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KIDP TECHNICAL ASSISTANTS TRAINING MANUAL

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TABLE OF CONTENTS

FOREWORD

All agricultural activity is dependent on soil, water, vegetation, plant and animal genetic resources. To capture the interaction of these basic resources and to use them for increasing food production in a fixed land unit, without land degradation, is the essence of sustainable agriculture in an ecosystem. The development objective for improving agricultural production implies the harnessing of organic energy patterns and systems arising from these basic resources. To start harnessing the existing organic energy systems, it is basic that an in depth understanding of each of these resources and its inter-dependency with the others is necessary. Only then can agricultural production and better land use be planned and implemented.

THE SOIL

"That human life should depend for its existence on less than one metre of mixed orgnic and inorganic debris may come as a surprise to modern man. Yet it is so. Our planet's soil , together with the atmosphere and the oceans, comprise what is known as the biosphere, a thin layer around the earth in which all living things exist.

The soil is the most complex of these three constituents. It is also the most easily destroyed. One thoughtless action by one human being can remove for ever tens of tonnes of soil from each hectare that he or she farms. In a few days the legacy of a thousand years of patient natural recycling can vanish for good. It is terrifying to consider what is at stake."

Edouard Saouma
Director-General
Food and Agricultural Organisation
of the United Nations
1983

INTRODUCTION

The soil is the medium on which all agricultural activity is carried out. A fertile soil is made up or inorganic minerals, organic matter and supports a healthy soil life of living organisms. Thus it is a living soil.

SOIL COMPOSTITION

The soil is the top layer of the earth's land surface and is composed of particles of decomposed rock, humus, water, air and living soil organisms. It is the environment in which plant roots proliferate and absorb plant food and water

Soil Solids

The solid part of the soil consists of mineral matter originating from broken down and weathered rocks, and organic matter which arises from the dead remains of living organisms. The mineral matter forms the bulk of the soil. It consists of material varying in size varying from large stones, small stone, gravel, sand, silt to clay particles.

For most cultivatable soils the major particles are sand, silt and clay. The proportions in which the different particles occur in a soil determine the characteristic of that soil. Soils with a large number of stones or gravel are unsuitable for cultivation.

Sand particles are large (ranging from 2.0 mm down to 0.06 mm in diameter). They are gritty to touch and have an abrasive feel. Sand grains are not porous, they are solid and their water holding capacity is directly related to their size and surface area. The large particles have less surface area per unit volume, consequently they hold less water than the same volume of finer sand which has a larger surface area. The water held onto the surfaces of sand particles by adhesion is readily removed by plant roots.

Sand particles neither hold nor release plant nutrients. Sandy soils are therefore low in fertility. Sand particles also do not adhere to each other.

Silt particles are smaller than sand particles ranging from 0.06 mm down to 0.02 mm in diameter. Most of the particles are non-porous and act largely like fine sand particles, but silt particles are not abrasive. Soils dominated by silt particles hold and release small amounts of plant nutrients. When silt particles are wet they have a soapy feel. Silt particles pack closely together but they do not stick together very well. Silt dominated soils have a higher water holding capacity than sandy soils.

Clay particles are mineral particles which are smaller than silt particles. They have a diameter of less than 0.02 mm. Clay particles are so small that the behaviour of electrical forces on their surfaces is of critical importance in the soil. These surface electrical charges hold and release plant nutrients to the plants. The absorption of nutrients prevents their loss from the soil by leaching. Clayey soils have a low to medium ability to exchange positive ions, necessary in creating and releasing essential elements. Due to a very large surface area, clay soils hold a large amount of water. However, much of it is held so tightly it is not available to plants, since clay particles are so small they can pack together very closely forming a continuous mass which restricts water movement. Thisoften causes waterlogging. Moist clay soils are plastic and can be moulded and shaped. On drying the soils harden, shrink and often crack.

Humus is made up of decomposed organic matter residues of dead living organisms brought about by micro-organisms in the soil. The process of the formation of humus is called humification. Humus coats the mineral particles of top-soil giving it a characteristic dark colour. Humus holds plant nutrients and releases them slowly to the plants. It improves the positive ion exchange capacity of the soil. It is very important in soils with low clay content. Humus adheres strongly to soil particles to form larger particles, building up soil structure and improving soil properties. Since humus is continually being decomposed in the soil it must continually be added to maintain its level.

Three classes of soils are recognised according to the texture (relative proportions of sand silt and clay particles in the soil) of the soil. These are a. Sandy soils b. Loam soils and c. Clay soils. They each have the following characteristics:-

Sandy Soils - Predominantly sand particles in composition
Few large spaces between particles
Loose well drained and aerated
Holds little water and nutrients
Easy to work
Quick drying.

Loam Soils - Mixture of sand, clay and silt in composition.
High water holding capacity
Naturally rich soils
Good drainage
Medium to high nutrient holding capacity
Good cation exchange capacity

Clay Soils - Predominantly clay particles in composition
Swells when wet and shrinks when dry
Particles stick together
Can be moulded
High water retention
High nutrient holding and exchange capacity.

You can test the texture of the soil by the following procedure:

1. Pick up a handful of slightly wet soil
2. Rub the soil between the thumb and forefinger
3. Squeeze the soil in your hand to form a cylinder
4. Decide the type of soil according to the following criteria:

Sandy soil -gritty, abrasive, rough, cannot be moulded.

Loam soil - slippery, soapy, smoother than sandy soil, a bit abrasive, it can be moulded but crumbles easily.

Clay soil -smooth, sticky, can be moulded and retains shape.

The main function of a soil in agricultural production is to supply nutrients and water for the growth of plants. A fertile soil will therefore support healthy plant growth. The fertility of a soil is the measure of its ability to provide the physical and chemical conditions favourable for vigorous root growth, supplying adequate water and nutrients for healthy plant growth.

The fertility of soils is influenced by:

The organic matter content
Availability of nutrients
Texture of the soil
Structure
Water holding capacity - water retention ability.
Drainage- ability to get rid of excess water
Depth - available root penetration length.
PH - measure of alkalinity or acidity
Tilth- soil condition at any given time and its capability to being worked. Tilth is influenced by moisture and compaction.

TRADITIONAL AGRICULTURE RECOGNISED THE DIFFERENT SOIL COMPOSTITIONS AND CROPPED THEM ACCORDINGLY

Sandy soils, known as "Nthangathi" were usually not used for crop production, being left under permanent pasture. Where such soils were used for crop production, only plants which have low nutrient requirements like cassava and sweet potatoes, were planted.

Loamy soils were the most extensively cropped soils as they are today. All types of crops were grown in these soils including millet, sorghum, pumpkins, gourds cowpeas, pigeon peas, green grams, maize and beans. Planting on loamy soils was usually prior to or at the onset of rains.

In clayey soils planting was usually later than in loamy soils. This was practised as a measure of seed conservation. As clayey soils are never drained in Kitui, early planting would lead to yellowing and stunting as a result of waterlogging. The factor of stored surplus was also acknowledged and utilised by exploiting the ability of clays to sustain crops for a longer period after the rains. Clayey soils known as "ilivi" were also recognised as high potential soils. Crops grown in clayey soils were the same as in loamy soils but the yields were usually higher.

SOIL STRUCTURE

The soil structure is the arrangement of particles in the soil. To create a suitable environment for root growth, the soil particles must be arranged in such a way that it holds water for plant growth and allows forthe exchange of air and gases.

In a well structured soil, water should be able to infiltrate easily and drain freely. The soil should have a network of interconnected spaces allowing roots to find water and nutrients without obstructions. The soil should not have large cavities which prevent contact between roots and soil and allow roots to dry out.

Plant roots and soil organisms proliferate in the spaces between the solid soil components called pores. In an ideally structured soil there are adequate small pores to ensure good water retention and sufficient large pores to allow free drainage, prevent water logging, facilitate gaseous exchange between the soil and the atmosphere and allow for root growth. The pore spaces depend on the grouping of soil particles held together by the adhesive forces of clay and humus.

Soil structure or the physical condition of the soil, controls the environment in which roots develop and soil organisms exist. It is for this reason that the pores are more important than the solid structures, ust as the room spaces in a house are more usable than the walls. It follows that compacted soils are structureless, because there are no spaces.

Soil structure formation is brought about by wetting and drying, cultivation, root growth and the activity of earthworms, bacteria and other soil organisms. Through these factors soil components are joined together to form small units or, alternatively, massive units are broken down to distinct units. The size and shape of these units depends on the type of soil and its management.

Wetting and drying occurs throughout the soil profile. In soils with medium to high clay content, the swelling and shrinkage of the soils is functional in creating structural units. Roots growing through the soil open cracks by exerting pressure and drying the soil around them. This way, they break down massive structures. Under an old pasture, a fine granular and crumb structure is developed by the numerous fibrous roots of grasses.

Cultivation has a strong impact on the structure of topsoil. It loosens the soil and divides larger structures into smaller units suitable for a seedbed. Cultivation however has a structure destroying effect as well with the formation of large clods due to compaction and puddling under wheels of heavy machinery or the feet of animals and people.

Soils which lose their structure easily when the rain falls, are termed unstable. The textures of soil likely to be unstable are sand, sandy loams, silt loams, silty clay loams and sandy clay loams.

Soils whose structure does not crumble readily are called stable soils. Factors which impart stability are clay content, organic matter, lime, aluminium and iron oxides. Soil which contains too little of these materials is liable to capping, slaking and panning which inhibit soil development.

Improvement and maintenance of structure is important for sustainable agricultural production. A soil with a good structure may be 60% pore space by volume, and about half of this volume is occupied by air when the soil is at 'field capacity', that is ie when the soil holds its maximum amount of water after draining the excess. A structure-less, over-compacted layer of soil may have 30-40% pore space with about 5% air space at field capacity. The loss of larger pores restricts movement of air, reduces the rate of drainage and compaction creates resistance to root growth and confines roots to cracks between structure-less clods.

Many factors make up good soil management which maintains and improves soil structure. Some of these are:

1. Growing of correct crops

It is essential to grow the right crops for the soil and climate by taking into account the fertility and workability of the soils. This means that the land must be put into its proper use. Unstable soils on slopes are not cultivated for example, and are left under permanent vegetation or replanted with fuelwood trees on the contours.

2. Minimum and timely cultivation

Generally cultivation prepares a seedbed for optimum seed emergence and root development. This is beneficial, however cultivation at the wrong time eg when the soil is very wet or of the wrong type, by using heavy machinery, can do harm and should be avoided.

3. Wheel slip

When tractors are used on wet soils wheel slip is a source of compaction and damage to soil structure. For wet soils, especially clay soil, crawler tractors are better suited than wheeled tractors.

4. Grass and farmyard manure

Intensive arable fields experience declining yield due to among other factors deteriorating structure. Heavy dressing of farmyard manure where available or grass or legume rotation are effective ways of correcting structure problems. Manure or grass rotations are important for unstable structured soils which are liable to deterioration. Whenever pans are formed they must however be broken for satisfactory root growth.

5. Neutralising acid soils

Acid soils inhibit biological activity which plays a role in aggregation of soil. Addition of lime to maintain neutral or alkaline soil promotes good soil structure

AVAILABILITY OF NUTRIENTS

The primary plant nutrients are nitrogen, phosphorous and potassium. The secondary plant nutrients are calcium, magnesium and sulphur. The plant micronutrients are zinc, copper, cobalt, molybdenum iron etc. All of them are derived from rocks which have weathered and decomposed.

Plant nutrients are mainly from rocks which have weathered into individual elements. The nutrient path moves from living plants, through litter to humus and to minerals stored in the soil up to living plants again. In a natural system this cycle is stable and self regenerating.

Mineralised rock nutrients are held and made available to the plant by clay particles and humus. Mineralised nitrogen in the form of nitrates is held in the same system.

Plant nutrients flow through the roots into the plant. They are held in store by the plant in plant parts; the roots, stem, leaves and shoots. As the plant dies these stored nutrients still remain as plant residues, soil biota, soil organic matter and exchangeable nutrients fixed to clay particles and in the soil solution. However, some nutrients are leached, or drained away into the deeper layers of the soil.

The removal of produce from the field also removes nutrients which must be replaced for continued well being of the plants in the field.

AVAILABILITY OF NUTRIENTS IN TRADITIONAL AGRICULTURE

"Itiko" is a natural depression in the land, in which water and alluvial soil collects. Formerly there was minimal clearing of land for cultivation and therefore limited soil erosion. However, even under natural conditions some slight soil erosion occurs. This erosion transports alluvial soil and nutrients towards the depression where the water collects.

The soil which is deposited in the depression is rich in nutrients. This is why "itiko", or "matiko" in plural, has always been such valuable land. In addition to being rich in nutrients, "matiko" retained surface run-off water from the surrounding land for a long time since there was no outlet for the water to flow away, and it could only infiltrate the soil.

These areas faavouredcrops such as sugarcane and arrow roots. At the outer limits of the very wet areas, other crops including vegetables, maize, beans and so on were grown. Further away, the drought resistant crops such as cassava, sorghum and millets were planted. These would exploit the capillary fringe of the underlying water-table.

Similarly stream channels have been used in the same way as 'matiko', taking advantage of the washed down nutrients from higher ground and the availability of water in the low lying areas. These were especially useful in the growing of sweet potaoes as a survival crop in years of poor rainfall.

SOIL BIOTA

The soil contains a very large biomass made up of a variety of organisms. Among them are:

- Microflora and microfauna; e.g., bacteria, fungi protozoa, rotifers and, nematodes.
-Macrofauna: e.g., mites, termites, worms, woodlice, centipedes,

millipedes, earthworms, beetles spiders, slugs, snails, ants, and crickets.
- Megafauna; e.g., moles, rodents, rabbits, and ant eaters.

We can think of these living creatures as a reserve of easily leached potential nutrients. They contain nitrogen, sulphur and phosphate which they store in their bodies. Their cycle of life and death releases these essential elements in wide distribution in the soil. The elements are held in the bodies of the soil biota and are released slowly in the soil by their death for uptake by plant roots and their associates.

The soil biota live on organic residues which they transform into their body tissues. In this way, they store nutrients in a mobile form and utilise energy obtained from the residues. In doing this they facilitate the breakdown of wood and large plant material for effective nutrient circulation.

A major role is played by the soil biota in the breakdown of organic residues in the formation of humus. Without bacteria and fungi, organic material will not decay (this is the principle of food preservation). Without the breakdown of the organic material, there would not be any nutrient circulation.

In addition, the larger forms of soil biota including earthworms, centipedes, millipedes and moles, help in the translocation of organic material from place to place. They pull down organic material to lower layers of the soil thus causing a vertical translocation as well as horizontal translocation of nutrients.

By their passage through, these soil animals create channels in the soil which are useful in aeration and water percolation.The burrowing animals such as earthworms turn over the soil thus bringing up some leached nutrients from lower layers of the soil.

Some of the soil organisms live in association with roots. Legumes and many non-legumes like casuarina, have root associates which are either bacteria or fungi, which fix nitrogen from the air into forms which can be used by plants. It is estimated that all the manufactured nitrogen fertiliser only makes about 6% of the nitrogen actually fixed by plants.

THE ROLE OF MANURE

Manure is any substance of either plant or animal origin, spread on the soil, or mixed with it, to fertilise it. It is a natural fertiliser that can take many forms, such as:

Compost

This form of manure is prepared by facilitating a quick efficient breakdown of organic matter into a fine tilth from which plants can absorb nutrients. It is made from a combination of plant and animal residues in the presence of soil to provide the decay agents. Combining these materials together, adding water and occasionally turning them over, facilities the transformation (decomposition) of the material into compost or humus.

Cattle or horse manure

This manure is rich in chemical elements and humus and is very useful in soil improvement. It should be used when mature, that is when it has weathered and dried out a little, and not when fresh.

Sheep and goat manure

This can be used either fresh or mature. It has a higher nitrogen content than cattle manure

Poultry Manure

This has a very high nitrogen content and can be harmful to some plants. It should be used with some caution, but it can be used to make compost quite safely.

Meat processing by-products

Blood meal and dried blood provide an excellent source of nitrogen. Crushed bones and bone meal supply phosphorous and calcium over a long period of time, when worked into the soil.

Green manure

Fresh green plants when dug into the soil decompose and become humus. A cover crop can be grown to become green manure in a rotational cycle.

Legumes

Plants such as cow pea, beans, crotolaria, and lupines are capable of converting atmospheric nitrogen to mineral nitrogen useful to the plant. These plants can be used as green manures or they can be grown in association with other plant which cannot fix nitrogen for themselves, in a form of intercropping.

Sea weed.

For people near the sea, this is an excellent source of material rich in chemical elements and yielding plenty of humus. However it is important to clean the seaweed properly to avoid adding too much salt to the shamba. Sea weed can abe used in making compost.

Wood ash
The ash obtained after cooking should be collected and used either for direct application in the field or for addition to compost heap. Wood ash contains potassium which is often lacking in tropical soils due to leaching.

Organic matter has a major influence in the fertility of the soil. It improves and maintains the fertility of the soil in the following ways:

1. Organic matter, when decomposed increases the water holding capacity of soils. More water is thus made available for the growth of plants for longer period.

2. Organic mater binds soil particles together increasing water infiltration and reducing erosion. The increased infiltration at the expense of run-off enhances the chance of the soil receiving and retaining more water than in the case of extensive run off.
3. The binding of soil particles facilitates air exchange between the soil and the atmosphere.

4. Organic matter supplies essential nutrients and trace element to plants.

5. Organic matter creates an environment in which the soil organisms, eg. fungi, bacteria and worms, which are helpful in making nutrients and other substances beneficial to plants, thrive.

6. Organic matter forms humus as its final transformation product. Humus has a high capacity of holding nutrients.

7. Organic matter rich soils produce plants which have a vigourous growth and have a high resistance to diseases and pests.

