogens infections.
b. Avoid water on the foliage, as water borne disease spread with droplets and fungal disease germinate in water.

8) **Conservation and promotion of natural enemies :**

a. Provide an ideal habitat for natural enemies to grow and reproduce. b. Avoid using products which harm natural enemies.

9) **Selection of optimum planting time and spacing:**

a. Most pests or diseases attack the plant only in a certain life stage; therefore it's crucial that this vulnerable life stage doesn't correspond with the period of high pest density and thus that the optimal planting time is chosen.
b. Sufficient distance between the plants reduces the spread of a disease
c. Good aeration of the plants allows leaves to dry off faster, which hinders pathogen development and infection.

**10) Use of proper sanitation measures:**

a. Remove infected plant parts (leaves, fruits) from the ground to prevent the disease from spreading.

b. Eliminate residues of infected plants after harvesting.

**Example: How the use of compost can reduce disease problems**

In addition to improving the soil nutrient levels, compost can also reduce disease problems. This is due to the presence of many different micro-organisms in the compost that either compete with pathogens for nutrients, produce certain substances (called antibiotics) that reduce pathogen survival and growth, or parasite on the pathogens. There is also an indirect effect on crop health. In Hai Phong, North Vietnam, farmers applied compost to a bacterial wilt infected soil. Compared to the "farmers practice" plot (usual practice in that area) the farmers found that tomato plants developed better and faster with compost than without, due to the improved soil condition which reduced disease incidence.

**Treatment of Seeds**

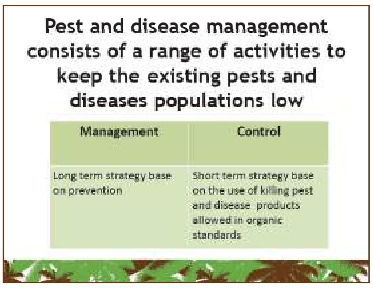
Seeds can be treated to control germs attached to the seed (seed-borne diseases), and/or to protect against pests and diseases in the soil that can attack seeds, emerging roots or young seedlings (soil-borne diseases). There are three main methods for seed treatment in organic farming:

1. Physical: sterilizing by soaking seed in hot water (typically 50–60 °C),
2. Botanical: by coating seeds with a layer of plant extract, such as crushed garlic.
3. Biological: by coating seeds with a layer of antagonistic fungi.

When seeds are bought from seed companies, attention should be paid to the type of treatment they underwent, as chemical treatment is not permitted in organic farming.

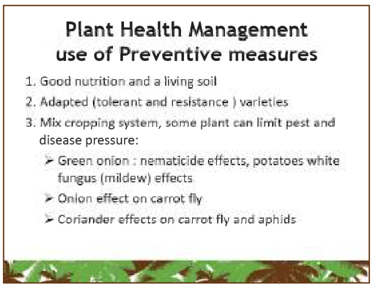
**Example: Seed treatment with biological agents**

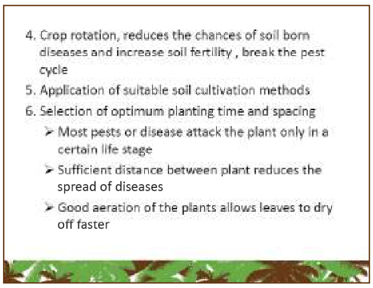
Seeds can be coated with a layer of biological agents. These agents are usually antagonistic fungi or bacteria that work against soil-borne pathogens. An example is the bacterium Bacillus subtilis, used as a seed treatment for the control of a range of seedling pathogens such as Fusarium spp., Pythium spp. and Rhizoctonia spp. that cause damping-off and root rot. It is effective in a wide range of crops including soybeans, peanuts, wheat, cotton and leguminous food crops. The antagonistic organisms grow and multiply in the area around the seedling's roots. They compete with pathogens that attack the new emerging roots and thus reduce the risk of infestation.




**Activity/ discussion points**

- *Discuss the advantage and disadvantage and the management and the control pest strategies*




**Activity/ discussion points**

- *Let the farmers exchange on their personal experience on each point.*
- *For the point 3, list on the board the crop repellant effect, participants have noticed on their field.*

### 5.1.3 Curative Crop Protection Methods

If all preventive crop protection practices fail to sufficiently prevent economic losses to the farmer, it may be necessary to take curative action. Curative action means controlling the pest or disease once it has already infested the crop. Several options exist in organic agriculture:

1) Biological control with natural predators or antagonistic microbe).
2) Natural pesticides based on herbal preparations or other natural products.
3) Mechanical control with traps or hand picking.

**Traps**
Traps can help to reduce the population of certain pests. If used at an early stage, their use can prevent mass multiplication. There are several types of traps:

- Light traps attract night active flying pest insects.
- Pitfalls catch creeping insects and slugs.
- Sticky traps, e.g. of a colour attracting a certain pest insect.
- Pheromone traps release a sex-hormone of the female insect, thus attracting the males which get stuck in the trap.

If a large number of small pheromone containers is distributed in an area, the male insects get confused and will not manage to find the females to reproduce.

An example of organic management of a cocoa disease
Diseases, rather than insects, are the biggest problem in cocoa. Black pod (Phytophthora palmivora) for example, is an important fungal disease, responsible for estimated losses of more than 40% of cocoa production every year. This disease attacks pods at all stages of their development. Steps for disease management are:

1. Using resistant varieties. Cocoa varieties with resistance to various pest and disease problems have been developed. Breeding for resistance in West Africa has focused on black pod and CSSV (Cocoa swollen shoot virus) resistance.
2. Maintaining crop hygiene. Removing and destroying harvested and disease infested pods can substantially reduce black pod. This practice can also help to reduce the population of the cocoa pod borer (Conopomorpha cramerella) in the subsequent season.
3. Biological control. Most of the work on biological control of cocoa diseases has been focused on Central and South America. There are two approaches: a. Non-pathogenic fungi can be applied to the trees to reduce the levels of infective spores of disease-causing fungi. In Ghana, certain species of the fungus Trichoderma have been found to inhibit growth of the black pod.

b. The introduction of a beneficial fungus into the tissues of the cocoa tree. The fungus has no deterious effect on the plant, but helps to protect it by attacking the pathogen or inducing resistance.


**Activity/ discussion points**

*Read with the farmers the list of allowed traps by the Pacific Organic Standard (Pacific Oragnic Standard Appendix 1, table 2), then ask if some of them have already used these products and what's they have observed.*

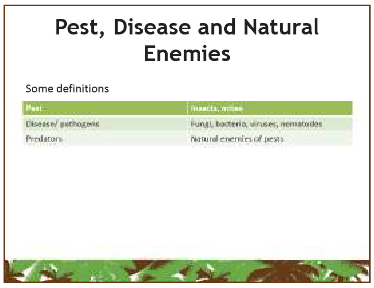
## 5.2 Natural Enemies

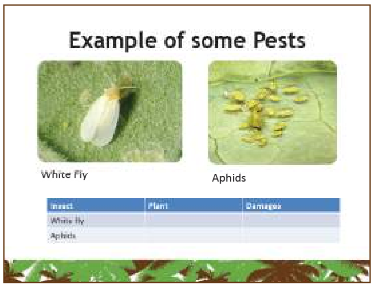
**Introduction**

Why do some insects become pests in some crops and not in others? Why are some diseases a major problem in one season but completely absent in another? To answer such questions, it is important to know the life cycle of pest and disease organisms and their interaction with the environment. Knowing the factors which influence pest and disease populations will give you a clue on how to manage them.

