Introduction to

Soil Fertility Improvement and Productivity Enhancement

AT UGANDA LIMITED

A SIMPLE GUIDE TO EXTENSION WORKERS

Introduction

Most Ugandan soils are old, with little weatherable minerals to replace removed nutrients. Crop nutrients are associated with soil organic matter occurring mainly in the surface layers (Top soil). These are however susceptible to losses through erosion and leaching (a process where nutrients dissolve and are transported along with water to lower soil depths where plant roots cannot reach). These losses coupled with deterioration of soil physical properties lead to gradual fall of crop yields especially where intensive cropping is practiced.

The soil fertility concept addresses the capacity of soils to supply essential plant nutrients in the amount and form that a plant can take them up easily. For this to be achieved, a physically, chemically and biologically good soil medium is required. A good fertility soil must thus:

- Be deep enough to enable roots penetrate without any obstruction
- Have good structure to ensure proper aeration, drainage and hence proper growth and development of roots
- Have a favorable soil reaction (i.e. for most crops a PH range of 5.5 - 6.5 is acceptable)
- Have a good supply of both available and reserve plant nutrients
- Be able to store soluble nutrients
- Contain sufficient organic matter

Soil Degradation

This refers to a state where the productivity of a soil declines. Soil degradation is caused by:

- Permanent flooding which kills soil fauna and flora
- Heat due to bush burning or prolonged exposure to sunlight. This dries up the soil, kills soil organisms and oxidizes organic matter.
- Physical pressure from rain drops, wheeled machinery may compress the soil leading to soil compaction

- Leaching which removes mineral salts
- Soil erosion
- Nutrient exports in harvested crops when not replaced.

Soil nutrients and their management

When a crop is grown on a piece of land and is then harvested, nutrients in the farm are removed from the soil. Over a period of time, if the nutrients are not replenished, the soil will no longer be able to produce any reasonable crop. The amount of mineral salts taken up by plants should be replaced as part of the regular farm management practice. Water availability affects the absorption of mineral salts by plant roots. Not only are plant nutrients absorbed when dissolved, but excess water may leach soil and carry away nutrients to the deeper layers where they are inaccessible to plant roots.

There are 19 essential elements for plant growth and development. Of these, 6 are taken up by plants in relatively large amounts. These are Nitrogen, Phosphorus, Potassium, Calcium, Magnesium and Sulphur. These nutrients are lost through leaching, crop harvesting, loss through gaseous form (volatilization), de-nitrification, soil erosion and through fixation by soil constituents (a process in which nutrients are held up in the soil in a way that they do not dissolve). When taken up in large amounts, these elements negatively affect plant growth and development. Their management is thus very essential for optimum plant growth.

Soil Nitrogen

Nitrogen is one of the most limiting of all the nutrients due to the many transformations it undergoes. It is required to induce growth in plants. It raises plant yields by elongating the stems and leaves. However, on its own, or if applied in excessive quantities, may lengthen the growth period of grain and fruits and/or make plants easy target of bacterial diseases with a likelihood of breaking due to their thickness.

Symptoms of nitrogen deficiency

- The plants are stunted and small in size
- In cereals the symptoms are evident during the bearing of grain - the cobs as well as the grains on them are fewer.
- In fruit trees, leaves fall off and a decrease occurs in the number of branches and fruits.
- The leaves are smaller, the colour of leaves turn from green to yellowish. This change starts from the tips of the lower leaves. The lower leaves appear scorched and wither prematurely, but the upper leaves remain green.
- Generally the life span of the plant is shortened and the yields are lower

Excessive amounts of nitrogen in the soil can lead to the following:

- Stems, branches and leaves grow very fast and the leaves are big and deep green.
- The stems are smooth, and full of water and easily break;
- Flowering and fruit production are delayed or do not occur entirely and
- Yields of storage tissues such as potatoes, sweet potatoes, yams, cassava are low.

