4.1 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 chemical 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

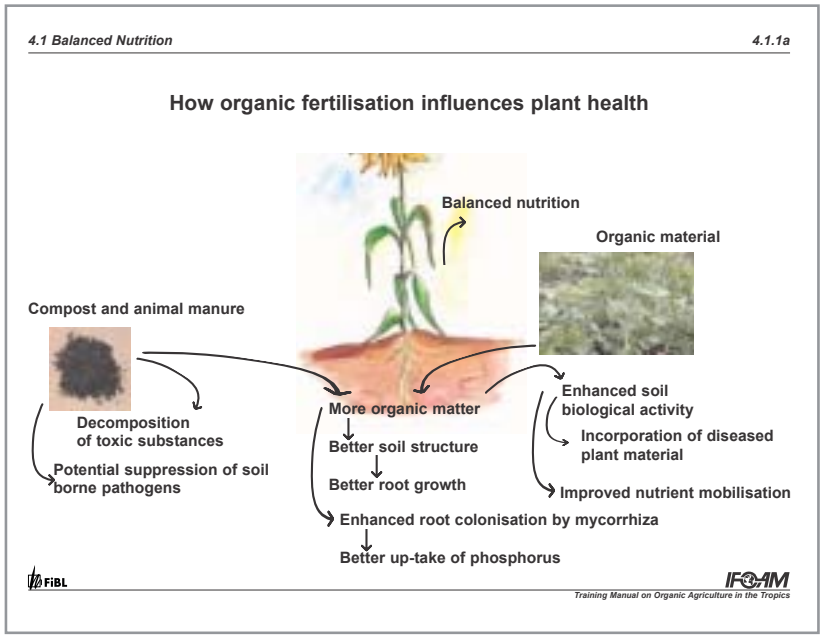
Synthetic or chemical fertilizers – advantages and disadvantages
The use of chemical fertilizers can lead to an impressive increase in yields. Chemical fertilizers offer large amounts of nutrients to the plants in an easily available form. This fact makes the use of nitrogen fertilizers especially tempting. 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, chemical fertilizers can also have a negative impact on plant health.

Motivation: Share experiences on the use of chemical and organic fertilizers
Discuss with the participants which experience (observations) they have made with chemical and organic fertilizers. Write the keywords on cards or on the board. Complete the discussion with the help of the transparency.

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.
- Chemical fertilisation 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 such 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.

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 chemical 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.



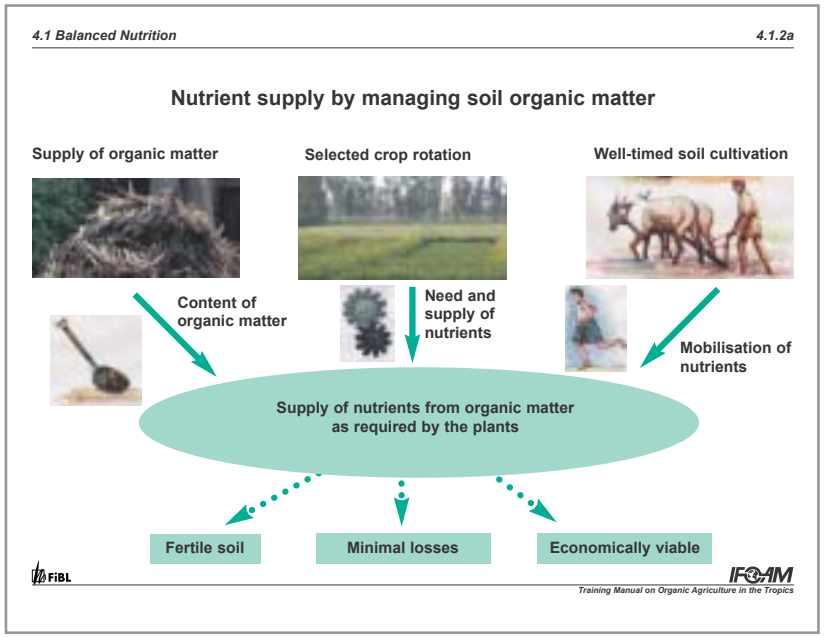
Transparency 4.1.1a: How chemical and organic fertilisation influence plant health.

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 (see also chapter 4.2.3).
- 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 (see also chapter 3.2.2). 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.

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.