In this chapter, we use the following definitions:

| | |
|---|---|
| Pest | : insects, mites |
| Disease/pathogens | : fungi, bacteria, mycoplasmas, viruses, nematodes |
| Predators | : natural enemies of pests |





**Activity/ discussion points**

- *Ask the farmers to fill the table and to identify the pest that cause these damages*

### 5.2.1 Ecology of Pests and Diseases

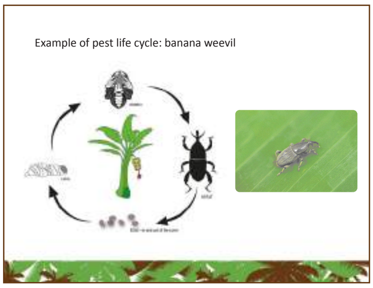
Ecology is the study of relationships between organisms and their environment. The environment of an insect or disease consists of physical factors like temperature, wind, humidity, light, and biological factors such as other members of the species, food sources, natural enemies and competitors (organisms using the same food source). In agro-ecosystems, insects are considered as populations rather than individuals. One single insect that eats a leaf will not cause yield loss in a large field but a population of ten thousand leaf-eating caterpillars might.

These interrelationships are a reason why insect or pathogen species cannot in all circumstances grow to large populations and damage crops.

The weather conditions may be unfavourable for a quick life cycle. The plant variety may not be attractive for the insects to eat or for the pathogen to develop. Or there may be a sufficient number of predators which eat the insects. So, the ecological environment determines the growth of the insect population and has an influence on whether it really becomes a pest or not.

**Life cycles of pests**
As not all the life stages of a pest are able to attack a plant, it is important to understand their life cycle. Knowing which life stages of insects or pathogens are damaging the plant, and when and where they occur, is crucial for implementing effective preventive measures. An insect zoo can help to acquire more knowledge about the life cycle of potential pests.

Furthermore, most insects or pathogens preferably infest the plant in a specific growth stage. Therefore, the interaction of pest and disease life cycle with the growing periods of the crop is equally important.




**Activity/ discussion points**

- *Ask the farmers to choose a pest and built with them its biological cycle*

**Insect zoo: studying life cycles and predators  of insects**
To study different stages of a life cycle of insects, try rearing the insects in an insect zoo. Although it may not be easy to study a full life cycle, it is possible to study some stages, for example the stages that cause plant damage. Collect some insects or eggs, pupae or larvae/nymphs from the field and put them in a glass or plastic jar with some fresh leaves from an unsprayed field. When studying life cycles of predators, feed them with the appropriate prey. Put some tissue paper in the jar to avoid condensation. Close the jars with fine netting that permits air circulation and keep them in the shade.

Insect zoos are also suitable to find out which insects (larvae/nymphs to adults) are emerging from egg masses. They are also suitable for rearing larvae or pupae that you find in the field and would like to know what species they are. Similarly, one can find out if an insect is a predator by placing it in an insect zoo together with some prey (e.g. aphids, small caterpillars) and monitor for a few days. You can also see how effective a predator is by counting the number of prey eaten per day and compare it with the reproduction speed of the prey insect.

**Population  dynamics  of pest and predators**
As previously stated, insects, mites, fungi, bacteria and others develop according to the environmental conditions. Whenever these are favourable, their population density will grow, and when they are unfavourable, it will decrease again. This interaction becomes very important for the population dynamics of pests and their predators. Whenever the pest finds suitable conditions to grow, it increases it's population. As a consequence, the predators which feeds on the pest finds more food and therefore increase in number as well. As a consequence of an increased predator population, however, the pest population will be reduced, as they serve as food for the predator. A reduced pest population will then limit the food sources for the predator and its own population will shrink again. That's when the pest population can increase anew and the whole cycle restarts. This is a general principle of population dynamics, which applies whenever the food resources are the limiting factor for the predator population density.

**Impact of pesticides**
The overuse (and misuse) of pesticides has led to very serious problems for agriculture in both temperate and tropical parts of the world. Smallholder rice farmers in Asia have had to rethink their pest control strategy because over-reliance on pesticides has led to new pest outbreaks, human health problems, and high input costs.

Two main negative impacts of pesticide use on pest and disease populations are:

- The resurgence of pest populations after elimination of natural enemies: In some cases, pesticides can be the cause of pest problems, rather than the cure. As many pesticides also kill beneficial organisms, pests may reproduce quicker after spraying, since no natural enemies are there to control their population growth. For the same reason, minor pests can become major pests. An example is red spider mite, which has many natural enemies but can cause severe problems in heavily sprayed fields. This phenomenon is known as resurgence.
- Development of insecticide-resistant populations: When pesticides are used continuously, the target pests can adapt themselves to the chemical and become resistant to it. Resistance means that an insect can tolerate a pesticide without being killed. Many of the major agricultural pest species now show resistance to some or several pesticides and hardly any chemical control options remain for these pests. Examples of resistant pests are: the aphid Myzus persicae, the colorado potato beetle, Leptinotarsa decemlineata, and the diamondback moth, Plutella xylostella.

Example: The diamonds back moth, cabbage pest resistance to any insecticide due massive use in the past. The consequence is important pest population on cabbage field and so one important yield loses

### 5.2.2 Promoting Natural Enemies

**Natural enemies and their use**
There are many different kinds of organisms in a field and not all of them are "pests"; in fact, many insects can have a beneficial function in the crop ecosystem. Others may be crop visitors, passing by and resting on the plants or soil, or they may be neutrals which live in the crop but do not feed on the plants nor influence pest populations as natural enemies. Even insects that feed on the crop are not necessarily "pests". Their population may not be large enough to cause damage to the crop because plants are able to compensate for some damage without an effect on yields. In addition, the insects can serve as food or as a host for natural enemies.

Natural enemies are the "friends of the farmer" because they help farmers to control pests or diseases in crops. Natural enemies of pests and diseases do not damage plants and they are harmless to people. They can be divided into four groups: predators (eating pest organisms), parasitoids (parasiting pest organisms), pathogens (causing a disease in pest organisms) and nematodes.

**Characteristics of natural enemies**
Predators

- Common predators are spiders, lady beetles, ground beetles, and syrphid flies.
- Predators usually hunt or set traps to catch a prey to feed on.
- Predators can feed on many different species of insects. Parasitoids
- Parasitoids of pests are commonly wasps or flies.
- Only the larvae are parasitic and they develop on or inside a single insect host.
- Parasitoids are usually smaller than their host.

  Pathogens

- Insect-pathogens are fungi, bacteria, or viruses that can infect and kill insects.
- Pathogens require specific conditions (e.g. high humidity, low sunlight) to infect insects and to multiply.
- Commonly used insect-pathogens are Bacillus thuringiensis (Bt), and NPV virus. Nematodes Nematodes are a kind of tiny worm.
- Some nematodes attack plants (e.g. rootknot nematode). Others, called entomopathogenic nematodes, attack and kill insects.
- Entomopathogenic nematodes are usually only effective against pests in the soil, or in humid conditions.

**Promoting and Managing Natural Enemies**
Active populations of natural enemies can effectively control pest and disease organisms and thus prevent their mass multiplication. Therefore, the organic farmer should try to conserve natural enemies already present in the crop environment and enhance their impact.

This can be achieved with the following methods:
- Minimize the application of natural pesticides (chemical pesticides anyway are not permitted in organic farming).
- Allow some pests to live in the field which will serve as food or host for natural enemies.
- Establish a diverse cropping system (e.g. mixed cropping).
- Include host plants providing food or shelter for natural enemies (e.g. flowers which adult beneficial insects feed on).