Soil Phosphorus

Most soil types in Uganda are deficient in phosphorus. Phosphorus is required at planting since it strengthens plant roots. Phosphate fertilizers should be applied to the soil either before or during planting time so as to help in the growth of the roots right from the start. In summary, the functions of phosphorus are:-

- It helps the growth and strengthening of plant roots so as to enable the plant to maximize the use of water and other soil nutrients,

- It increases the fertilization rate of flowers, thus giving rise to better yields of fruit and seeds
- Enables the flowers to appear in the presence of large amounts of nitrogen, which would have otherwise hindered the growth.
- Enables plants to mature and ripen faster
- Strengthens the stalks of grain-producing plants so that they are not easily felled by wind
- Enables plants withstand diseases
- Raises the quantity and quality of produce

Symptoms of Phosphorus deficiency

- The plant has lower growth rate and it may wither
- The leaves change their colour to brownish or purplish
- Fruit trees manifest their symptoms by shedding leaves prematurely, having fewer and smaller fruits with an unappealing colour that ripen slowly and take longer to mature.
- Low yields

Potassium

Potassium mainly occurs naturally in soils. It is mainly lost through erosion, leaching and crop harvesting. Soil acidification also affects its availability. The major functions of Potassium are:-

- It raises yields
- Boosts sugar levels in such crops as potatoes, sweet potatoes, e.t.c.
- Strengthens and hardens the stems thus making the plant resistant to bacterial diseases, problems related to diffusion processes and the brittleness of stems
- Regulates water use in the plant
- Enables plant to use other nutrients in the soil
- Enables the produce to stay in storage for long

- It is thus more important in the growing of tubers as in different types of potatoes, cassava and oil plants such as coconuts.

Symptoms of Potassium deficiency

- Stunted plant
- Leaves have small patches of white, yellow or brown, leaves are yellow, reddish or curled
- Fruits are small with severe wounds/bruises that make them spoil easily after harvest
- The edges of the leaves change their colour to yellow and later dry up
- The stalks of plants such as maize and millet break easily.

Calcium, Magnesium And Sulphur

Sulphur and Magnesium have similar functions. They are associated with the manufacture of chlorophyll and formation of new cells. Calcium is essential for the growth of roots and formation of cell walls. It also helps reduce soil acidity.

Soil Organic Matter

The fertility of our soils mainly depends on soil organic matter. Soil organic matter is derived from dead plant and animal matter. It imparts a darker colour and forms a thick spongy layer in forested areas and some perennial plantations. This layer is however usually thin in continuously cultivated crop fields. Soil organic matter plays an important role in the structural quality of a soil. For example, it increases water-holding capacity of sandy soils. It can be lost through burning, exposure to the sun, poor tillage practices and erosion. Good organic matter management thus implies recycling of crop residues rather than burning, use of compost, farmyard manure, green manures, cover crops, zero/minimum tillage, etc. It also implies prevention of soil erosion since organic matter is mainly found in the topsoil.

Managing soil nutrients

Soil nutrients can be managed through the following ways:

- Controlling soil erosion
- Recycling crop and animal residues
- Using less easily leached forms e.g. Ammonium as opposed to Nitrate for nitrogen fertilizers
- Split applying nitrogen fertilizers rather than single application
- Using leguminous crops/plant species in cropping cycle
- Adding fertilizers that contain the nutrients required e.g. Rock phosphate, SSP, TSP or DAP for Phosphorus; Urea, CAN or DAP for Nitrogen; MOP for Potassium
- Crop rotation
- Applying liming materials e.g. agricultural lime, kitchen ash, compost
- Zero/minimum tillage practices

Methods of Improving Soil Fertility

Below are the main elements of possible strategies for improving soil fertility. Recommendations should however, be location specific and take into account not only the soil characteristics but also socio-economic situation of the farmer. Currently, AT Uganda is Carrying out Farmer Participatory On-Farm experimentation with a range of technical options and farmers will be expected to adapt better land husbandry practices and technologies which suit their own specific needs and opportunities.