ACCUMULATED ORGANIC MATTER IN TRADITIONAL AGRICULTURE

The tradition in Kitui homesteads, like in many other parts of the country, was transient. The homestead was moved regularly and re-sited at intervals usually of ten years. The site of the abandoned homestead locally known as "Ianzo" (maanzo pl.) was always rich in organic matter. This organic matter originated from households waste and livestock manure.

Thus 'maanzo' provided extremely nutrient-rich soil patches for crop production. Many soil organisms thrived here. An 'Ianzo' of someone with a large number of livestock would be approximately two acres. Livestock enclosures would have been shifted several times before the homestead was transferred altogether. After moving the homestead this area would subsequently be used for healthy crop production.

Unlike freshly cleared bush which would be used for cultivation for only 3 -4 years before shifting to new plots, an 'Ianzo' could be cropped for twice the length of time before abandoning.

The slow release of nutrients by organic matter and the binding of these nutrients facilitated this extended use of abandoned homesteads for crop production. The uses of 'Ianzo' provides the most vivid example of the understanding the role of organic matter in soil improvement for production in traditional cropping systems.

WATER HOLDING CAPACITY

The water holding capacity of a soil varies enormously and is dependent on the composition and structure of a particular soil. Sands absorb and retain water more quickly than clays, but clays hold more water per unit volume than sands over time.

Water holding capacity can vary from 2-40% of the soil volume. Too little water in the soil leads to poor growth from lack of water, while too much also leads to poor growth by excluding air which is required by the soil organisms as well as plant roots. Too much water also dilutes the soil solution and produces as apparent scarcity of nutrients.

A fertile soil must have a balance between large and small pores to enable excess water to drain off and allow air circulation whilst holding enough water for healthy plant growth.

The water holding capacity can be influenced by:

Contouring or Terracing

The physical structure will dam water and increase the time of infiltration on the soil rather than allow run-off. This is an important method in clay soils which have slow infiltration rates.

Loosening of Soils
This also increases the infiltration rate of water into the soil by breaking down the hard pan at the surface or just beneath the surface of the soil. Loosening of the soil counteracts the effects of compacting such as caused by overgrazing and heavy machinery.

Introduction of Water Holding Organic Matter
Introducing organic matter which has a water holding capacity, glues particles together, promotes soil structure formation and acts as an absorbent pad in the soil.

Finally, improving of soil structure can be achieved through ripping the soil, adding flocculating agents and planting of deep rooting plants such as trees together with grasses which open the soils and keep then open.

SOIL EROSION

Erosion, or weathering by the elements, is a natural process, and the creation of true soil is the result of a part of the process over thousands of yers from parent material, or rock. However, if the process is allowed to continue unchecked by plant growth and the development of a good soil structure, soil particles become fineer and finer until they can be moved by the rain and the wind. Then the land is vulnerable to soil erosion on a massive scale.

Splash or Rain Drop Erosion
Splash erosion is the result of the impact of raindrops on bare ground. It is the most important form of erosion on crop land. It detaches large volumes of soil. This type of erosion is most significant at the beginning of the rainy season. The detached soil is then carried away later when the soil has been saturated with water.

The mechanism of splash erosion is as follows:

On level ground the soil particles are transported horizontally and do not travel very far. However, on sloping ground there is a large movement of detached particles down slope.

Erosion control is very important in the tropical countries due to the intensity of our rains. The heavy rainstorms detach soil particles through splash erosion and break up soil aggregates. The detached particles seal the soil with a thin layer of clay particles and block the pores through which water infiltrates into the soil.

Apart from the horizontal transportation, the detached particles can be transported vertically. This will result in closing of the pores and reduction of infiltration with the resultant increase in run-off.

Stream Erosion

There are two major types of stream erosion; rill erosion and gully erosion, each with similar mechanisms. With rill erosion, as the rate of rainfall exceeds the rate of infiltration of water into the soil, surface flow starts. This water collects into small streamlets called rills. Many small rills flow and furrow the ground causing wash or sheet erosion, which is often hard to detect in its early stages. Therefore, sheet or wash erosion is the result of raindrop or splash erosion and the transport capability of rill erosion.

Long slopes will have a higher velocity of water than shorter slopes, and the quantity of water will be higher hence the rill will cut deeperchannels, or scours, often called scour erosion.

When a rill has furrowed so much that it cannot be smoothed out by normal tillage methods it has become a gully.

Gullies develop significantly in loams and silts which are easily erodible soils. Clay is resistant to erosion and sand soil has a high infiltration rate. Gullies are usually short, cutting back into a hill side without a large catchment area.

Gullies are usually started through insignificant flows, such as along foot paths or cattle tracks. Extension of a gully at the head is through a waterfall type of erosion cutting backwards into the slope. The flow over the bottom deepens the gully until it reaches a solid rock. The gully widens through the collapse of sides into the bottom.

River Erosion

In rivers, erosion occurs on the bends. Here the velocity of the stream is concentrated on the river bank. On the opposite side of the eroded bank, sand and silt are deposited. River erosion occurs only during floods, and the soil on the banks should be protected against the high flood levels.

Most of the soil transported by a river originates from the catchment area, with some from the river bed and very little from the river banks. It is all transported down to the sea, and lost to the farmers.

Wind Erosion

Transportation by wind can be along the ground or as suspended particles in the air. Wind drift where sand is moved along the ground occurs on beaches and arid climates like deserts.

The usual form of wind erosion, where fine material is lifted in the air and transported in suspension, occurs when particles are detached from the ground by wind. Soil particles of sand, silt or clay are detached from the ground, if the soil is bare and dry, the ground is smooth and the wind has a high velocity. Wind erosion can remove a large volume of topsoil with disastrous after effects.

Erosion Control

Erosion is a natural phenomenon which cannot be eliminated. However under natural conditions, there exists mechanisms which make soil erosion effects negligible. Originally most of the earth was covered by vegetation which protected the soil from erosive action of water and wind.

Mans activities in the removal of this protective cover over the soil through damage to forests and grasslands, is the root cause of massive soil erosion. We must fundamentally observe the ancient principles of 'return to the soil', by restoring forests and cover vegetation on the same national scale thet we have destroyed them. But each farmer can immediately begin to implement specific technologies to control erosion on his land, and the passage of the nutrients and water cycles through it. Splash, rill, and gully erosion can be checked in the following ways:

Man damages native vegetation thereby causing erosion in the following ways:

1. Clearing of trees, shrubs and grass for cultivation.
2. Cultivation down hill especially damaging on steep slopes.
3. Inappropriate farm management.
4. Mono-cropping without interceding fallows periods.
5. Non rotation of crops.
6. Poor maintenance of organic matter in the soil.
7. Overstocking which results in:

a. Compacted soils through trampling.
b. Selective species damage.
c. Damage of vegetative cover leaving bare soil patches.
d. Development of stock tracks which result in gullies on slopes.

8. Burning of vegetation leaving bare ground open to splash and stream erosion
9. Removal of vegetation or overgrazing of river banks resulting in soil erosion in peak flows..

Splash Erosion

This form of erosion can generally be controlled by protecting the ground from the energy of large rain drops. This is quite easily done on flat land by a cover crop, or by mulching, using the techniques of good farm management that promotes stable soil structure. On gently sloping land, contour ploughing reduces the effect of the slope, and prevents splash transport downhill. On steeper land, bench terracing creates a levelling effect which enables more horizontal splash and less down-slope transportation.

Rill Erosion

The worst effects of rill erosion can be controlled by trash lines, contour farming, strip cropping, terracing, and creation of infiltration zones.

Contour farming means carrying all the farming operations along the contour rather than down the slope. In contour farming earth ridges hold up the water preventing rill erosion.

Strip cropping along the contours is depended on cultivated and non cultivated cropping of the land. For example a strip of maize alternating with a strip of grass. Water from the maize strip on reaching the grass strip is distributed among the grass. Its speed is reduced and its soil load is deposited. The grass strip has a more stabilised soil with a better developed structure. A rotational scheme like this would provide an effective method of soil erosion control.

Terracing controls the flow of water down a slope by breaking up the slope into a series of steps which are more or less flat. This decreasing of the slope effectively reduces rill and sheet erosion.

Permanent crop zones with mulch on the ground stop rills, slow down the water flow and cause soil deposits to occur. The slowing down of the water coupled with an open soil structure under the mulch facilitates infiltration. The water is thus prevented from causing erosion below the zone.

Gully Erosion

This major form of erosion can be controlled with a series of measures, and the earlier this is started the better.

Cut off drains.

A cut off drain is a diversion ditch which leads the water away from the gully head and to a safe disposal area.

Piling Materials

To prevent waterfall erosion at the gully head piled bed of straw, brush or stones is used.

Check Dams

To prevent the erosion of the floor deepening the gully the use of check dams creating steps of sediment is employed. Strips of grass or stones piled across the floor act as barriers to flow and facilitate depositing of sediment.

Grass Planting

Prevention of gully side erosion is achieved by planting grass shrubs or trees to stabilise the soil.

The measures taken to control soil erosion are known as conservation measures. They are divided into two major groups, biological or cultural methods and physical or mechanical methods.

Biological Methods

Biological or cultural methods of erosion control are those farming practices in which use of vegetation to minimise erosion is employed. The methods aim to produce a fertile good structured stable soil, which is well aerated and has good infiltration and water holding capacity. These methods include:

- Good farm management.
- Intercropping
- Mulching
- Plant Rotation
- Contour Farming
- Ridging
- Strip Cropping (Rotational Strips)
- Infiltration Zones (Permanent crops).
- Buffer strips (perennial or semi-perennial crop)
- Wash Strips (trash lines, grass strips or sisal hedges bush hedges)
- Agroforestry (hedgerows planting).

Mechanical Methods

Physical or mechanical methods of erosion control function as drains or facilitate infiltration of excess water during a storm and function as moisture retainers between rainfalls. The mechanical methods include:

- Cutoff drains
- Terraces
- Waterways
- Microcatchments

Erosion Control is very important in the tropical countries due to the heavy rains. The rain storms which are very intensive detach soil particles through splash erosion and break up soil aggregates. The detached particles seal the soil with a thin layer of clay particles and block the pores through which water nfiltrates into the soil. This increases runoff and therefore erosion.

Soil Rehabilitation

A rich soil can be ruined by bad management practices and by exposure to sun, wind and torrential rain. This has happened more often than not. However starting with a poor soilit is possible to create a well structured soil with the use of organic matter.

The old system of leaving land fallow to recover its fertility depended on natural soil structure improvement processes. These included the opening up of the soil by roots, covering the soil, mulching by leaf fall the activity of soil organisms, build up of humus, and the reversal of the leaching process by the nutrient pump action of deep rooted trees.

Soil rehabilitation must embody these processes. However, because of the more intensive land use required these days, rehabilitation must occur in a shortened space of time. Most soils which need rehabilitation are compacted, their structure has collapsed and they are eroded. Such soils can be conditioned using either mechanical or biological methods, such as improved fallows.

Mechanical Soil Conditioning

Mechanical loosening of soil is appropriate to all agricultural soils that have been compacted. Chiselling aerates the soil allows water penetration and supports a vigorous root growth. The roots which die serve to support soil organisms which add manure and by their tunnelling contribute to the aeration of the soil.

Improved Fallow Rehabilitation

The shortened fallow periods necessitate the introduction of trees and shrubs that accelerate soil recovery. The relevant species are those which enhance soil fertility by nitrogen fixation, have a dense leaf growth and establish ground cover quickly.

The strategy employed depends on the results which are expected. These maybe short-term economic gains, or long-term soil improvement. Grass for example gives back to a soil 85% of its stability to erosion in the first year, and 100% in the second year. However, the nutrient levels of the soil do not improve as dramatically due to non-exploitation of the sub-soil in this method.

Agro-forestry systems in fallow management allow the shortening of fallow periods hence more intensive use of the land in production. Fallows protect the soil from erosion, eliminate weeds, pests and diseases especially in a mono-cropping system. Trees increase organic matter content of the soil, bring up nutrients from the sub soil, improve soil structure and water holding capacity and tilth.

Trees are also used to rehabilitate stony, steep slopes, laterite soils, or even difficult terrains where the use of implements is not possible. Tree roots act as chisel ploughs which open the soils allowing aeration and water infiltration to support life biota. The leaf fall from the trees increases humic acids in the soil which together with carbonic acid produced by the carbon dioxide from soil biota help in releasing nutrients in the subsoil for plant root absorbtion and also contribute to breakdown of rock.

Proper Land Use

Nearly all human activities directly or indirectly use the land. As society develops and technology improves, greater demands are made on the soil which then becomes a limiting factor of development. The soil is required to produce more food on a smaller surface area.

Competing uses for land now include much more than agricultural land for crops or animal production for food, along with forests for tree products. We now need land for public bildings, factories, schools, hospitals and private houses. We need it for communication systems like road networks, railway infrastructure and airfields. Public amenities such as playgrounds, urban parks, nature reserves and national parks take up large areas of land. So do reservoirs for power generation and water supply, and waste disposal and dumping grounds.

As the growth of population and development increases the competition for land use, so in the land available for agricultural production, there is incresed competition among the modes of productive activity, such as field cropsor animal production, forestsversus field crops and so on. This competition often leads to the mis-use of land through over-exploitation which can damage and even destroy the land.

Today we are familiar with environmental pollution of vegetation caused by industrial wastes and fumes from factories and cars. We have the modern hazards of air, water and soil pollution due to the excessive addition of pesticides, herbicides and fungicides, to our mono-crop agricultural production which encourages the build-up of pests, and nematodes in the soil in the first place. Thoughtless deforestation and grassland burning leads directly to massive soil erosion. Poor cultivation and irrigation using deep ground water, or in unsuitable soils, has led to salinisation of farm lands. We need to understand land use systems more wisely and care for the land thoughtfully.

Land can be classified into capability classes. This classification is based on the limitations that effect the land. These limitations include the slope of the land, nature and depth of the soil and the climate. These are permanent limitations. Other limitations are temporary and they include nutrient content, poor drainage, poor soil structure, and so on.

The United States Department of Agriculture (USDA) system of land capability classification, for example, uses eight classes (1 to 8) based on the amount of limitations present. Class 1 has the least and class 8 the greatest limitations.

Class 1: The land is flattish the soils deep, well drained and fertile. The land can sustain intensive cropping continuously depending on the availability of water.

Class 2: This land has limitations such as slope, erosion hazard, shallow soil, poor structure. Conservation methods must be employed and may include contour cultivation, strip cropping, terracing and rotation. The choice of plants and intensity of land use is reduced by these limitations.

Class 3: This land has severe limitations and requires special conservation measures. The limitations are as the result of moderately steep slopes, high erosion hazard, shallow soil, poor soil structure, poor drainage or slow permeability. This reduces the choice of plants. Conservation measures include terracing, strip cropping, contour cultivation, drainage, special rotation and choice crops.

Class 4: This land can be cultivated but is severely limited by steep slopes severe erosion hazard, shallow soils low water holding capacity, poor drainage. The choice of crops is severely limited and serous conservation measures are necessary.

Class 5-8: Are not suitable for cultivation. Erosion is the major limiting factor. In addition other factors include short growing season, rocky soils, marshes and ponds. This land is limited to use as pasture, forests or wildlife conservation areas.

WATER

INTRODUCTION

All living things are made up of molecules, which are the smallest portions to which a substance can be reduced by subdivision without loosing its chemical identity. In plants and animals, ninety nine molecules in every hundred are water! That is how important water is to all life on earth.

Happily, water is an abundant commodity on our planet. It is found in the oceans and seas, lakes, rivers and in the ground, and in the air as water vapour. However, very little of the world's water reserves are directly available for human needs. Many arid and semi-arid areas of the world face an absolute shortage of water for humans and water for agriculture. In these areas strategies for conservation and control of water resources must be understood and practised.

THE WATER CYCLE

Water in the tropics exists in two basic forms as a liquid and as a vapour. The third possible form "ice" exists only on the very high mountains and is negligible.

As a liquid, water always flows downwards. Raindrops fall from the sky, water in stream flows down the slopes, stationary water, such as in a dam or cut off drain, infiltrates into the soil. Liquid water is turned into a vapour by heat. Water vapour rises upwards into the sky. When the water vapour is cooled high up in the atmosphere it forms clouds. The clouds contain both liquid water droplets and water vapour. As the surrounding air cools further the droplets become bigger and become rain drops which fall to the ground.

Water also moves laterally. The liquid which infiltrates into the ground does not necessarily remain there. It may come out a long way off from its place of infiltration as a spring. If it is surface run off it forms a river ultimately. The rivers carry the water back to the seas and lakes. This results in a lateral movement of water. Another lateral movement of water is through the displacement of clouds by the wind. This displacement shifts water vapour which has risen from the oceans seas or lakes to the land where rain is required. The three types of movement of water constitute the water cycle.

No matter whatever our location in the world, rain always originates from wet, humid areas such as oceans, lakes, swamps, forests, out of which large quantities of water evaporate to begin the cycle.

The global water cycle is a phenomenon which man is powerless to control or modify on a global scale. On the local scene however man can make efforts to contain the water received on a local area, for thetime needed to use it productively.

Water Tables

There is a necessity to retain water in the soil both at superficial and deeper levels. Run-off, flooding and drought go hand in hand. The water which falls on the ground as rain can either run off and is lost to the locality or it can infiltrate into the soil if conditions are favourable and recharge the ground water reservoirs.

In arid and semi-arid lands there are two types of vegetation. These are seasonal and perennial plants. The seasonal plants use superficial moisture. They are quick growing. They start growing on the onset of rains and have produced and die by the end of the rains. They spend the dry season in their seed form and repeat their growth at the onset of the next rains. By loosening the soil, enough moisture is retained in the superficial layers for their growth.

During the dry season, the superficial moisture quickly disappears as a result of transpiration and evaporation. For perennial plants to survive they must have moisture to maintain their buds in a dormant state otherwise they will dry and die out. At this time the water to maintain these plants must come from the water table. The water is made available to the plants by capillary action in the capillary fringe.