### 5.2.3 Bio-Control

Of all the methods and approaches presently used for the management of pests, diseases, and weeds, biological control is by far the most complex and, as a consequence, probably the least understood.

Biological control is the use of natural enemies to manage populations of pests and diseases. This implies that we are dealing with living systems, which are complex and vary from place to place and from time to time. The basic principles of biological control systems are ex- plained below in brief. More extensive information on the use of natural enemies is available from work on Integrated Pest Management (IPM).

**Releasing natural enemies**
If populations of natural enemies present in the field are too small to sufficiently control pests, they can be reared in a laboratory or rearing unit. The reared natural enemies are released in the crop to boost field populations and keep pest populations down. There are two ap- proaches to biological control through the release of natural enemies:
- Preventive release of the natural enemies at the beginning of each season. This is used when the natural enemies could not persist from one cropping season to another due to unfavourable climate or the absence of the pest. Populations of the natural enemy then establish and grow during the season.
- Releasing natural enemies when pest populations start to cause damage to crops. Pathogens are usually used in that way, because they can not persist and spread in the crop environment without the presence of a host ("pest"). They are also often inexpensive to produce.

**Example: Trichogramma to control tomato fruitborer**
The tiny black wasps of Trichogramma brasiliensis search the eggs of the tomato fruitborer (Helicoverpa armigera) to lay their own eggs into them Instead of a fruitborer larva, a tiny

wasp emerges out of the egg. Trichogramma is harmless to the tomato plant. Trichogramma is massreared and can be released into the field on “trichocards”, cards containing several thousand parasitoid eggs.

**Using Antagonistic Microbes**
Natural enemies that kill or suppress pests or diseases are often fungi or bacteria. They are called antagonists or referred to as microbial insecticides or bio-pesticides.

Some commonly used antagonistic microbes are:
- Bacteria such as Bacillus thuringiensis (Bt). Bt has been available as a commercial microbial insecticide since the 1960s. Different types of Bt are available for the control of caterpillars and beetles in vegetables and other agricultural crops, and for mosquito and black fly control.
- Viruses such as NPV (nuclearpolyhedrosis virus), effective for control of several caterpillar pest species. Every insect species, however, requires a specific NPV-species. An example: The armyworm Spodoptera exigua is a major problem in shallot production in Indonesia. Since experiments showed that SeNPV (NPV specific for S. exigua) provided better control than insecticides, farmers have adopted this control method. Many farmers in West-Sumatra are now producing NPV on-farm.
- Fungi that kill insects, such as Beauveria bassiana. Different strains of this fungus are commercially available. For example: strain Bb 147 is used for control of corn borers (Ostrinia nubilalis and O. furnacaiis) in maize, strain GHA is used against whitefly, thrips, aphids and mealybugs in vegetables and ornamentals. Several species of fungi can occur naturally in ecosystems. For example, aphids can be killed by a green or white coloured fungus during humid weather.
- Fungi that work against plant-pathogens. For example Trichoderma sp., widely used in Asia for prevention of soil-borne diseases such as damping-off and root rots in vegetables.
- Nematodes such as Steinernema carpocapsae control soil insects like cutworms (Agrotis spp.) in vegetables.


**Activity/ discussion points**
*Read with the farmers the list of allowed micro-organisms by the Pacific Organic Standard (Appendix 1, table 2)*
*Ask the participant about their experience with products releasing antagonistic microbes or beneficial insects. Did it work? Was it effective? Did they grow the organisms themselves or buy products? How long can they can be stored?*

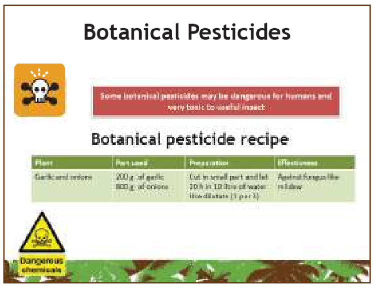
## 5.3 Natural Pesticides

**Introduction**
Strengthening the plant is the best protection against pests and disease. Through adapted cultivation methods and with good management of the ecosystem (beneficial organisms), infestations can be prevented or reduced. In some cases, however, preventive measures are not sufficient and the damage by a pest or a disease may reach a level of considerable economic loss. That is when direct control measures with natural pesticides may become appropriate. Contrary to conventional farming practises, where it has become a widely held view that pesticides are the best and fastest means to reduce pest damage, organic farmers know that preventive methods are superior and that only if prevention is not sufficient, natural pesticides should be applied.

### 5.3.1 Botanical Pesticides

Some plants contain components that are toxic to insects. When extracted from the plants and applied on infested crops, these components are called botanical pesticides or botanicals. The use of plant extracts to control pests is not new. Rotenone (Derris sp.), nicotine (tobacco), and pyrethrins (Chrysanthemum sp.) have been used widely both in small-scale subsistence farming as well as in commercial agriculture. Most botanical pesticides are contact, respiratory, or stomach poisons. Therefore, they are not very selective, but target a broad range of insects. This means that even beneficial organisms can be affected. Yet the toxicity of botanical pesticides is usually not very high and their negative effects on beneficial organisms can be significantly reduced by selective application. Furthermore, botanical pesticides are generally highly bio-degradable, so that they become inactive within hours or a few days. This reduces again the negative impact on beneficial organisms and they are relatively environmentally safe.

However, despite being “natural” and widely used in agricultural systems, some botanicals may be dangerous for humans and they can be very toxic to natural enemies. Nicotine for example, derived from the tobacco plant, is one of the most toxic organic poisons for humans and other warm-blooded animals. Before a new botanical pesticide is applied in a large scale, its effect on the ecosystem should be tested in a small field experiment. Do not just use botanical pesticides as a default option! First understand the ecosystem and how botanicals influence it!




**Activity/ discussion points**
*Experience sharing, which locally available plants are used by participants to prepare botanical pesticides. Discuss the different recipe and refer to the Organic Pacific Standard to check if they may be used in organic plant production (Appendix 1, Table 3).*

### 5.3.2 Preparation and Use of Botanical Pesticides

The preparation and use of botanicals requires some know-how, but not much material and infrastructures. It’s a common practice under many traditional agricultural systems. Some commonly used botanicals are:

- Neem
- Pyrethrum
- Rotenon
- Quassia
- Ginger
- Chillipepper,
- Mexican Marigold
- Garlic

**Neem**
Neem derived from the neem tree (Azadiracta indica) of arid tropical regions, contains several insecticidal compounds. The main active ingredient is azadiractin, which both deters and kills many species of caterpillars, thrips and whitefly.

Both seeds and leaves can be used to prepare the neem solution. Neem seeds contain a higher amount of neem oil, but leaves are available all year.

A neem solution looses its effectiveness within about 8 hours after preparation, and when exposed to direct sunlight. It is most effective to apply neem in the evening, directly after preparation, under humid conditions or when the plants and insects are damp.
High neem concentrations can cause burning of plant leaves! Also, natural enemies can be affected by neem applications! This can be checked in insect zoos.

There exist different recipes for the preparation of a neem solution.

Neem seed kernel extract: the recipe
Neem seed kernel extract has a very good repelling effect on diamondback moth (Plutella xylostella). Here is the recipe:

Pound 30 g neem kernels (that is the seed of which the seed coat has been removed) and mix it in 1 litre of water. Leave that overnight. The next morning, filter the solution through a fine cloth and use it immediately for spraying. It should not be further diluted.