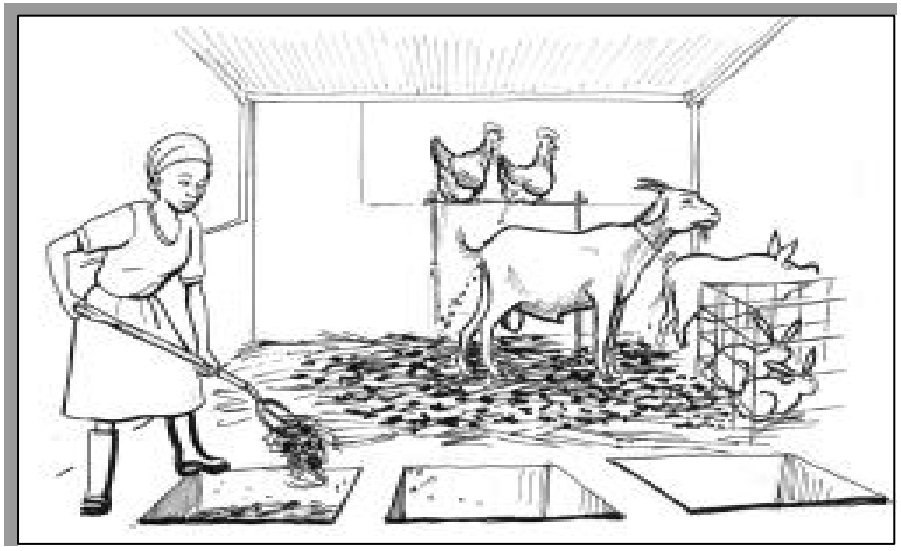
1. Use of Organic Fertilizers/Manures

These are sources of plant nutrients originating from either plant or animal material. This is one way of reducing soil nutrient mining by

returning some soil nutrients removed from land through crop harvests and grazing. The different types of organic manure include:

a) Farm Yard Manure (Boma compost)

This is made by composting dung and urine from farm animals with straw and other bedding materials. The plant nutrients found in the Farm Yard Manure (FYM) depends on the nutrient content of the feed given to the animal, the nutrient content of the straw used for bedding and loss through volatilization and washing out. It thus needs to be applied in large quantities to be effective. When applied directly to crop fields, FYM may burn the crops as they rot. It is therefore necessary that there are applied before the crops are planted or away from the crop roots. Efficient collection of dung and droppings requires that animals be kept in enclosures for some time. This calls for structures such as stables, kraals and/or housing.



Collecting dung and urine from farm animals with straw and other bedding materials

Advantages

- Nutrients are released slowly over along period of time
- Improves physical property of soil and creates healthy soil
- Increases water holding capacity of soil
- Its beneficial effects on plant growth are often difficult to duplicate with other materials

Disadvantages

- Low nutrient contents which leads to need to use large quantities
- High labour demand for handling bulky material
- Dirty working environment
- Requires many animals

b) Liquid Manure/Plant Tea

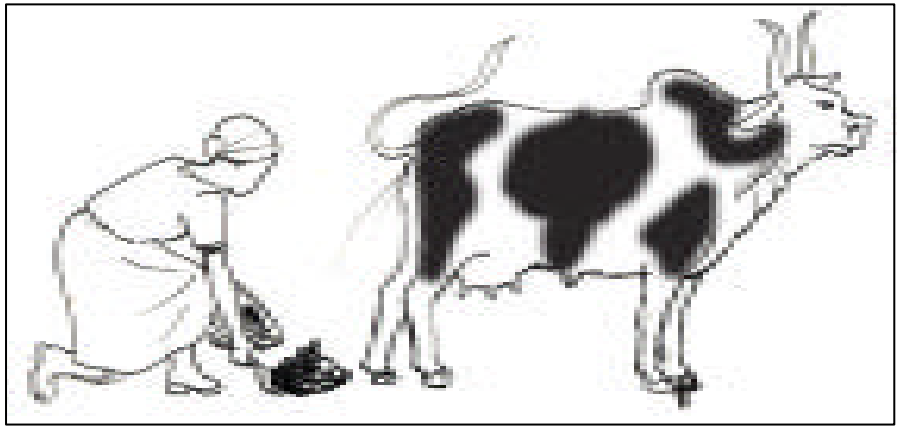
This is made by soaking either animal dung or chopped grass/ soft green leaves and branches or collecting and fermenting animal urine for 14 days and then diluting the resultant solution before applying in the field. It is used to provide crops with natural plant nutrients quickly during the growing season. It is best to apply liquid manure every 2-3 weeks.

Advantages

- Provides nitrogen
- Easy to make
- Waters crops as well

Disadvantages

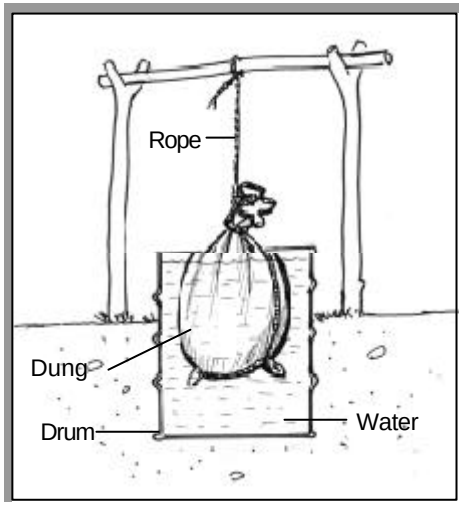
- May be difficult to apply
- Containers may be expensive



