Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Ethical Tea Partnership

Extension officer training manual: Adapting to climate change in the tea sector

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Document Overview

Introduction

This manual has been produced to support extension officers of the Kenyan Tea Development Agency (KTDA) in providing climate change adaptation training to tea producers within their catchment. The manual provides information on a number of key adaptation initiatives including new tea clones that perform well in changing environmental conditions, soil and water conservation techniques, drought and frost management practices such as the planting of shade trees and compost and liquid manure production.

It is anticipated that the information in this manual can be used by extension officers to roll out training to tea producers within the farmer field school framework (FFS's) or on a needs basis at specific locations. In addition, it is recommended that extension officers support tea producers in understanding how to implement climate change adaptation techniques through the use of 'demonstration plots' or 'trial farms' whereby tea producers can learn from practical experience.

How to use the manual

This manual provides two services. First it provides an introduction to climate change concluding with a description of the problems caused by climate change and how these will likely impact the tea sector (chapter 1). Each problem has associated adaptation techniques and these can be found in the second part of the manual (chapters 2 to 6). For each adaptation technique, information and activities are provided that can be used by extension officers to deliver training on the topic to tea producers. It should be noted that this manual is intended to be a work in progress with new adaptation options included as information materialises or demand requires.

The following table provides a summary of potential adaptation options to a number of key climate change problems. This table can be used to help identify the information in this manual. The left hand column details the main climate change problems. These problems will have 'impacts' on tea producers and these impacts are detailed in the middle column. Finally, appropriate adaptation options for each climate change problem and impact are listed in the right hand column. Where the adaptation options are covered in this manual a page reference is provided to facilitate location of the appropriate material.

Table 1: Climate change problems, impacts and solutions

Climate change problem	Impact	Possible Solutions (adaptation option)
Increased temperatures	Drying of the soils causing reduced water content in the tea and decreasing quality	• New tea clones (p.19) • Composting (p.42) • Conservation farming (p. 28) • Rainwater harvesting and irrigation (p.54)
	Drying of the soils causing increased soil erosion	• Composting (p.42) • Conservation farming (p. 28) • Mulching of young tea fields (p.35)
	Arrival of new pests and diseases not previously present	• New tea clones (p.19) • Pest and disease identification (not covered) • Improving integrated pest management (not covered)
	Changes in the suitability of existing tea growing areas	• New tea clones (p.19) • Shade trees (p.17) • Soil and water conservation (p.21)
	Sun damage decreasing quality	• New tea clones (p.19) • Shade trees (p.17)
	Biodiversity loss (including tree loss)	• Energy saving stoves (not covered) • Planting indigenous tree varieties (p.17) • Nursery development (not covered)
Reduced water content of tea crop	Decreases leaf quality	• New tea clones (p.19) • Rainwater harvesting and irrigation (p.54) • Composting (p.42) • Liquid manures (p.50)
	Reduces resilience of tea crops	• Pest and disease identification (not covered) • Natural pest management (not covered) • Soil and water management (p.21) • Crop insurance (not covered)
Changing rainfall patterns	Uncertainty in when to apply fertilisers	• Early warning systems (not covered) • SMS information sharing (not covered)
	Water scarcity and drought	• Water harvesting and irrigation (p.54) • Compost (p.42) • Conservation farming (p. 28) • Eucalyptus replacement along rivers (not covered)
	Extreme rainfall events	• Terracing and contour ridging (not covered) • Cover crops (p.31) • Drainage channels and water harvesting

		(p.54) • Mulching of young tea fields (p.35)
Increase in extreme weather events such as hail storms, floods, landslides	Crop damage and failure	• Crop insurance (not covered) • Early warning systems (not covered) • Disaster action plan development (not covered)
	Increased financial vulnerability of tea farmers	• High nutrition kitchen gardens (p.67) • High productivity kitchen gardens (p.63) • Crop diversification (not covered) • Crop insurance (not covered) • Energy efficient stoves (not covered)
	Soil fertility loss through erosion	• Composting (p.42) • Liquid manures (p.50) • Conservation farming (p. 28) • Indigenous tree planting (p.17) • Nursery development (not covered) • Mulching of young tea fields (p.35) • Cover crops (p.31)
	Frost	• Shade trees (p.17) • New tea clones (p.19) • Light pruning (not covered)
Reduced productivity of subsistence crops for tea farmers	Increased vulnerability of tea farmers through food insecurity	• High nutrition kitchen gardens (p.67) • High productivity kitchen gardens (p.63) • Natural pest control (not covered) • Composting (p.42) • Liquid manures (p.50) • Soil conservation (p.21)

1. Climate Change in the Kenyan Tea Sector

1.1 What is climate change?

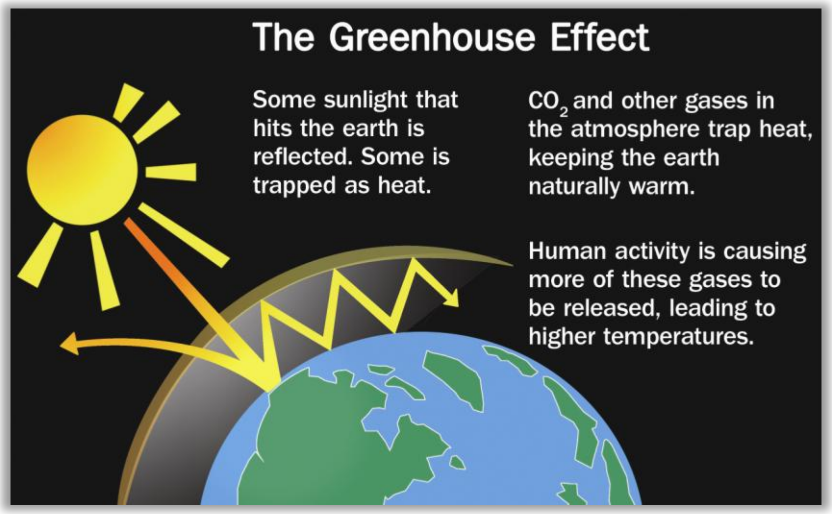
Climate change is an internationally recognised problem that is having impacts across the planet. Whilst the climate has always been changing naturally, the current impact of human activities is causing the climate to change in an unnatural way and at a faster pace than ever before. This unnatural and human induced climate change is problematic as it is causing shifts in the normal climatic conditions such as rainfall and temperature, which in turn is placing pressure on the planet's natural environment and having negative impacts on the planet's people. In particular climate change is having a significant impact on agriculture, especially those crops that are dependent on consistent climatic conditions.

1.2 What is causing climate change?

Climate change is happening because humans are releasing and thus increasing the amount of heat-trapping gases in the earth's atmosphere called 'greenhouse gases'. Greenhouse gases occur naturally in the atmosphere and are important as they make the earth's temperature warm enough for life to exist. Without these heat trapping gases the planet would be far too cold making it uninhabitable. However, as humans increase the amount of these gases in our atmosphere, more and more heat is trapped which in turn is causing the climate to change.

Greenhouse gases act like the walls of a greenhouse. As warm energy released from the sun travels through the earth's atmosphere it heats the planet and provides us with a warm environment. Some of this warm energy is released back into space and some bounces back into the atmosphere when it hits the greenhouse gasses. This process whereby greenhouse gases trap the sun's heat is called the greenhouse effect.

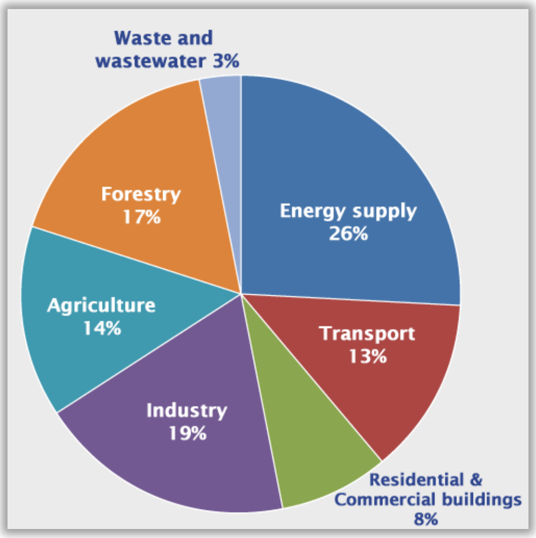
Figure 1: The Greenhouse Effect

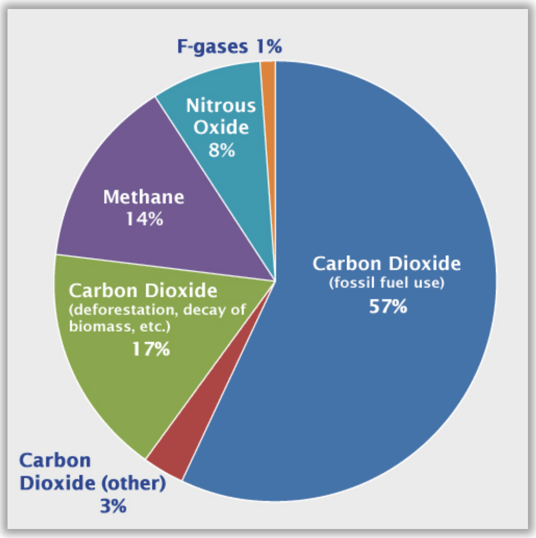


Natural greenhouse gases provide us with a warm and comfortable environment. However, as humans add more and more greenhouse gases into the atmosphere, more and more heat from the sun is captured making the planet hotter and hotter. This is what is causing a slow but steady temperature increase and eventually the climate to change.

Human activities release a range of greenhouse gases however there are three gases that are causing the majority of climate change; carbon dioxide, methane and nitrous oxide. Carbon dioxide is the major global contributor to climate change and is released through the burning of fossil fuels (oil, coal and gas) and the removal of biomass, especially deforestation in the tropics. The second most important greenhouse gas is methane. Here the majority of emissions arise from agriculture and in particular from the management of manure and the decomposition of organic waste. The third key greenhouse gas is nitrous oxide, which is also released during agricultural activities such as the application of nitrogen fertilisers. The final category of greenhouse gases is fluorinated gases, these are emitted during industrial processes but have a minimal impact compared to the other gases.

Figure 2: Global greenhouse gas emissions by gas and source (IPCC 2007[1])





Global emissions by source **Global emissions by gas**

In terms of emissions by source, the burning of coal, oil or gas for energy supply releases the most greenhouse gases globally (26%). After energy supply, the emissions released from industry are the next biggest contributor. Again this is primarily through the burning of fossil fuels to provide energy for processing and manufacturing. Next, deforestation and the clearing of land for agriculture provide 17% of global emissions. Agriculture is responsible for 14% of global emissions with emissions arising from the management of soils, fertiliser application, livestock management and the burning of biomass.

[1] Intergovernmental panel on climate change (IPCC), 2007, 'Climate change 2007: Synthesis report', http://www.ipcc.ch/publications_and_data/ar4/syr/en/spm.html

1.3 The impacts of climate change

The release of greenhouse gas emissions is causing the Earth to get warmer. Warmer temperatures are causing other major changes around the world because temperature is interrelated to the Earth's global climatic systems. Impacts include a rise in weather related incidents such as floods, droughts, frosts, hailstones and destructive storms; the extinction of countless plant and animal species; the loss of agricultural harvests in vulnerable areas; the changing of growing seasons; the melting of glaciers; the disruption of water supplies; the expansion of infectious tropical diseases; the rising of sea levels and much more.

One of the sectors most affected by climate change is the agricultural sector as it is dependent on environmental stability in terms of water supply, atmospheric temperatures, soil fertility and the incidents of pests and disease. Furthermore, the most vulnerable to the expected impacts of climate change are developing countries and their citizens who have a lower resilience to climate change impacts due to limited financial and technical resources to support adaptation. Smallholder farmers in rural areas, such as the tea farmers in Kenya, will be especially hard hit unless action is taken now to ensure they are aware of the impacts of climate change and are supported to address these impacts using locally appropriate solutions.