The water is made available to the plants by capillary action in the capillary fringe. The height of the capillary fringe depends on the type of soil. There is a higher rise by capillarity in clay soils than loamy soil and sandy or stony soils.

Maintaining of the water table is important since lowering it, such that the capillary fringe is beyond the roots of the perennial plants, kills them. This leads to vegetation loss, production loss and eventually desertification.

The water stored in a water table is variable and depends on:

1. The amount of infiltrating water:
2. The amount being lifted by plants and people
3. The amount which is lost through evaporation from the soil surface: and

4. The amount moving laterally in the ground.

The amount of water consumed every year must not exceed the water stored in the water table by infiltration. This is why one cannot sink an unlimited number of wells without taking measures to prevent run off so as to store water in the water tables.

The water that runs off, instead of infiltrating into the ground, affects agriculture. First, the soil remains dry despite heavy rainfall. Only the top few centimetres of the soil is moistened. This moisture is quickly removed by the sun rays through evaporation. Seasonal plants wilt and die before they produce seeds. Second, water tables are no longer replenished. People, plants and animals run short of water supplies. Wells are no longer filled from the water supplies.

Water tables are formed by infiltration of rain water into the ground which accumulates on top of a layer of impervious rock or clay. The depth of the water table varies from a few centimetres to a few metres depending on the depth of the impervious layer.

The water in the soil is held with varying degrees of tenacity. It varies from free water to absorbed (hygroscopic) water which is firmly held on the surface of soil particles. When the soil has been saturated and the free water drains down to the water level, it is said to be at field capacity. Plants growing in the soil will extract moisture until they cannot extract any more at which point they will wilt and die. Then the soil is at wilting point. The amount of water available between wilting point and field capacity is referred to as available water.

Interaction of Water and Soil

When rain falls and infiltrates into the ground it flows downwards into the deeper layers of the soil. As the water flows through the soil, it dissolves mineral salts and carries them into the lower layers of the soil. This is the leaching process. This process changes the composition of the soil. Infiltrating water impoverishes superficial soils while enriching deeper layers of soil with nutrients. These nutrients accumulate in the water table, below which water does not move further downwards due to an impermeable layer usually made of clay or rock.

Most cultivated crops draw their nutrients only from the top layers of soil. Leaching is thus harmful to soils. It removes crop plant nutrients and leaves the soil infertile. Tree which are deeper rooting bring up nutrients from the deeper layers of the soil to the surface and store them in their leaves branches and stalks.

Trees release the nutrients as organic matter when they die. This is why it is wise to combine crops with herbaceous plants and trees which tap nutrients from deep layers where they accumulate and are not available for use by shallow rooted crop plants.

WATER HARVESTING

Water harvesting is a traditional agricultural concept, that of collecting rain water for sustainable agricultural use, that we now recognise has four main aims:

1. To store freshwater for cooking and drinking.
2. To divert sheet-flow and run-off water safely into gardens, farms.
3. To convert the destructive energy of water into a more useful life creating energy in the growth of crops and trees.
4. To recharge ground water reservoirs for crop and tree growth.

Conservation of Rainwater.
To obtain fresh water we must intercept it before it washes salt from the soil or runs-off roof areas and rock. Roof water or rock catchment can be collected by gutters into tanks, cisterns or sealed wells for household use.

The extra water harvested from roofs can be led to other ground storage for trees and gardens. These storage units include ponds, swales (contour depression on the land for holding water temporary to allow infiltration like cut off drains), earth dams, earth tanks, subsurface dams or large surface dams.

Earth tanks can be made of clay. These tanks should be deep and narrow, should intercept a run off area, and should be covered to reduce evaporation.

Water harvesting on open ground to create a soil reserve can be made from landscape run off. Harvesting of ground water can be achieved through interceptor banks to storage structures such as swales, dams, ponds and earth tanks. This water is used for livestock, kitchen gardening and growing trees.

Microcatchments are small structures which hold water on planting sites and allow it to infiltrate slowly into the soil. The size of the catchment area is dependent on the amount of precipitation. The higher the rainfall the smaller the micro catchment. These structures are useful in the harvesting of water for the establishment of trees in the arid and semi-arid climates.

Their shapes might be semicircular or triangular (v shaped). They collect the water which is directed to the planting hole at the bottom of the micro-catchment. Contour ridges or furrow can also be used as micro-catchments as would the bottom of bench terraces.

Most of the measures used to control erosion effectively slow down the rate of flow of water off the precipitation area and facilitate infiltration into the soil and recharging of the water table.

Aquifer recharge originates from hill country where subsurface channels go deep into the soil infiltrating water through loose gravel ridges, shattered or soluble rocks, heavily forested ridges, high slopes of porous materials such as limestone and fissured rocks beneath water tables allowing seepage into lower levels. From these intakes water enters the soil and rock strata and travels underground for long distances to springs, wells and artesian basins. Satellite telemetry can outline these underground streams.

Aquifer intakes can be improved by:

1. Planting trees on ridges and slopes.
2. Building contour interceptor drains on ridges and on plateaus.
3. Leading surface drains to wells cut in shattered rock.
4. Making rock banks, pits or swales in gravels.
5. Ripping stone caps to allow water infiltration.

WATER AS A DESTRUCTIVE FORCE

Water as a liquid is a great transporter of soil. The beating action of raindrops tears off fine particles of soil which are carried away by the run-off water. This soil is transported from the high grounds to the low grounds and deposited there as the water slows down. Soil erosion starts the moment soil particles are torn off by rain drop splash. The loose soil particles torn from clods or crumbs are apt to be carried away by only a slight flow of water downhill.

The tiny particles are picked by rain water as it moves downwards into the soil by infiltration or penetration. This downward transport clogs the gaps in the soil and prevents subsequent water penetration. The soil is packed very closely and compactly. Compacted soil is a major obstacle to ground water recharge as it prevents infiltration and increases run-off.

Raindrop splash is the first stage of erosion. The splash caused by the energy contained in the drop as it hits the soil. The energy dissipated on impact dislodges the soil particles causing both horizontal and vertical translocation.

The second stage of erosion by water is an overland flow of the water down a slope known as run off. The speed with which the water flows depends on the gradient of the land. On gently sloping ground with little or no vegetation the water moves slowly and is spread out. This is called sheet erosion.

As long as water is moving slowly on a gentle slope the soil particles tend to drop out. The large sand particles are not shifted at all and only the finer clay particles are displaced.

With increasing gradients the water begins to collect in small depressions in the land. It starts to move much faster, cutting into the soil and carrying larger and coarser particles. This is how gullies and ravines are formed.

The channels join together uniting their forces and increasing the speed of flow. They sweep everything in their path, clay, silt, sand and stones. The water eats away the sides of the gully causing banks to collapse. If the water is not slowed it carries its load of soil to the sea. However, if the water is slowed, the run off water is not powerful enough and the coarser particles are deposited, whilst the smaller particles will continue to be transported.

On uplands where the clay, silt and sand has been removed , only stones remain and red laterite gravel. Laterite is largely the result of erosion. When water carries of soil particles laterally and vertically the exposure to the sun heats and dries the uncovered soil, which oxidises and binds together as iron-coloured pebbles and rock known as laterite.

GROUND COVER CROPS

The planting systems in traditional agriculture took into account ground cover systems as an integral part of farming management. The rain pattern in Kitui is bimodal. The long rains occur in October to early January and the much shorter rains fall in April and May. The shorter rains are more intensive and therefore more erosive. The longer rains start more slowly in October, peak in November and start failing off in December.

Crops such as pigeon peas, pumpkins, gourds and cassava are planted at the beginning of the long rains. As the short rains start in April at least a part of the shamba was covered by these crops. The ground cover reduced erosion by absorption of drop impact, facilitated infiltration and caused physical impediment to runoff. Supplementing these live crops were the remains of harvested crops such as stable stalks and other crop litter which was not removed from the fields. Apart from adding organic matter to the soil, this undecomposed material was instrumental in controlling erosion by acting as a physical impediment, like trash lines today.

To utilise the short rains effectively crops with short growing periods were preferred. Early maturing varieties of cowpeas, green grams, beans were intercropped with maize, millet or sorghum. Such systems ensured an early grand cover and soil protection.

CONTROLLING THE DESTRUCTIVE FORCE OF WATER

The amount of run-off and soil erosion can be minimised using a number of methods. The simplest and the most effective method of controlling the destructive force of water is to keep the ground surface permanently covered by vegetation. The force of the drop is absorbed by the soil cover and causes no splash. There is no loosened soil. The vegetation litter, trunks and roots become barriers to flow and hold back the rainwater for infiltration. Roots further open the soil and greatly enhance infiltration. A soil covered with vegetation has a rich soil life. The soil microfauna further open the soil for infiltration of water. Thus vegetation cover turns the destructive force of water into an energy store in plants and animals. Steep slopes should always be covered by vegetation. These can be forests, orchard crops or grassland.

In cultivated lands it is not possible to have the surface constantly covered by vegetation. Other cultural and mechanical means must be employed to minimise the effects of the force of raindrops and form barriers which slow or prevent the flow of water limiting its destructive force and storing it in the ground. These methods include:

Cultural Methods or Biological Controls

- Contour planting and farming
- Good farm management
- Companion Crops
- Mulching
- Crop rotation
- Ridging
- Strip cropping
- Infiltration zones
- Buffer strips
- Wash stops

Trees

Physical Measures or Built Structures

Cut off drains
Terraces
Artificial waterways

For these methods to be effective the whole community should be involved as erosion is not confined to a single field but affects a large area. Its control requires communal effort. Failure to heed the loss of fertility in the soil is to condemn future generations to poverty. The eventual loss of soil fertility has been responsible for collapse of many civilisations.

Once soil has been lost, it cannot be recovered. Soil formation is a long slow process taking millions of years to form a small layer of soil. Eroded land is therefore land which is lost for production.

The control of the destructive force of erosion is necessary to avoid drought and desertification. It is ironical that the destructive force of water which cause soil erosion and flooding, results in drought! This is because all the water is carried away from the land and none is stored in the soil storages or in the biological reservoirs. This water, which supports vegetative growth, is reduced. The result is less and less rain leading to desertification.

NATURAL WATER CONSERVATION FOR PRODUCTION

The forests and other biological water storage mechanisms, in the form of fruits and nuts, form the basis for proliferation of life where no free water otherwise exists. Browsers, insects and fungi draw on these biological tree reserves year round and perform many useful functions in any ecosystem. Many plants such as palms, cactus and aloe, all present in Kitui, have specific tissue or organs to store water.

In the local microclimate the water in vegetation greatly moderates heat and cold extremes. It releases to and absorbs water from passing air streams. Plants such as cassava will produce a crop as a result of humidity provided by the surrounding vegetation.

Trees are cloud formers as a result of evapotranspiration. The clouds which form above forest are a mixture of the forest water vapour and oceanic water vapour. This has been identified by isotope analysis. The water vapour from the forests contains more organic nuclei than the water from the ocean. Through this humidification of the air, the forests play a role in the recycling of water.

Current evidence shows that vegetation plays a major role in the weather. It has been observed that where vegetation has been cleared on high ground, the existing cloud cover has lifted off. Deforestation is clearly linked to the ensuing drought and

For agricultural production, we therefore need to preserve our vegetative cover over the land to receive, not only more rain but a better spread of rain. This natural water conservation will not only increase ground recharge, thus raising water tables, but will also extend the rainy seasons and moderate the climates.

Forests further provide large condensation surfaces for water vapours on their leaves. The relatively warmer land creates inshore air flows towards the evening. In many areas by the coasts, water laden air flows inland. Where the moisture-laden air flows over cooling surfaces, condensation occurs and water drops form. This condensation may far exceed precipitation caused by rainfall. Condensation drip may be as high as 80% of precipitation at the sea coasts. The effects of condensation may quickly be destroyed by felling of trees which causes rivers to dry up. This can occur in the lifetime of a person. This drying up has been observed in Kwale district in recent years.

It is important that urgent measures be taken to save the existing forests and plant trees on hills that face the sea for increased condensation and inland for increased evapotranspiration and penetration in the soils. This vegetation cover is the only way to conserve water for agricultural production.

HARVESTING FOREST RESOURCES FPR SURVIVAL

Traditional households have used wood for fuel, lighting and security from wild animals as long as fire has been tamed. The traditional household obtained its firewood from dead trees. Living and healthy trees were not cut for fuel or charcoal. Man thus existed in a state of equilibrium with nature, taking only what he required without undue and wanton destruction of nature.

Although considerable quantities of wood was used to construct living quarters, the population ensured that an area was not over-exploited by taking their requirements over an extended area. This practice allowed a quick regrowth and vegetation recovery.

Under shifting agriculture, whenever a new plot was cleared for crop production, large trees were normally left intact. These trees functioned as nurse trees when the land was left fallow and helped in reseeding.

Conventional wisdom further discouraged the clearing of hills and steep slopes for growing crops. This was realised as a futile exercise as crop returns were poor on steep slopes as a result of excessive soil losses.

The translation of these practical ideas into modern agricultural practices would be helpful in the protection of tree cover on the hills for water resource management, appropriate land use and an enhanced agricultural production.

MAN MADE STRUCTURES FOR CONSERVATION

If vegetation is not abundant and the soil is bare, the only way to prevent run-off and help infiltration, to keep the water in the soil and recharge the water table, is to use mechanical means. These are basically barriers to run-off flow which hold the water on the land for longer periods preventing an horizontal flow and allowing a vertical flow of water deep into the soil.

The increased length of time water is held over the land will increase the amount of water held in the soil, raise the water table and facilitate vegetative growth for longer periods of time. This will improve the vegetation on the land which in turn will further improve the infiltration of water due to channels created by roots. As a result the soil water holding capacity will be improved by the resulting increase in humus content. The land then starts on the road to recovery. Dry periods shorten and the land becomes productive again.

The first steps towards mechanical water conservation **MUST** start in the individual small fields. In these fields the water has not bulked together and gathered much force. It is here that the destructive energy must be tamed before it becomes too big a force. In the field, it is also in the interest of the owner to maintain as much water as possible for his own production. Many examples can be seen where one local field will produce a crop, even in a bad year, when all the neighbours fields give no yield at all. The construction of low earth barriers as contour ridges or terraces retain as much water as possible in the field and force it to infiltrate into the soil, to be stored there for future plant use. The slowed water can be channelled through definite pathways, towards where it is next needed. This is the essence of the catchment approach.

The farmers in a catchment area should work side by side each working on his small field to control his own field. Each should build contour ridges or bench terraces on their land. This process will gradually control all run off from a small catchment area. The community in the catchment area should however lay out cut-off drains and spillways together for the protection of all the fields.

This building of contour ridges and terraces is an important step towards controlling water run-off and improving infiltration. It is an efficient way of keeping soil and water on the village lands. The proper lay-out of all land in a catchment area allows the village to collect water, allow it to infiltrate into the soil and safely discharge excess water cutting out the formation of gullies. The struggle to prevent erosion and improve infiltration is a problem for the whole community.

Small scale dams provide an efficient method of controlling run-off and facilitating infiltration. The soil which is eroded from the catchment area is deposited in the dam and water which is flowing slowly infiltrates to the water table. Small scale subsurface or sand dams can be built in stages. They can be built higher year after year and their effects extended. Small scale dams are used as barriers to flow in shallow bed streams.

When it rains in the catchment area, which has been improved by contour ridging or terracing, some of the water infiltrates in the fields. Excess water runs down the slopes carrying soil particles with it. Run off water concentrates in the dam. In the case of intense precipitation, some water flows over the dam and is lost from the area together with the soil suspended in it.
As the rain ceases some water is left stagnant in the dam. This water follows the contour line formed by the top of the dam. This water can either infiltrate into the soil or evaporate. Infiltration can be helped by planting trees or plants with deeply penetrating roots. A series of dams built one after another will greatly increase the water infiltration from the basin.

Small scale subsurface, sand or check dams in the long run result in more water infiltrating and being stored in the water table. They maintain a higher water level in wells during the dry season which can be used for gardening and tree irrigation. They lead to the capillary fringe rising with the water table. As a result trees and shrubs can be planted and maintained easily. Vegetables can be planted during the dry season and irrigated by well water thereby improving nutrition and increasing agricultural production and employment.

The first dam must be built as close as possible to the head of the stream. This is the point where the run off water begins to erode the soil. Subsequent dams are placed in such a way that their crest at full development are level with the base of the dam above. The sequence creates a series of sub-surface dams in which the water is stored in the soils and have no exposed surface for evaporation. These dams can be constructed cheaply using gabions or locally available stones.

HARVESTING RUN-OFF FOR AQUIFER RECHARGE

Aquifers (water carriers) are deposits of permeable rock such as sandstone containing water that can be used to supply wells. Permeable rocks under the soil layer allow water to travel downwards in the ground until it reaches an impermeable layer which permits no further downward movement. The upper level of saturation of water in the ground forms the water table. The level generally follows the level of the land. Below the level of saturation the water holding rock or deposit, the aquifer is saturated and becomes a water reservoir.

An aquifer rock will supply water to a spring where the impermeable layer of rock surfaces below the aquifer. Surface wells can be dug to harvest water from shallow aquifers where the water table is high.

Artesian basins are formed from aquifers which are sandwiched between two layers above and below of impervious rock. This water is not naturally available for vegetation. Plant roots cannot penetrate through the impervious rock and normally these basins are found deep in the ground. Artesian basins receive their water recharge at positions where the aquifer rock is exposed to allow percolation. These areas are found in mountains plateaus and ridges. To harvest rainfall for recharge of artesian basins the hilly areas where these intakes exist must retain their vegetative cover to allow maximum infiltration.

The normal aquifer recharge is achieved by measures which allow for maximum infiltration of water in the soil. These include contour ridging and subsurface dams in rivers combined with cultural measures to help rainfall infiltration and prevent run-off.