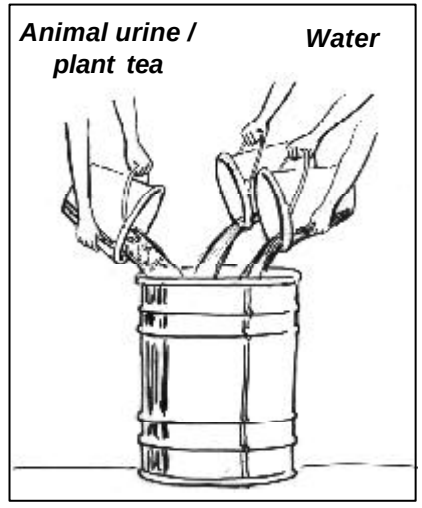
Collecting dung and urine from farm animals

chopping grass/soft green leaves and branches

Soaking chopped leaves in water for 14 days



Dung in a sack suspended in a drum of water under a shade.



Diluting the resultant solution after fermenting. Animal urine / plant tea is used in one portion to two portions of water

c) Compost

Compost is decomposed plant and animal waste. It is made by pilling up organic residues or organic materials mixed with a bit of soil, moistening the materials and letting these materials

Applying liquid manure to perennial crops

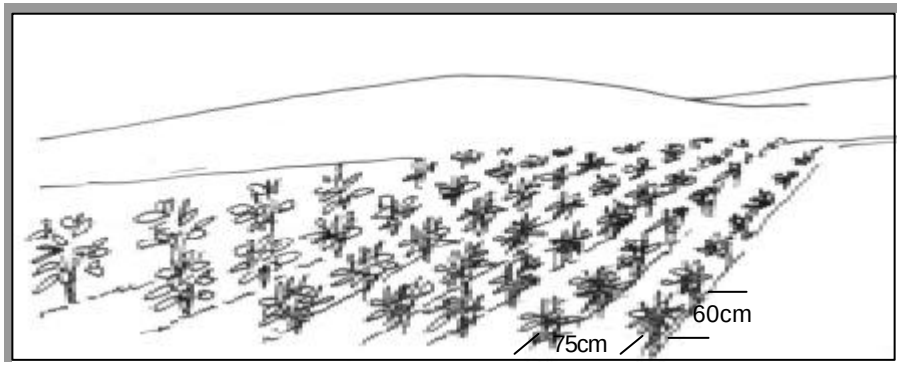
undergo decomposition. Good compost has the following benefits:

- It slowly releases nutrients into the soil
- When incorporated into the soil, it makes the soil an excellent habitat for the soil organisms.
- It gives soil the dark brown colour.

- It regulates the soil structure and softens hard soil; it also brings together sandy soil. This facilitates easy absorption of excess water by soil, water retention by the soil, soil's ability to withstand erosion, easy sprouting and growth of roots and adequate air circulation in the soil.
- It improves the environment and the economy by giving rise to better utilization of rubbish.
- It reduces the use of artificial fertilizers and chemicals thus preventing negative effects to the soil, plants, farm and human life.