1.4 Climate change and tea

The tea sector will be significantly impacted by climate change due to its dependence on stable temperatures and consistent rainfall patterns. Some of the specific climate change impacts and challenges for the Kenyan tea sector are as follows:

Table 2: Climate change problems and impacts for tea producers

Climate Change Problem	Impact
Increased temperatures	Drying of the soils causing reduced water content in the tea, decreasing yields and negative impacts on quality
	Drying of the soils causing increased soil erosion
	Arrival of new pests and diseases not previously present
	Changes in the suitability of existing tea growing areas
	Sun scorch damage decreasing yields and lowering tea quality
	Biodiversity loss (including tree loss)
Reduced water content of tea crop	Decreases leaf quality
	Reduced resilience of tea crops

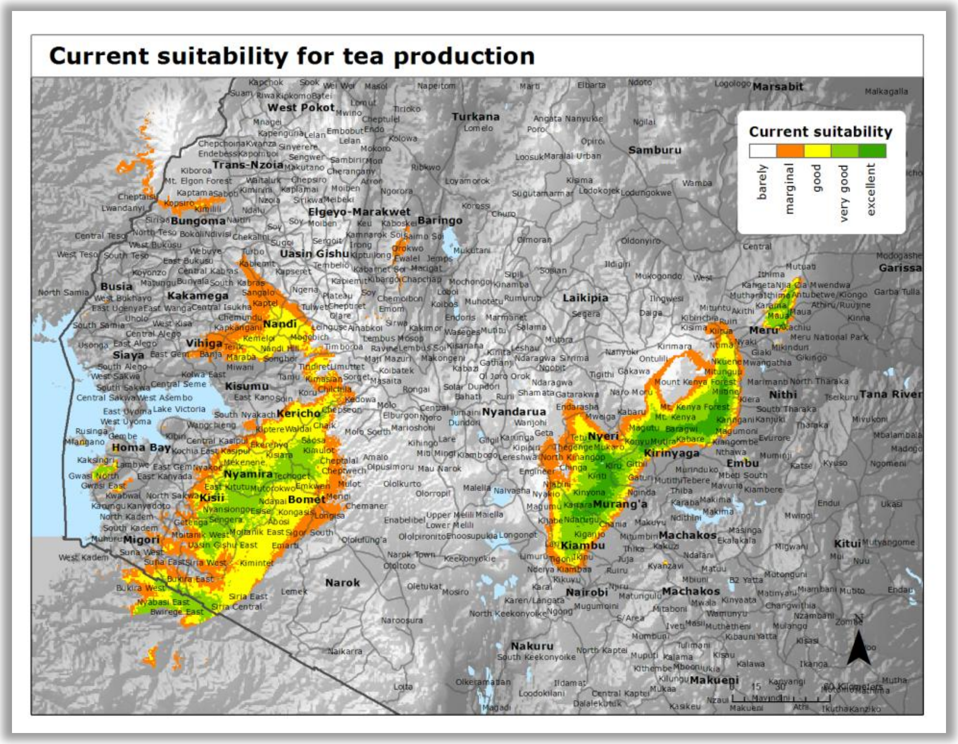
Changing rainfall patterns	Uncertainty in when to apply fertilisers
	Water scarcity and drought
	Extreme rainfall events
Increase in extreme weather events such as droughts, hail storms, floods, frosts and landslides	Crop damage and failure
	Increased financial vulnerability of tea farmers
	Soil fertility loss through erosion
	Frost damage
Reduced productivity of subsistence crops for tea farmers	Increased vulnerability of tea farmers through food insecurity

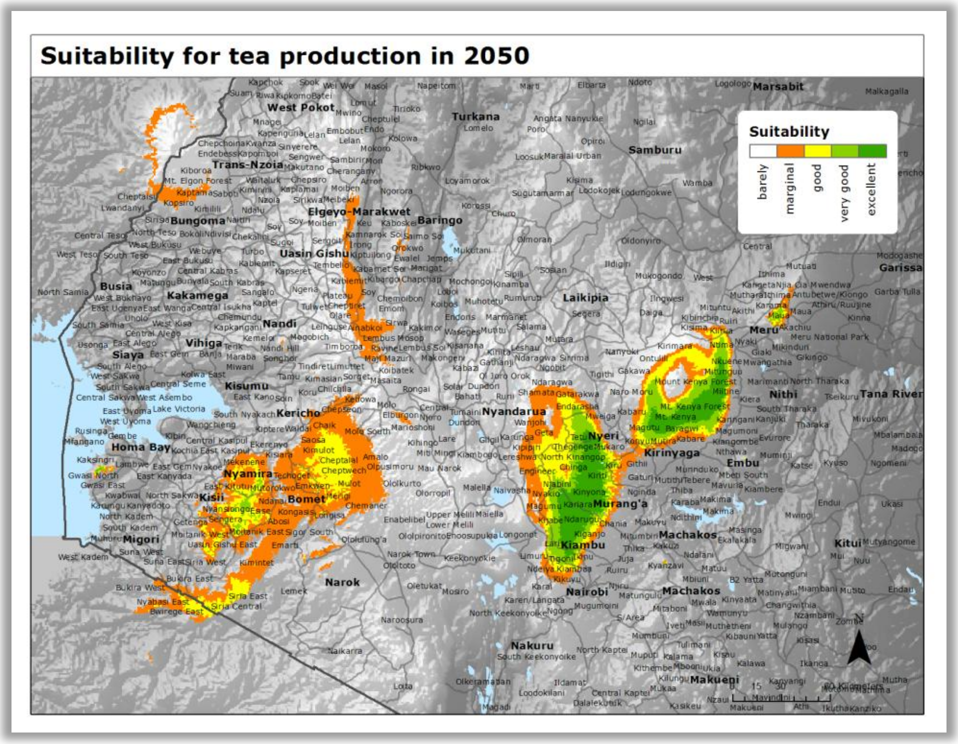
Furthermore, the combined impacts of climate change will likely reduce the tolerance of tea crops making them more susceptible to changing environmental conditions. These negative impacts on tea crops will have further negative impacts on smallholder tea farmers leading to issues of financial insecurity and the wider issues of poverty and food insecurity. For example, during times of drought the Tea Research Foundation of Kenya (TRFK) estimate that crop yields reduce by an average of 20 – 30% which reduces income and increases the vulnerability of small-scale farmers.

1.5 Climate change predictions for Kenya

To understand the extent of the problems climate change will impose on smallholder tea farmers in Kenya, modelling has been developed to assess the climatic suitability for tea growth in Kenya both in 2020 and 2050. The results of this analysis are demonstrated in Figure 3 below. As can be seen there are significant changes in the predicted suitability for tea growth between now and 2050. First, significant areas west of the Rift Valley will reduce in their suitability for tea growth by 2050, with the most notable reduction in suitability being around the Nandi County. Second, many areas around Mount Kenya still remain highly suitable, although there is a reduction in suitability at lower altitudes. This is because the suitable zone for tea growth shifts to higher altitudes. Of course, even though the suitability has shifted it may not be possible to grow tea at these new locations due to restrictions from the presence of national forests and parks and other land ownership issues. When assessing the tea suitability maps it should be recognised that the 'suitability' is based on the assumption that the current tea clones and management practices are in place. With improved clones and management practices (climate change adaptation) it may be possible to grow tea in areas identified as 'unsuitable'.

Figure 3: Predicted tea suitability change between now and 2050 in Kenya (CIAT 2011)[2]





[2] The International Centre for Tropical Agriculture, Climate change impacts on the Kenyan Tea Sector, A report for ETP and GIZ, www.ciat.cgiar.org

The changes in climate associated with these suitability predictions are as follows:

1. Temperatures will markedly increase across Kenya by 2020 and then progressively increase up to the year 2050 by which point the average temperature will have risen by 2.3^{0}C on average.

2. The small increase in mean annual rainfall will be outweighed by the increase in temperature and associated higher evapo-transpiration so that on average there will be a higher water deficit.

3. The optimal tea growing zone will shift upwards to 2000 – 2300 meters above sea level (masl) by 2050. Areas under 2000 masl will reduce in suitability.

1.6 Responding to climate change: Adaptation and Mitigation

The content of this manual focuses on supporting farmers to address the new and challenging issues posed by climate change and thus this manual supports climate change adaptation. However, adaptation and mitigation are both ways to address climate change and it is important to understand the difference between the two.

The term climate change adaptation is used to describe activities that help to manage the social, environmental and economic impacts of climate change. In essence adaptation activities reduce a population’s vulnerability to climate change. Because tea farmers are already feeling the impacts of climate change, adaptation is already needed on the ground. However, because the climate will continue to change over coming decades, adaptation is not something that is implemented just once or that has only one solution. Instead, adaptation needs to be a process of change that is implemented in response to a continually changing environment.

Climate change mitigation is classed as any activity that reduces the emissions of greenhouse gases (the gases responsible for climate change). Through reducing emissions now, the future scale of climate change can be minimised. The main greenhouse gases are carbon dioxide, produced through the burning of fossil fuels and deforestation, and methane, produced during the decomposition of organic waste and from cattle. In the agriculture sector, the application of fertilisers also results in the emission of greenhouse gases. For smallholder tea farmers, climate change mitigation is not such an important issue as few greenhouse gases are released. However, at the factory level, mitigation becomes more important as this is where the majority of greenhouse gas emissions are emitted during the production of tea. Often, a reduction in emissions is associated with cost savings providing additional benefits.

Figure 4: Climate change adaptation and mitigation

Adaptation	Mitigation
• Improve resilience of social and physical infrastructure • Change of clones and agricultural practices • Improve water and soil management • Prepare for future pests and diseases • Manage existing environmental threats	• Energy efficiency • Low carbon energy source • Change of agricultural practices e.g. judicious fertiliser use • Change in consumer behaviour

2. Techniques for Climate Change Adaptation

The remainder of this manual provides details of climate change adaptation options. The topics covered are as follows:

For each topic an introduction is provided followed by information on how the activity helps smallholder farmers adapt to climate change. Examples of how to address these topics and activities that can be delivered with farmers both in a classroom and in the field are provided.

3. Tea Production in a Changing Climate

Smallholder tea farmers are already feeling the impacts of climate change. Challenging growing conditions have resulted in losses in the quantity and quality of tea leaf as a direct result of changing weather patterns. Some of the key issues faced by farmers are as follows:

- Frequent occasions of prolonged droughts reducing the quality and quantity of tea production
- Very heavy rains leading to landslides which damage tea farms and reduce accessibility to markets
- Extremely cold temperatures at night and during the cold season damaging green tea leaf
- Very high temperatures during the day time
- Frostbite in areas that never used to be affected by frost which can kill tea bushes and reduce tea quality
- Hailstone damage, reducing productivity and quality of the tea
- Changes in the timing of seasons e.g. delay in the onset of rainfall and extension of cold season creating challenges to effective farm management
- Daily and seasonal unpredictability in weather creating challenges to effective farm management

The livelihoods of tea producers, and in particular those of smallholder farmers and their families are being adversely affected by these new challenges.

Whilst the rest of this manual focuses more on farm based climate change adaptation solutions, this chapter details two adaptation options that can directly support the continuation of tea growth into the future.

Key methods for continuing tea production in a changing climate

- Adaptation Option 1: Shade Trees (page 17)
- Adaptation Option 2: Drought and frost resistant tea clones (page 19)

3.1 Tea Production: Adaptation Option 1 - Shade Trees

Shade trees are commonplace in tea growing regions around the world but they are not currently a common practice in Kenya. Shade trees provide both advantages and disadvantages to tea production, however they can help to combat some of the impacts of climate change as they help to regulate climatic conditions. For example, when temperatures are very high, the shade trees provide protection to the tea leaf. During times of drought, shade trees help to reduce evapotranspiration from the soil and tea bushes which reduces the risk of the tea bush drying out and dying. Similarly, shade trees protect soil and crops from the drying effects of wind. Finally, shade trees have demonstrated benefits during incidents of frost. This is thought to arise from their ability to create a micro-climate which reduces the ability for frost to form on the tea leaves. Thus, investing in shade trees is particularly useful in frost prone valley bottoms.

Figure 5: Shade trees in a tea plantation

Benefits of shade trees

- Regulate climatic conditions
- Reduce the negative impacts of high temperatures
- Reduce evapotranspiration
- Help to negate the impacts of frost
- Can improve soil fertility, particularly if leguminous varieties are grown
- Protects tea bushes from drying and dying

Problems with shade trees

- Can slightly reduce tea yields in high altitudes
- Trees compete over water with tea bushes
- If incorrect varieties are grown can encourage pests and disease

There are a number of shade trees that are recommended by the TRFK and these are as follows:

- *Grivellia Robusta* (Silly Oak)
- Tea bush allowed to grow into a tree
- *Hakea Saligna* (Willow Hakea)
- *Millettia dura*
- *Sesbania Sesban* (Egyptian pea)

It is important to **use the shade trees that are recommended by the Tea Research Foundation of Kenya (TRFK)** as other trees may bring pests to the tea plantations and/or interfere with tea production or productivity. Advice should be sought from TRFK on the most appropriate shade tree to use in each tea growing region of Kenya. Seeds for the trees recommended by TRFK can be obtained from the Kenyan Forestry Service or the Kenyan Forestry Research Institute (KFRI).

Shade trees should be planted in rows throughout the tea plantation. It is recommended that the spacing of the rows should be approximately ten times the standard height of the tree that is being used. For example, if the tree size is 6m at its maximum size, then the rows should be planted at 60m intervals. Again, advice should be sought from TRFK on the most appropriate intervals for the shade tree being used.

KEY POINT: Tea bushes should not be uprooted when planting shade trees.

3.2 Tea Production: Adaptation Option 2 - Drought and frost resistant tea clones

Some clones are drought and cold sensitive and are likely to suffer stress or even die during such conditions. Susceptible clones include AHP S15/10, TRFK 6/8 and TRFK 54/40. One key method of ensuring that tea can be grown in a changing environment is to ensure that when new tea clones are planted, clones that perform well under the changing climatic conditions are chosen. New clones have recently been developed by the Tea Research Foundation of Kenya (TRFK) that have improved performance under drought and frost conditions and demonstrate resistance to pests and disease.

Key new clones include the following:

- **TRFK 301/4 and TRFK 301/5:** These clones are 'tolerant' to drought and both clones have been observed to tolerate moderate to harsh adverse abiotic and biotic stress factors. TRFK 301/5 is a high yielding tea clone and is thus good for infilling.

- **TRFK 430/90 and TRFK 371/3:** These two clones are both considered to be drought 'tolerant'. They have high yields too, out yielding TRFK 31/8 (TRFK's baseline clone), by more than 68%. The quality is good and comparable to TRFK 6/8 and the clones have resistance to mites and root knot nematodes. The two clones also recover relatively fast from pruning and drought effects. Clone TRFK 430/90 has the added advantage of being suitable for mechanical harvesting/plucking.

- **TRFK 306/1:** This is TRFK's new purple tea. The tea from this bush has higher medicinal properties than green and black tea varieties. It is also deemed to be drought and frost resistant, pest and disease resistant, high yielding and grows in similar weather conditions to green tea species. Purple tea contains high levels of Anthocyanin, a substance that is widely marketed for its health enhancing properties and if the right markets can be found, it can fetch 3 to 4 times the revenue of standard black teas.

KEY POINT: Clones perform differently in different environments. <u>Always</u> check with TRFK before planting a new clone.

It is important to note that drought 'tolerant' does not mean that the tea clone is totally drought resistant. Tolerance means that the clone performs better under drought conditions than other tea clones. For example, a drought tolerant tea clone will not dry as much or as quickly as the other clones during times of drought, it will take less time to recover from drought conditions and productivity does not reduce as much as with other tea clones. Drought tolerant tea clones typically have a higher water use efficiency than other clones meaning they can still be able to produce substantial yield in reduced water environments.

Figure 6: Tea clone 'TRFK 306/1' (TRFK)

Pigmented tea - anthocyanin pigmented tea

Ordinary tea with green leaf pigmentation Chlorophyll

Planting new clones

TRFK recommend that new tea clones are planted at the spacing of 4x2 -2.5ft resulting in a plant population of about 13,450 plants/ha. TRFK have found this to be the most economic spacing. If spacing is closer, the tea bushes will be in strong competition with each other for nutrients and water.