CATCHMENT PLANNING FOR MAXIMUM WATER UTILISATION

A catchment area is an area of land bounded by watersheds draining to a river basin or a reservoir. The area may be small or large. Large catchment areas must be divided into small units for management of the water resources.

The main reason for planning a catchment area are:

1. To save our energies in the system to cope with the energies entering the system ie sun, wind and rain:

2. To place all units, plants, earthworks and artifacts in the best possible arrangement in the landscape to suit the climate and site: and,

3. To provide a wide range of necessities for man in a way that is achievable.

To create an effective plan for a catchment area the community must be involved in the planning to first, decide what is to be done and second how to do it.

The basic problem about catchment planning is that the necessary activities do not have immediate results. People must be convinced that it pays to have an intergraded plan for the whole area. It is therefore necessary to start the operations in small scale rather than on a large scale which will collapse.

A catchment area is bounded by watersheds. The main purpose for planning a catchment area is to retain as much water as possible in the area and to prevent water run off and erosion of soils.

Effective catchment planning must allocate land to proper land use. Steep lands are for trees and permanent vegetation, moderately steep lands for forests and livestock and cultivatable lands on gentle slopes and lowlands.

After assigning the land to its proper use, afforestation steps must be taken by planting trees if there has been deforestation or if there are not sufficient trees for the community's needs.

For the cultivation lands, soil conservation and run off control measures must be undertaken to ensure maximum infiltration of water and recharge of ground water reservoirs. These measures include both cultural and mechanical measures of preventing the destructive force of water.

VEGETATION

INTRODUCTION

The natural condition of non-degraded land is to have a vegetative cover typical of a particular environment. Cultivation and grazing interferes with the natural vegetation balance. With increasing agricultural activity the forces of erosion (the most destructive force ever released by man) are released if appropriate counter measures are not taken.

THE ROLE OF VEGETATIVE COVER IN PROTECTING LAND

Plants have the following effects in protecting the soil:

1. Leaves and plant litter absorb the energy of raindrops and prevent degradation of the soil by rain-splash.
2. Vegetation is a store of water. Living plants together with their residues make the environment more drought resistant.
3. Under the shade of vegetation water can penetrate into the ground more easily. There is lower rate of evaporation due to the shading.
4. Abundant roots open up the soil and facilitate infiltration of water and recharge of aquifers increasing resistance to and escape from drought.
5. The litter fall from vegetation supports soil organisms which are instrumental in the transformation of biological residues into humus. It acts as mobile nutrients store in the soil and plays a big role in soil structure and fertility.
6. Under vegetative cover, wind erosion is curtailed as the wind cannot dislodge soil particles and transport them away.
7. A varied vegetation facilitates nutrient circulation. Deep rooted plants lift up nutrients from deeper layers and make them available for shallow rooted plants.

On cultivated land the land, the soil is most open to degradation in the dry season and at the beginning of the rains. During the dry season the soil is loose due to lack of water. There is no cohesion. This soil is vunerable to wind erosion. Cultivated land can be protected from this type of erosion and degradation by hedgerow planting, strip cropping or maintaining windbreaks. All these will ensure that the force of the wind is absorbed by the vegetation and does not carry away soil.

At the onset of the rains the dry soil absorbs a lot of the rain falling on the land. It is in the interest of the farmers to minimise the effect of the first heavy rains by keeping plants which would safely protect the soil from the pounding of rain. Crops such as beans give much more protection to the soil than maize crops of the same age. An intercropped field of maize and beans will be better protected in a shorter period than a field only planted with maize.

Other plant residues such as straw, branches and dead leaves protect the soil from rain splash. These vegetative products are just as good as living vegetation in protecting the soil.

Since vegetative cover cannot be maintained on cultivated fields, measures must be taken to prevent run-off and the carrying of soil from cultivated fields. Run-off is controlled by the planting of anti-erosive strips. These strips, planted along the contours line, are either single or mixed herbaceous plants and trees which slow down the flow of water allowing infiltration and deposition of soil particles borne in the water.

REINTRODUCING VEGETATIVE COVER SYSTEMS FOR PRODUCTION

The over-exploitation of arid and semi arid lands leads to land degradation, soil erosion, drought and desertification. This dried- out land needs to be rehabilitated for production. To re-establish natural vegetation, it is best to start with small nuclei which expand outwards mulching and returning plant litter to the system as it expands. Our best allies in this are drought resistant multipurpose trees.

Some of the strategies which help to re-establish trees in an arid area include.

1. Planting in the cool season. High temperatures can damage the shallow roots by cooking them when the soil temperatures are higher than 30 degrees Celsius.
2. Supplying a large quantity of mulch in pits around the plants.
3. Establishing a system to collect, absorb and retain moisture eg contour excavations (swales) sloping pits or other water harvesting techniques.
4. Planting a ground cover crop around the tree to cool the root area.
5. Watering the tree until the tree root area is self shaded.
6. Shading the young tree with dead brush or other shading materials.
7. Keeping away rabbits, hares, goats, etc. from the young

trees by fencing, poisoning, or dogs.
8. Planting a hardy tree legume intercrop to help with wind erosion, sun baking, and to produce fertilizer and mulch.
9. Raising, in a nursery, pioneer legume and more crop trees in large containers and using forest soil wherever possible.
10. After the pioneer trees grow, planting preferred trees between the pioneers and allowing a forest to evolve.

The trees planted for revegetation of an area must be suitable for the area. These are trees which have been known to exist in the area before degradation or those which exist in areas of similar climatical conditions and soils.

PLANTS AS BIOMASS ZONES

A tree exist in two media with a boundary layer at the interface of the two media. It therefore forms an aerial mass and a soil mass. In addition the litter which falls off the tree, the dead tree mass influences the tree's growth by its modification of the soil on which the tree stands.

A tree, or any plant for that matter, is made up of three main area. The visible tree, with a crown and a stem. The soil/air boundary of the litter and the humus, and the underground tree, including the roots and root associates.

The visible tree is the 'factory' which uses the energy of the sun to transform simple plant foods into complex biological products. The simple plant foods include carbon dioxide absorbed directly from the air, nitrogen from the air which is transformed by nitrogen fixing bacteria into mineral nitrogen (nitrate) and is then picked up by plant roots and mineral elements dissolved in water to make soil solution originating from the breakdown of rocks.

The transformations of nitrogen, carbon dioxide, mineral elements in the presence of water takes place in the leaves and is driven by the ability of the leaf to capture the sun's energy. These transformations build up the biomass of the tree both above and below ground. The biological products produced by the leaves include carbohydrates, proteins, fats, plant protectives, support tissues etc. The leaves are the most complicated factories on earth. The variety of the products made in the leaf is vast. Some of their products are so complex that they are yet to be fully understood.

The tree stands on a soil/air boundary. This is the zone of decomposition. The tree sheds many times its mass over the earth. This mass comes from the self-pruning of the tree, leaf fall as a means of excretion, fruits, seeds and direct feeding of insects and animals on the tree. The decomposition layer is a zone of transfer of energy captured from the sun into grasses, other plants, bacteria, fungi, insects, birds and mammal life. In addition to supporting this biomass, the tree detritus is transformed by the same life into humus which supports the tree in holding nutrients and water and releasing it slowly for the survival of the tree.

The underground tree mass is made up of roots which anchor the tree into the soil, pick up nutrients and water required by the tree, and support the root associates. The root exudates support a soil life, and the root associates, bacteria and fungi, interact with water soil and the atmosphere to manufacture cell nutrients for the tree.

The ability of the tree, and plants in general, to transform simple products of nature into complex biological products is the base of all biological life. Without the energy transformation capability of plants there would be no food for animals. There is an interaction of the biomass of a tree and all biomass. The tree is central in the interaction of animals, insects, fungi, bacteria which are dependent on the tree and on which the tree depends in complex inter-relationships.All ecosystems contain plants, and all food chains start with plants.

THE EFFECTS OF VEGETATION ON MICROCLIMATES

Microclimate describes the environmental conditions at a site as effected by local factors. These factors include topography, soil, vegetation, water masses and man made structures. These factors influence the climatic conditions of a region to give local conditions as measured by the temperature and temperature ranges, the wind and any precipitation.

Vegetation moderates the climate. It is cool in the forest on a hot day, since the soil rarely dries out and rainfall under a forest canopy is a slow soft dripping pleasant affair not the hard beating and eroding rain of open ground. At higher altitudes on a cold day, it is warmer in the forest than in the open, exposed to the cold wind.

Conditions within vegetation, forming a microclimate, are mild because of the nature of radiation absorption, reflection and transfer of the heat by plants. Some of the incident radiation is reflected back into the atmosphere. Some is absorbed by the plant. Some penetrates the canopy into the lower layers of the forest. Part of the radiation is trapped beneath the canopy of the forest which acts as a heat store and radiates heat at night. Combining the absorption, reflection and transfer by plants of incoming radiant energy results in small temperature changes between day and night and also small temperature ranges over the seasons.

Inside close vegetation such as a forest, winds are low or absent. The tops of the vegetation is a zone of turbulence from the wind but the wind does not penetrate deep into the vegetation. The absence of wind translates into low evaporation rate, absence of cooling effect due to rapid evaporation and a stable humidity.

The precipitation received in a forest can be divided into intercepted rainfall and through-fall rain. Sometimes light showers may not reach the ground as evaporation removes the water held in the tree crowns. This interception combined with the uptake by plants and infiltration into the soil reduces run-off in a forest to almost nil. Trees stop erosion.

Although the forest environment provides a favourable microclimate for growth of plants below the canopy, this growth is limited by the amount of light passing through the canopy. An open system of forest, clearing, hedgerow field, woodland and intensive crop cultivation would be capable of a higher production. This system is influenced by the forest edge, clearing hedgerows and windbreaks.

The microclimate of a forest edge is dominated by the effects of transition from forest to open ground. Depending on the orientation the edge affects radiation and wind.

A forest clearing has a much more moderate climate than open ground. Variations in rainfall, evaporation, dew and radiation give a considerable variation of microclimate in clearings.

Windbreaks are a very powerful very powerful tool in changing microclimates. The effect of a windbreak on winds varies considerably and is dependent on tree density, height and species. A medium dense belt, that filters the wind, is more effective than a denser belt, that acts like a wall. Winds which are tangential to the wind break tend to speed up whereas those which are perpendicular to the wind break are slowed down.

Opened-up forests are similar to an open woodland. The microclimatic effects are dependent on the density of the canopies, and their shape. Winds in a thinned or opened forest are slower. This slower wind and the amount of radiation reaching the ground is responsible for the favourable microclimate.

VEGETATION AND PRECIPITATION EFFECTS

As rain falls on a forest, the tree canopy shelters and protects the soil from the impact of raindrops. If the rain is light, there is little penetration of the canopy. The water spreads on the surface of leaves and stems and is held there by surface tension. Most of this water is evaporated and some is absorbed by trees through their canopies. This phenomenon is known as interception. It is a very important effect of trees and forests on rain. It is influenced by crown thickness, crown density, season, intensity of rain and evaporation rate after rain.

When more rain falls, water starts to move down towards the ground. This water is known as through-fall. Through-fall depends on the intensity of the rain. The through-fall washes the canopy of extraneous matter like plant exudate, soil dust, trapped nutrients, dead plant tissue and insects. It also fills any aerial reservoirs the forest might hold. Through-fall water reaching the ground enters the humus layer of the forest, which act as a sponge and absorbs a large quantity of water.

The root-mass in the top layer of soil absorbs this water which has dissolved nutrients and transports it up the tree to transpire again into the air. The water entering the soil coats the soil particles with a thin film of water wetting them. This film is available to plants. Only when the particles have been wetted that water enters the interstitial spaces and percolates slowly to the streams and then to the sea.

Imagine the tree you see as 90% water, then imagine the amount of water held in the humus (the boundary tree) and also the water held in the underground tree which is 40% of the total tree. You will then realise that forests make lakes which are managed and recycled for their survival.

What happens in the forest generally also happens in the single tree although in a lesser extent. A single tree creates its own microclimate and moisture storage capacity for its survival. Some trees exude gels from their roots for holding water. A tree does not exist on its own but in association with other creatures which support its survival.

CHOOSING ENVIRONMENTALLY SUITABLE VEGETATION TYPES.

The climate of an area is the basic limiting factor in determining the species and diversity possible of the area. Excepting local variations such as topography, the chief limiting climatic factors in the tropical savannas is the rainfall regimes. The tropical savannas are characterised by wet seasons of variable length followed by a period of drought. In some areas the wet period coincides with low temperatures and in other cases with high temperatures. The importance of rainfall lies in the intensity and the distribution. The savannas have a high radiant energy input throughout the year. Temperatures and net radiation are therefore adequate for plant growth throughout the year. The high temperature and high solar radiant energy input however means that the evaporation rate is high.

As a general principle, where the annual rainfall exceeds the evaporation rate, forests occur. Where the evaporation rate exceeds the rainfall, then grasslands predominate.

The climate also controls the weathering of rocks and the release of soil nutrients. One must therefore consider local climatic influence effecting the inputs and losses of nutrients in the ecosystem through weathering and leaching. The high temperatures and moist conditions promote the decomposition of silicates in rocks and soil particles. When conditions are wet, soluble bases are lost by leaching and drainage. The liberated silica, aluminium and iron hydroxide move downwards in the soil. In an undisturbed forest the decomposition of litter makes nutrients available to plants. The lower parts of the soil however are impoverished by leaching.

Alternating wet and dry conditions result in little organic matter returned into the soil. At the wettest period organic acids and soil solution percolate downwards and promote basement rock decomposition, producing iron and aluminium hydroxides. The strong leaching of humid climates is however lacking and the bases are concentrated just below the top soil. As the soils dry and crack, roots decay or through insect activity, holes are left which allow air into the soil. The air oxidises the hydroxides to less mobile oxides of aluminium and iron. This forms a hardened lateritic layer which influences water penetration.

Having examined the limiting factors in climate it is sensible to start with species which have been known to survive in the locality for your choice. For example, <u>Acacia tortilis</u> has been known to survive in Kitui. This tree has multiple uses such as bee forage, its high feed value to animals and it fixes nitrogen. It sheds its leaves during the dry season and goats feed on these and its pods, when there is no grass. The tree can therefore be used for pasture improvement, since it does not intercrop well, providing shade for livestock, and eventually providing firewood and good charcoal.

After gathering the information from the local community and implementing these trials of other species can be carried out. Maybe try another Acacia species which is not available locally but which has obvious advantages.

Some of the factors which one might consider in choosing vegetation species on a particular area include:

1. The yield per plant
2. Yield habits as effected by deciduous characteristics, wet and dry cycles, length of dry period etc.
3. The quantity of the plant products emanating from the species
4. Maturity period to full yield
5. The importance of the species in subsistence
6. The availability of information on utility and culture under local conditions.
7. The ease of propagation in time money and skills.
8. The value to the community

In considering these factors however one must be aware the species should be suitable for the area and their influences on the plant environment.

VEGETATION IN SOIL REHABILITATION

The potential of vegetative reclamation of degraded land is well known. Vegetation increases fertility through leaf fall and humus. This in turn serves as the energy input for soil organisms. The interaction between the vegetation and the soil facilitate greater infiltration and less run off. The trees act as soil formers in this way. In addition the vegetation plays a role in the modification of microclimates which promotes the growth of less hardy vegetation than the pioneering vegetation thus creating vegetation diversity and stability.

The first move towards reclamation of degraded land is the establishment of a full vegetative cover. The initial establishment of pioneers should include some nitrogen-fixing species to supply nutrients to the rest of the vegetation. There must be initial protection of the young plants from animals to allow plant residues to reach the ground to form humus, start a health soil organisms culture and retain moisture in the soil.

As run off is minimised and controlled by vegetative cover, tree detritus on the ground builds up, and the soil is opened up for infiltration of water to recharge aquifers and springs. Then as sufficient soil organic matter is built up, the vegetative system could provide ways of combining continued improvement of the land with production.

The rehabilitation of the quarry lands of Bamburi uses Casuarina equisetifolia as a pioneer species. This is because the tree, like all other casuarinas, can grow in a nutrient-deficient soil due to its symbiotic associations with soil micro-organisms. One of these associations is with bacteria frankia which fixes nitrogen. Some other microorganisms, mycorhizas, on its roots increase the uptake of phosphorous.

The mulch from the plantation of casuarinas facilitates the growth of other trees and plants which could not have survived in the harsh nutrient poor quarry wastelands. Once the new ecosystem was established, new plant species have been introduced naturally by birds and animals and the wind. This rehabilitation gives a vivid example of the associations made by a tree and the interdependence of different life forms on each other.

MANAGING NATURAL VEGETATION FOR PRODUCTION

Nature feeds any system with the forces such as the sun, the wind and the rain, necessary for the survival of the system. Living components of the system translate the incoming energies into useful reserves. These are the resources of the system. Some of these resources are used by the system to maintain itself. The surplus of resources above the system's needs is the yield of the system. The yield is the sum of conserved, stored and generated energy surplus to the system, freely available to others.

The base translators of energy are the plants which can capture sunlight and make it available to life forms. They capture the rain and store it within their bodies, in the soil and the excess is released slowly to charge the aquifers and feed springs and rivers. In a natural state, a forest renews itself by saving the energy which enters it. It does this by recycling waste, nutrients, water and insulating itself against excessive radiation by reflection, covering the ground to prevent soil erosion and protecting itself against wind effects.

When animals are integrated in the system, as in the wild, they aid in the cycling of energy of the system and do not destroy the system. A complex association between the primary producers and other biological energy converters live in harmony to achieve a balanced energy use. Unused or wasted energies create chaos and undermine the basic resources. This limitation of energy entering the system is observed in the reduction of the destructive energy of raindrops by forest canopies and reflection of excess radiation by the leaves.