**Pyrethrum**
Pyrethrum is a daisy-like Chrysanthemum. In the tropics, pyrethrum is grown in mountain areas because it needs cool temperatures to develop its flowers. Pyrethrins are insecticidal chemicals extracted from the dried pyrethrum flower. The flower heads are processed into a powder to make a dust. This dust can be used directly or infused into water to make a spray.

Pyrethrins cause immediate paralysis to most insects. Low doses do not kill but have a "knock down" effect. Stronger doses kill. Pyrethrins are not poisonous for humans and warm- blooded animals. However, human allergic reactions are common. It can cause rash, and breathing the dust can cause headaches and sickness.

Pyrethrins break down very quickly in sunlight so they should be stored in darkness. Both highly alkaline and highly acid conditions speed up degradation so pyrethrins should not be mixed with lime or soap solutions. Liquid formulations are stable in storage but powders may lose up to 20 percent of their effectiveness in one year.

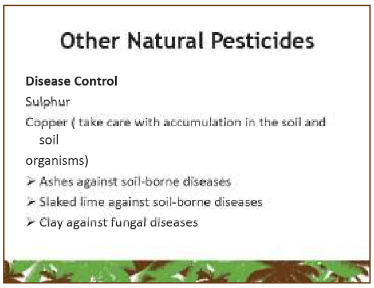
Attention: Pyrethroids are synthetic insecticides based on pyrethrins, but more toxic and longer lasting. They are not allowed in organic farming!! They are marketed under various trade names, for example Ambush or Decis. Some pyrethroids are extremely toxic to natural enemies! Pyrethroids are toxic to honey bees and fish. Sunlight does not break them down and they stick to leaf surfaces for weeks killing any insect that touches the leaves. This makes them less specific in action and more harmful to the environment than pyrethrin. In addition they irritate human skin.

### 5.3.3 Other natural pesticides

Besides extractions of plants, there are some other natural pesticides, which are allowed in organic farming. Although some of these products have limited selectivity and are not fully biodegradable, there are situations, when their use is justified. However, in most cases, the desired effect is best reached in combination with preventive crop protection methods. Below, some examples:

Disease control:
- Sulphur; against fungal disease,
- Copper; against fungal disease (gets accumulated in the soil and harms soil organisms!),
- Sulphuric acidic argillaceous earth; against fungal disease,
- Ashes; against soil-borne disease,
- Slaked lime; against soil-borne diseases,
- Clay; against fungal diseases,
- Baking soda; against fungal diseases.

Pest control:
- Soft soap solutions; against aphids and other sucking insects,
- Light mineral oil; against various insect pests (harms natural enemies!),
- Sulphur; against spider mites (harms natural enemies!),
- Plant ashes; against ants, leaf miners, stem borers etc.





**Activity/ discussion points**
- *Read with the farmers the list of allowed natural pesticides by the Pacific Organic Standard (Appendix 1, table 2)*
- *Ask the participant about their experience with these products Did it work? Was it effective??*

## 5.4 Weed Management

**Introduction**
Weeds are plants which grow in places where they are not wanted or in unwanted periods of the cropping season. In a field, weeds are usually unwanted because they compete with the crop for water, nutrients, and sunlight and therefore prevent the crop from an ideal growth.
Weeds may also directly reduce profits by hindering harvest operations, lowering crop quality, and by producing seed or rootstocks which infest the field and affect future crops.


**Activity/ discussion points**
- *Discuss with farmers on what makes a weed a weed ?*
- *Is it an indicator for special soil conditions?*
- *Does it host any natural enemies of pest and disease?*
- *Does it contribute to a better soil structure or fertility?*
- *Visit a field with the participants and study the different weeds at the place where they actually grow. Carry out the same characterization on the spot by analyzing the environment they grow in*

### 5.4.1 Ecology of Weeds

Weeds grow in unwanted places and often win the growth competition with the crop. There are several reasons why this happens, but an important one is definitely their good adaptation to the prevailing conditions. This is why they are often useful indicators of soil fertility and structure. When soil conditions favour the growth of weeds over the crop it signifies that there is a problem which should be tackled. Weeds can take advantage of high salinity for example, whereas crop plants would encounter stress. Or they can survive well in soil that has low nutrient availability. These weeds are therefore useful indicators for infertile soil. The presence of other types of weeds indicates soil compaction, water logging, acidity, low soil organic matter content etc.

Besides their important function as indicators for soil conditions, weeds have other benefits:

- They can serve as host plants for certain beneficial organisms . This can make them a valuable instrument in controlling the spread of pests.
- Several weeds are edible for farm animals or even suitable for human consumption.
- Some weeds have a medicinal use.
- Weeds have taken up nutrients from the soil and these can be returned to the soil by using weeds as much or as green manure.
- Weeds can help to prevent soil erosion.

However, weeds may also alter the environment of the crop in a negative way. Light and air circulation, for example, are reduced between the crop plants. In this darker and more humid environment, diseases find ideal conditions in which to spread and infect plants.

### 5.4.2 Management of Weeds

As we have seen many times up to this point, a basic working principle in organic farming is to prevent problems, rather than to cure them. This applies equally to weed management.
Good weed management in organic farming includes creating conditions which hinder weeds from growing at the wrong time and in the wrong place and then become a serious problem for the crop cultivation. Competition by weeds doesn't harm the crop throughout the whole cultivation period in the same way. The most sensitive phase of a crop to weed competition is in its early growth stage. A young plant is vulnerable and depends highly on an ideal nutrient, light, and water supply for a good development. If it has to compete with weeds at this stage, the crop may grow weak, which also makes it more vulnerable to pest and disease infections. Weed competition later in the cultivation period is less harmful. However, some weeds may cause harvesting problems and reduce the crop yield in that way. Therefore, weeds should not be completely ignored after the most critical growth period of the crop, but in general, they become less important.

These considerations should influence the selection and timing of weed management measures. In general, such measures aim at keeping the weed population at a level which doesn't result in economic loss of the crop cultivation or harm its quality.

Preventive measures and suppression of weeds
Several preventive measures may be applied at the same time. The importance and effectiveness of the different methods depend to a large extent on the weed species and the environmental conditions. However, some methods are very effective for a wide range of weeds and are therefore regularly used:

1. Mulching: the weeds find it difficult to receive enough light to grow and may not be able to pass through the mulch layer. Dry, hardy material, that decomposes slowly, keeps its effect longer than fresh mulch material.
2. Living green cover: The cover competes successfully against the weeds for light, nutri ents, and water and therefore helps to prevent weed growth by winning the competition for resources.
3. Crop rotation: Rotation of crops is the most efficient measure to regulate seed and root weeds. Changing the conditions of the crop interrupts the living conditions of the weeds thus inhibiting their growth and spread.
4. Sowing time and density:
   a. Weed pressure during the critical period (youth stage of the crop) can be reduced by choosing an optimal sowing time.
   b. One can increase sowing density when high weed pressure is expected.
5. Balanced fertilization: it can support an ideal growth of the crop, which promotes the growth of the crop over the weeds.
6. Soil cultivation methods can influence the total weed pressure as well as the composition of weeds:
   a. For example, minimum-tillage systems can increase the weed pressure.
   b. Because weed seeds can germinate between soil cultivation and sowing of the crop, weed cures before sowing can be effective at reducing weed pressure.
   c. Use of superficial stubble treatment works against persisting weeds. It should be done under dry weather conditions to allow the weed roots which have been brought to the surface to dry out.
7. Prevent dissemination of weeds by eliminating them before seed dispersal.
8. Prevent insemination of crops by weeds by
   a. avoiding the introduction of weed seeds into the fields through tools or animals.
   b. using only weed free seed material.