Training young tea plants to develop deeper rooting systems ensures that the plants are more able to survive drought conditions. After planting, it is important to not pluck the new bushes until they are ready. If plucking happens too early it has a serious negative effect in the development of the root system.

Further Information

Additional information should always be sought from TRFK before planting new tea clone. TRFK can be reached at +254 52 20598/9 or info@tearesearch.or.ke

4. Soil Conservation and Management

Fertile soil is vital for sustaining agriculture and livelihoods. Thus, maintaining and improving soil fertility is an important way in which farmers can increase their resilience to climate change. Indeed, if action is not taken it is likely that climate change will cause soil fertility to reduce. High temperatures, floods, droughts, winds and increased evapotranspiration can all cause a reduction in soil fertility. It is therefore important to address these issues by ensuring that soils remain healthy. This will in turn help to reduce the impact of climate change on the agriculture sector and assist small scale producers in continuing to make a living from the land.

This chapter explores a number of ways in which soil fertility can be maintained or improved as a method of climate change adaptation and covers soil conservation and methods to increase the organic matter and nutrient content of soils. First, background information on soil fertility and its importance is provided.

Key methods of soil conservation and management for climate change adaptation

- Conservation farming (Page 28)
  - → Adaptation Option 1 - Cover crops (Page 31)
  - → Adaptation Option 2 - Mulching (Page 35)
  - → Adaptation Option 3 - Double digging (Page 38)
- Increasing the organic matter and nutrient content of the soil (Page 40)
  - → Adaptation Option 4 - Compost application (Page 42)
  - → Adaptation Option 5 - Green Manures (Page 49)
  - → Adaptation Option 6 - Liquid manures (Page 50)

What is soil fertility?

Before looking at methods for soil conservation and management, it is first important to understand soil fertility.

The fertility of soil is defined by its capacity to hold water and nutrients and supply them to plants. Thus a highly fertile soil is able to hold enough water and nutrients for successful and productive plant growth. To achieve fertile soil, soil must contain the following ingredients; organic matter, soil organisms and nutrients. Soil structure is also important, it must be loose and crumbly and not compacted.

KEY FACT: Mineral fertilisers can improve soil fertility through adding nutrients to the soil, however, they do not improve soil organic matter content, microorganisms and soil structure. In comparison, compost is beneficial to all these elements.

The components of soil fertility

Fertile soils have the following key elements; a good soil structure, soil organic matter, soil organisms and available nutrients for plant uptake.

Soil structure

Plant roots prefer soil with a crumbly structure. Such soil is well-aerated and the plant roots are able to grow through it easily. In soil with a good structure, the plant roots can grow both wide and deep to access available water and nutrients to support strong plant growth.

Soils with a good structure have high organic matter content, the presence of soil organisms such as earthworms, bacteria and fungus and are not compacted. Thus, to improve soil structure the following steps can be taken. Organic matter can be added to the soil such as in the form of compost. Biological activity can be encouraged such as through using natural pesticides rather than chemical ones. At the same time, incorrect soil management practices such as tilling the soil in wet conditions, which causes compaction, should be avoided.

Soil organic matter (humus)

Soil organic matter, known as ‘humus’, consists of decomposed plant or animal residues such as compost or well-rotted manure. Though humus only makes up only a few percent of typical agricultural soils in the tropics, it is of high importance to soil fertility.

Soil’s capacity to hold water and nutrients is closely linked to its humus content. Humus holds nutrients in the soil that may otherwise be washed away by rain. The humus then slowly releases these nutrients making them available to plants. Humus also acts like a sponge for water, increasing the water holding capacity of soil.

The more humus a soil has, the more fertile it is likely to be. Humus is normally indicated by the colour of the soil. Darker soils with a brown/black colour tend to have more organic matter and are, hence, more fertile than lighter coloured sandy soils.

See page 40 for more information on composting, a key way to add organic matter to the soil.

Compost: A good source of organic matter

Compost provides an important source of organic matter for soil. Produced through the decomposition of farm waste, compost can be added to the soil to provide multiple benefits. It helps to hold water and air in the soil and provides a steady release of key nutrients, all of which are important for healthy plant growth. For information on how to make compost **see page 42**

The benefits of organic matter

- Holds up to 5x its mass in water (acts like a sponge)
- Holds nutrients and releases them slowly for plants
- Improves soil structure
- Provides food for soil organisms
- Prevents soil from becoming acidic

Soil organisms

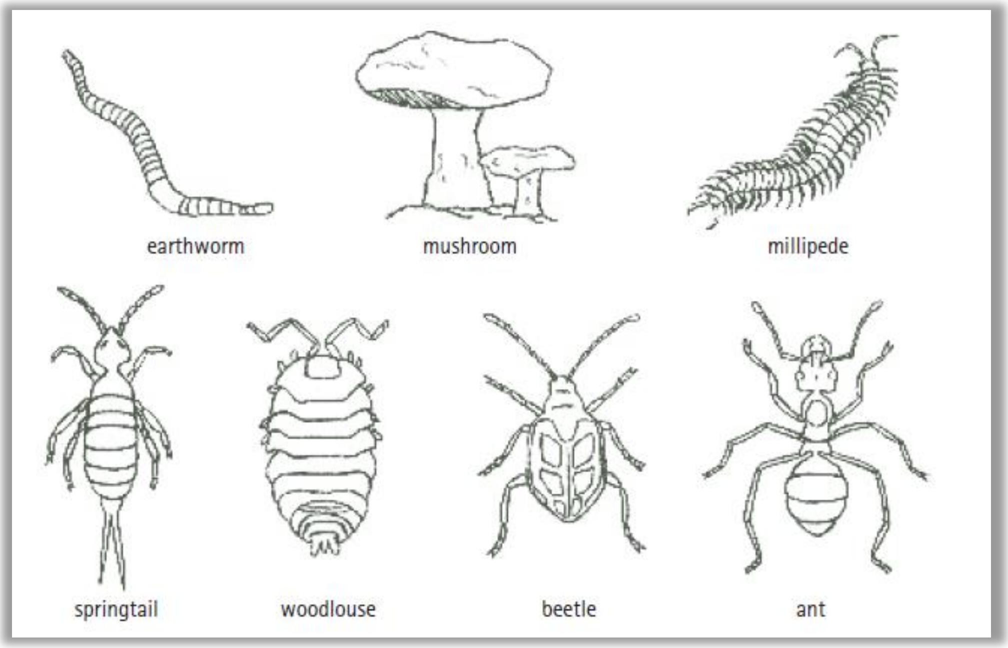
A teaspoonful of fertile soil contains billions of soil organisms. Some can be seen with the naked eye such as earthworms, mites, springtails or termites, while others (fungi, bacteria) are so small that they can only be seen with a microscope and are called microorganisms.

Even if we cannot see most soil organisms, the majority are very important to the quality and fertility of soil. They contribute to the decomposition of organic material into humus, to the improvement of plant health by controlling pests and diseases and to releasing nutrients so that they are available for plants.

KEY FACT: ***Soil organisms produce humus from organic material, control pests and diseases and release important nutrients into the soil necessary for healthy plant growth. Chemical pesticides harm soil organisms.***

Most soil organisms prefer the same conditions as plant roots: humid conditions, moderate temperatures, air and organic material.

Figure 7: Some key soil organisms that help keep soil healthy (FAO, 2011)[3]



Among the most important soil organisms are earthworms, rhizobia (bacteria) and the mycorrhiza fungi. For example, earthworms are important because they accelerate the decomposition of plant material and in doing so help to improve soil structure. The tunnels they create promotes rainwater to travel through and be absorbed by the soil and they thus contribute to the prevention of soil erosion and water-logging. Rhizobium bacteria help some plants to fix nitrogen from the air. These bacteria grow in the roots of plants and supply nitrogen to the plant. Mycorrhiza fungi are also important and grow in symbiosis with about

[3] Food and Agriculture Organisation (2011) 'How to make and use compost' www.fao.org/docrep/014/i2230e/i2230e14.pdf

90% of all plant roots. The plant roots provide sugar for the fungi and in return the fungi bring water and nutrients to the plants.

The capacity of roots that are in symbiosis with mycorrhizae to take up water and nutrients exceeds 1,000 times that of plant roots without its symbiotic partner. An additional benefit of mycorrhizae is their ability to improve soil structure.

Activities that help soil organisms

- Adding organic matter (compost)
- Well drained moist soils
- Warm temperatures
- Good soil structure (crumbly)
- Crop rotations

Activities that harm soil organisms

- Pesticides
- Water logging
- Dry soils
- Tillage
- Burning of organic matter
- Hot and exposed soils

Nutrient availability

The fertility of soil is also dependent on the presence of certain nutrients that are required by the crops for healthy growth. To determine the nutrient content of soil typically requires laboratory analysis. The nutrients in soil can be divided into macro (major) and micro (minor) nutrients.

Macronutrients include nitrogen (N), phosphorus (P) and potassium (K). These major nutrients are usually depleted from the soil first because plants need them in large amounts for their growth and survival. The secondary macronutrients are calcium (Ca), magnesium (Mg) and sulphur (S). These nutrients are usually available in sufficient amounts in the soil.

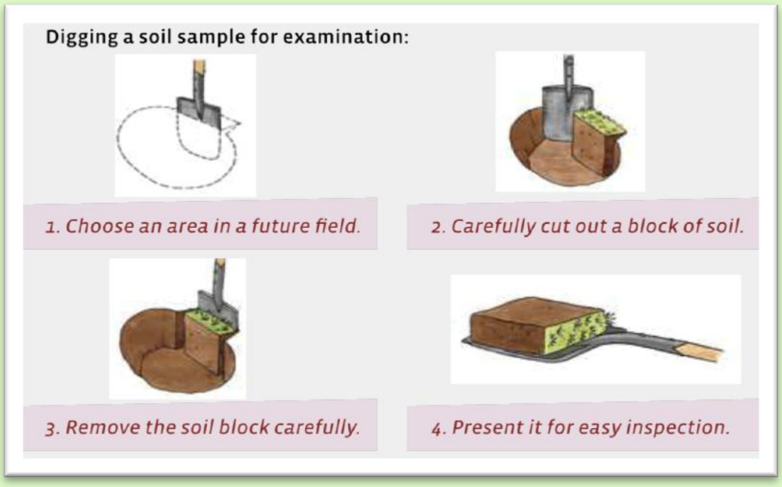
The micronutrients are boron (B), copper (Cu), iron (Fe), chloride (Cl), manganese (Mn), zinc (Zn) and molybdenum (Mo). Making liquid manures (page 50) and composting organic matter (page 42) such as crop residues and tree leaves is an excellent way of providing micronutrients, as well as macronutrients, to growing plants.

Facilitating with farmers: Soil Fertility Analysis

In the classroom: Collect soil samples from the area and keep them in plastic bags to preserve their moisture. Place the soil samples in small heaps on a table. As part of the exercise, write the origin of each sample on a piece of paper and turn it upside down, to be revealed at the end of the exercise. Ask the farmers to analyse the soils attributes such as:

- Structure (dry, sticky or soft and crumbly, how easily can roots grow through it?)
- Colour (soil with high humus contents are dark, with low content are light)
- Moisture content (does it have enough water to supply plants?)
- Soil organisms (are they present?)

In the field: Dig a hole and extract a cross section of soil. Look at the structure, colour, presence of soil organisms, root growth, moisture content.



Also, it is possible to assess the fertility of soil through using indicator plants and the type of vegetation on a given land. Presence of a diversity of weeds of full colour, and specifically species such as *Commelina* and *Amaranth* are indicative of fertile soils. On the other hand, the prevalence of certain weed species such as *Striga* (witchweed), *Digitaria* (crabgrass), is an indicator of poor soils. On crop land, crop yields are good indicators of the fertility of the soil.

Discuss the findings together: Ask ‘how can the soil fertility be improved?’

What causes soil fertility loss?

Fertile land is vital for sustaining agriculture and livelihoods. It is therefore important to understand how soil fertility is lost and how to address these problems:

- **Agriculture without the input of organic matter (humus):** Organic matter is vital in ensuring water, air and nutrients are available to plants and provides a source of food for soil organisms. A key solution is to add compost or well rotten manure to soils (see page 42).
- **Soil erosion from wind or water:** Organic matter and nutrients are located in the top layer of soil. When this is removed by water or wind erosion soil fertility is reduced. Therefore farms without erosion protection measures will have low soil fertility. A key solution is to implement conservation farming measures (see page 28).
- **Deforestation and tree removal:** Trees can help to protect the soil and their removal can cause soil degradation through erosion resulting in fertility loss. Tree planting can thus help protect soils.
- **Burning of organic waste:** The burning of organic waste on farms is very bad for soil fertility. The burning process will damage important organisms in the soil that are required for healthy soils. Also, organic matter should always be added back into the soils to increase fertility through composting (see page 42).
- **The use of chemical fertilisers:** Whilst these provide nutrients to plants, this is short lived. They leave damaging salt particles behind in the soil which reduces its fertility. Natural fertilisers and compost provide an alternative to chemical fertilisers (see pages 42 and 50).
- **The use of pesticides:** As well as killing pests, the use of pesticides can kill soil organisms which are important in creating healthy productive soils. Some pests can be avoided through the use of certain growing techniques or organic pesticides which do not impact soil organisms.
- **Insufficient vegetation cover:** Exposed soils are vulnerable to erosion. It is therefore important to ensure that soils are covered and protected (see page 31).
- **Compaction and drying:** The compacting of soil prevents soil roots from being able to access nutrients and water and inhibits soil organisms, preventing them from providing their role in maintaining healthy soils. It is therefore important to use conservation farming methods that do not compact soils (see page 28).

Facilitating with farmers: Identifying soil conservation measures

Field assessment of soil and water conservation: Divide the farmers into small groups and send them to different fields to assess soil conservation measures being practiced in the area. Ask them to assess to what extent measures are undertaken to keep the soil covered, to reduce the movement of water and to hold the soil together. Share and discuss the findings.