A balanced use of the energy system is observed in the feeding habits of animals in the savanna. Giraffe feed on acacia and other leaves up to five meters, rhino eat lower parts of the acacias, zebra feed on high grasses, topi eat lower grass and wildebeest feed near the ground level. As a whole the grazing prevents the development of a closed canopy which would exclude grasses, while the feeding of some animals on fallen tree fruits and seeds help to spread the plants. Populations are controlled by predators which feed on the browsers and grazers.

The whole ecosystem is then in a balance since all living things must die and the energy stored in them is released back to the system for circulation through other biological forms. Modern research has confirmed for us that the savanna grasslands have maintained this steady state , balanced ecosystem for centuries until man's intervention.

The management of native vegetation for production would therefore include basically two important issues. These are the prevention of run-off by promotion of infiltration of rain and recharge of aquifers, and the appropriate land use for maximum utility of sunlight for transformation of the sun's energy into biological energy.

The systems which are used to achieve the two basic aims include:

1. Afforestation of steep area
2. Agro-forestry techniques
3. Cultural measures of soil conservation
    - Strip cropping
    - Infiltration zones
    - Cover crops
    - Companion cropping
    - Buffer strips
    - Mulching
    - Crop rotation
4. Good management of pasture lands.

THE ROLE OF ANIMALS IN MANAGING NATIVE VEGETATION

The most important animals reacting directly with vegetation are the herbivores, the grass-eaters. Their survival is depended on the availability of vegetation. They transform the vegetative energy store in the plants into a different form of biological energy in their bodies. The carnivores, the meat-eaters, then feed on these animals completing another link of the chain. In the end all biological forms die, their bodies are decomposed by microorganisms which store energy from these tissues in their bodies and hold it in the system. Eventually the nutrients are picked up by plants and recycled.

A natural ecosystem without interference from man has many different components and is self-regulating. The plant species in the savanna for example are many and varied. It is unusual in nature to find one kind of tree, herb or grass only. The mixed vegetation caters for different animals, which become adapted to them. The herbivores feed on the native vegetation by browsing or grazing each at its own particulars level. The giraffe and elephant feed up to a level of about five metres; rhino consume the lower shoots of the acacias; zebra feed on the taller grasses and herbaceous plant tops: topi eat the middle level grass and wildebeest buffalo etc feed on the low level grasses near the ground. By grazing and browsing at selected levels animals maintain the ecological balance of the environment. Not only do the animals feed at particular level, but also most animals feed on particular species.

In addition to the animals feeding selectively, they also do not overfeed in a particular habitat. They are constantly on the move. this movement allows the vegetation of a particular area to recover without permanent damage. This selective feeding in conjunction with constant movement of herds protects the environment from the destruction of native vegetation and subsequent erosion. It keeps the habitat open for maximum use of incoming radiation. It also ensures the distribution of plant seeds.

Where man has settled, he has disturbed this natural balance by keeping only selected types of animals. The result has been the destruction of native vegetation by overusing the selected species preferred by the animals. Without the natural controls, these animals have exceeded the carrying capacity of the environment. This has resulted in poor vegetation regeneration, soil compaction and increased soil erosion.

To improve rangelands, the cattle keeping system must be improved. The rangelands must be rehabilitated and overgrazing checked by reducing herds. Animals kept in feedlots will not have an adverse effect on the environment, if the system is well managed.

CROPS

INTRODUCTION

The reason for most vegetation clearing is the growing of crops. The historically derived system in Kitui was based on 'slash and burn' followed by fallowing. This system is increasingly being transformed to a perpetual cropping system. Its basic ingredients are monocultural, a lack of ground cover, soil baking, panning, wind erosion and finally flash-flood erosion. This is not a sustainable agricultural system, and increasingly it cannot carry the base population. To reverse the land degradation trends of this system new concepts of sustainable land use need to be introduced.

PLANT FEEDING AND BALANCED NUTRIENT UPTAKE

A plant is made up of different parts. These include roots, stems, leaves and flowers fruits and seeds. Each individual part has a role to play in the nourishment of the plant at sometime during its life. Let us examine each in turn.

Roots

-form the underground plant.
-fix the plant to the soil.
-absorb water and nutrients through root hairs.
-exude waste products into the soil.
-carry the absorbed water and nutrients to stems.
-form food stores sometimes as in cassava yam etc.

Stems/Trunks and Branches

-form above ground plant.
-provide frame work supporting leaves, flowers and fruits.
-contain channels of transport from the leaves to roots and vice versa.
-can store food.

Leaves

-are the processors of plant nutrients and water into sugars, proteins and fats forming the living matter.
-capture suns energy for biological transformations.
-facilitate gaseous exchange. Take up carbon dioxide from the

air to make into plant food.
-transpire, sending off water vapour into the air

Flowers, Fruits and Seeds

-fruits are formed from flowers and nourish the seeds, which reproduce plants.

The plant takes its food from the air and the soil. Carbon dioxide and oxygen are absorbed by the plant directly from the air through the leaves. Some plants can absorb nitrogen indirectly through the root associates which fix nitrogen. Otherwise the nitrogen, which is needed by plants must be transformed by other means to mineral nitrogen which is absorbed through the roots.

From the soil the plant takes up water, mineral salts, and other substances in the soil. These substances are transported to the leaves through channels in the roots and stems. The major nutrients which are taken by the plant in large quantities are:

1. Nitrogen

It is essential in making biological tissues. It is a component of all proteins and any new growth is dependent on it. It is found in the atmosphere in living matter and its residues.

2. Carbon
Carbon combines with nitrogen to make proteins and with water and air to make sugars and fats. It is found in the atmosphere.

3. Phosphorous
Plants need it to flower and bear fruit and develop strong roots. It is a component of bones and is found in the ground.

4. Potassium
Potassium maintains healthy activity in biological tissues. It is important in fruit and tiber enlargement.

5. Calcium
Calcium is an important component in bones and teeth of animals and plant cell walls.

6. Magnesium
Magnesium is a component of chlorophyll which enables the plant to capture light energy.

7. Other substances

Other substances known as trace elements, are taken in small quantities to nourish the plant. These include iron, copper, zinc, boron and molybdenum. They are essential to healthy plant growth although very little quantities are required.

All these nutrients, apart from carbon, are taken by the plant from the soil. They travel, via water, in solution through channels to the leaves for their transformation into plant tissue building blocks and are then distributed throughout the plant in different channels.

When plants die, they decay with the formation of humus and release of carbon to the atmosphere. The mineral salts, nitrogen, phosphorous, potassium, calcium and magnesium, together with the trace elements, are trapped in the humus, sand, silt and clay. These nutrients can be absorbed by plant roots to start producing organic matter once more.

The plant nutrients therefore exist in two phases. In one phase the nutrients are in the soil and the atmosphere. In the other case, the nutrients are locked in plants in the form of organic matter. Organic matter decay is decomposition carried out by the action of animals and microorganisms in the soil. This slow process of humification is the best way of improving the soil structure. It ensures that plants receive a regular food supply. The mineral salts are released gradually into the soil and they are used by soil inhabitants that retain them in their body tissues before getting rid of them as waste or dead remains. These in turn are food for other living things.

When all the plant residues are returned to the soil, mineral nutrients are built up in the soil. This is what happens in the forest and in the recovery of fallow land. If there is removal of organic matter from the field, the amount of nutrients returned to the soil is reduced. Continual removal exhausts the soil. Plants grown in this kind of soil are malnourished. Their leaves turn yellow and the plants are sickly.

Another way by which nutrients are lost from soils is through leaching of nutrients into the lower layers of the soil. These nutrients are too deep to be reached by crop roots. For healthy growth, crops must receive a balanced supply of nutrients. This can be achieved only by putting nutrients back into the soil. Efforts should be made to prevent the loss of nutrients through leaching.

The replacement of mineral nutrients lost through removal when crops are harvested or through leaching can be achieved through the use of organic fertilizers, ground rocks like phosphate or dolomite rocks, and chemical fertilizers.

Plants can only receive a balanced nutrient uptake if a sufficient supply of nutrients exists in the soil.

CROP ROTATION

Every crop exploits a particular soil layer from which it obtains all the nutrients it requires. This particular layer of use is determined by the root structure of the particular crop. As the crop is harvested agricultural material containing nutrients from the exploited layer are lost to this layer of the soil. This soil layer is therefore impoverished by the harvesting of crops. The lack of sufficient nutrients in this layer of the soil is seen in the diminishing yields on subsequent plantings of the same crop.

If two or more crops are grown in sequence in the same field, each crop utilises a layer of the soil determined by its root structure and nutrient requirement. With time however cultivated plants exhaust the nutrients in the soil due to removal of produce. The fertility of the soil must be maintained to allow continued use of the soil and prevent land degradation. It is in the interest of the farmer to remove only that which can be consumed and return as much as possible of the crop residues to the field to maintain soil fertility.

Due to the crop removal, the nutrients in the soil should be supplemented from external sources such as fertilizers or ground mineral rocks to maintain soil fertility.

Most crops have their specific pests and diseases which attack them. The pests which prey on maize do not attack cassava for example. When a crop is planted season after season in the same field there is a carry-over of pests from the last crop to the new crop. The infestation in the new crop is bound to be higher than in the previous crop. If a different crop is planted during the ensuring season however the pest numbers fall due to the lack of the preferred host. Thus we have two major reasons for crop rotation. These are a balanced use of soil nutrients, and disease and pest control.

SPATIAL CROP ARRAYS IN KITUI

Pigeon peas, or Cajuns cajan, was always recognised as a soil improver. Although the term agroforestry was unknown, the plant was used in th emanner we would use an agroforestry tree today.

Pigeon peas are planted in October and are harvested in August the following year. The usual practice has been to interplant alternating rows of maize and pigeon peas in October. The maize is harvested in January and the pigeon pea plants are left in the field to mature. The trees form a complete canopy and cannot be interplanted with any crop on the ensuing short rains.

The usual practice has been to plant pigeon peas in strips, interspersed with strips of other crops. For example a planting pattern in October maybe a strip of pigeon peas and maize, a strip of sweet potatoes, a strip of sorghum with cowpeas, a strip of pumpkins with millet or maize, or many other combination of plants. The strip planted with pigeon peas this year would be used for growing other crops. This practice was employed to reduce the incidence of diseases like "Kathoa" in pigeon peas.

During the following year, crops grown in the strip previously planted with pigeon peas benefitted from the nitrogen enrichment, resulting from the fixation of atmospheric nitrogen by the pigeon pea plant. In some cases pigeon peas were grown together with pumpkins, gourds or sweet potatoes. These crops are prolific biomass producers and a plot growing this combination of crops received a large accumulation of organic manure when the crops were harvested.

CROP SELECTION TO SUIT CLIMATE AND SOIL TYPE

The plants which grow in an area are determined by the prevailing climatic conditions. In the tropics the major factors of climate are the rainfall intensity, extent and temperature. Different plants require different soil conditions depending on their nutrient demands from the soil. Some plants grow only in deep well drained soils. Others will survive in waterlogged soils. Some plants need highly fertile soils whilst others survive in nutrient deficient sands. Crops which grow in an area are thus adapted to the climate and the soils.

For identification purposes, plants with similarities are grouped together in families. More marked similarities within the family allow them to be sub-divided into groups called genera. In each genera there are distinct types called species, and each species can have several forms called varieties. Thus in the Legume family, there is a genus called Vigna, amongst which is a distinct called <u>Vigna unguiculata</u> or cowpea, which has many varieties.

Generally the varieties of the same species can interbreed. When interbreeding occurs some of the characteristics of the two varieties are combined. The resulting plant bears some of the characteristics of each of the parents.

The farmer should gain a working knowledge of the characteristics of the different varieties and their distinctive features for all the crop grown in the field. Indigenous knowledge has information on which varieties are likely to survive in a locality. Different varieties of the same species are planted during different seasons for example late maturing beans during the long rains and early maturing beans in the short rains.

Some of the following factors could be used to determining the characteristics of the available varieties which are of special interest to the farmer.

Early Maturing or Late Maturing Varieties

Early maturing variety will give a yield during a short period of time but will be spoiled in the field during the long rains since it will not have time to dry and be harvested. Late maturing varieties are suitable for long rains but the short rains will be gone before they have brought forth fruit.

Root systems

Shallow root system varieties obtain their water and nutrients only from the top layers of the soil. Deep rooted varieties use a wider range of the soil profile and are likely to be more drought resistant.

Intercropping

Some varieties can be intercropped, others cannot mainly because they have the same root systems and thus compete in using the same nutrients. The best intercropping is across varieties for different varieties have different nutrient and pest demands.

Light demand

A farmer needs to know whether a variety needs full exposure to sunlight, partial shading, or it can tolerate shade. This will determine whether the variety can be used in a multistorey system, and where.

Pest resistance

Examination of the resistance to pest connected with the species in the locality should establish whether the species is to be recommended.

Hardness of grain

Soft grains are more easily damaged by grain borers than hard grains. This is why the coastal Duruma and Chonyi, have selected hard grain maize varieties for their use.

Palatability

Some varieties are sweet and can be eaten directly, other varieties are bitter and contain substances which must be removed before consumption. The bitter cassava for example contains acids which must be removed by soaking and cooking before eating. So are some of the new sorghums. They are able to escape bird damage because of their bitterness.

Nature of stems

Whether a species is a climber, erect or creeper is important in interplaiting because the nature of the stem can interfere with the intercrop and also since the different varieties use light differently.

Height of the plant

This determines the nature and ease of harvesting. Tall trees must be climbed to harvest fruit.

Other characteristics which may be of interest are: recovery after stress, method of propagation, use of produce etc. Farmers must know the characteristics of the varieties available to them in order to design cropping systems suitable for their area.

MONOCULLTURE VERSUS POLYCULTURE

Historically polyculture, many plant species together, has been the dominant cropping system in the tropics. This was good given the light weathered soils, heavy intensive rainstorms and long periods of drought.

The European cropping system evolved into sole cropping or monoculture. This system suited Europe due to its heavy soils, which are not highly weathered and are characterised by receipt of much less radiant energy. It is not suitable for the tropics.

Monoculture allows for higher productivity of labour by application of machinery, especially where labour is scarce and large tracts of land are available. However heavy machinery compacts the soil and deters infiltration, increases run off and land destruction especially in the tropics where the soil is effected more than in Europe.

Due to the nature of feeding of plants, monoculture can only be supported with the aid of artificial fertilizers. The fertilizer industry developed in Europe to support this type of cropping system for replacement of nutrients.

The replanting of the crop, season after season, in the same field, results in the build up of pests and diseases. The solution to this problem is the use of chemicals for the control of disease and pests in the field.

Mono cultural practices ignore the improvement of soil through the addition of organic matter into the soil. The absence of humus in the soil impoverishes the soil of soil living organisms. This practice has an effect on the soil structure in the long run.

Monoculture depends on external inputs onto the farm. Most of the inputs are not manufactured in tropical countries. These imports have to be purchased with the scarce foreign exchange in these countries. The inputs are too expensive for the small scale farmers. Secondly, the system needs large tracts of land whereas the average small-scale farmer owns less than hectare of land. An alternative system to monoculture therefore must be made available for the survival of the small-scale farmer. Such a system is polyculture, traditionally the cropping system of Africa.

Polyculture or multiple cropping, intensifies yield in small areas in terms of space and time. In polyculture two or more crops are grown in a year either in sequence or simultaneously. When crops are grown in sequence on the same field in one year or season, the intensification of cropping is in terms of time. The second crop is planted after the first crop has been harvested and there is no competition between the crops. Simultaneous growing of crops on the same field intensifies cropping in both time and space. It creates competition between crops. There are several systems used in polyculture. Some are:

Mixed intercropping

This is random distribution of two or more crops at the same time.

Row intercropping

Two or more crops grown simultaneously in rows.

Strip Intercropping or Alley Cropping

This is the growing of two or more crops in different strips spaced such as to achieve multiple cropping effects.

Relay intercropping

This is the growing of two crops simultaneous for a part of their life. The second crop is usually planted after the first crop has reproduced but before harvesting.

Multistorey cropping

This is an association of tall tree crops with shorter herbaceous biennial annuals or seasonal crops.

In polyculture more than one crop is grown. This spreads the risk of total crop failure. It seems like this was the conventional wisdom which promoted polyculture rather than monoculture in the tropics before the advent of European industrialised agriculture.

MULTI-CROPPING SYSTEMS OF KITUI

Pure stands of any particular crop were a rarity in traditional agriculture. One would find millet interplanted with cowpeas; millet with maize; millet, sorghum and maize; pigeon peas and sorghum; pigeon peas with millet; sweet potatoes with pigeon peas; pigeon peas with maize and pumpkins; green grams and maize; beans and millet and so on.

These integrated cropping system bore the advantages of poly-cultural cropping systems. They provided a balanced use of soil nutrients and facilitated nutrient uptake from different layers depending on the root penetration of the crops concerned.

Mixed cropping was used as an insurance against crop failure. When rains failed, it was possible to obtain a yield of crops with a short growing period such as cowpeas or of drought resistant crops such as millet whilst losing crops such as maize.

Mixed cropping also diversified the food base of the people. As a result the nutritional base was broadened. For example, nursing mothers were fed on a diet of milk and millet "wimbi" which is high in iron content, they consumed sweet potatoes which are high energy food and also took different kinds of fruits found wild.

Millets and sorghums which are the traditional grains of Africa were extensively grown before the introduction of maize. The introduction of maize and beans in native agriculture brought with it the monocultural cropping systems and almost eliminated the traditional grains.

ADVANTAGES OF INTEGRATED CROPPING SYSTEMS

The integrated cropping systems of polyculture have many advantages for farmers. They produce a ground cover which protects the ground from desiccation and erosion for a large part of the year. They provide a spread of labour demands on the farmer thereby reducing seasonal peaks by the staggering of planting and harvesting times of individual crops. They produce a diversity of crops which reduces the incidence of disease and pest infestations. The yield per unit area is increased due to a better more balanced use of available water and nutrients in the soil coupled with a better circulation; provide an even distribution of food supply throughout the year with a spread of risk due to crop failure, if one crop fails other crops in the field provide a yield.