**Mechanical control**

With the necessary preventive measures, weed density can be reduced, but it will hardly be enough during the critical periods of the crop at the beginning of cultivation. Therefore, mechanical methods remain an important part of weed management.

Manual weeding is probably the most important one. As it's very labour intensive, reducing weed density as much as possible in the field will bring less work later on and should therefore be aimed at. Using the right tool can increase work efficiency significantly.

Flame weeding is another option: Plants are heated briefly to 100°C and higher. This provokes coagulation of the proteins in the leaves and a bursting of their cell walls. Consequently, the weed dries out and dies. Although it is an effective method, it is quite expensive, as it consumes a large amount of fuel gas and needs machinery. It is not effective against root weeds.

**Example: The Cyperus rotundus invasion**

Cyperus rotundus is one of the most invasive weeds known, having spread out to a worldwide distribution in tropical and temperate regions. It has been called "the world's worst weed" as it is known as a weed in over 90 countries, and infests over 50 crops worldwide. Its existence in a field significantly reduces crop yield, both because it is a tough competitor for ground resources, and because it is allelopathic, the roots releasing substances harmful to other plants.Bad soil cultivation methods such as leaving for a long time the soil nude, increase the infestation of these weed.

**Some preventive methods:**

- Avoid soil cultivation methods which can cut the Cyperus tubers
- Use organic manures to enrich the soil (Cyperus thrives in poor soils).
- Practise crop rotation


**Activity/ discussion points**

- *Ask the participants to complete the list of preventive measures with examples of weeds which can actually controlled by these measures*

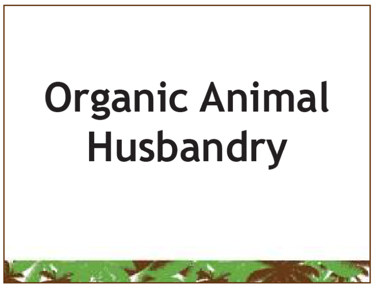
# 6 Animal Husbandry

## 6.1 Keeping Animals

**Introduction**
Integrating animal husbandry into crop producing farms is one of the principles of organic farming. In temperate and arid zones, animal husbandry plays an important role in the recycling of nutrients, while it is less emphasised in the humid tropics.

Animal husbandry in organic farming is different from both extensive animal husbandry, which is often environmentally damaging (e.g. overgrazing of common lands), and from intensive animal husbandry which keeps animals under ethically unacceptable conditions.

**Lessons to be learnt: 6.1**
- Farm animals can have many functions on a farm, but not all farms are suitable for keeping animals.
- Organic animal husbandry puts a central focus on welfare and health of the animals.
- In order to obtain a sustainable farming system, it is crucial to select the right kind and number of animals.
- Sheds and beddings must be developed in a way to ensure the welfare and health of the animals.





### 6.1.1 The Role of Animal Husbandry

**Integrating animals into the farm**
Integrating animals into a farm can help to recycle nutrients. By-products such as straw, biomass from field margins or kitchen wastes, can be used as cheap and easily available fodder. At the same time, the dung should be returned to the fields in the most efficient way in order to increase the fertility of the soil. Animal products such as milk, eggs, and meat can both be used for the family as well as for selling, thus generating income for the farmer.

Reasons to keep farm animals
- Many farm animals have a multi-functional role. They can:
- Produce dung which is of great importance for soil fertility.
- Yield products such as milk or eggs for sale or own consumption continuously.
- Recycle by-products such as straw or kitchen waste.
- Serve as draught animals for tillage or transport.
- Produce meat, hides, feathers, horns etc.
- Serve as an investment or a bank.

- Help in pest control (e.g. dugs) and weed management (e.g. grazing on barren fields).
- Have cultural or religious significance (prestige, ceremonies etc.).
- Produce young stock for breeding or sale.

The significance of each role will vary from animal to animal and from farm to farm. It will also depend on the individual objectives of the farmer.


**Notes:** *The trainer will use slide 3 to introduce the different types (classification) of conventional animal farming systems, i.e. extensive/ free range, semi intensive and intensives.*
*The trainer will introduce the principles of integrating animals into farming systems, then the trainer will have a class discussion get feedback on how the different components of farm relate to each other and compare those with the local situation.*

- *Types of animal conventional farming systems.*
- *Introduction (principles) of animal integration into farming systems.*


*Group work/class discussion on the "Role of animal husbandry". (Participants will break up into several groups depending on how large the group is, and then each group will select a food animal and discuss their findings in relation to the following questions listed below. Group presentations to follow.*

**Questions:** *Which roles do farm animals serve in the region? What are the reasons to keep animals? Which other functions could be utilized in addition?*

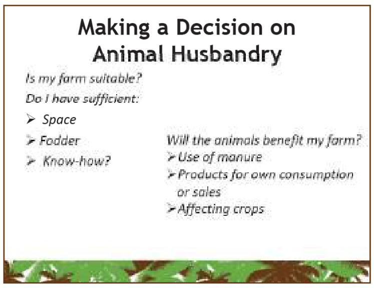
**Making a decision on animal husbandry**
There are several reasons for taking up animal husbandry as a part of your farming activities or even as the main one. There are also a number of critical aspects to be taken into consideration. In order to make a decision on whether and how to get involved in animal husbandry, you should ask yourself a number of questions:

Is my farm suitable?
Do I have sufficient space for shedding and grazing, sufficient fodder or by-products to feed, sufficient know-how on keeping, feeding, and treating the specific kind of animals?

Will the animals benefit my farm?
Can I use the dung in a suitable way? Will I get products for my own consumption or sales? Will the animals somehow affect my crops?

Can I get the necessary inputs?
Is sufficient labour available within or outside my farm? Is enough fodder and water of good quality available throughout the year? Will remedies and veterinary support be available, if needed?
Can I get suitable breeds of animals?

Will I find a market for the products?
Does anyone want to buy my milk, eggs, meat etc.? Is the price worth the effort? Am I able to compete with other farmers?




**Notes:** In this slide the trainer discusses some general reasons for keeping animals and the groups of participants select a food animal and record their roles in the region.
The Pacific Organic Standards are then discussed to see how they relate to the local situations of the participants.
The individual farm assessment chart and questions are next discussed to prepare the participants for making assessments for animal husbandry integration into farming systems.

### 6.1.2 The Requirements of Farm Animals

**What animals need**

- Organic farmers try to achieve healthy farm animals which can produce satisfyingly over a long period of time. To achieve this goal, various needs of farm animals have to be considered:
- Fodder in adequate quality and quantity; for non-ruminants: diversity in fodder is usually required.
- Sufficient access to clean drinking water.
- Clean sheds of sufficient size and with adequate light and fresh air.
- Sufficient freedom to move around and perform their natural behaviour.
- Healthy conditions and veterinary follow up, if needed.
- Sufficient contact with other animals, but no stress due to overcrowding.
- For herd animals: an appropriate age and sex distribution within the herd.

**What the Pacific Organic Standarads say on animal husbandry**
Pacific farmers have long raised pigs and chickens, while other animals are also important in some regions. Animals are an essential component of the mixed farming systems found throughout the region. They have cultural value, and also contribute to food security and soil fertility. A wider range of animals are now being farmed in the Pacific and this standard has been designed to incorporate the best approaches from traditional experience and organic principles. The adoption of this standard will ensure that livestock

husbandry is based on maintaining a harmonious relationship between land, plants and livestock, with minimum disruption to ecosystems. It will also ensure that the physiological and behavioural needs of livestock are respected and the animals are fed good-quality organically grown feedstuffs.

The livestock standard covers livestock and livestock products from the following: cows and cattle; pigs; sheep and goats; deer; poultry; crocodiles; and bees.