Ask the farmers: What are they doing to help improve the health of their own soils?

How to prevent soil fertility loss?

Preventing soil fertility loss is a very important method of climate change adaptation. Fertile soils will help crops to address some of the challenges posed by climate change. The increased water holding capacity of fertile soil will help in times of drought, low rainfall or increased evapotranspiration. Improved soil structure will help avoid soil erosion during heavy rains, floods or dry windy periods. Further, the reduced need to add mineral fertilisers will allow farmers to save money that can be redirected towards other needs.

Soil fertility management can be seen as a three-step approach:

Step 1 – Conservation Farming: The first step consists of measures that conserve the soil, soil organic matter and soil water from loss. Applied measures aim at protecting the soil surface from erosion, ensuring water is not lost from the soil and reducing soil disturbance to protect the existing soil structure. The overarching aim is **to establish a stable and less vulnerable soil as the foundation to managing its fertility.**

Step 2 – Composting: The second step consists of improving the organic matter content of the soil and enhancing biological activity in the soil. The aim here is **to build an active soil with good structure which can hold water, support soil organisms and supply plants with nutrients.**

Step 3 – Liquid manures: The third step consists of supplementing the nutrient content of soil. The aim here is to **improve the growing conditions for plants**.

For further details on soil conservation and management

- Organic Africa: http://www.organic-africa.net/1311.html?&L=0
- FIBL (2011) Soil Fertility Management http://www.organic-africa.net/fileadmin/documents-africamanual/training-manual/chapter-02/Africa_Manual_M02_low.pdf

4.1 Soil Management: Conservation Farming

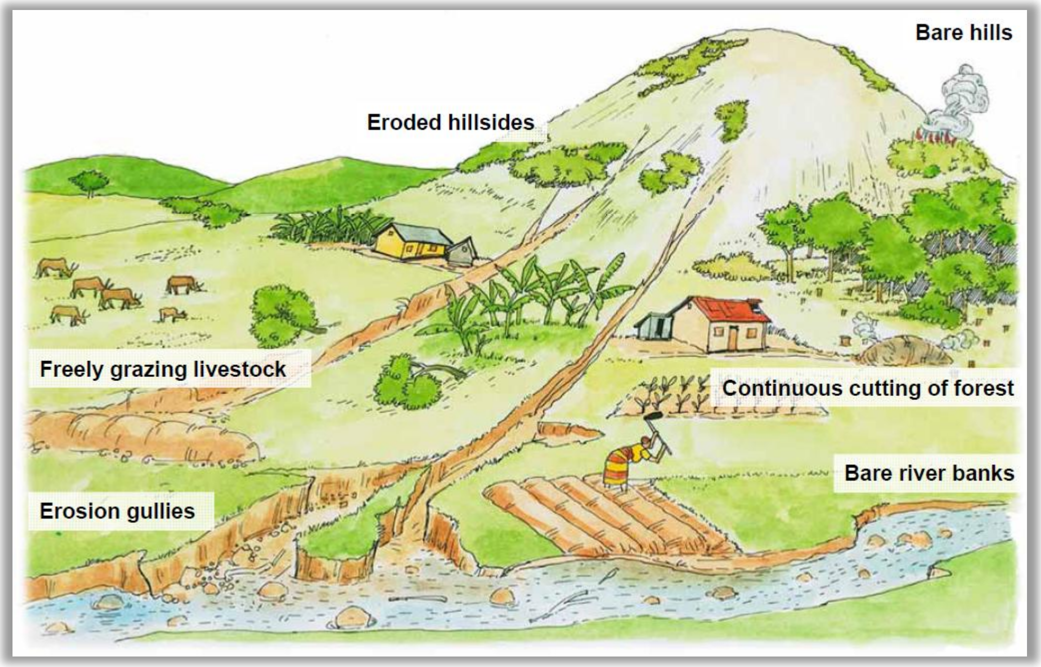
In Kenya, climate change is causing rainfall to become more unreliable. Unexpected droughts are being experienced, leading to reduced yields. Sometimes when the rain comes, it is heavy and washes away the soil, destroys plants and causes floods or landslides. The extent of damage is usually greater on croplands along hill slopes, a typical feature in Kenyan tea growing regions. Depending on the extent of damage, the productivity of the land is instantly or gradually reduced, because either all or part of the topsoil (the section of soil rich in organic matter and nutrients) is lost to the lowlands, leaving behind the less productive part of the soil.

One method to reduce the risk of the erosion of topsoil is to implement 'conservation farming'. The two main principles of conservation farming are:

1. To **prevent the soil from being eroded by wind and rain** by keeping it covered as much as possible. Soil can be covered with living plants (cover crops page 31) or dead plant materials (mulching page 35). The speed and movement of water is reduced by encouraging water infiltration and storage in the soil achieved by terracing and drainage gullies.

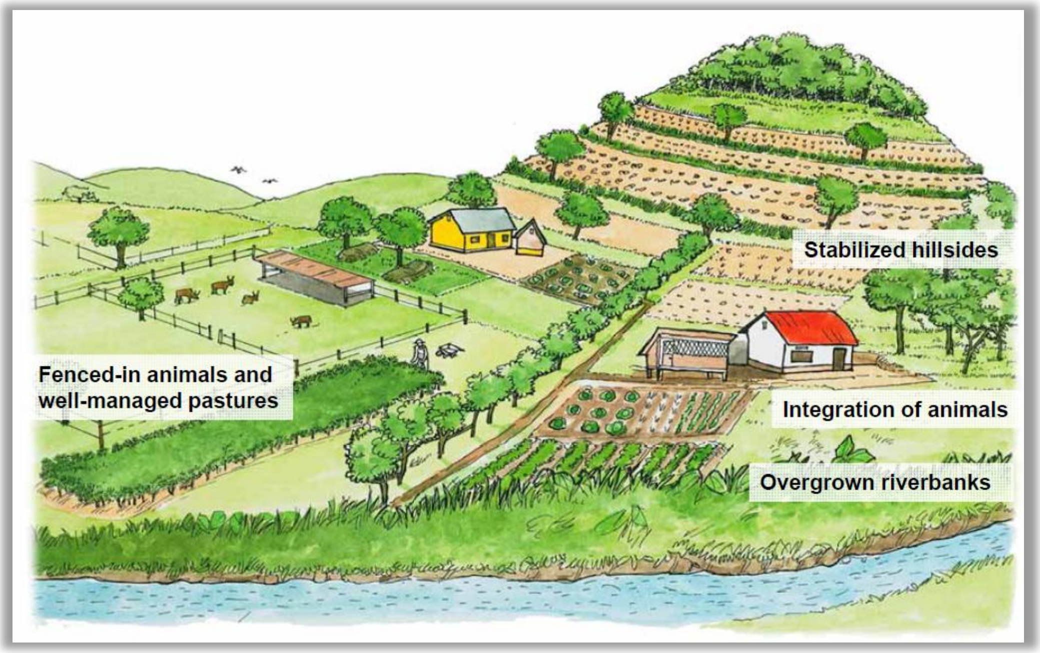
2. To **minimise soil disturbance**. It is beneficial to reduce tillage, maintain protective cover over soils and allow early land preparation before heavy rains. This helps to protect soil structure, increase water infiltration, reduce runoff and reduce compaction.

Figure 8: A degraded landscape (FiBL 2011)[4]



[4] FIBL (2011) Soil Fertility Management http://www.organic-africa.net/fileadmin/documents-africamanual/training-manual/chapter-02/Africa_Manual_M02_low.pdf

Figure 9: A well-managed landscape (FiBL, 2011)

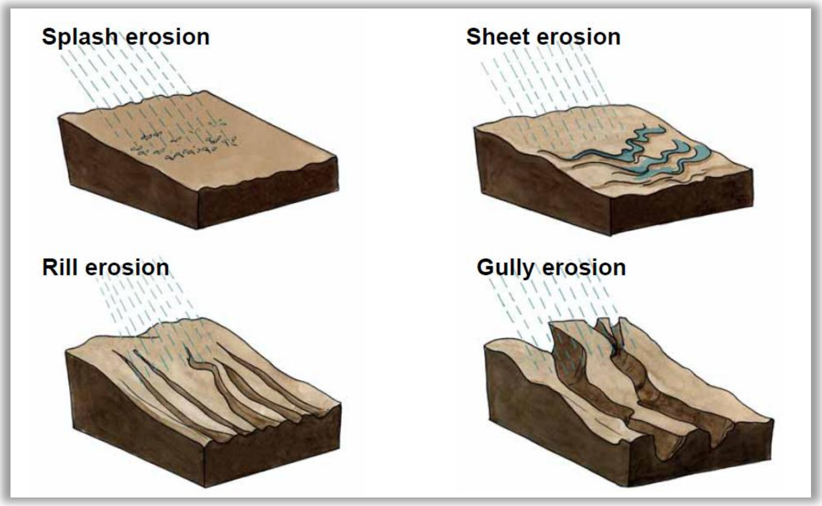


Preventing soil erosion

Before teaching on soil conservation techniques it is important to provide farmers with an understanding of soil erosion and the importance of its prevention. Soil erosion provides challenges for maintaining soil fertility. Whilst soil erosion happens naturally, human activity can accelerate the process, and this should be avoided at all costs.

Soil erosion is the physical movement of soil particles and organic matter from a given site by the action of water or wind. The extent of soil erosion will advance from sheet erosion (uniform removal of a thin layer of topsoil), rill erosion (small channels formed in the field) to a more destructive stage, gully erosion (large channels formed in the field).

Figure 10: Common forms of soil erosion (FiBL 2011)



Soil erosion results in the loss of soil organic matter from upper soil layers which destroys the physical properties of the soil, its structure, aeration, water-holding capacity and biological activity, and involves loss of soil nutrients, which leads to nutrient deficiencies and poor plant growth.

What causes soil erosion?

Human activity can accelerate naturally occurring erosion in the following ways:

- **Overgrazing** and reducing plant cover, exposing the soil surface to rain and animal stamping impacts, which in turn loosens the topsoil making it susceptible to erosion.
  - → Solutions include penning in livestock, using cover crops and ensuring that all soil has some form of vegetative cover
- **Over cultivation** of cropland resulting in exhaustion of soil organic matter destroys soil structure and makes soils very susceptible to erosion.
  - → Solutions include adding compost, green manures and liquid feeds and implementing crop rotations
- **Utilisation of erosion susceptible areas (e.g. farming on steep hills)** without any soil conserving measures such as terracing or contour planting will result in soil erosion.
  - → Solutions include terracing, contour ridging and drainage gullies
- **Deforestation and tree removal**. Continued removal of forests and trees for firewood, charcoal and new cultivable land leads to soil erosion, floods and landslides.
  - → Replanting in areas of deforestation and planning new trees on field edges and by rivers
- **Man-made climate change** is resulting in heavy rainfalls which can wash away soils and longer and more severe droughts which dry soils and make them more susceptible to wind and water erosion.
  - → Solutions involve implementing climate change adaptation options

Facilitating with farmers: Soil Erosion

Field assessment: Inspect together with the farmers local fields located on slopes. Can any splash, sheet, rill or gully erosion be observed? Ask the farmers what their observations are during strong rains. Does the soil take up rainwater easily or does most of the water runoff? What do their soils look like after strong rains? Ask the farmers about activities they can implement to stop the process of erosion.

The outcomes of this exercise should help to frame the content of teaching on conservation farming practices.

Demonstration: If available, pour some water over a heap of ripe compost and a heap of soil of poor quality. What can be observed? Do the crumbs stay stable? Does water run in easily?

4.1.1 Soil Management: Adaptation Option 1 - Cover Crops

The easiest way to protect the soil from being eroded by water or wind is to keep it covered by a living plant, i.e. a cover crop, or a plant residue, i.e. a mulch (page 35). Erosion from rainfall can be a major problem for annual crops where the land sometimes needs to be opened for planting and this time coincides with the rainy season. To avoid erosion during this period, cover crops and mulches can be used to cover the space between plant rows with digging and ploughing only performed in the planting strip. However, this practice needs to be carefully considered as if left in place during the planting season cover crops can compete with annual crops for soil water and nutrients. It should thus be decided on a location by location basis if and how cover crops are to be used.

KEY POINT: ***Use cover crops to protect exposed soils from soil erosion, especially in the rainy season.***

What are Cover Crops?

Cover crops are short term crops planted to provide soil cover and improve soil fertility. They are planted as intercrops or during the no-crop or fallow seasons or on vulnerable patches of soil. They cover the soil and prevent weed growth. Typically cover crops are pruned at the time of planting of the main crop or completely cut to act as mulching material. Sometimes cover crops are left in place when annual crops are planted and in these instances they may be in competition for water and nutrients to the main crop. It is also important to remember that cover crops require labour to establish and maintain them.

Any plant that covers the soil and improves soil fertility can be referred to as a cover crop. It could be a leguminous plant with other beneficial effects, or a plant that exhibits rapid growth with an enormous production of biomass. The most important property of cover crops is their fast growth and their ability to keep the soil permanently covered. Some cover crops can also be used as a source of food and feed. The following characteristics make an ideal cover crop:

- Has low competition for water and nutrients with the main crop e.g. has shallow rooting system whilst the main crop has deep roots
- The seeds are cheap, easy to get or to reproduce on the farm
- Grows fast and covers the soil in a short time
- Is resistant to pests and diseases
- Does not transmit any pests or diseases to the main crop
- Produces large amounts of organic matter that can be used as a mulch or a compost material
- Tolerates drought
- Fixes nitrogen from the air and provide it to the soil
- Has a root system able to decompact soil and regenerate degraded soils
- Is easy to sow and to manage
- Can be used as fodder or grains for food

Facilitating with farmers: Cover Crops

Discussion: Ask the farmers about plants they know that are grown as cover crops. Why are these plants grown? What are their characteristics?