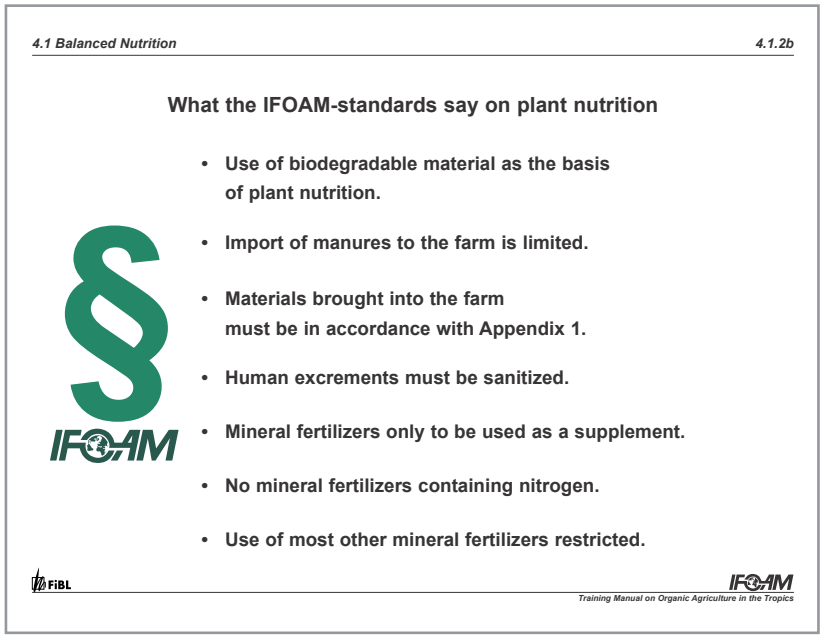
Transparency 4.1.2a: Nutrient supply by managing soil organic matter

Discussion: How can organic matter for plant nutrition be managed?
Write a typical crop rotation on the board. Discuss with the participants how nutrients may be supplied by managing organic matter.

What do the IFOAM standards say on plant nutrition?
IFOAM Basic Standards define how plant nutrition should be approached in organic agriculture and which materials are allowed, which are allowed with restrictions and which are prohibited.

IFOAM's Main Standards on Plant Nutrition:

- Biodegradable material builds the basis of the fertilisation programme.
- The total amount of biodegradable material brought onto the farm unit is limited.
- Animal runs should be prevented from becoming over-manured where there is a risk of pollution to rivers or groundwater.
- Brought-in material shall be in accordance with Appendix 1 of the Standards.
- No manures containing human excrements can be used as fertilizer on vegetation for human consumption, if not first sanitized.
- Chemical fertilizers shall be used only as a supplement to organic nutrient sources.
- Chemical fertilizers shall be used only in their natural composition.
- No chemical fertilizers containing nitrogen can be used, Chilean nitrate and all synthetic nitrogenous fertilizers, including urea, are prohibited.
- Only restricted use of chemical potassium, magnesium fertilizers, trace elements, manures and fertilizers with a relatively high heavy metal content and/or other unwanted substances, e.g. basic slag, rock phosphate and sewage sludge is permitted.



Transparency 4.1.2b: What the IFOAM standards say on plant nutrition

4.1.3 The Main Plant Nutrients and how to Ensure Their Supply

Macro- and micronutrients
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.

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.

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.

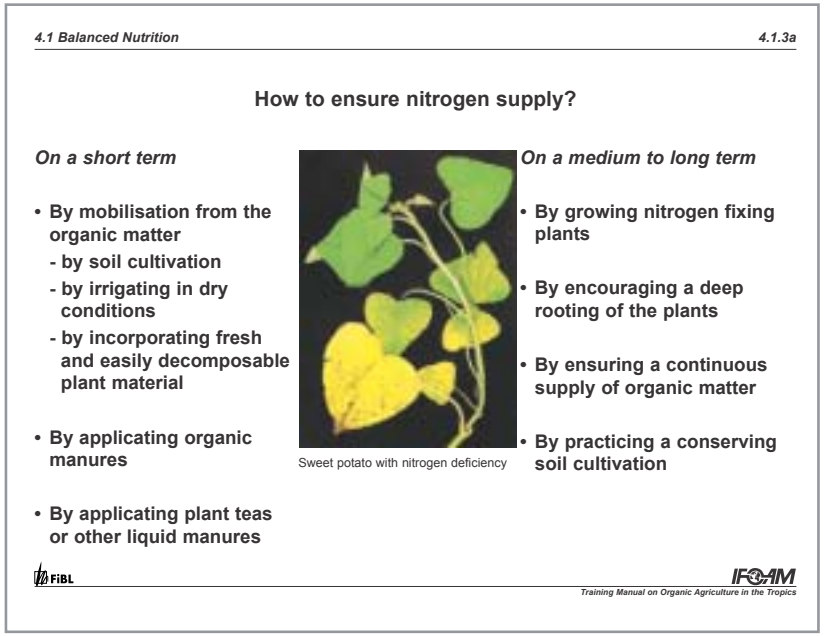
An important source of nitrogen is the fixation from the air through microbes (rhizobia) associated with certain plant species (especially legumes) (see also chapter 4.5). Because of their potential to supply nitrogen for other crops, legumes play an important role in organic farming, be it in the form 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 (see also chapter 3.1.2).