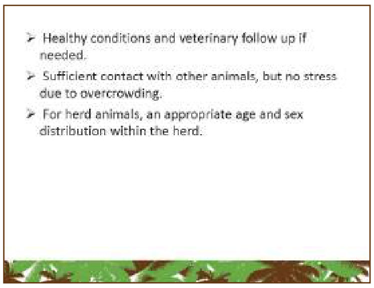
Pacific livestock farmers traditionally selected livestock that were adapted to local conditions and management systems. This resulted in a great diversity of breeds, and aligns well with organic livestock breeding principles.

Under traditional management, a wide range of preventive strategies were developed by Pacific farmers to protect the health of their animals. This included the use of herbs such as 'mile a minute' (Mikania micrantha), vaivai (Leucaena leucoephala), lupus and papaya to treat disorders such as internal parasites, birthing difficulties and other ailments. Many of these practices align well with organic management practices, which promote and maintain the health and well-being of animals through balanced organic nutrition, stress-free living conditions and selection of breeds resistant to diseases, parasites and infections.

**How many animals to keep?**

- In order to identify the appropriate number for a specific kind of animal on a farm, the following points should be considered:
- Availability of fodder on the farm, especially in periods of scarcity (e.g. dry season).
- Carrying capacity of pastures.
- Size of existing or planned sheds.
- Maximum amount of manure the fields can bear.
- Availability of labour for looking after the animals.

In tropical countries, farm animals are frequently found to be underfed. When defining the number of farm animals, keep in mind that the economical benefit will be higher when fewer animals are kept, but fed well. Not only the amount, but also the quality of the available food must be taken into consideration.


*Group work/class discussion on the needs of farm animals, (Participants will break up into several groups depending on how large the group is, and then each group will select a food animal and discuss their findings in relation to the following questions listed below. Group presentations to follow.*

**Questions :**
*What are the needs of the different kinds of farm animals typically found in the region? Which needs are frequently neglected in conventional farming? How can they be met in organic farming?*

*Discussion on Pacific Organics Standards, animal husbandry standards. Small group activity to identify basic standards in Animal welfare; Veterinary medicine, Feeding and Purchase and Breeding*

### 6.1.3 Sheds

The type of shed should be specific to the type of animals to be sheltered. Poultry, for instance, should be housed in sheds that do not get too hot. Contact of the animals with their faeces should be avoided as much as possible.

**Planning sheds**

With the exception of nomadic lifestyles, most farm animals are temporarily kept in sheds. The combination of animal husbandry and farm activities requires control of their movements so as to avoid damage to crops. For the welfare and health of the animals, sheds must be cool and aerated, and protect from rain. They should be constructed in a way ensuring:

- Sufficient space to lie down, stand up, move and express natural behaviour (e.g. licking, scratching etc.).
- Sufficient light (as a rule, one should be able to read a newspaper in the shed).
- Protection from sunlight, rain, and extreme temperatures.
- Sufficient aeration, but no draught.
- Appropriate beddings (see section below).
- Elements to exercise natural behaviour (e.g. for poultry: perching rails, sand baths and secluded laying nests).
- Sheltered pits or heaps to collect and store manure.

For economic reasons, sheds can be built with simple, locally available materials. Many countries have a rich tradition of shed constructions, and have developed the most efficient and appropriate shed systems for the conditions of the region. If techniques of this heritage are combined with the above principles, a locally adapted and at the same time animal friendly system may be obtained.

**Beddings**

Beddings are materials used in sheds for keeping the floor soft, dry, and clean, which is important for animal health. They absorb the excrements of the animals and need to be replaced from time to time. Beddings can be of straw, leaves, twigs, husks or other locally available material. They can be replaced daily or kept for several months while adding fresh material


*Group work/class discussion on stocking rates for ruminants and non ruminants. (Participants will break up into several groups depending on how large the group is, and then each group will discuss their findings in relation to the following questions listed below. Group presentations to follow.*

**Questions**; *How many animals do farmers keep in the region? Note the number of different stocking densities (animal per land holding size) in different farming systems.*

*What are their reasons for keeping more or less animals? Note the constraints as suggested by the participants. (Pictures of conventional shed structural designs can be sketched on the whiteboard)*

*Notes: The trainer will use slide 6 to elaborate the principles of shed designs and stocking rates in relation to organic animal husbandry. Then some stocking rate exercises will be done with the class before the class is broken up into groups for group exercises.*

## 6.2 Feeding Animals

### Introduction

The availability of fodder is one of the limiting factors in animal husbandry. Unlike landless systems in conventional farming, organic husbandry should be mainly based on the fodder produced on the farm itself. As is the case with humans, there is a direct link between the quantity and composition of the food and the health status of the animals.

### 6.2.1 A Balanced Diet

**Food Requirements of Animals**

If farm animals are to be productive (milk, eggs, meat etc.), it is important that they get suitable food in sufficient quantities. If the fodder production of one's farm is limited (which usually is the case), it might be economically valid to keep less animals but supply them with sufficient food. The appropriate quantity and the mix of feed items will of course depend on the type of animal, but also on its main use (e.g. chicken for meat or egg production, cattle for milk, meat or draft etc.). In milk production for example, cows producing milk should be given fresh grass and possibly other feed items of sufficient protein content. On the same diet, draught animals would rapidly become exhausted.

A balanced diet will keep an animal healthy and productive. Whether or not a farm animal receives the appropriate amount and kind of fodder usually can be seen by the shine of its hair or feathers. For ruminants, a majority of the fodder should consist of roughage (grass, leaves). If concentrates or supplements are used (e.g. agricultural by-products and wastes), they should not contain growth promoters and other synthetic substances. Instead of buying expensive concentrates, there are a variety of leguminous plants rich in protein which can be grown in the farm as cover crop, hedges or trees. If mineral content in the available fodder is not sufficient to satisfy the animal's requirements, mineral salt bricks or similar feed supple- ments can be used as long as they do not contain synthetic additives.


Group work/class discussion on choices of fodder crops to grow for livestock. (Participants will break up into several groups depending on how large the group is, and then each group will select a food animal and discuss their findings in relation to the following questions listed below. Group presentations to follow.

Questions; Which fodder is used for feeding? In which season are the fodder available? Which other grass varieties could be cultivated as fodder? Which tree crops are used as well?

- Field trips, 2 farms, i.e. one that practices grazing and the other shed feeding.
- Stakeholder invited to share their experience on fodder cultivation.

**Notes:** The trainer will use this slide to elaborate and discuss the differences between grazing and shed feeding according to the Pacific Organic Standards.
The AHP paravet manual on developing feed rations for livestock will be an addition here to give the participants a background on locally available feed resources, and the proportions for feed ration.

Field trips to two farms are anticipated as this will give the participants firsthand experience on farm practices of grazing and shed feeding.
The trainer will have a session where a stakeholder is invited to present to the participants giving them firsthand accounts of the experience of fodder production.

### 6.2.2 Fodder Cultivation

**Grazing versus shed feeding**
In many regions of the tropics, favourable periods with abundant fodder alternate with less favourable periods when there is almost nothing to feed to the animals. However, keeping animals means providing fodder throughout the year. Fodder can be produced on the farm as grazing land or as grass or tree crops used for cutting. While grazing requires less labour than shed feeding, more land is needed and appropriate measures to keep the animals away from other crops must be undertaken. Grazing may lead to a lower productivity (milk, meat) but usually is the more favourable option concerning health and welfare of the animals. Shed keeping, however, has the advantage that the dung can be easily collected, stored, or com- posted and applied to the crops. Whether grazing or shed feeding is the more suitable option will mainly depend on the agro-climatic conditions, the cropping system, and the availability of land. A combination of shed feeding and grazing in a fenced area may be an ideal combination of high productivity and animal friendly husbandry. In extensive grass lands of semi-arid areas, however, grazing may be the only suitable option.