Examples of Cover Crops

Cover crops can be grouped into legumes, grasses, leguminous shrubs and other crops such as pumpkin or watermelon, which also cover the soil well. Usually legumes are preferred, as they fix nitrogen from the air and decompose quickly when cut. This means that the nutrients become available to the next crop. For a lasting soil cover, a mixture of legumes and grasses is best, as their root systems usually complement each other well in their growing depths and together they provide a balanced source of food.

The most common cover crop species include:

Legumes: Cowpea (Vigna unguiculata), crotalaria (Crotalaria spp), Desmodium (Desmodium intortum), Jackbean (Canavalia ensiformis), Lablab (Dolichos lablab), Alfalfa (Medicago sativa), Mucuna or Velvetbean (Mucuna pruriens), Mungbean or green gram (Vigna radiata), Pigeon pea (Cajanus cajan) and Siratro (Macroptilium atropurpureum), groundnuts and monkey nuts.

Grasses: Pearl millet (Pennisetum glaucum), Andropogon, gamba grass (Andropogon gayanus), kikuyu grass, vetiver grass and napier grass and guinea grass

Leguminous shrubs: Sunn hemp (Crotalaria juncea), Calliandra, Gliricidia (Gliricidia sepium), Sesbania (Sesbania sesban), Tephrosia (Tephrosia candida)

Ideally cover crops contribute to a more or less permanent cover of the soil in an existing cropping system. To choose the right species, cover crops must match the local crops and local climatic and soil conditions. Cover crops should not compete with the main crop for nutrients, water and light.

KEY POINT: As with food crops, cover crops should also be rotated to avoid build up of pests and diseases.

Methods of planting Cover Crops

Cover crops can be planted in different ways depending on the site conditions, the main crop and intended benefits:

1. **Intercropping**: The cover crop is planted at the same time as the main crop. In this case, the main crop should be one that grows high like maize to avoid being smothered by the cover crop. Creeping cover crops like mucuna should be avoided, because they will also smother the main crop. Intercropping is preferable in perennial crops.
2. **Relay cropping:** The cover crop is planted in an advanced growth stage of the main crop. For example, in a maize-bean intercrop the cover crop can be planted after beans are

harvested. Here the farmer is able to harvest more crops and the risk of competition is greatly reduced. The cover crop is then left to continue growing, protecting the soil and smothering weeds.

3. **Crop rotation and improved fallows:** In this case, the cover crop is planted after the harvest of the main crop. If the soil has enough moisture, this can be done immediately after harvesting or it can be done as part of the main crop rotation cycle or incorporated during the fallow season.

4. **Permanent cover:** Sometimes cover crops are required on pieces of land that will not be used for other purposes and which are highly susceptible to erosion. For example, a patch of soil at the edge of the tea plantation, on a very steep slope or a strip of soil next to a river bed. In such instances cover crops are important to hold the soil in place and prevent it from being washed away. Good cover crops for this purpose include kikuyu or napier grass.

Facilitating with farmers: Cover Crops

Activity 1: Ask the farmers to select a main subsistence crop on their farm and to produce an agricultural calendar for this crop detailing the different activities including digging, planting, weeding, harvesting etc. Ask them to indicate the dry and rainy seasons, and the periods when the soils are most affected by soil erosion.

Based on this calendar ask the farmers if and how they can use cover crops in order to avoid soil erosion.

Activity 2: Ask the farmers to assess their farms. Which soils are susceptible to erosion? Which cover cops can be used to reduce the erosion risks?

Using Cover Crops on the tea farm

For smallholder tea farmers cover crops are particularly important as many tea farms are located on steep slopes which are highly susceptible to soil erosion. If left unchecked, soil erosion will become worse year on year and cover crops should be used to protect any exposed soils. Cover crops can be used to protect both soils around the tea plantations and soils in the kitchen gardens. Essentially all exposed soils benefit from the use of cover crops. If the smallholder has a river running along the edge or within the boundary of their farm, cover crops should be planted along the river boundary as they prevent soils being washed into the river during times of high rainfall.

Tea farmers should select cover crops for use that are appropriate to their specific needs. However, Napier grass is a particularly useful cover crop for use on a tea farm. Napier grass can help to secure unstable field boundaries as it binds the soil well. It also serves as a feed for animals.

If the farm has particularly steep slopes, fodder grasses such as vetiver grass (Vetiver zizanioides), napier grass (Pennisetum purpureum) and guinea grass (Panicum maximum), Bahia grass (Paspulum notatum) can be planted in strips at intervals across the slope to slow down run-off of water. In addition to reducing soil erosion, the grasses provide feed for the animals. The grass strips can be mixed or replaced with a hedge row of leguminous fodder trees such as Leucaena diversifola, Calliandra calothyrsus, Sesbania sesban (Egyptian pea), Gliricidia sepium.

4.1.2 Soil Management: Adaptation Option 2 - Mulching

Mulching is the second way in which soils can be protected from erosion and soil fertility can be maintained. Mulching is the process of covering the topsoil with dead plant material such as prunings from tea bushes and shade trees, leaves, grass, twigs, crop residues or straw and thus providing it with a layer of protection from the elements. This is important in terms of climate change adaptation as with changing weather conditions, soils will be exposed to increasingly harsh condition including increased temperature, longer periods of drought and increasingly heavy rainfalls. Mulching will help to protect soils against these conditions and support farmers to continue to grow strong and healthy plants.

Why use mulch?

Covering the soil with a mulch has many advantages, including protecting the topsoil from being washed away by strong rain and from drying out by the sun. Protection reduces evaporation of water and thus keeps the soil humid. As a result the plants need less water or can use the available rain more efficiently.

A humid soil also enhances the activity of soil organisms such as earthworms, and microorganisms such as rhizobia and mycorrhiza which are important in providing healthy soils for strong plant growth. As the mulch material decomposes, it both releases nutrients and is transformed into humus, increasing the soil organic matter content. A thick mulch layer further suppresses weed growth by inhibiting their germination. For all these reasons mulching plays a crucial role in preventing soil erosion and maintaining soil fertility and thus adapting to climate change.

Sources of mulch

Sources of mulching material include weeds or cover crops, crop residues, grass, pruning material from trees, cuttings from hedges and wastes from agricultural processing or from forestry. Fast growing nitrogen-fixing shrubs that tolerate strong trimming provide good and considerable amounts of mulching material.

The kind of material used for mulching greatly influences its effect. In humid climates green material will decompose rapidly providing nutrients to the crops. Soil protection is then limited to 1 to 3 months. In this case application can be repeated. Hardy materials such as straw or stalks will decompose more slowly and therefore cover the soil for a longer time.

Where soil erosion is a problem, slowly decomposing mulch material will provide long-term protection compared to quickly decomposing material. Slow decomposing material is often carbon rich. When using such material it should be applied to the soil at least two months before planting or sowing the main crop. The decomposition of the mulch material can be accelerated by spreading organic manure such as animal dung on top of the mulch, thus increasing the nitrogen content.

In humid climates loose, bulky materials are usually more appropriate for mulching, as they ensure adequate ventilation. When mulch material is introduced to a crop field, attention must be paid to prevent the introduction of any unwanted seeds.

Applying mulch on the tea farm

Mulching in tea, particularly in the early stages of plant establishment, has been found to be beneficial.

For established tea bushes, mulch can be applied between the rows of tea bushes and around the edge of the tea fields and wherever there is exposed soil, such as on sites that require infilling. Tea bush pruning material is a particularly good mulch for tea farms and should always be used as a mulch when pruning takes place. Prunings should never be taken away from the field for other purposes and in particular they should never be burnt.

Mulch is also important when new tea bushes are being planted as there will be exposed soil directly around the new bushes. Mulching material will help to maintain water and nutrients in the soil to support the new tea bushes to grow. However, it is recommended that mulch should not be placed too close to the tea rows as this can stunt the development of feeder tea root making the plant more susceptible to droughts during the dry season. Also, mulching in this way will help to prevent attack of the tea bushes by ants and termites. In tea, avoid using mulches that can raise the alkalinity and PH of soil as this can have adverse effect on tea plant growth. Suggested mulches include *Eragrostis curvula* and bulky materials include tea bush prunings.

***KEY POINT**: The ideal strategy for mulch application depends on local conditions and the crops that are grown. Whether mulch is best applied before or after planting, in strips along the rows or evenly over the entire surface, in a thick or a thin layer, must be found out through testing. This can be achieved in farmer field schools.*

Figure 11: Using mulch on young tea bushes

Applying mulch to other annual and perennial crops

If possible, the mulch should be applied before or at the onset of the rainy season, as this is when the soil is most vulnerable. If mulch is applied prior to sowing or planting, the mulch layer should not be too thick in order to allow the seedlings to penetrate the mulch.

Mulch can also be applied to established crops. It can be applied between the rows, directly around single plants (especially for tree's) or evenly spread on the field. On vegetable plots it is best to apply mulch only after the young plants have become somewhat hardier, as they may be harmed by the pby-products of decomposition from fresh mulch material.

Facilitating with farmers: Mulching

Discussion: Ask the farmers about possibilities for covering the soil to protect it. What materials are available for mulching? What plants may be grown to cover the soil? Which approaches to cover the soil may be most advantageous? Do any of the farmers practice one or the other method?

4.1.3 Soil Management: Adaptation Option 3 – Double Digging

As has been discussed in earlier sections of this manual, climate change will likely increase soil erosion and reduce soil fertility due to its impacts on heavy rains and droughts. Activities that reduce soils susceptibility to erosion are thus important in terms of climate change adaptation.

Double digging is a process that improves soil structure through aeration and de-compaction. If hardpan exists, double digging is a good method of remediating the soil. In particular double digging remediates soil by improving water filtration and drainage through opening up the soil. Double digging also improves the water holding capacity of the soil, in part through enabling water to filter through the soil but also as the process allows for the maximum incorporation of compost. Double digging is therefore a useful climate change adaptation technology that will support crops in times of drought through the soils increased ability to hold moisture. Also, in times of heavy rainfall, the increased water infiltration properties will help prevent water runoff, soil erosion and the fertile top soil from being washed away.

Before starting the process of double digging it is important to recognise that much work is involved to prepare the beds in this way. This should be effectively communicated to the farmers so they can make a decision on the time costs against the benefits. Also, double digging should only be used when the soil is of poor quality, poor structure or requiring significant addition of compost. Thus double digging is most useful for deep rooting high value crops that require high nutrient intake.

How to prepare a bed using double digging

TOP TIP: It is vital not to mix top soil with subsoil as this can harm soil organisms such as earthworms. Mixing the soils will reduce soil fertility.

The use of double digging to prepare a bed ready for planting is simple. The general process involves loosening the topsoil and adding compost to increase fertility and loosening the subsoil to aid water penetration and drainage. Double digging is a method that allows the farmer to achieve this without mixing the topsoil with the subsoil.

The first step in double digging is to mark out the bed to be prepared. A recommended bed size is 4ft by 24ft. The width of 4ft is recommended because this allows the farmer to work on the bed from both sides without stepping on the soil, thus avoiding compaction.

TOP TIP: Do not stand on prepared beds, it compacts the soil and inhibits root growth and decreases soil fertility.

Divide the marked bed into sections, each 4ft by 3ft. In the first section, dig out the topsoil. This will be around 6” to in 1ft deep. Put the soil in a wheelbarrow and take to the end of the bed for later use. Ensure that the hole is dug out to the full width of the bed (4ft). Once the topsoil has been removed the subsoil can be broken down using a fork or hoe. Now move onto the second 4ft by 3ft section. Drag the topsoil from this section into the prepared hole and on top of the loosened subsoil. If compost is being added, dump it on top of the second

section and drag and mix the compost and topsoil together into the prepared hole. Once all the topsoil from the second section has been moved into the first section continue to breakup and loosen the subsoil in the second section. The process is completed along the whole bed. In the last section the topsoil from the first section is used to complete the bed.

KEY POINT: It should be noted that the purpose of loosening the subsoil is to facilitate drainage. Roots do not grow into subsoil so there is no need to add compost to this soil.

Facilitating with farmers: Double Digging

Discussion: Ask the farmers about the advantages and disadvantages of double digging. What crops and sections of their farm could benefit from double digging?

Activity: At a demonstration farm select a piece of land that has been impacted by soil erosion. Use double digging to prepare the soil on one half of the land. Plant some vegetable seedlings and observe the difference in their growth over the season.

4.2 Soil Management: Adding Organic Matter

Organic matter is a key component of soil necessary for creating a good soil structure that holds water and nutrients necessary for plant growth. Organic matter consists of partially decomposed plant or animal residues or humus (well-decomposed organic matter) (see page 21 for further background information).

Organic matter and humus are important for a number of key reasons including:

- Soil organic matter is one of the main nutrient pools for the plants. It supplies nutrients to the plants in a balanced way, which contributes to good plant health.
- It increases the water holding capacity of the soil as it acts like a sponge with the ability to absorb and hold up to 90 percent of its weight in water.
- It improves soil structure and increases water infiltration, making the soil more resistant to erosion. Better soil structure also enhances root growth.
- Soil biological activity is enhanced, which improves nutrient mobilisation from organic and mineral sources, increasing their availability to plants.
- There are many benefits of building organic matter in the soil; however it is a long-term process that can take a number of years and requires much time and energy on behalf of the farmer.

There are different ways of maintaining or improving soil organic matter:

- Growing **green manure** such as legumes which are cut and worked into the soil before they flower or **cover crops** such as velvet bean, tithonia, lablab, lucerne.
- **Mulching** with tea bush prunings, shade trees or other trees and shrubs that cannot be easily composted (see page 35 for further details) and letting the material decompose and then be worked into the soil.
- **Composting** crop residues from harvested crops in the form of husks, leaves, roots, peelings, branches, twigs and stalks and incorporating this into the soil.
- Integration of **livestock** can improve soil organic matter when livestock excreta and bedding are properly recycled.

Facilitating with farmers: Organic matter

Discussion: Assess together with the farmers available sources of organic matter in the local context.

- How are they used by the farmers?
- What are the potentials and constraints related to their use?
- What sources have not been used so far?
- How can the use of organic materials be improved?

Discussion: What are the problem of burning organic matter

- Do the farmers burn organic matter that could be used on the farm?
- Is there a need to burn organic matter for fuel?
- If so, what trees can be planted now to reduce this need in the future?