The integration of trees in cropping fields preserves the fertility of the soils and contributes to the economy of the landowner. Tree products such as firewood, timber and fodder, reduce the expenditure of the farm. They also increase the efficiency of the land unit in that less time is spent on collecting firewood. This time can be used in a more productive manner. Trees also improve productivity by providing a more conducive working environment.

Further to the improvement of the economy of the land owner, trees in an integrated system, fulfil the following functions.

Erosion control

Trees and shrubs protect the land against erosion not only in forests but also in agricultural land. Ground cover, water infiltration, mulch and physical impediment to flow are important factors in erosion control.

Water infiltration and detention

Trees increase water infiltration into the soil by opening up the soil with their roots and improvement of soil structure. The mulch obtained from falling leaves decomposes into humus which has a high potential in water absorption. The increased water retained in the soil is effective in extending the growing period of crops. The shading of trees reduces evaporation losses from the soil. This water can therefore be used more profitably in production.

Nutrient pumping

Deep rooted plants draw nutrients from deep layers of the soil which are beyond the range of crop roots. These nutrients are brought to the surface of the soil as plant residues and from mulch which supplies plant organic mater to the soil when leaves fall. The mulch is decomposed by soil animals and micro organisms to form humus which binds the crop nutrients and prevents their loss through leaching and fixation of nutrients. Further the humus promotes the growth of a healthy association of soil organisms which are beneficial to plant growth.

Microclimate influence.

Trees influence the climate within their proximity forming a microclimate. Slight shading increases the humidity, reduces soil temperature and modifies the rate of decomposition of humus. Crops or pasture in the vicinity of the tree are influenced by these modified conditions. In the tropics where high temperatures and high solar radiation exist and are not limiting factors to production, multistorey cropping systems could provide an effective use of solar radiation which prevents excessive heat generation in the system. This system would be economic in the use of water which is a limiting factor in many cases.

MULCHING AND RELATED PRACTICES

Mulching, green manuring and composts employ basically organic matter to cover, produce humus and supply mineral nutrients to the soil. The form in which the organic matter is applied to the soil determines the effect it will have on the soil.

Mulches

A mulch creates a microclimate in the top soil over which it is spread. It regulates the temperature and air humidity in the soil at levels independent of the prevailing conditions the drying out of the surface . The moist conditions and moderate temperatures created under the mulch layer promote the decomposition and mineralisation of organic matter.

By covering the ground a mulch protects the soil from the erosive forces of rain and wind. The mulch layer decomposes sequentially from the bottom upwards as a result of being acted on by soil animals and microorganisms. The root fungi associates develop well in this situation. They supply plants with nutrients from the mineralised nutrients through their mycorhiza. Therefore, no nutrients are lost through leaching or fixation. In addition humus in formed and is worked into the soil be millipedes, earthworms and other soil organisms.

Mulch is obtained from crop residues, fast growing trees in an alley cropping systems, or transported from outside the farm.

Green manure

Nitrogen is the most limiting of the major nutrients in many cases. To maintain soil fertility with adequate levels of nitrogen in permanent cropping systems, ground covering legumes can be grown in association with crops. This under sowing stimulates soil organisms and can lead to increased decomposition of organic matter. Used properly green manuring improves the physical and chemical properties of the soil and increases yields with little external resources or capital.

The draw back of green manuring is the amount of labour required in non-mechanised systems. In semi arid climates the water demand limits the use of green manures to some extent.

Composts

Composts are made by controlled biological and chemical transformation of biological residues and wastes to produce humus. Mineral nutrients can be added where necessary for example by addition of lime, phosphate rock and wood ash. Composts have many advantages including sanitation by decomposing toxic substances, destruction of pathogenic substances, weed seeds and roots by the heat generated in the compost heap. Composts improve the nutrient balance as a result of their stable humus with long chain humic acids which increase the ion exchange capacity. This is a crucial factor in tropical soils which lack clays and are subject to heavy nutrient leaching. Composts increases biological activity which increases the solubility of phosphates and the availability of nitrogen. Soil structure is improved by adding composts which increases soil fauna which in turn promotes biological stabilisation of soil particles. This increases water absorbtion and retention reduces erosion and improves soil aeration. Compost improves plant resistance to diseases and pests. All organic manures have been shown to increase the plant resistance to pests and diseases. Current thinking attributes this effect to the association of certain micro-organisms in the soil with plants. It is thought that the plants absorb certain substances made by these micro-organisms which help the plant to protect itself against pests and diseases. These substances are absorbed through the plant roots.

SELECTION FOR YIELD AND VIGOUR/ ON-FARM GENETIC IMPROVEMENT

The individual members of a species-variety population are never completely identical. In one manner or another each individual varies however slightly from other individuals of the population.

Individual variations may originate from differences in the genetic complement of the different organisms, or genome, resulting in genotypic variations. Alternatively, variations may arise due to environmental factors on individuals with the same genome. This type of variation is known as phenotypic variation.

In phenotypic variations, individual organisms might adapt in response to climatic factors. Sometimes when phenotypic response occurs in the developmental stage of the organism, the change maybe fixed. Usually phenotypic adaption is not fixed. For example, animals can repeatedly acclimatise to different temperature ranges.

Genotypic variation which brings about evolution through selection, arises basically from mutation and recombination. Genetic information is conveyed from one generation to another as developmental instructions coded on DNA molecules. DNA is duplicated during gene replication at cell division. In this process random errors can occur resulting in genetic changes known as mutations. In other cases, mutations are controlled by mutator genes which are subject to control by natural selection.

Under natural conditions, when adverse conditions prevail, the fittest individuals survive to continue the species. These are the individuals whose phenotypes can adapt to the prevailing tough conditions. These phenotypes provide the genetic pool for the species in future.

The basis of natural selection is that most phenotypes have different fitness, and that most phenotypes are sufficiently hereditary.

Observation and character rating of a crop is basically a system of phenotyping the crop. For example, if we select for our next seasons crop only maize with two or more ears, we will be improving our maize stand by harvesting more ears per plant. We might then select short plants with two ears or any other combination that we might prefer.

On farm genetic improvement of crops is dependent largely on the farmer's knowledge of preferred characteristics of their crops. Selection of seed from plants with these preferred characteristics will pass on the characteristics to the new generations.

Vigorously growing individual plants will in most cases be disease and pest resistant. They may have better root system to absorb nutrients or they may have a better utilisation of nutrients as compared to the rest of the crop population. Selection for this vigour will be passed on to the progeny.

Thus on-farm genetic improvement should not be confused with the process which occurs in research stations. In research stations the selection is more genome based than phenotype based. The plants which are produced might leave a definite gene composition for a definite characteristic.

CROP DIVERSITY

Diversity is the number of different components in a system. In a cropping system this would mean the growing of different kinds of crops in the system. Intercropping is one method of creating crop diversity. Crop rotation is another method of diversifying the crops grown in an area. Crop diversity has many advantages. Among them are:

- Control of pests and diseases
- Safe recycling of wastes.
- Modification of microclimates
- Minimisation of risk of crop failure
- Diversification of food sources
- Improvement of human health
- Labour peak spread

To control the build up of pests and diseases on the farmer's fields, a farmer can increase the time between planting of susceptible crops. Root nematodes which attack potatoes will be reduced when maize is planted in the field, since they will not have a host to attack. If a crop of potatoes is planted continuously the infestation will be so heavy as to seriously affect the crop.

Some crops like grains and vegetables are heavy feeders. They remove a lot of nutrients, especially nitrogen, from the soil. These should be normally followed by crops such as legumes which are heavy givers and which enrich the soil by fixing nitrogen.

Where trees are integrated in the cropping system, they modify the climate by their shading effect. Tree roots improve water infiltration and bring up deep lying nutrients to the surface.

Crop diversity reduces many of the risks and uncertainties which trouble farmers. In a diversified situation, not all crops fail at the same time. If one crop fails, another survives to produce a yield. The various crops produce different foods and eliminate single crop dependency. As the times of maturity for different crops are different, the labour demands on the farmer is spread out and does not have sharp peaks which occur in a single crop system.

Crop diversity influences soil fertility in that the soil is covered for a longer time than in single crop system. It thus protects the soil from rain and wind erosion and from the desiccating effects of the sun.

In a diversified farm, other economic activity such as animal rearing and beekeeping can be undertaken. Bees forage produced on the abundant flowers which are produced and fodder crops for the animals can be employed for rotation and erosion control strips on the fields.

Crop diversity was always used in tropical Africa in the past. It was later discarded as outdated. Diversity was then replaced by mono-cropping. It has now been shown by experience and research that crop diversity is more efficient and sustainable than mono-cropping. The mono-cropping system causes soil deterioration, results in nutrient deficiency and soil erosion. Some semblance of soil fertility in mono-cropping system can only be maintained by costly external inputs. Mono-cropping produces a dead soil and the crops are supported by artificial nutrient fertilizers and chemicals.

To produce healthy crops without resulting to expensive inputs in the farm we need to employ systems which diversify the crops we grow.

TREE CROPS

Some of the tree crops grown in this country are: coffee, tea, cotton, cashew nut, coconut, citrus fruit, plums, mango, avocado, custard apple, guava, loquat, macadamia, and many more.

Many products of tropical tree crops like coffee, tea, macadamia nuts, mango and so on, enjoy a great popularity in other countries of the world. Large populations are employed in the cultivation of tree crops as commodities. In addition other people are employed in the processing and the trading of these products. Most of the tree crops are currently grown for export. Several million hectares of fertile land in the tropics is devoted solely to their cultivation. Apart from fruit and nut trees in home gardens, few tree crops have been grown for local consumption. With the fall of commodity prices and an increase in the cost of inputs, the returns from these tree crops have become marginal. At the same time indigenous forests have been harvested severely without adequate regeneration or replanting. This has led to shortage of timber especially of the tropical hardwood varieties.

Future development of tree crops must of necessity move away from export orientation and be focused on local industry and food supply. This would include tree crops for industrial purposes such as timber and timber products, tree crops for fuel wood, fruits, seeds, nuts and fodder.

The trees must be chosen for the purpose they have to fulfil and for suitability in the prevailing climate. For timber and related products tree crops should be fast growing, straight-trunked, give the right wood density and wherever possible be soil improvers.

Fuel-wood crops should be fast growing prolific producers, should coppice easily, should not contain obnoxious substances and should burn effectively. Both industrial and fuel-wood crops can be grown in woodlot or hedges. They can form windbreak systems and in a well designed system are beneficial to other crops grown in the farm.

Fodder crops like Leucaena leucocephala and Acacia tortillis could be important tree crops in some areas. The acacias are important for stock survival in arid areas during the dry season. The stock feeds on the leaves and the pods. The plant shed their leaves during the dry season. These fodder tree crops of the leguminous family also enrich the soil by fixing nitrogen. Other useful fodder crops are sesbania and calliandra species. These crops can be integrated in cropping systems as hedgerows to improve the soil and control erosion. They can also be grown in woodlots for fuel-wood.

The commonest orchard crops grown in the country are citrus fruits, followed by the mango. There are however many fruit trees which have been neglected and which do well in local climates. This neglect of indigenous fruit trees results in a situation where fruits are available only for a short period of time during the year. To increase the spread of availability of fruits we need to nurture more varieties of fruit. The rehabilitation of indigenous fruits is therefore important.

Other food products from trees are nuts and seeds which give oil and carbohydrates. Tree crops such as date palms provide a basic food. If date cultivation is increased in the drier pastoral communities, dates and milk would make a complete food for these communities which are usually short of food. Cotton seeds and coconuts give oil for consumption.

The growing of tree crops can supplement household economies in cash income reduction of expenditure and diversification of food. The integration of tree crops in traditional cropping systems has advantage in soil fertility improvement and water infiltration.

ACCELERATED FALLOW SYSTEMS

The practice of leaving cropland to lie fallow for a period to recover its fertility is a well known phenomenon in the history of tropical agriculture. Due to the shortage of land, the fallow periods are increasingly becoming shorter and shorter. As the fallow period becomes shorter, it becomes necessary to introduce trees and shrubs that help in soil recovery. The best trees for a quick recovery of the land seem to be those that enhance soil fertility and which establish ground cover quickly. The purpose of leaving land fallows is to: increase organic matter content of the soil; improve aeration, water holding capacity and tilth; cycle and trap nutrients from the subsoil; and to eliminate undesired plants (weeds), pests and diseases detrimental to the cropping system.

A fallow system must, in addition, protect the soil from erosion and desiccation from incident radiation. Different strategies used in the introduction of trees in a fallow rotation system all result in; increasing site fertility, soil protection and production of tree products.

An accelerated fallow system might consist of a single species, mixed species of shrubs or mixed species of shrubs and trees. Although fallows are not permanent, they can be planned to evolve into an agroforestry system such as alley cropping, strip cropping or a dispersed tree cropping system. The choice of trees used in a fallow system must be selected to suit the farmer's future development plans.

During the fallow period, apart from the major aim of soil improvement, the farmer should aim to get some economic gain. Some of the products which maybe obtained from fallow land are, timber and poles, fuelwood, fruit and fodder or own use products like fibre, animal fodder and vegetables.

Some of the trees which maybe used in accelerated fallows include Acacia mearnsii (black wattle or munyoonyoo), which is a soil improver, and which further produces tannin as a by product; Leucaena leucocephala, gliricidia and calliandra species. Timber trees can be included in the fallow system species to be left as solitary trees or as clumps dispersed in the field.

Soil enriching herbaceous plants such as ground nuts, cow peas, lab beans, and pigeon peas, are useful additions to fallows in arid lands. These crops can be used as cover crops during the establishment of fallow tree crops. Some other important plants include sun hemp (Crotolaria ochroleuca) for the suppression of weeds, combating of nematodes and increase of soil fertility. Sun hemp is reported to add 300 kg/ha. of nitrogen to the soil and it is a cattle feed.

Using Sesbania sesban (munyonyo) as a short-term rotation, fallows, observations in Kakamega and Siaya districts have shown an improved maize yield on fields formerly occupied by the plant.

In addition Sesbania sesban produces fodder and fuelwood.

Accelerated or improved fallows depend on establishing of species which have pronounced soil enrichment properties and which have alternative uses or can be intercropped with other plants which give other products. Apart from shortening the fallows period they in effect shorten the non productive period of the land.

SLASH AND BURN THEN FALLOW

Traditional agriculture in Kitui was based on the 'slash and burn' then fallow, cycles. Once a plot was slashed and burnt it was cultivated for approximately three years after which it was left under natural fallow for extended periods. It is important to note that the traditional slash and burn as practised in Kitui was not a total clearance of all vegetation. It was rather the removal of the herbaceous plants to allow for crop growth, whilst leaving the larger trees in the plot standing. This practice differed somewhat to what happened in the homestead where the slashed vegetation was piled against the trees to burn and kill them.

The trees left in the slash and burn plot had several roles to play. They acted as wind break, provided shade for people working on the plot, provided shade to the crops, increased crop survival rate by superior water infiltration in their vicinity and microclimate modification. Some trees had survival value, like the baobab which provided food and was tapped for water during extended droughts and famine, or acacias which provided animal feed when it was dry.

During the fallow cycle the trees which were not felled, served as nurse trees for the re-establishing vegetation. They produced seed for the reseeding of the fallow plot. Although slash and burn system modified the vegetation of a plot in the short-run, the extended fallow of about tewnty years re-established the natural vegetation.

PRESERVATION AND STORAGE OF PRODUCE

In nature nothing lasts forever and each product of nature is continually being transformed into other forms of natural products. The cells in our bodies are continually being renewed. All organisms die and are totally transformed into other organisms. The produce which we obtain from our farms is transformed in the same manner and decomposed into new substances. This transformation, which we call decay or spoilage of produce, is natural way of utilising substances of nature and recycling energy and nutrients. The decomposition of produce is caused by the enzymes within the produce and micro-organisms.

Preservation of food is the prevention of deterioration and spoilage or prevention of decay and destruction of food. Storage of food is the keeping aside of food for future use.

Enzymes are chemical substances which are found in all living organisms and causing catalytic chemical reaction in nature. They work quickly in warm conditions. They work slowly when cold and are destroyed by high temperature.

Micro-organisms exist everywhere is nature, in the air, in the soil and in water. Most of the micro-organisms are beneficial but some are harmful and cause disease. The micro-organisms which cause decay include fungi and mould, yeasts and bacteria. These are found in all produce.

To preserve food or produce we must prevent the action of enzymes and microorganisms. The action of enzymes is prevented when they are destroyed by heat or when the temperature is lowered so that their activity is extremely slowed down. Microorganisms are also destroyed by heat. Their action is controlled by creating conditions which are not conducive to their multiplication such as, drying produce, excluding air, reducing temperature, using strong concentrations with high osmotic pressures, or using chemical preservatives.

Once the activity of enzymes has been curtailed and the growth and multiplication of enzymes has been severely limited, then the food can be stored for future use. The food will remain in a marketable condition.

Food is preserved to:

- Prevent waste,
- Save surplus food for future use,
- Give independence of the market
- Enable quick meals (convenience),
- Buy when supply is high and prices are low rather than when

prices are high an supply is low (economise)

The storage of food endeavours to maintain food reserves,guardagainst crop failure, maintain domestic supplies. For successful storage, food must be conditioned by one or more of the preservation methods which remove the activity of enzymes and limit the growth and multiplication of micro-organisms. The storage system chosen for a particular item must be suitable for that item and must prevent the onset of conditions which would promote spoilage.

Storage systems include bottling and canning for wet vegetables and fruits. Dried fruits and vegetables can be stored in sealed systems as would dried, salted meat and fish. Grains are stored in bins, cribs, silos, and warehouses.

Stores in general must be dry maintain a uniform temperature, exclude vermin (rodents, birds) and facilitate protection from insects.