**Integrating fodder cultivation in the farm**
In most smallholder farms, fodder cultivation will compete for space with the cultivation of crops. Whether fodder cultivation (and thus animal husbandry) is economically more beneficial compared with crop production must be assessed case by case. However, there are some options for integrating fodder crops in farms without sacrificing much land. Below are some examples:

- Grass or leguminous cover crops in tree plantations
- Hedges of suitable shrubs
- Shade or support trees
- Grass on bunds against soil erosion
- Grass fallows or green manures in the crop rotation
- Crops with by-products such as paddy straw or pea leaves

**Management of pastures**
The management of pastures is crucial for a good herd management. It is also important to practice appropriate management throughout the year. There are many different types of grasses, and every climatic region has grasses which are specifically adapted to the conditions. In some cases it may be worth considering to till the grazing site and sow grass varieties that are more appropriate to the animal's needs.

Overgrazing is probably the most significant threat to grass land. Once the protective grass cover is destroyed, the top soil is prone to erosion. Degraded pastures or land with little plant cover is difficult to recultivate. Therefore, it is important that the use and intensity of grazing on a particular piece of land is appropriate to its production capacity. Sufficient time must be given to a pasture to recover after intensive grazing. Fencing off of areas and rotation of the grazing animals on several pieces of land is a suitable option. This will also reduce the incidence of infection from parasites encountered while the animals graze.

The intensity and timing of grazing as well as the cutting of the grass will influence the varieties of plants growing in the pasture. If certain weeds are a problem, the organic farmer will have to change his management practises as weedicides cannot be used.

## 6.3 Animal Health and Breeding

### 6.3.1 What keeps animals healthy

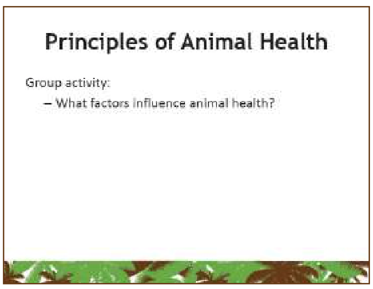
**Factors influencing animal health**

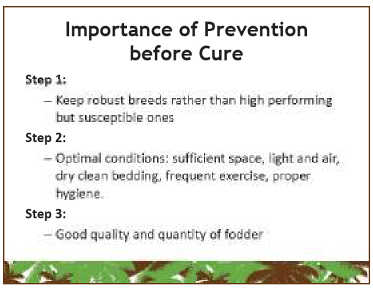
Disease causing germs and parasites are present almost everywhere. Like humans, animals have an immune system which is usually able to cope with these germs. And as with humans, the efficiency of the immune system will be disturbed if animals are not properly fed, can not practise their natural behaviour, or are under social stress.

Health is a balance between disease pressure (the presence of germs and parasites) and the resistance (immune system and self healing forces) of the animal. The farmer can influence both sides of this balance: reduce the quantity of germs by maintaining good hygiene, and strengthen the animal's ability to cope with germs.

Organic animal husbandry puts its focus on improving the living conditions of animals and on strengthening their immune systems. Of course: if an animal gets sick it must be treated. But the farmer should also think about why the immune system of the animal was not able to fight the disease or the parasite attack. And the farmer should think of ways to improve the ani- mals living conditions and hygiene in order to strengthen it.
Prevention before curing
Similar as in crop health, organic animal husbandry puts the main emphasis on preventive measures in order to keep animals healthy, rather than on curative methods. This starts from keeping robust breeds rather than high performing but very susceptible ones. Next, the conditions in which the animals are kept should be optimal ones: sufficient space, light and air, dry and clean bedding, frequent exercise (e.g. grazing) and proper hygiene etc. The quality and quantity of fodder is of crucial importance for the health of the animal. Instead of feeding commercial concentrates which make animals grow faster and produce more, a natural diet appropriate to the requirements of the animal should be achieved.

Where all these preventive measures are taken, animals will rarely fall sick. Veterinary treatment thus should play only a secondary role in organic farming. If treatment is necessary, alternative medicine based on herbal and traditional remedies should be used. Only if these treatments fail or are not sufficient, synthetic medicines (e.g. antibiotics) may be used.



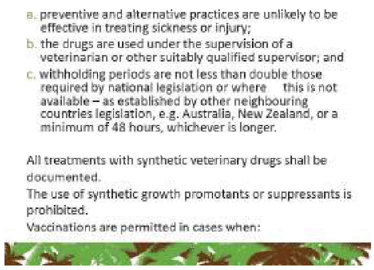



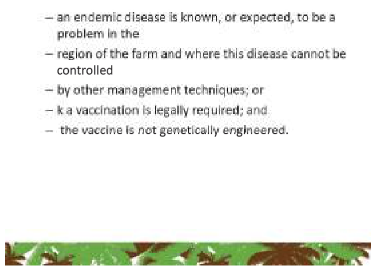
*Group work/class discussions on factors that affect animal health. (Participants will break up into several groups, depending on how large the group is and then each group will select a food animal and discuss their findings in relation to the following questions listed below. Group presentations to follow.*

**Questions:**
*Draw a picture of a farm animal, and discuss which factors influence the health of the animal and its ability to cope with diseases? Note down the suggestions around the animal, distinguishing supportive and negative factors.*

*Which preventative measures do the participants in the group know? What are the experiences of farmers in the region? Some topics can be fodder, breeds, hygiene, and pasture management, husbandry techniques etc.*

*Which curative measures do the participants in the group know? Based on local knowledge, which plants can be used to treat animal injuries and diseases?*
*Select an animal disease, discuss and note points on how an organic management plan could be developed?*




Notes: *The trainer will use this slide to elaborate on the importance of factors that influence animal health as well as the importance of prevention before cure in relation to organic animal husbandry. The trainer will discuss both the standards for veterinary medicine from Pacific Organic Standards*

### 6.3.2 Veterinary Treatment

The main principal for veterinary treatment in organic animal husbandry is: get to know the causes of (or factors that favour) diseases in order to enhance the natural defence mechanisms of the animal (and to prevent its manifestations in the future, see above)

**What the Pacific Organic Standard says on veterinary medicine**
Unlike in crop production, synthetic means are allowed to cure sick animals if alternative treatment is not sufficient. Here, reducing the suffering of the animal is given priority over the renunciation of chemicals. However, the standards clearly demand that priority is given to management practices which encourage the resistance of the animals thus preventing the outbreak of a disease.

Therefore, an outbreak of a disease shall be considered as an indicator that the conditions under which the animal is kept are not ideal. The farmer should try to identify the cause (or causes) of the disease and prevent future outbreaks by changing management practises.

If conventional veterinary medication is applied, withholding periods must be adhered to before the animal products can be sold as "organic". This shall ensure that organic animal products are free from residues of antibiotics etc. Synthetic growth promoters are not allowed in any case.

**Controlling parasites with herbal remedies**
Herbal medicines are widely used in many countries. Some traditional farming communities have a vast knowledge of local plants and their healing properties. Plants can definitely support the healing process, even if they do not eliminate the germ of the disease directly. Still, farmers should not forget to identify the cause of the disease and also to re-think their management practises. For parasite problems, changing the living conditions or the management of pastures will be more effective in the long run than any treatment.