Figure 12: Sources of Organic Matter (FiBL 2011)

KEY FACT: Do not burn organic matter other than firewood. The benefits that can be obtained from incorporating it into soil will be lost, beneficial organisms will be killed and carbon, sulphur and nitrogen are released into the atmosphere.

4.2.1 Soil Management: Adaptation Option 4 – Compost Application

Chemical fertilisers (agrochemicals) derived from fossil fuels are commonly used to replace lost nutrients in soils. However, with the increasing costs of fossil fuels causing fertilisers to increase in price and the advent of climate change, this is becoming a problematic solution. An alternative to chemical fertiliser is compost, an organic material that can be added to land to create biomass-rich soils that in turn create productive and healthy agro-ecosystems.

Compost is a freely available resource that is created by combining organic materials at specific ratios. Over time, and with some management, these ingredients will breakdown to form dark brown soil with a high nutrient and humus content. The resulting compost can then be added into soils to provide both improved soil structure and improved growing conditions for crops.

KEY POINT: Compost is the most reliable method of converting the nutrients held in organic waste materials into a useful resource

This section of the training manual provides details of how smallholder tea farmers can produce compost for use on their farms.

Benefits of compost

- Easy to produce
- Provide a slow long term release of nutrients to plants
- Supports soil organisms
- Improves soil structure
- Improves soil aeration
- Humus in soil significantly increases the amount of water the soil can hold
- Improves the value of manure

Problems with compost

- Labour intensive: Takes time to gather the materials and build the heap
- Materials may not always be available

Problems with chemical fertilisers

- Costly
- Supply nutrients to the plants for a short period only
- Can cause river and ecosystem pollution
- Does not improve soil organic matter, soil structure or water retaining abilities of the soil
- Can be harmful to people and animals

Benefits of chemical fertilisers

- Not labour intensive
- Can be crop specific by replacing specific nutrients
- High crop yields in their first year of use

What is compost?

Composting is used to describe the controlled decomposition of plant and animal materials (mainly animal manure) into a form that can be easily applied to the soil and where the

nutrients can be easily be used by plants. Compared to the uncontrolled decomposition of organic waste, composting occurs at a faster rate, reaches higher temperatures and results in a product of higher quality.

Composting is important because it helps to improve long-term soil fertility, especially for smallholder farmers with limited access to manures and fertilisers. However, compost is more than a fertiliser as it provides long term improvements to soil structure including its capacity to hold and provide both nutrients and water to plants. When added to the soil, compost has also been demonstrated to enhance the drought resistance of crops. However, it should be remembered that producing compost can be a time consuming and laborious operation.

KEY POINT: Compost is a key way of maintaining long-term soil fertility and is free to make.

Facilitating with farmers: Compost

Discussion: Find out what the farmers know about compost and how they value it compared to mineral fertilisers

- Have the farmers heard of composting?
- Do farmers practise any variance of composting like heaping crop residue under a tree and waiting for it to decompose then applying onto crops?
- Do they think it is worthwhile to invest in compost?
- Do they know the benefits of compost?
- How much do they spend on fertilisers?

Find a local farmer that regularly uses compost and let them discuss the benefits that they see from using compost

Climate change adaptation and composting

In terms of climate change adaptation, compositing provides numerous benefits. First adding compost to soil improves soil structure, texture and aeration, which means better moisture-holding capacity, nutrient retention and, ultimately, reduced vulnerability to water and wind erosion. For example, in clay and compacted soils, compost will work as an aerator and loosen soils to enhance root growth and help roots access nutrients and water. In sandy soils, compost acts as a water retainer due to the increased organic matter added to the soil. It is estimated that 1kg of humus (a component of compost) can hold up to 6 litres of water. In terms of water retention, the addition of compost has multiple benefits. As well as allowing more water to be held in the soil, it also allows water to be held for longer periods. For example research from Ethiopia has shown that in dry periods, crops grown on soils with high compost levels can grow for two extra weeks after the rains have stopped when compared to crops grown on soils given chemical fertiliser (FAO 2012). Further, when it rains, the addition of compost helps water to infiltrate into the soil rather than running off the surface. This has the multiple benefits of reducing the likelihood of flooding, reducing the likelihood of springs drying up in the dry season and reducing soil erosion. The addition of compost also protects against wind erosion as the humus in the compost helps to bind the soil together.

The soil's improved capacity to retain nutrients and water through the addition of compost has a direct effect on crops by increasing yields and the health of the plants. Specifically, compost is a good source of Nitrogen, Phosphorus and Potassium as well as trace elements and micro-nutrients which all support plant growth throughout the growing season. As such, compost helps to increase both income and food security for farmers. Organic matter in the compost provides food for microorganisms, which keeps the soil in a healthy, balanced condition. In addition, the coverage offered by healthy vegetation can help to reduce wind erosion of the soil.

KEY POINT: Compost helps with climate change adaptation as it improves the resistance of plants to droughts and is the best type of fertiliser in dry conditions.

Making compost

There are many different ways in which compost can be made. This manual describes one method but descriptions of other methods are available as detailed in the box below.

1. **Selecting a location:** Key to all methods of compost making is choosing an appropriate location. The composting process should be conducted in a place that is easy to access for easy transport of materials to the composting site and close to the fields where the compost is to be used after production. The compost should also be close to a water source as it must remain damp and requires regular watering. Dampness is vital for the decomposition of the waste. If no water source is available then the compost should be made during the rainy season.

   A well drained and levelled ground is important too. Natural shade such as a tree or a purpose built shade structure will help to reduce evaporation. The compost site should also be an appropriate distance from short term crops such as vegetables to avoid the risk of contamination, especially if animal waste is used.

2. **Collection of materials:** Compost requires a mixture of materials. Fresh green materials should comprise about 75% of the compost mix and dry materials the other 25%. A good balance between wet and dry materials is important because if too much fresh wet material is used there will not be enough air available for the microorganisms to break down the waste and nitrogen will be lost. This will result in a pungent compost heap. Similarly, if there is not enough fresh material the microorganisms will not have enough food and again the waste will not be broken down into compost.

   Good sources of fresh material include weeds (but not persistent perennial weeds), grasses and any other plant materials cut from inside and around fields, in clearing paths and in weeding. Crop residues are another good source of fresh green materials, especially after harvest. Dry materials can take the form of dry grass, hay and straw left over from feeding and bedding animals. Animal bedding is very useful because it has been mixed with the urine and droppings of the animals. Dropped leaves and prunings from almost any tree and bush except those which are especially woody also provide a good source of dry material.

Only 10% of the total material should be 'woody' as this is difficult for the microorganisms to break down. Woody materials should be chopped into pieces 5–10 cm in length before use.

Whenever possible animal manure should also be added to compost as it accelerates the composting process and results in a compost of higher nutritional benefit. Ash can also be spread in thin layers between the other materials. Soil rich in organisms or old compost should also be mixed into compost because soil contains a ready source of microorganisms which are vital to the composting process.

Materials for composting

- A mix of fresh green and dry brown materials
- Manure should be added when possible
- The addition of rich soil or old compost provides the microorganisms that break down the organic materials
- The compost must be wet and hot to aid decomposition of the organic materials

Materials not to use for composting

- Materials from diseased or pest infested plants
- Plants that have been sprayed with pesticides or herbicides
- Materials with hard prickles or thorns or large amounts of woody materials
- Persistent perennial weeds
- Eucalyptus leaves as they are acidic and hard to decompose
- Plants with milky sap e.g. Euphorbia spp

3. **Digging a base for the compost heap:** The compost heap can be started in a shallow pit of around 2 feet deep. This ensures that the compost heap is steady and will not fall over. It also helps to keep the moisture in the compost heap. The diameters of the pit will determine the size of the compost heap and it should be 1.5 meters wide and as long as is needed based on the amount of material available for composting. The soil at the bottom of the pit should be loosened to increase microbial action.

   TOP TIP: The soil extracted from the pit should be saved for use in the compost layering.

4. **Layering the compost:** Once a pit has been dug, the compost heap should be built up in layers.

   Layer 1: The first layer should comprise of 30 cm of prunings from a tree or bush or maize stalks. This is to ensure that drainage of the compost heap can happen. This initial layer should be watered well.

   Layer 2: 3 - 5 cm of soil (pesticide free). This provides the microorganisms

   Layer 3: 3 - 5 cm of manure (optional)

Layer 4: 20 - 30 cm of chopped fresh green material

Layer 5: Sprinkling of ash (optional)

Layer 6: Sprinkling of water

This layering should be repeated until the compost heap is around 1 – 1.5m high and finished with a layer of green material. Make sure to water each new layer well to create humid conditions. As for composting, aerated conditions are needed, the compost heap should not be stamped. A well-made heap has almost vertical sides and a flat top.

Figure 13: Building a compost heap

5. **Covering the compost:** The final compost heap should be covered with a 10cm layer of soil, to prevent gases from escaping from the compost pile. Lastly, cover the whole pile with dry vegetation or banana leaves to prevent loss of moisture through evaporation.

6. **Inserting a compost temperature checking stick:** Take a long, sharp, pointed stick and drive it into the pile at an angle. The stick helps to check the condition of the pile from time to time. After one week, pull the stick out and place it on the back of the hand to feel the temperature. The temperature of the compost should be checked every 7 days. If a problem is found, check the compost every 3 days until it is back in good health and the stick is presenting as 'warm'.

   Warm stick: If the stick is warm then decomposition has started and is normal.

   Cool/cold stick with no compost on the stick: If the stick feels cool or cold the temperature is too low. This may also be demonstrated by white mould growing on the stick. A low temperature usually means that the materials are too dry, and some water should be added. Lift the top layers of the compost and add water. Replace material in layers of 25cm adding water along the way until the heap has been replaced. If the temperature is still cold when the stick is rechecked in 7 days, the compost has stopped working. Pull the compost out, mix to aerate and rebuild the compost heap.

Bad smell: If the stick is warm and wet and there is a very bad smell like ammonia, this indicates that there is too little air and too much water in the compost. The materials will be rotting and not making good compost. Lift the top half of the compost and add dry material to the bottom portion of the compost. Observe the top materials, if they are wet and decaying, put in alternate layers of new dry plant materials with the wet materials. If the top materials are moist and brown showing compost making has started, put them back as they are.

Very hot and/or smoking: If the heap is very hot it means that more water is required. Add 3 – 5 buckets.

Testing for heat and moisture should be done every 7 days until mature compost is made.

7. **Keeping the heap moist:** If the compost heap is made during the dry season then it should be watered every three days to ensure that moisture is present. This is necessary to help the microbes break down the organic materials into compost. Constructing the compost heap in the shade and keeping it covered with soil and dry materials will also help to keep the moisture in the compost heap during the dry season.

8. **Turning the compost:** The compost heap can be turned after 21 days (3 weeks). Before the heap is turned, a new hole of the same proportions should be dug next to the original hole. Remove the soil and dry material covering the heap and put to one side for later use.

   Pull the top and side layers of the compost pile into the bottom of the new hole so that they form the middle of the new compost pile. This ensures that all materials in the compost pile go through the proper composting process. Do not add any extra materials to the compost pile. Recover the compost with the soil and dry material and leave for a further 21 days when the process is repeated a second time.

The final compost will be ready after the third turning, about 60 days.

KEY POINT: The compost will be ready when the temperature will be constantly low and the materials well broken.

Facilitating with farmers
It is recommended that extension officers take the farmers to a demonstration farm in the community and demonstrate the construction of a compost heap. The demonstration should be used to discuss the importance of the different input materials and go through the important steps in compost development including how to identify if compost needs more water or more dry materials.

Using compost on a tea farm

Mature compost will be black-brown in colour and have a pleasant small. Once ready it can be used immediately or stored until it is needed. If stored, the compost should be kept moist and covered with a layer of dry material such as banana leaves or topsoil.

There is no such thing as adding too much compost to the soil. Instead, because there is a limit to the amount of compost a farmer can make, it is important to apply compost so that it has the biggest benefit to the crops as possible. Compost should thus be added to the soil so that it can be used as a source of nutrition and moisture by the intended plant.

It is likely that farmers will decide to apply compost to the crops in their kitchen gardens rather than their tea fields however compost can be beneficial to tea plants as it will increase the water holding capacity of the soils and thus increase productivity in the dry season. Compost will also provide nutrients to the tea bushes. If farmers decide to add compost to their tea fields the best times to do this is after pruning when space is available. The compost should be lightly dug into the soil. Compost can also be added to the soil when infilling gaps on the farm with new tea bushes. Adding compost is a beneficial way to increase soil fertility and improve growth of young immature tea bushes.

Compost is typically added to vegetable fields. Where crops are being planted, it is best to mix compost with top soil and apply it into the planting holes. Compost should be applied first to plants with high nutritional demand such as tomatoes. If seeds are being sown, compost can be mixed into the topsoil prior to planting. Compost is beneficial in seed beds but it must be well composted before being applied. Compost can also be hoed into the topsoil as a top dressing.

For further guidance on compost making please consult one of the following documents

- FAO ‘How to make and use compost’ http://www.fao.org/docrep/014/i2230e/i2230e14.pdf
- FIBL (2011) Soil Fertility Management http://www.organic-africa.net/fileadmin/documents-africamanual/training-manual/chapter-02/Africa_Manual_M02_low.pdf
- FAO ‘On farm composting methods’ ftp://ftp.fao.org/agl/agll/docs/lwdp2_e.pdf

4.2.2 Soil Management: Adaptation Option 5 – Green manures

Green manures provide a second way in which to add organic matter to the soil, increasing the health of the soil and providing nutrients for plants. Green manures are plants that are grown in the soil with the purpose of incorporating them back into the soil to increase organic matter. Green manures also provide a cover for the soil and will prevent erosion in times of heavy wind and rain and reduce evaporation in times of increased temperature. Thus, green manures help in combating climate change through increasing the health of plants, making them stronger and more robust and protecting soils from changing weather patterns.

This manual does not cover green manure application but further information may be obtained from one of resource in the box below.