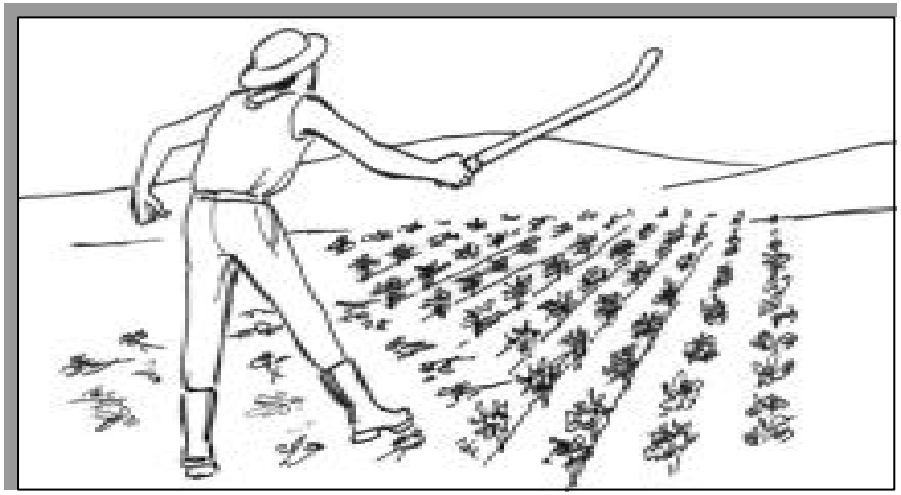
d) Green Manure Use/Improved Fallows

This involves either using green crops, weeds and other vegetative materials that are incorporated in soil or left on surface to maintain or improve soil fertility or planting legume species that fix large quantities of Nitrogen as relay crops (in which case the legume species are planted and after the crop has been harvested the fallow continues to grow for 3 - 6 months depending on whether the legume type is short or long term).



Green manure planted as pure stand e.g Mucuna, lablab

Green manure plants can be grown specifically for fertilizing the soil and ploughed into the ground just before they flower. Plants that make good manure grow very fast, have many leaves, and decompose quickly



Cutting down green manure at flowering

when ploughed into the soil. The most effective green manure plants are therefore those belonging to the legume family and these include

Green manure uprooted and left on the surface as mulch

calliandra, sesbania, mucuna, tephrosia, crotolaria, lablab, canavaria and others.

Benefits of Green Manure

- Adds organic matter to soil
- Reduces loss of mineral nitrogen by leaching
- Acts as a ground cover and protects soil during unfavorable

Incorporatng/digging in green manure

- Their root system breaks up clods of soil and promotes porosity
- Can provide fodder

Drawbacks

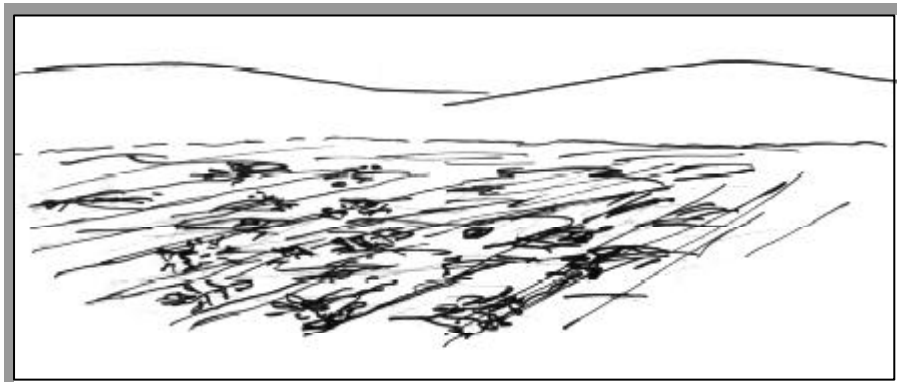
- Results are long-term
- May compete with the crop
- Can become weed seeds

e) Crop Residues

These are materials left after harvesting and processing. They can be composted or used as mulch or directly incorporated in the soil when preparing land, e.g. fruit pulp, coffee husks, bean haulms, wood shavings.

f) Mulching

This is the practice of covering the soil surface to reduce moisture loss, control weeds and erosion. Materials used include crop residues, grass (especially elephant grass), banana stems, coffee husks, and others.



Crop residues used to cover the soil surface

Benefits

- Protect the soil against the impacts of raindrops
- Improve rain water percolation
- Conserve the soil moisture by reducing evaporation
- Enrich soils with nutrients when they decompose
- Improve soil structure
- Enhance activities of microorganisms in the soil
- Reduce weed growth

2. Use of Artificial (Inorganic) Fertilizers

Artificial fertilizers are usually manufactured and contain a high concentration of mineral salts soluble in water. Because of this, they have immediate effect on plant growth as they are immediately available to plants. They supplement the natural nutrient supply of the soil and are used to correct nutrient deficiencies and thereby satisfy the nutrient demand of the crop. They also help to compensate for nutrients lost through crop removal, leaching, and erosion. They are thus a compliment and not a substitute for appropriate soil management practices. In addition, they are less labour intensive to transport and apply as they are far less bulky.