**Example: Using Sweet Flag against parasites**
One example to use a herbal remedy against parasites is sweet flag (Acorus calamus). This plant grows both in tropical as well as subtropical regions and is found on the banks of rivers and lakes and in swampy ditches or marshes. The powdered dried rhizomes (thick root parts) act as an effective insecticide against fowl lice, fleas and house flies.

Treating fowls infested by lice: Use around 15g of powdered rhizome for an adult bird. For dusting the bird with the powder, hold it by its feet upside down so that the feathers open and the dust will work its way to the skin. The treatment is reported as being safe to the birds.

The sweet flag powder is also reported to be effective against house flies when dusted on fresh cowdung infested by fly maggots. It further shall protect new-born calves of vermin infection if washed with a water infusion.

Attention! Herbal remedies against parasites can also have a toxic effect on the farm animals! Therefore it is important to know the appropriate dose and application method!

**Homeopathic Treatment**
The concept of homeopathy was developed in the 18th century for treatment of humans. In recent times, some veterinary doctors use this alternative medicine for treating sick animals. Homeopathy is based on highly diluted substances which would cause similar symptoms as the disease if given in high concentrations. Homeopathic treatment aims at stimulating the self healing forces and the immune system of an organism. A specific dilution process transfers the "information" of the substance to the next dilution level. Usually, the remedies itself do not contain detectable amounts of the original material anymore.

As with treating humans, a large amount of experience is crucial for properly using homeopathy for veterinary treatment.

### 6.3.3 Breeding in organic animal husbandry

**Principles and methods**
As preventive measures for maintaining good animal health are of high relevance in organic farming, the selection of breeds suitable to local conditions and to organic feeding is of crucial importance. This requires that suitable breeds are available . Traditional breeds of farm animals may be a good starting point for organic animal breeding. Animals can be improved by selection of individuals especially suitable for organic conditions. They can be crossbred with suitable new breeds, thus achieving an animal with the positive aspects of traditional breeds and the satisfying production of the new breeds.

For breeding, organic farming uses natural reproduction techniques. While artificial insemination is allowed, embryo transfer, genetic manipulation, and hormonal synchronisation are not permitted according to the Pacific Organic Standard.

**Breeding  Goals**

Over the last decades, traditional breeds have been replaced by high performing ones in many regions. Similar to high yielding plant varieties, these new breeds usually depend on a rich diet (concentrates) and optimal living conditions. As high performing breeds in general are more susceptible to diseases than traditional varieties, they need frequent veterinary interventions. Thus, these new breeds might not be the right choice for small farmers, as the costs of food concentrates and veterinary treatment are too high compared with what can be earned by selling the products.

In addition, for organic farmers the main animal product (e.g. milk) is not the only reason to keep animals. Breeding activities therefore should try to optimise the overall performance of the animal, taking into consideration the different goals of an organic farmer. For example a poultry breed suitable for organic smallholder farms might not be the one with the highest egg production, but one in which meat production is good, and kitchen wastes and whatever is found on the farm yard can be used as feed. Suitable cattle breeds would produce sufficient milk and meat while feeding mainly on roughage and farm by- products (e.g. straw), be of high fertility and good resistance against diseases, if required, they can also be used for draught and transport.

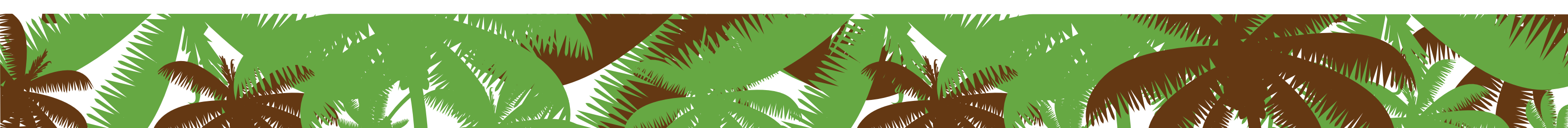
**Maximum performance or life production?**

When comparing the production of different breeds of cows, usually, only the production per day or year is taken into consideration. However, high performing breeds usually have a shorter life span than traditional ones with lower production. The life milk production of a cow giving, for example, 8 litres per day, but over 10 years, therefore would be greater than the one of a high-breed cow yielding 16 litres per day, but dies after 4 years. As the investments to get a milk producing cow are quite high, i.e. the rearing and feeding of a calf or the purchase of an adult cow, continuous production over a long life span should be of high interest to the farmer. This should be reflected in the breeding goals, which so far mainly focus on the maximum short term production.


*Group work/class discussions on traditional varieties and cross breeds. (Participants will break up into several groups, depending on how large the group is and then each group will select a food animal which they feel is relevant for organic farming in the country. The group will further discuss their findings in relation to the following questions listed below. Group presentations to follow.*

**Questions:**

*From the selected food animal, please list the available breeds present in the country, what are the current production levels, what are the animal food requirements, what diseases are they susceptible too, and which would be suitable for organic farming?*



# Annex

8.1 Work Material

The following pages are work material referred to in the recommendations for interactive sessions.

1.1

| Checklist: How organic are traditional systems? | The local traditional |
|---|---|
| system | |
| Standard Requirement | |
| No synthetic fertilizers | |
| Nutrient supply based on recycling of organic material | |
| No burning of biomass | |
| No clearing of natural forests | |
| Measures to improve soil fertility | |
| Prevention of soil erosion | |
| No synthetic pesticides | |
| Preventive methods to improve plant health | |
| Crop diversity | |
| Maintenance of biodiversity | |
| Sustainable use of water | |
| Animal friendly keeping and shed systems | |
| Sufficient free move of farm animals | |
| No mutilations of farm animals | |
| Animal fodder from organic farm | |
| No use of preventive antibiotics and growth promoters | |
| Socially just | |

| Soil Assesment Questionaire | Origin of the Soil Sample |
|---|---|
| **Tactile properties (Feel it!)**<br><br>**Take a teaspoon of soil in your hand:**<br>gritty? ► rich in sand<br>smooth, but not very sticky? ► rich in silt<br>smooth and sticky? ► rich in clay<br><br>**Try to make a firm square of soil. Next try to roll up the square into a thin roll.**<br><br>roll is not possible ► sand or sandy loam<br>thin roll is possible ► loam or clay<br><br>**If a roll was possible, try to bend the roll into a ring**<br><br>ring not possible ► loam<br>ring with cracks outside ► light clay soil<br>firm ring without cracks ► heavy clay soil | **How does it feel between your fingers?**<br><br>**Is the soil sticky enough to form a square and a roll?**<br><br>**Is it possible to form a stable ring?** |
| **Visual Properties (Look at it !)**<br><br>Describe the coloure of the soil. What might be the reason for the colour?<br><br>Can you find structures of plant residues? Which?<br><br>Do you find traces of soil organisms? Which? | |
| **Smell**<br><br>Can you feel a smell of the soil? which kind of smell? | |

| | |
|---|---|
| **Site Information**<br><br>On which kind of place was the sample collected, or on whic sites is this soil usually found.<br><br>How are theses ususally used? what crops are grown? | |
| Is this type of soil suitable for agriculture use?<br><br>Will it keep moistre well?  Will water logging occur?<br><br>Is it easy to till? Does it have a good structure?<br><br>Do you suppose to find earthworms in this type of soil?<br><br>Is it rich in nutrients? Whic crops would you grow on it? | |
| **How should such a soil be treated for improving it's fertility?**<br><br>soil cultivation, tillage:<br>fertilisation, manuring:<br>plant cover, mulching:<br>crop rotation, fallows: | |
| **Remarks** | |