For further guidance on green manures please consult one of the following documents

- Green manure action sheet (PACE Project) http://www.paceproject.net/Userfiles/File%5CSoils%5Cgreen%20manure.pdf
- Kenyan Institute of Organic Farming (KIOF): www.kiof.org
- FIBL (2011) Soil Fertility Management http://www.organic-africa.net/fileadmin/documents-africamanual/training-manual/chapter-02/Africa_Manual_M02_low.pdf

4.2.3 Soil Management: Adaptation Option 6 - Liquid Fertilisers

As well as adding soil organic matter to soil in the form of compost or green manures, the addition of liquid fertilisers can also help to improve soil fertility, especially when soils are deficient in certain nutrients.

Liquid fertilisers can be made on the farm and provide a cost effective solution in comparison to chemical fertilisers. Liquid fertilisers can be made from animal manures or chicken waste creating 'liquid manures', compost producing 'compost tea' or specific green plant materials which can produce 'plant tea'. Liquid manures and plant tea provide a good source of nitrogen and compost tea provides a more balanced general fertiliser.

Liquid fertilisers are mostly used in vegetable gardens and it is important to apply them correctly. Liquid manures in particular should not be sprayed onto plants but instead should be added to the soil so that plants can absorb the extra nutrients through their root systems.

Making Liquid Manure

Fresh manure from cattle, chickens, goats, sheep, rabbits can be used to produce liquid manure. The procedure for its production is as follows;

1. Fill a bag (preferably a nylon 'gunny' bag) with about 50 kg of manure and tie it securely with a rope. Hang the bag with the manure to a pole placed over a 200 litre capacity drum to allow it to suspend into the drum, then fill the drum with water so that it just covers the manure filled gunny bag. If a smaller drum is used then the manure should take up about half the space of the drum by volume.

2. Cover the drum, such as with a polythene sheet, and let it stand under shade.

3. Stir the mixture in the drum every 3–5 days by partially lifting the bag in and out of water several times using the pole.

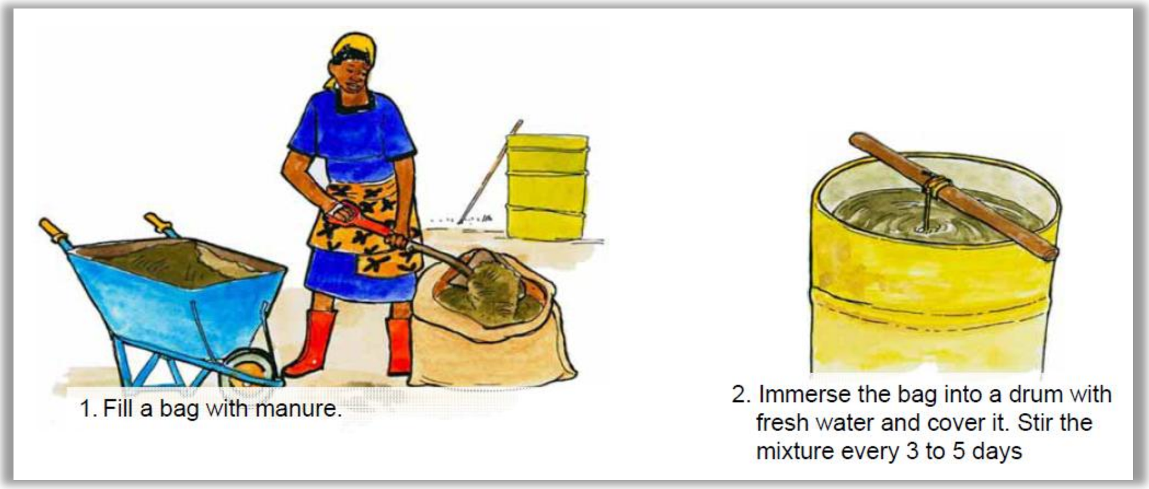
4. After 2–3 weeks, the water will have turned dark and most of the nutrients will have been dissolved into the water. The darker the colour, the more concentrated the mixture. It is then ready for use. Remove the bag from the drum and the water solution is ready for use.

5. Dilute the liquid manure with 2 parts of water for every 1 part of liquid manure. However, if the liquid manure is very concentrated (very dark) use 3 parts of water to every 1 part of liquid manure.

6. Apply the liquid manure to the crops, giving between 1/2 to 1/4 litres per plant starting 2–3 weeks after planting. Apply the liquid manure around the stem and not on the leaves. Repeat the application every 3–4 weeks. Apply in the early morning or evening or on cloudy days.

KEY POINT: Liquid manures should not be used as a foliar spray and should be added to the base of plants.

Figure 14: Liquid manure production (FIBL 2011)



TOP TIP: If the farmer has a drip irrigation kit installed, liquid fertilisers can be easily be added to the plants using the drip system as long as the liquid is strained to remove sediment and a suitable filter has been installed on the drip irrigation system to ensure that there is no clogging of the drip lines .

Making Plant Tea

To make plant tea, nutrient rich material is soaked in water for several days or weeks to undergo fermentation. Frequent stirring encourages microbial activity. The resulting liquid can either be used as a foliar fertiliser or be applied to the soil.

Plant tea can be produced using the following steps:

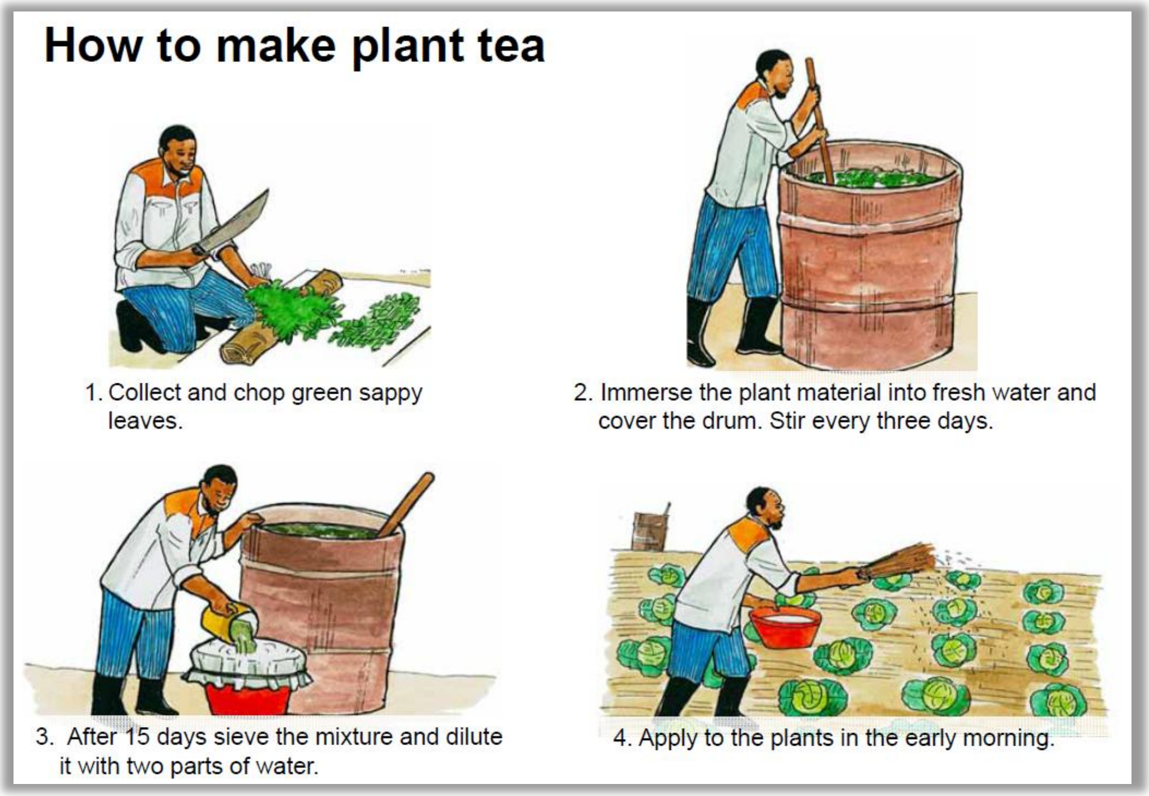
1. Chop the green plant materials like tithonia (Mexican sunflower), comfrey, maigoya (plectrunthus barbatus), nettle, velvet bean, castor bean, amaranth, pigeon pea or any other sappy material, and put in a drum or any sizeable container until it is about three quarters full. Fill with water and keep it under shade or cover to prevent excessive evaporation.

2. Stir every three days and the mixture will be ready in about 15 days.

3. Remove the remains of the plant material, sieve the mixture and dilute the tea with 5 parts water for every 1 part of tea. Apply the diluted mixture as a top dressing, giving between ½ to ¼ litres per plant for as long as is needed. If using on seedlings it should be diluted to 10 parts water to one part plant tea.

KEY POINT: The plant tea is too strong to use without dilution.

Figure 15: Plant tea production (FIBL 2011)



5. Water Conservation and Management

Kenya has huge amounts of rain but in the dry season there are often droughts. The frequency and severity of droughts are increasing as a consequence of climate change and this pattern is predicted to further intensify. Moreover, the timing and patterns of rainfall are becoming increasingly uncertain placing water conservation and management high on the agenda in arable areas.

Water is one of the most import requirements for good tea growth and is a limiting factor in terms of crop yields. There are many ways in which farmers can take action to improve the water content of soils and many of these have already been discussed in this manual. Activities such as terracing, contour ridging and minimum tillage increase rainwater infiltration into the soil. Mulching and cover crops help to keep water in the soil through reducing evaporation. The addition of organic matter, in particular compost, significantly increases soil's ability to hold and retain water.

However, even with all these initiatives, in times of drought, there may be the need for farmers to add extra water to the soil. This can be achieved through a process that captures rainwaters during the rainy season, called 'rainwater harvesting' and stores it for use in the dry season, called 'water storage'. Water can then be distributed to the required crops using a simple 'drip irrigation' set. This chapter of the manual provides technical advice on how low cost rainwater harvesting and drip irrigation can be installed on smallholder farms.

Facilitating with farmers

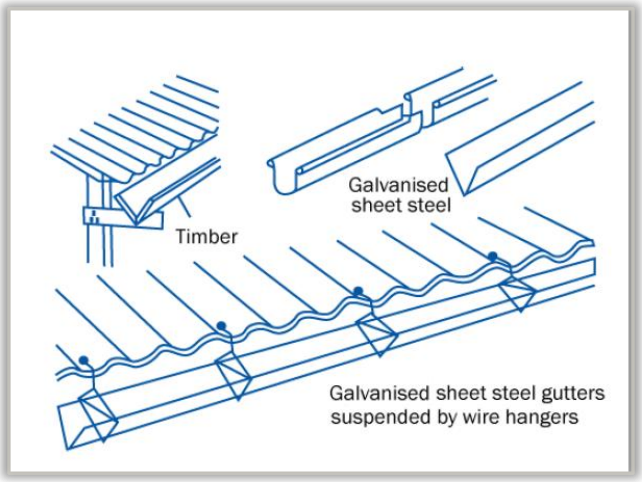
Ask the farmers about how they harvest and store water in the area. Do they practice any measures to ensure maximum harvesting and storage of rainwater?

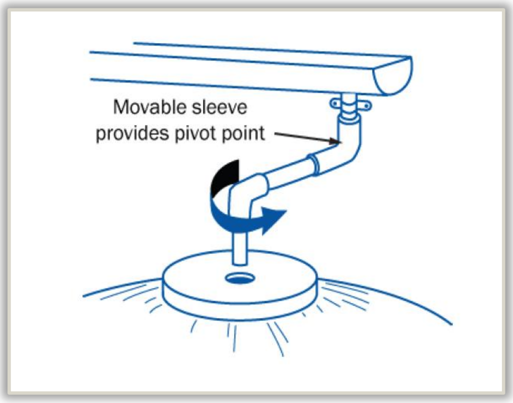
5.1 Water Conservation and Management: Adaptation Option 1 - Rainwater Harvesting and Storage

Rainwater harvesting is the collection of rainwater as it runs off a surface. The easiest place to catch rainwater is from a roof where the rainwater is collected as it runs off the roof into guttering. The guttering can then direct the rainfall into a collection tank. Low cost guttering can be made from 22 gauge galvanised mild steel sheeting and bent to form a 'V' shape. Alternatively, cheap 4-5 inch PVC pipes can be used and split through the middle to form gutters. The guttering can then be attached to the roof using a galvanised wire stitching, wooden brackets or other means. The guttering is used to directly guide the water into a water storage tank or a drain pipe/duct can be fixed to the end of the guttering for the same purpose.

The water storage tank will likely be the most costly aspect of the rainwater harvesting system and can range from a small food container to a purpose built tank. The size of the tank should be chosen in relation to the water requirements of the farm, the availability of space, and the cost of the tank, materials and labour. Storage tanks can be made of natural pods (e.g. calabash, gourds), clay (e.g. pots), canvas, porcelain, fibre glass, concrete, sheet metal or plastic.