Transparency 4.1.3a: Photo of a sweet patato plant with nitrogen deficiency; possibilities how to ensure nitrogen supply on a short and a medium to long term basis.

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 bound by chemical particles and thus becoming almost not available 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

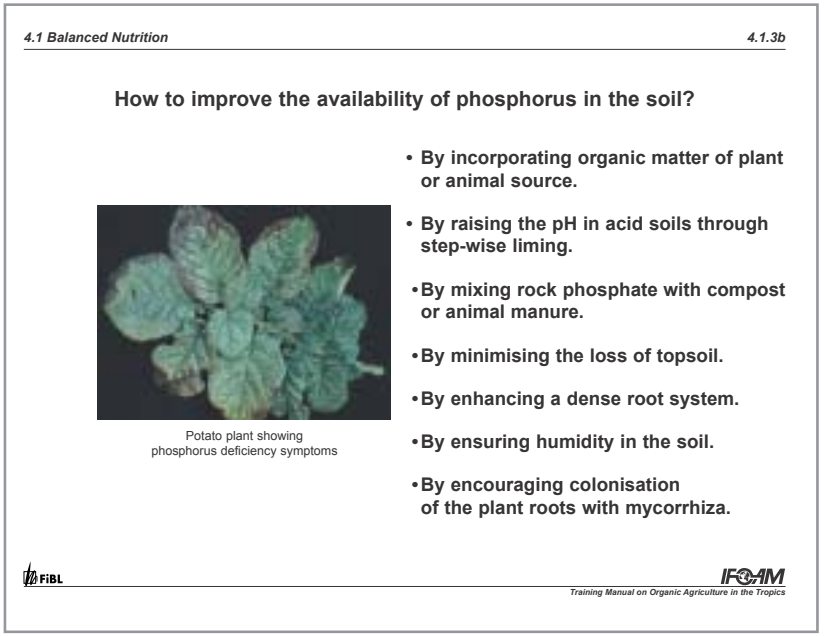
Potassium is necessary for the synthesis of amino acids and is involved in the process of photosynthesis and in the plants ability to develop resistance to diseases. Good supply of potassium during growth also improves the storing capacity of the harvesting goods. Plants ideally contain potassium and 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 chemical particles and thus not readily available. Some potassium is adsorbed onto the surface of chemical 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 chemical 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.



Transparency 4.1.3b: Photo of a potato plant with phosphorus deficiency; possibilities how to improve the availability of phosphorus in the soil.

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.

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.

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 participants: «How can we optimise nutrient cycling in our farms?».

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 (see chapter 3.4) 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.

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.

- 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.

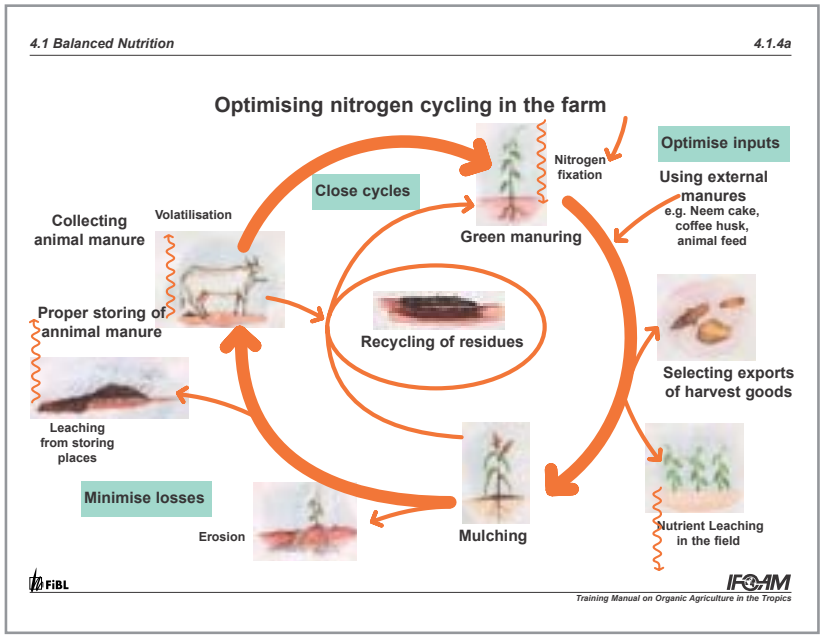
Principle 2: Closed nutrient cycles

- 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.
- Chemicals 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.



Transparency 4.1.4a: Optimising nitrogen cycling in the farm. Scheme of a farm with fields and animals showing inputs, outputs and losses.

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 from a field work in India):

- *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, com-*

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.

post 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.).

Recommended Readings:

- *«Soil fertility management», Agrodok-series No. 2, Agromisa.*
- *«Soil fertility management», KIOF.*
- *«Agriculture in African Rural Communities», Land and Life.*