Drawbacks

- Because of high solubility of some of them, excess dissolved quantities present in the soil are easily leached out of the soil by rain.
- They require technical know-how in terms of what to apply, amounts to apply for each crop, how to apply and timing of the application.
- They are expensive and may not be available
- They contain no organic matter

3. Biological Nitrogen Fixation (BNF)

A lot of nitrogen is present in the atmosphere. Unfortunately this Nitrogen exists in a form that cannot be used by crops and has to be converted into a form that can be used by crops. One of the ways through the process called BNF. Bacteria known as Rhizobia fix Nitrogen when they are inside nodules found on the root system of leguminous plants. Rhizobia, which can fix enough Nitrogen, can be added by inoculating either seeds or the seedbed with the recommended Rhizobia. Rhizobia inoculants are produced commercially and can be obtained from the Department of Soil Science at Makerere University at a small fee. Cropping systems that exploit Rhizobia include use of legumes in crop rotations, use of legumes as green manure and crop covers, and use of leguminous tree and forage species to improve fallows.

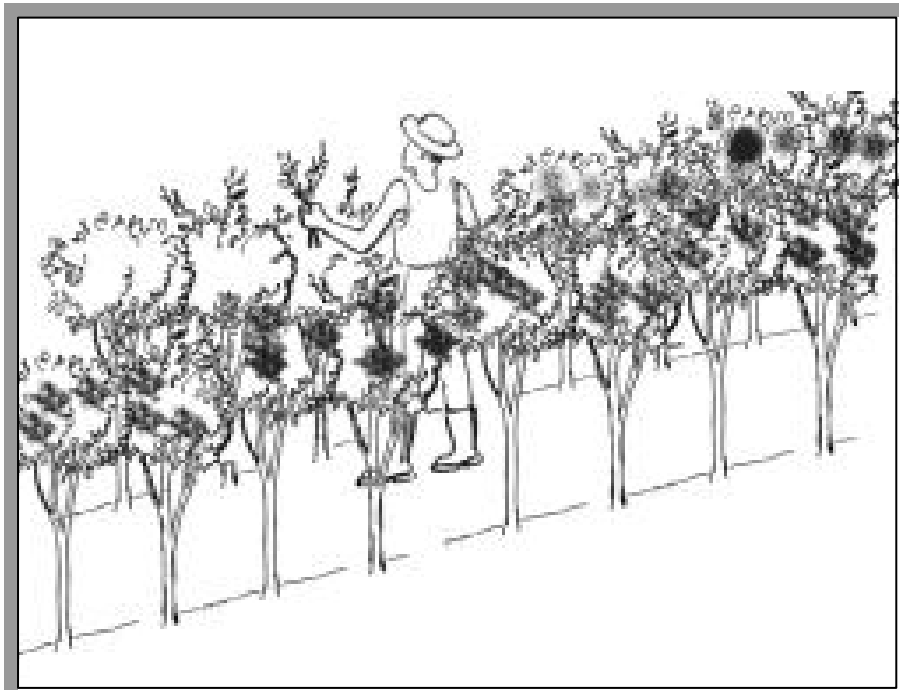
5. Agroforestry

This is a land use system in which trees and shrubs are deliberately integrated with crops or animals. This practice includes:

a) Alley/hedgerow cropping in which several rows of food crops are intercropped with rows of trees or shrubs. The leafy shoots and branches are harvested after establishment (usually one year after planting) and used as mulch or incorporated into the surface soil. The trees/ shrubs are planted in single or double rows (4 to 6 meters apart) in an east-west direction to avoid shading of crops.

b) Boundary planting where suitable tree species are planted at the boundary and harvested regularly for use as mulch or feed for livestock.

c) Contour hedgerow cropping: this process is similar to boundary planting, but the trees are planted along the contour.



Hedgerow / boundary planting calliandra, luceana. Branches are cut and used as mulch or incorporated into soil

The regular pruning of agroforestry trees such as Leuceana during the crop-growing period provides large amounts of green material for digging into the soil or using as mulch and reduces competition with the crop. The trees and shrubs suitable for agroforestry should be fast growing, vegetative and able to fix nitrogen. Examples include calliandra, luceana, gliricidium, sesbania and others.

Benefits of Agroforestry

- They address multiple issues (food, fodder, fruit, soil fertility, mulching, fuel wood, shade, fencing, wind breaks)
- They require low maintenance
- Their benefits are long term

Note: The use of soil fertility improvement technics will not in itself raise yields. Other modern agricultural practices also need to be applied. These include planting modern types of seeds which are high yielding and resistant to diseases and pests, good farm preparation, recommended spacing, early planting, pests and weed control and availability of adequate rains or water for irrigation.

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