FOOD RESERVES

As droughts are a common feature in Kitui and crop failures occur regularly, food storage has been developed to a substantial degree in the society. The major foods stored for consumption in times of scarcity were millet, sorghum, pigeon peas, cowpeas and pumpkins.

After harvesting, the heads of millet and sorghum were threshed on a specially prepared ground, known as "kivuio". The grains were then winnowed using calabashes cut into halves , "Nzua". The clean grain was thoroughly dried in the sun. Pigeon peas and cow peas were also threshed winnowed and dried. Each product was placed in a wicker basket, "kiinga". The baskets were placed on a platform and the store house was thatched. Well conditioned grains stored for a long time. Cowpeas and pigeon peas could store for longer periods when mixed with millet.

A survival portion of food, usually millet, to guard against really adverse droughts was stored in a specially prepared wicker basket stored under the floor of the house. Only 'the lady of the house' was supposed to take food from here. She would regulate this last supply of food to last as long as possible and ensure the survival of the household.

Pumpkins were not conditioned but left to mature completely in the field. These mature fruits were stored on open wood-work raised crib with a thatched roof. Pumpkins can be stored thus for more than a year.

CONSUMPTION PATTERNS

The three basic rules for a healthy food consumption are: always eat enough food; eat a varied diet, including a combination of foods that contain healthy giving qualities: and drink clean water.

The foods we eat are composed of many substances. Each of these substances has a role to play in nutrition. Proteins build up muscles and tissues. Carbohydrates give the body energy. Oils and fats are also energy giving substances. Mineral salts and vitamins build tissues and keep the body healthy. Water provides a medium for body processes.

Cereals, which include millet, sorghum maize, rice and wheat, contain largely carbohydrates, some protein and small amounts of mineral salts and vitamins in the thin outer layers of the grain. These foods give energy and are body builders due to the protein, mineral salts and vitamins they contain.

Seeds are commonly of two types. Oil seeds are rich in oil. Examples are sunflower, cotton and sesame. Legume seeds, such as beans and peas, are high in protein content. Seeds rich in protein are body builders and are essential addition to carbohydrate foods that provide energy.

Tubers, like cassava, yam, arrow root, sweet potato and potato, largely contain starch. Bananas are also starch food and so is bread fruit and the baobab fruit. These starchy foods can be dried, ground into flour which is mainly starch. These starch foods supply energy but do not build muscle or tissue.

Fruits and vegetables supply vitamins and mineral salts. They provide protection against diseases. Vegetables in addition supply proteins. Some of the more common fruits are pawpaw, mango, pineapple, lemon, orange, grapefruit, passion fruit, guava, custard apple, avocado and tomato. Some common vegetables are black night- shade, amaranth, cabbage, kale, onion, carrot, cowpea, arrow root and pumpkin.

Foods of animal origin are rich in proteins and fats. They serve to enhance the staple foods of plant origin. Only small quantities are required to keep the body healthy. These foods include meat, fish, eggs, milk and milk products. A healthy consumption pattern is one which includes all the various foods required for proper body function.

In many cases only the staple is consumed due to lack of other foods. This shortage of variety can be solved by diversification of crops grown through intercropping or rotation. These systems ensure availability of different food sources and lead to healthier food mixes. Integration of animals in the farm gives animal products essential body builders especially for young children.

FOOD VARIETY AVAILABILITY

In the not too distant past, people in Kitui and the rest of Ukambani, depended on several cereal grains. These included millets, sorghum and only partially maize. There was a broad staple food base. As most households kept livestock, milk and milk products were available. People consumed large quantities of both fresh and sour milk plus ghee. Unfortunately goat milk has never been popular. The most commonly consumed meat was chicken with occasional goat and beef. After hunting parties wild game meat was served. It is a mystery that the people of Kitui never embraced any form of meat drying techniques as a matter of routine, since the long distance hunters used dried meat of neccesity.

Several types of green vegetables were consumed routinely especially mixed with maize and cowpeas, pigeon peas or beans to make "mukimwa". These included; cow peas, pumpkins, arrow root, black night-shade, amaranths and many other local leafy plants.

A myriad of fruits existed in the wild. Most of these fruits are now quite rare. As different fruits ripened at different times of the year, fruits and their vitamin C, were available for most of the year. Some of these fruits were; "Ngawa, Ngomoa, Matoo (our chewing gum), Ngavu, Ndula, Ngambua, plus Mangoes, Guava, Kungumanga, Citrus, Avacado and Custard Apples.

With this range of produce, there was plant for everyone who was willing to exploit the communal lands. Malnutrition was rare except in times of extreme drought.

ANIMALS

INTRODUCTION

Animals play several roles in agricultural systems. Among these are, transformation of natural ecologies, provision of food, provision of manure, traction and other by-products. Under the traditional slash and burn agricultural system, animals were central in the development of grassland or pastures as opposed to thickets. With the development of a monocultural agricultural system, the centrality of animals in transforming nature is reduced as the range of animals who use specific niches are eliminated. Ironically the impact of domestic animals as a land degradation agent has increased. The keeping of excess livestock per unit of land, has major detrimental effects on the land due to compaction of soil leading to increased run-off, destruction of soil structure and overgrazing or selective destruction of native vegetation. This leads to loss of top soil through accelerated erosion.

ANIMALS IN INTEGRATED FARMING SYSTEMS

Animals were traditionally kept in free range. Under free range conditions, animals select their food from a diversified systems. This selection allows for their complete nutrition. For example, chicken will graze, eat seeds and scratch for ants in the soil. Pigeons on the other hand, will only eat seeds and nuts. Cattle will graze, browse and feed on seeds from the system, while pigs will graze, eat seeds, pods, nuts, and dig up roots. Thus different animals have different feeding habits. A diversity of animals in the system will use the system in different ways. Even for foragers and browsers the level of browsing is specific for different species.

Animals on free range forage for themselves. In this situation animals perform other functions in the system. One of these functions is manuring the land. Another important function is vegetation control. Yet another function is the use of many plant species which cannot be harvested. At the same time they are responsible for planting different seeds in different places.

Keeping animals on free range involves minimal human labour. The function of human labour is mainly controlling by moving animals to different parts of the free range system.

Animals in an integrated farming system provide motive-power for ploughing and transport and can be used as cultivators themselves. Cattle, horses, donkey, or buffalo can abe used as harness animals for pulling ploughs or transport carts. Mobile hen houses can be used as cultivators of the land.

One of the major functions of bees in any system is the fertilisation of flowers. In addition to this, bees produce honey, pollen and beeswax. Honey is composed of 75% sugar in water. It contains many minerals. Honey kills germs and has unlimited shelf life. Beeswax is used in polishes, candles, a sealant, electrical insulators and water proofing. Pollen is used as a high protein additive to flour.

Other useful animal products include foods; eggs, meat, milk and milk products, fats and oils: as well as industrial products like glue and soap leather, furs, hair and wool, horn and bone and feathers.

Some animals act as pest controls. For example, ducks feed on parasites such as liver-fluke which kill sheep, cattle and chickens. Maggots and other gnats will be controlled by chicken on range.

In a complete farming system animals are essential. Their role in vegetation control, pest control, nutrient circulation, along with their many products make them invaluable to the system.

GRAZING LAND MANAGEMENT AND IMPROVEMENT

Livestock enterprises are a major factor of production in African savanna and the tropics in general. The enterprises are primary geared for the production of meat and meat products; and milk and milk products. In order to improve the grasslands they must be managed properly to enhance their productive potential. Some of the management priorities to be considered include; the diversification of forage species, changes in the environment, conservation measures, and stock management.

In the traditional pastoral systems, animals were extensively grazed over wide areas of communally controlled grazing grounds. This system was appropriate as the human populations were low and the grazing grounds could sustain the livestock populations without stress or damage. The land had enough time to regenerate. Currently the number of animals exceed the carrying capacity of the land.

As a result of this high animal population, there is poor grass regeneration, compaction of the soil and increased erosion. To alleviate these problems, traditional cattle keeping system must be improved by rehabilitating grazing areas by active management of the range resources.

The diversification of forage species in rangelands enhances all the effects of diversity in any ecosystem. It enables the ecosystem to use its soil resources in balanced and non-exploitive manner whether the introduced species are grass, legumes or trees.

Trees in grazing or rangelands provide fodder, food sugars, seed carbohydrates or fruits. A tree such as leucaena provides useful fodder, enriches the soil with nitrogen rich mulch and circulates deep lying nutrients. Another useful tree in rangelands is Acacia tortillis. But there are several other acacias that are kknown to do well in the district, such as Acacia albida, A. eliator, A. nilotica, A. polyacantha, A. senegal, A. seyal, as well as a broad range of multipurpose drought resistant trees. A list of these trees and their climate types is included in Appendix A. Necessary changes in the environment for improvement or rangelands include those which improve water infiltration. An increased infiltration ensures an extended availability of water in the soil. This increases the time of growth of forage and shortens the period of drought. Improvement of soil structure also improves the water storage capacity of the soil and promotes growth of soil organisms by aerating the soil. The provision of windbreaks and shelter belts reduces the drying effect of the wind and also reduces the transport of loose soil from the rangelands.

Water infiltration can be increased by holding water in the land by constructing contour ditches (Wamatengo pits) which hold water on the land to increase the time available for infiltration. When trees are planted on these contours the infiltration is more effective due to the opening up of the soil by the tree roots.

Conservation measures on rangelands are achieved through rotational or periodic rests from grazing. The use of hay or silage, supply of protein or urea supplements and carbohydrates (molasses or grain) during drought conserve the land and the animals. Stocking should always be kept below critical numbers. Excess stocks trample and over-exploit the land.

Stock management controls the numbers of animals the land can carry to avoid stress or damage of the land. Although animals are beneficial to the land, excessive animal populations lead to destruction of the ecosystem. Stocks should be managed in such a way that they are in tune with seasonal and longer-term fluctuations. During the dry season, for example, if there is not enough feed for the animals, they will lose weight and are then susceptible to disease in this weakened state. It is better to sell the animals and rebuild the stock during better times. The cyclical nature of wet and dry years should also be taken to account. When this is ignored large numbers of stock are lost with dire consequences and destruction of rural economies. Sensible stocking will be able to maintain a breeding stock and guarantee an income to the stock owner rather than a total loss if one holds on. We better remember the bitter lessons of the droughts of the seventies, culminating in the disaster of the 1984 drought which almost decimated the cattle industry in Kenya.

PASTURE MAINTENANCE

Livestock has been a major factor of agriculture in Kitui from time immemorial. It was important therefore, that traditional clan grazing lands were protected and managed for stock survival.

The grazing lands were under the jurisdiction of the clan elders who allocated grazing areas on rotational basis. This practice avoided overgrazing in localised areas and desertification, ensuring the availability of animal fodder all the year round. Controlled burning was used to remove coarse grass, allow grass regrowth, eliminate thicket undergrowth and as a disease control measure of killing ticks and other pests.

During the dry season as the grass dried out, livestock supplement the poor dry grass diet with fallen tree leaves and pods. The pods and leaves of these trees act as feed concentrate for livestock. The ripening and dropping of pods of most acacias and most commiphora coincides with the dry season. These trees also progressively shed their leaves as the dry season continues. The leaves are dried by the sun and do not decompose. They together with the pods make a good reserve for livestock in the dry season.

Trees like Acacia tortillis, other acacias and other commiphora trees whose deciduous behaviour was conducive to livestock survival were 'protected' trees. Even when a plot was cleared for cultivation these trees were never cleared completely. Staggered mature trees were left for reseeding the plot and to provide shade for people working on the plot. Other trees like the Baobab were also left standing to provide fruit and as a survival measure through water supply and shade for animals.

ZERO GRAZING

This is a system of keeping livestock on very limited land. It as been brought about by the growth of population, which limits the amount of land available to each person. It can also be known alternatively as penned animal system, or cut and carry system.

The increase of population has converted former pasture lands to crop lands and concentrated stock on smaller and smaller areas, thus creating an enormous ecological pressure on pasture lands. Two ways are open to relieve this pressure, either by destocking or by changing the system to zero grazing. Under zero grazing animals perform all the functions which make them important in an integrated farming system, without their destructive effects which cause degradation of the land.

Zero grazing is an intensive animal husbandry system based on getting greater output from a small area. In zero grazing stock is confined in a stall and fodder is cut and brought to the stock in the stall. Rather than keep many animals which have a small return, it is more economic to keep fewer animals with a higher output. Improved animals for meat and milk production are therefore an incentive to destocking.

For successful zero grazing system, different aspects must be fulfilled. These are, provision of fodder; building of a feeding and housing stall; labour for feeding, milking and calf rearing; planned breeding and provision for treating the animals.

To start a zero grazing unit, one must have available fodder. The constitution of the fodder must provide both energy and protein for the animals. Grasses like kikuyu, napier grass and so on, provide energy, while nitrogen rich plants such as desmodium and leucaena fodder, Melia volkensii or A. tortillis, provide the protein. Mineral salts must be supplied as supplements to the fodder, along with calf pencils.

The fodder is usually planted on contour lines and serves also as an erosion control measure. It can also be planted as strips and used for rotation. Other fodder crops which can be used include potato vines, centro, siratro, lucerne, cowpea, clover, and trees, calliandra, sesbania and others.

The fodder is cut not too close to the ground so as to allow regeneration and brought to the stock in the stall. Its better to feed chopped fodder four to five times a day for maximum utilisation of feed. Feed supplements to compliment and supplement forage include cotton seed cake, groundnut cake, maize bran, bean straw, sweet potato vines, sugarcane residue, potato peels and cabbage leaves, sukuma wiki (kale) especially for lactating stock.

The stall is designed to reduce animal stress. It has areas for sleeping, eating, exercising and a calf pen. Enclosing animals has many advantages. The animals do not cause soil erosion since they are confined. Soil erosion on farm land is stopped by contour lines of grass and legumes for fodder. Manure can be collected piled and composted easily. Animals can be easily treated.

Exposure to disease causing pathogens and vectors is reduced. Animal manure is worked into fields restoring fertility and improving soil structure.

The manure pit is an integral part of the stall. Here manure is piled and properly aged before it is applied to the fields. The pit is divided into two sections one for fresh manure and the other for maturing manure.

For dairy animals, the proper milking techniques must be practised for several reasons. Firstly is to reduce the chances for udder infections and milk contamination. Secondly, the standard of milking is the major determinant of quality of milk. Poor milking techniques produce poor quality milk. Proper hygiene must be practised when milking. Good milking technique involves sequential pressure application from top of the treat to the bottom without pulling the teats. Proper milking techniques must be practised as it produces the maximum amount of milk.

HOMESTEAD VERSUS PLAINS (WEU) LIVESTOCK PRODUCTION

Most of the livestock owners in Kitui and similar places in the country held a small part of their livestock at their homestead. The greater part of their livestock was out at a livestock post "kyengo" which could be many kilometres (several days walk) away from the homestead in the clan grazing lands.

The small number of animals held in the homestead were for provision of animal products, like milk and ghee. A small number of animals for occasional slaughter was also held here. As the lactation period of cows was finished they were dispatched off to the herding posts and new lactating cows brought to the homestead.

As most homesteads did not have extensive grazing lands, only a few animals could be kept there. This homestead holding of stock is the closest that the dwellers of Kitui came to the idea of zero grazing. It should be built on as part of the extension of animal production in the district for there is understanding of handling animals in confined space. There also is evidence that the emerging land holding and use system is trying to keep the distinction between the "Musyi" and the "Kyengo" intact.

Mulango and Matinyani people for example have their "syengo" in Yatta. Migwani families have theirs in the Kiluluma (Tana) river area to the west. Nuu, Mutito, Miambani and Southern Division families have extensive syengo in the statelands to the east. Working with this persistent historical model of production may lead to better land use as well as higher productivity for the whole district rather than confining all animals to one area permanently.

MANURE AND BIOGAS PRODUCTION

All animals wastes and plant decomposable materials make up organic manure on complete decomposition. The most important form of animal manure is the farmyard manure, which is a mixture of animals waste (dung and urine) and their bedding material plus waste feed. Other forms of organic manure are compost, which is a mixture of vegetable waste decomposed together in a pit or heap. Green manure is made from plants grown and buried in the soil to rot.

Any type of organic manure returns back to the soil the minerals they contain. The manures contain substances which help plants to develop and improve resistance to diseases and pests. Plants which grow in soils rich in organic matter are more resistant to diseases, pest and drought than those plants in organic matter poor soils.

Farmyard manure like all organic manures improves soil structure. It contributes in the formation of soil aggregates amidst which water, air, plant roots and soil organisms thrive. A good soil structure allows for vigorous root development, increase in moisture content of the soil, better workability of the soil and improved resistance to wind and soil water erosion. Organic manures like clay increase the cation exchange capacity of the soil. In the tropics where the soils are lacking in clay, organic manure is very important for soil improvement. The organic manure is the major agent in the soil for holding, reserving and storing mineral salts. If mineral salts are not held in the top layer of the soil they are leached into deeper layers and are lost to crop plant use for most crop plant roots are shallow.

Organic manure absorbs water. It retains this water until decomposition is complete. If there is no organic manure in the soil, this absorbed water is lost. In addition, a well aggregated soil holds more water than a structureless soil due to the distribution of small pores in which water is held by adhesive forces. Further, by improving the structure of soil, one allows for higher infiltration and reduces water run off after it rains.

A major role of organic manure is the provision of food to soil organisms which transform the manure to humus releasing the mineral content for use by plants. Soil organisms play a role in aerating the soil and turning over the soil, bringing up nutrients from the deeper layers of soil. They hold mineral salts in a mobile form and release them slowly as they die and are decomposed by other organisms themselves.

It can be seen therefore that manure is a very important product of animal keeping. It is not a by-product but an integral part of an integrated farming system. Through the use of manure, the cropping fields are able to regain lost fertility and humus. Care should be taken therefore to ensure that all animal wastes return to the fields as organic fertilizer.

Biogas (methane gas) is a fuel produced by the decomposition of organic matter in the absence of air. The major raw material used for the production of biogas is animal waste matter, although other agricultural residues can be used. The gas is produced in digesters which are airless containers. Micro organisms and enzymes breakdown the organic matter and produce the gas, methane, in the digesters. This gas is a fuel and can be used for cooking, lighting and heating.

Biogas production has economic and environmental advantages. Biogas produces fuel for cooking and lighting thus reducing the dependency on firewood and the labour load required for cutting and collecting firewood. It decreases environmental pressure by reducing the number of trees which would have been cut for use as firewood. The original minerals and nitrogen in the raw material are maintained and the sludge can be applied to crops immediately after removal from the digester. In the preparation of biogas, harmful organisms are destroyed and the remaining sludge is sanitised. A direct saving of the money which would have been used for wood, fuel or electricity is achieved.

The process of making biogas works by addition of cow dung, urine and bits of straw to the digester, which is usually underground, twice a day. The charge is fed in through a 4 inch pipe. Manure from three to four cows is enough to produce fuel for a family of five. The gas is stored in a floating reservoirs and is tapped from there. The spent manure or sludge is collected in the overflow pit. The sludge can be dried and stored during the dry season for use later in planting. Otherwise, it can be transported by ox or donkey cart directly to the fields.

ANIMAL HEALTH

The best resistance to disease is a well fed healthy animal kept in clean well ventilated surroundings. But animals do occasionally get sick. If this happens or you notice any abnormalities such as listlessness, lack of appetite or diarrhoea, contact a veterinary attendant promptly. Many diseases can be treated and prevented from spreading if diagnosed and treated early.

Although feeding correctly and good management are conducive to good disease resistance, certain disease preventive measures must be undertaken to protect the animals. These measures are, spraying to kill ticks which carry diseases such as E.C.F., vaccination against diseases such as foot and mouth, rinderpest, black water, and anthrax and deworming every six months.

The application of hygienic methods in animal husbandry is a fundamental factor in animal health. Hygienically kept animals have less problems and lower incidence of diseases. Although hygiene reduces the danger of disease, it cannot altogether be eliminated.

As hygiene keeps away diseases, the health of the animal gives it the greatest resistance to disease. To keep healthy animals, they must be fed on a balanced diet. In the traditional method of keeping animals by herding, the animals had their food from different preferred plants and their nutritional requirement were met through the diversity of the feed. For penned animals one must provide the balanced diet.

There are several causes of disease in animals including:

Microorganisms. (viruses fungi bacteria and protozoa)
Mechanical injuries
Thermal injures
Poisons
Congenital diseases and
Nutritional deficiency.

Any of these factors will cause the breakdown and death of cells. When many cells of an organ break down or die, the organ cannot perform its functions and the animal will show the dysfunction as a symptom of disease.

It is not necessary for a farmer to possess a thorough knowledge of all the disease causing factors. What is of great importance is for the farmer to acquire sufficient knowledge of disease symptoms. This technical knowledge is extremely important for animal production as disease effects animal production adversely. This knowledge enables the farmers to prevent diseases and control them after an out-break.

Prevention embodies the practices that a farmer employs to protect affliction of his stock by disease. Previous encounters with a disease makes it familiar and suggests steps to be taken to prevent it.

The control of disease employs means of containment of the disease that has already occurred. For example, if an animal is afflicted by foot and mouth disease, then the farmer concerned should make sure that the other animals do not get the disease and that the sick animal is treated for recovery. The first thing to do is isolate the animals to prevent it infecting other animals and then treat it.

The farmer has to cultivate the ability to read disease symptoms. He has to observe his animals keenly and note any abnormalities. Only genuine interest and serious involvement in livestock will help the farmer to cultivate this ability extensively. He has no choice but to know the symptoms of the disease which inflict livestock locally and be able to identify these symptoms in his stock.

Some of the major symptoms which indicate the presence of disease are:

The appearance of milk.
Lack of appetite and animal isolating itself.
Continuous salivation.
Copious nostril discharge.
Animal lies down with its head turned sideways for long.
Blood shot and teary eyes.
Irritation

Once these symptoms are observed in an animal, a closer investigation is necessary to identify which disease is applicable and treat it. Good animal husbandry is a major factor in animal health. This includes the following issues in animal management that encourage disease prevention:

1. Adequate feed to maintain the animal in full health.
2. Shelter and comfort
3. Access to fresh clean water
4. Adequate protection from all sorts of predators
5. Prevention rapid diagnosis and treatment of injury, parasitic infection and disease
6. Freedom of movement allowing the animal to stand, lie down, turn, stretch, preen, groom, scratch, and exercise most normal patterns of behaviour.
7. Avoidance of any form of stress to the livestock.

Disease control measures include the following:

1. Quarantine
2. Creation of unfavourable conditions for disease-spread by:
    a. Keeping animals tolerant to the disease like ndama

cattle in trypanosomiasis infected areas.

b. Keeping resistant animals; only animals resistant to the disease, as sheep can be maintained areas with contagious bovine pleuropneumonia.

c. Control of vectors such as tsetse fly, for elimination of trypanosomiasis

d. Vaccination to produce immunity in the animal.

3. Disinfection by treating the sick animal thus removing the disease or physical disinfection by killing the disease-causing organism by heat, like burning infected carcases, cleaning infected floors with hot water and so on. Chemical disinfection uses various chemical eg phenols chlorine and formaldehyde etc to kill disease causing agents.

4. Parasite control.

a. Ectoparasites ie flies, mites, ticks, lice. fleas, bugs, beetles and cockroaches are controlled by such compounds as lindane, malathion etc. Some of these compounds can be used for dipping or spraying the animal and disinfecting animal houses.

b. Endoparasites control depends largely on the control of an intermediate host. To control liver fluke one has to control the snail which is the intermediate host. This should be coupled with deworming the animals

The farmer should call a veterinary attendant as soon as he notices symptoms of disease in their livestock. A clear description of the symptoms will aid the veterinarian in quickly diagnosing the disease, and the start of treatment, thus controlling the disease and maintain the health of the herd.

HANDLING OF SICK ANIMALS

The identification of animal disease was based traditionally on the observation of symptoms exhibited by the animal. Significant symptoms were, the nature of the coat, such as hair standing on end, coughing, salivating, colour of the eyes, constipation, irritation, restlessness, difficulty in walking, swollen glands and foaming in the mouth. Using a combination of symptoms, animal treatment specialists were able to diagnose the sickness of the animal.

The treatment of animal diseases was accomplished by the use of herbs, after diagnosis, which was given to the sick animal either singly or as a combination of herbs for the treatment. Usually sick animals were isolated from the rest of the herd. They were held in a sort of a 'sick bay'. These animals were fed in the sick bay until they recovered. The isolation technique was a good containment measure for disease.

FODDER CROPS

Fodder crops are grown as a bulk-feed for stock and enable one to keep animals in confined spaces. With the diminishing land holdings where it is not possible to keep animals on free range, animal integration in farming is still possible by the growing of fodder crops. The growing of fodder crops and keeping of animals in enclosures has several advantages. The animals are not free to roam over the land causing soil compaction and erosion. Planting of fodder crops on contour lines helps to control erosion on cultivated land. Nitrogen-fixing fodder crops enrich the land. Tree fodder crops cycle nutrients from lower levels of the soil and improve water infiltration. Tree fodder crops in rotation constitute an improved fallows and allow the land to improve much faster than would be the case under natural fallows system.

Grass is the most important fodder crop for a livestock farmer. It is therefore important to improve pasture lands all the time. Pastures can be improved by planting of soil improving trees such as A. tortilis and other acacias, combretum species, Terminalia brownii, Balanites aegyptica, which in addition provide leaf fodder and pods to livestock in the dry season.

In the making of hay, young succulent grass is cut, dried and stacked for use in feeding livestock during the dry season. Hay is stored in thatched haystacks. Young maize plants are cut for making silage in a pit or a bunker to combat feed shortage during the dry season. Sorghum can be harvested repeatedly every six to eight weeks to make silage. Sorghum, unlike maize, regrows and can be harvested six to eight times before desowing. Sweet potato vine cannot be stored but can be grown for fresh fodder. It can be repeatedly cut every four months as long as there is moisture for regrowth. Other fodder crops include legumes: cowpea, beans, desmodium, and many others.

One of the highest yielding fodder crop is napier grass. Napier grass can be cropped all year round where there is sufficient moisture for its regrowth. Some other important tree fodder crops, in addition to those mentioned above, include sesbania species, calliandra species, prosopis species and leucaena species. Livestock can browse on these trees or fodder can be cut and fed to the animals. However, livestock should not be fed large amounts since some, like leucaena, have injurious factors if taken in large amounts.

Many local trees provide leaf and pod fodder and have been instrumental in the survival of livestock during drought times. It is very important to gather all the information on these trees from the local communities and document it. The community should also be encouraged to grow these fodder crops for their stock. Apart from genetic preservation, such as action could be important for livestock survival in a changing ecosystem.

BREEDING AND SELECTION

Breeding of stock is based on selection of animals with desired characteristics. When a breeder requires large animals, for example, he should mate the largest bull with the largest cows. If he wants to breed for milk production, one should choose cows which are good milk producers and mate with bulls born by cows who are good milk producers. However, rather than use only one trait, the breeder might decide to combine several characteristics together in the breeding programme. For example, to increase milk yield together with disease resistance, one may take local cows who are disease resistant and cross them with a highly bred bull from high milk yielding stock. The calf born in this case bears the genes of the improved bull and those of the local breed. This is an improved calf which would have a higher milk yield than the mother's breed but less than the father's breed. However, since the local breed has been adapted to the harsh climate, the calf will be hardy and more likely to survive than a calf from the bull's breed. Several steps like this is series produce a new breed with the desired characteristics.

Breeding is the process of producing plants or animals by using genetically-unlike individuals. Selection is a process by which certain characteristics of an organism are reproduced and perpetuated in the species in preference to other characteristics. Under natural conditions the process results in the survival of those individuals from the population that are best suited to the existing environmental conditions.

The most adapted animals seem to have more vigour and produce more offspring than the less well adapted individuals. This changes the composition of the population increasing the well adapted individual and reducing further the less well adapted individuals. Artificial selection on the other hand, selects for desired characteristics from the farmer's point of view. A beef farmer will select for size and efficiency of conversion of feed or the rate of addition of weight, whereas a dairy farmer will select for smaller frame and a high milk production or for more butterfat is he is producing butter.

Using selection and breeding methods, it is possible to improve the productivity of livestock at the same time retaining resistance to diseases and adaptation to the environment. Let us for example examine the situation of the Zebu cattle which are indigenous to Kenya. These animals have a small frame generally and are poor milkers, but they are adapted to poor diets in the dry season. They are hardy and can walk long distances for water. In addition, through natural selection, only animals which have been resistant to the diseases found in the region have managed to survive. The animals have an in-built resistance to these diseases. On the other hand exotic breeds, such as Ayshire, are good milk producers but poorly adapted to the harsh conditions and poor diet of the Zebu.

If we combine the environmental adaptability of the zebu with the milk productivity of the Ayshire, the result is a Zebu/Ayshire hybrid. The newly created animal can both survive due to the adaptability of the Zebu and have a higher yield due to its Ayshire genes. However the hybrid will not be able to walk as far as the Zebu for water. It will not survive on as poor a diet and does not tolerate the sun as well as the Zebu parent. A more intensive management system is thus required for hybrids if they are to maintan their higher milk yields.

Farmers can use this system to improve their livestock in whatever direction they require. One of the easiest methods is to use the Artificial Insemination Services offered by Ministry of Livestock Development. This service is relatively cheap as keeping bulls is a very expensive affair. Using the service, which has bulls which have been bred for different characteristics, one could choose in which direction he wanted to improve his herd.

Using the same type of logic one can breed local goats with improved bucks to produce hybrids which have a higher production in both meat and milk. The Diocese of Kitui has taken this approach to goat improvement and no doubt this has contributed to the improvement of the goat breeding stock in the district.

A successful livestock improvement has been exemplified by the cock exchange programme which has served to improve the size of table birds in several districts in the country.

BULL EXCHANGE SYSTEMS

Breeding schemes were elaborate with Kitui herdsmen. There was constant identification, selection and use of breeding bulls for stock improvement. There was the constant exchange of breeding bulls between stockholders to introduce new blood in their herds. Stock-owners were in constant search of breeding bulls which they exchanged with bulls of their own in a barter system. The bull one stock-owner gave away for a breeding bull did not have to be a breeding bull. The new owner might decide to slaughter it for meat. Once a bull had been requested for breeding from one stock owner he was under obligation to give it to the requesting party unless he himself needed it for breeding. In this way a broad based genetic pool was gained by the society.

Cows with special qualities like large bodies and good milk yields were mated with the best bulls in the locality. Their offspring, especially males were used for breeding purposes. Using this method reasonable advances were made in stock breeding in Ukambani in general. However, the good work was all lost during the destocking period of the 1940s and 50s when the larger animals were selected for confiscation and contribution to taxes.

At all times inbreeding must be avoided as it was in the past. Traditional knowledge and practice was very clear on the negative impact of inbreeding. It generally leads to weak animals susceptible to disease. That is why in times past farmers made great efforts to go looking for breeding stock outside their immediate areas and at times across ethnic lines. Some of the Kitui livestock has blood lines of Orma, Somali, Maasai, as well as Meru, Kikuyu and Boran breeds. There is historical evidence that breeding stock historically circulated in the wider East African region covering Ethiopia, Kenya, Uganda, Tanzania and Somali and all the wy to southern Africa.

Breed improvement should therefore not be seen as just including European blood lines into the breeding programme through Artificial Insemination alone. Much can be achieved by selecting local animals for size and milk yield and disease resistance.

This historical circulation of livestock genetic resources has been reinstated with the export of the improved Boran semen from Kenya to southern Africa. Perhaps it is time to import the semen of the wonderful Iskander breed to Kenya.

THE ROLE OF SMALL ANIMALS IN AGRICULTURAL PRODUCTION

In most of the tropics, and especially the semi-arid areas, there is a shortage of meat, milk and other animal products. This problem is likely to become more acute rather than diminish. At the same time there is less and less land for big herds of grazing cattle as the grazing lands are reduced yearly because more land is being cultivated.

As individual plots become smaller and smaller, through division of land, it will become increasingly impossible to keep the large types of livestock. To meet the nutritional needs of the people, the alternative would be to go for smaller sized stock, to meet the homestead animal protein needs. This would include such small animals as rabbits, chickens, ducks, turkeys, penned sheep, goats and pigs. This adaptation was first made in China where the population pressure on the land increased long time ago. Among the smaller still wild animals which may be domesticated for this purpose are dik diks and other small antelopes.

These animals would provide a source of protein required to give a balanced diet for the ASAL populations. In addition they would provide a source of farmyard manure which could be used in the production of badly needed vegetables and for soil improvement in the gardens.

Small animal farming has many benefits to the farm economy, among them are:

1. Provision of food
    - meat from chickens, rabbits etc.
    - milk from goats
    - eggs from poultry, ducks and turkeys
2. Leather which can be tanned to produce numerous articles
3. Abundant compost for garden and field plays an important role in soil conservation
4. Provision of a means of income generation keeping young people on the land instead of running off to towns.
5. Provision of water for the animals can be obtained by

water harvesting techniques which will contribute to conservation.

Small animals breed quickly and produce more young than larger animals. It is therefore possible to butcher for meat much more often since the size is small. Since a chicken will supply the dietary required meat for a family of seven, there is no need to preserve meat. The family can always have fresh meat. A few layers will provide eggs for the family. At the same time they produce animal manure which can be used in the fields.

Food for small animals, such as fodder, seeds and nuts can be grown in the fields. Goats and sheep need far much less fodder than cattle. Yet improved goats have been shown to produce about two litres of milk per day. This would be a welcome addition to many a family diet. Goat milk has more value than cow milk since it is more digestible.

The production of meat and related products by small animals is a direct saving of the households income. This income can be used to improve the quality of life. Consumption of adequate protein improves the health of the family. Healthy bodies are more productive than weakened ones. The extra energy can be channelled to other forms of production. The excess produce can be sold in the open market. Excess animals are sold bring an income. The small animals further act as a reserve which can be converted into cash when required.

IMPROVED HUMAN NUTRITION THROUGH ANIMAL PRODUCTION

Foods of animal origin contain protein of high biological value. They are important for supplementing many African diets which are low in protein value. However animal protein are very expensive and are therefore not often consumed. A way of providing animal protein in the house is through the rearing of small animals in the household.

Infants and young children require more protein than older people. Milk and its products and eggs are important for growing up children. In addition to protein, animal products contain metals, vitamins and fats. Meat contain iron, vitamins and fats. Eggs, made up of a high proportion of protein, are rich in calcium, iron and vitamins. Milk is an essential food for infants containing all substances required for their growth and survival and is a useful supplement for missing elements in adult diet.

It should be clear then that the improvement of animal production has direct impact on the health of the people.

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Index

SAP IN ASAL

KIDP TECHNICAL ASSISTANTS TRAINING MANUAL

The consultant will:

a. Prepare a manual to be used in primarily in the retraining of TAs in sustainable farm production in ASALs and secondarily as a source book for Kitui farmers.

b. The content of the manual must cover the scientific basis of production in ASALs. Among these are water, soils, vegetation, crops, trees and livestock. Existing public materials, prepared for more humid areas, will be reviewed and where relevant included. Special emphasis should be made on the mandated policy of the catchment approach.

c. Specific techniques needed for the schools programme will be included. Among these are soil conservation on catchment basis, composting techniques, types of livestock available nationally, zero grazing techniques and fodder production techniques and integrated farming systems. Materials on plant identification are also to be considered.

d. Where traditional adaptations to ASAL production have been made in Kitui, their relevance and utility must be evaluated and included for educational purposes.

e. The manual will be illustrated and produced in modules to enhance its use as a teaching tool.

muticon
April 1991.