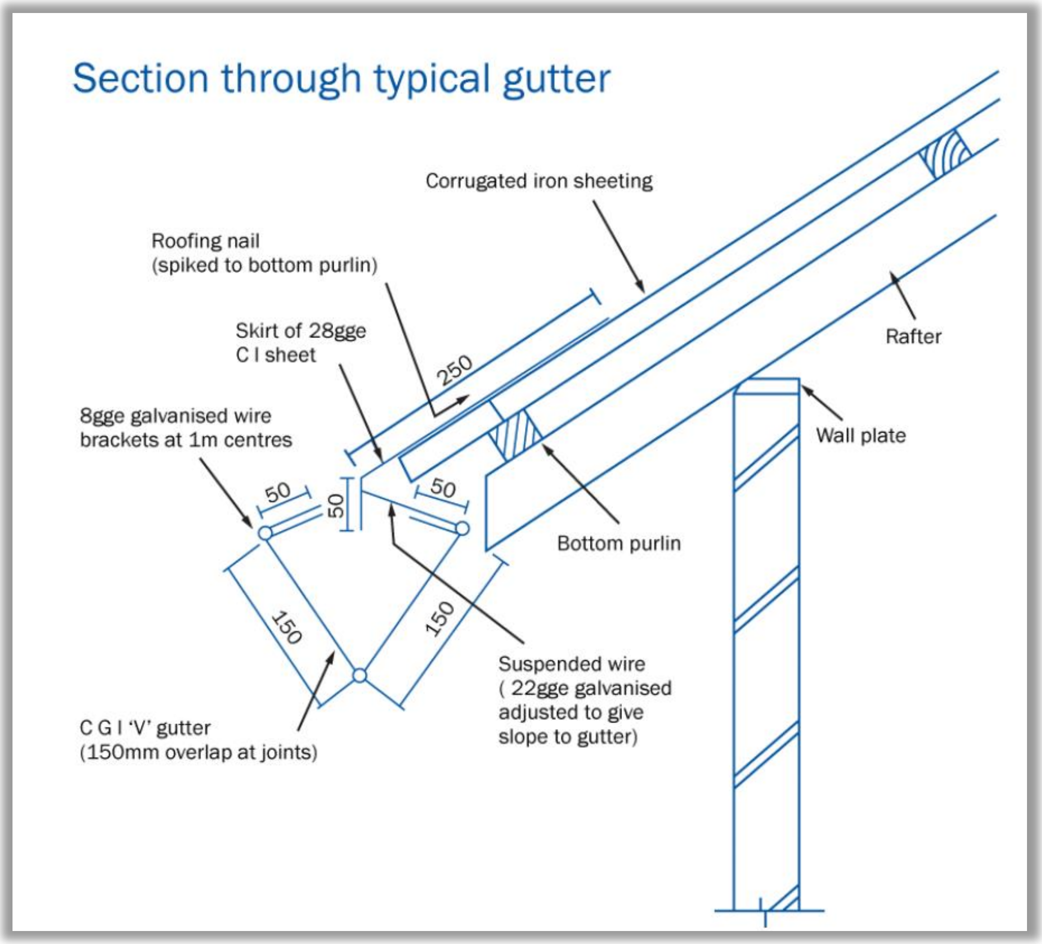
Figure 16: Examples of guttering (WaterAid 2011)





Debris, dirt and dust will collect on the roof during the dry season. It is therefore important to prevent this material from flushing into the water collection tank. The easiest way to do this is to disconnect the rainwater harvesting system from the tank during the dry season. Once the rains come, the water will wash the roof and the guttering. When the water is running clean, the system can be reconnected and the rainwater diverted into the collection tank. Other more complex solutions exist, such as the use of a tipping gutter or floating ball system. Further information on these initiatives can be found in the referenced resources at the end of this section.

Figure 17: Example guttering (WaterAid 2011)



KEY POINT: Disconnect the rainwater harvesting system from the tank during the dry season to ensure debris does not end up in the tank.

The second way to collect rainwater is to collect runoff water from the ground and collect it in a small reservoir, pond or underground tank. This is not currently covered by this manual. Further guidance can be found in the document produced by PACE referenced below.

For further guidance on rainwater harvesting please consult one of the following documents

- Practical action: Rainwater Harvesting Technical Brief
  http://practicalaction.org/docs/technical_information_service/rainwater_harvesting.pdf
- Water Aid (2011): Rainwater Harvesting
  http://www.wateraid.org/documents/plugin_documents/rainwater_harvesting.pdf
- PACE project: Rainwater Harvesting - Action Sheet 14
  http://www.paceproject.net/Userfiles/File/Water/Runoff%20rain%20harvesting.pdf

5.2 Water Conservation and Management: Adaptation Option 2 - Cost Effective Drip Irrigation

Drip irrigation is a method that allows water to be applied to plants through a network of pipes. Drip irrigation has many benefits including the following:

- Helps to increase crop yields as plants put energy into growth instead of searching for water
- Highly efficient use of water with water savings between 30 - 70%
- Easy and accurate fertiliser application thus reducing fertiliser requirements
- Low cost option for small scale farmers
- Reduces labour input
- Reduced weeding as water is only dripped where the crops are and suppressing weed growth
- When combined with rainwater harvesting, allows effective crop growth during droughts
- Increased control over market timing for crops as not dependent on rain

Drip irrigation setup

The setup of a low cost drip irrigation system is relatively straight forward. However, it is necessary to have the right equipment. This can be purchased from an agricultural supplies store.

Step 1: Tank location

The first step in setting up the drip irrigation is locating a suitable tank for holding the irrigation water. The tank must be of a suitable size, sturdy and have a lid to prevent water evaporation and loose materials from falling in. Plastic tanks are available from hardware shops countrywide. A simple drip irrigation system is 'gravity fed', this means that the water flows through the system by gravity. It is therefore important that the water tank is located at a point 'higher' than the pipe system to allow the water to flow through the system without the need for a pump. If there is no natural site for the tank then a suitable structure should be built using local materials such as bamboo or wood. The structure (tank platform) should be 1.5-2 meters above ground to allow the water to flow easily through the pipe system.

Step 2: Affixing pipe, valve and filter to the tank

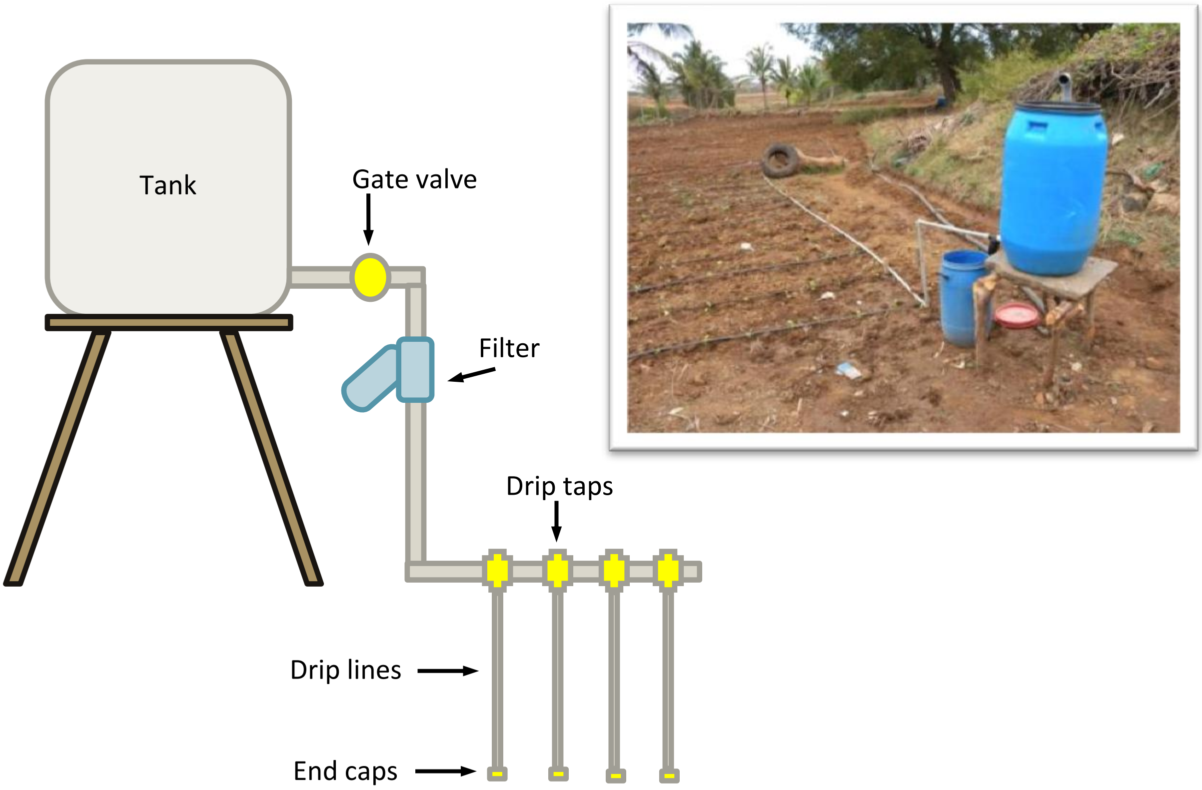
The second step in setting up the drip irrigation kit is to make a hole near the bottom of the tank so that a piece of solid piping can be attached to the tank for the water to exit from. The hole is made 3-5cm from the base of the tank using a hot metal rod. Next, a galvanized iron nipple is driven through the hole and secured both on the inside and outside of the tank using

two back-nuts. It may be necessary to use a pipe wrench or large pliers to tighten the nuts. Once the pipe has been attached a 'gate valve' must be attached to the pipe to control the flow of water. After the valve a screen filter should be attached to the pipeline. The filter is important as it will remove any sediment within the water. If the water is not filtered then there is the risk that the drip line drippers will become blocked and no longer work. The filter should be easily removable so that it can be regularly washed.

KEY POINT: Always use a filter and ensure it is well maintained to prevent the drip lines from blocking

Once the filter has been attached, vertical piping should be fitted to the ground level pipes that run to the location of the field that requires irrigation. The pipe should be solid ¾ inch PVC or PPR piping. This is to ensure that the drip taps can be effectively installed as detailed in step 3. It is also recommended that the distance between the location of the water tank and the drip lines is as short as possible as this will both reduce costs and reduce the potential for damage and leaks.

Figure 18: Drip Irrigation set up

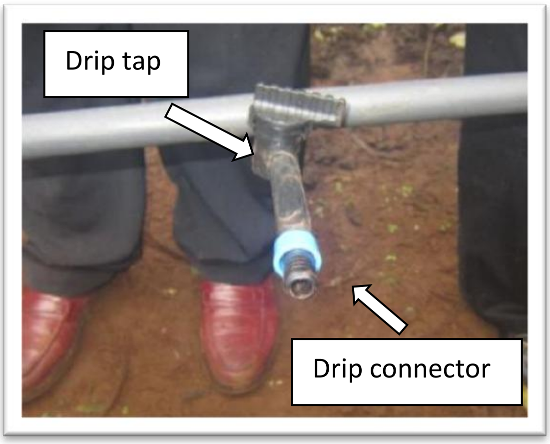


Step 3: Fixing drip taps

The next step is to fix drip taps to the ground level piping. Holes should be made in the piping. This can easily be achieved through the use of a hot 15mm metal rod as demonstrated in figure 13 below.

The drip taps should be spaced along the pipe at the same spacing as the crops that the irrigation system will water. Care should be taken to make sure the holes are at regular intervals and on a straight line to ensure the drip lines all lie flat on the ground. Once holes have been made the drip taps can be attached. First, a rubber seal (glomet rubber) is inserted into each of the holes on the pipe to ensure that there is no leakage. Next, the drip tap is inserted. At the end of each tap a short piece of PVC/PPR pipe (5-10cm) is fitted. This will serve as a receptacle for the drip connector, or 'starter' connector. The drip connector is then attached and is used to connect the drip lines to the drip taps.

Figure 19: Drip Irrigation – Fixing the taps



Step 4: Laying the drip lines

Once the taps have been connected, the next step is to 'lay' the drip lines. Drip lines are available for different crops depending on crop spacing so it is important to ensure that the correct ones are used. This should be discussed with the agricultural supplier. The drip lines should be placed along the lines of crops so that when they are turned on they feed the plants with water. If the field is being prepared for planting, the drip lines should correspond with the recommended spacing for the particular crop to be planted. It is important to ensure that the drip lines are laid flat with the drippers facing upwards and ensuring that there are no twists or kinks as this may damage the drip lines. Once the drip lines are in the correct position, connect each of them to the drip connector by pushing the drip line into the space between the drip connector and its loose cap. To secure the system in place, drive wooden pegs into the ground around to secure the pipe and drip connectors. At this stage the gate valve on the water tank should be opened to flush the system and allow water to remove any dirt or debris from the pipes. Finally, stretch each drip line and attach an end cap to its end. The end caps have a hole in them which can be used to drive a wooden peg through to secure the drip lines in place.

Figure 20: Drip Irrigation – Laying the drip lines

Maintenance of drip irrigation

It is very important to remember to keep the filter of the drip irrigation system clean. If using municipal water the filter should be cleaned once weekly or fortnightly. If using any other water, such as water from a river or from rainwater harvesting, the filter should be washed at least weekly. If the water appears visibly dirty then the filter should be washed after every use (daily). To clean the filter it should be placed in soapy water and left for 10 minutes and then rinsed. Avoid scrubbing as the filter is delicate and any abrasion will cause it to tare.

KEY POINT: Ensure the filter is regularly cleaned to stop the drip kit tubing from getting clogged with dirt. Do not scrub the filter as this will damage it.

It is also recommended to flush the whole system out once a week to ensure that sediment does not build up in the pipes and damage the drip irrigation system. To do this, the drip irrigation should be turned on using the main valve and the drip lines flushed by taking off the end caps. The water should be left on until it runs clean, and then turned off and the end caps replaced.

Facilitating with farmers

Demonstration: The best way to facilitate this topic with farmers is to set up a drip irrigation system on a demonstration farm. The activity should be conducted in a manner that allows the farmers to participate and learn the techniques for themselves so that they have the confidence to set up drip irrigation systems on their own farms if there is a benefit in doing so.

Figure 21: Drip Irrigation Kit list

DRIP KIT REQUIREMENTS FOR A 25 FOOT PLOT (CURRENT)	
ITEM	**NUMBER**
BACK NUT	2
NIPPLE	2
LONG NIPPLE	2
ELBOW	1
GATE VALVE	1
TEE	1
VALVE SOCKET	2
PPR STAND	1
P.E. PIPE	6
CONNECTORS	12
RUBBERS	12
FILTER	1
DRIP CAPS	12
DRIP TAPS	12
DRIP LINE	100
TANK (100L)	1
Targit glue	25ml
16mm PE pipe	1
3/4 Gi end caps	2
Thread tape	1 roll
The Piping & fittings are of 3/4 inch diameter.	

For further guidance on drip irrigation:

- http://www.ideorg.org/OurTechnologies/IDEal_Drip_Technical_Manual.pdf
- Low cost drip irrigation manual http://www.rcsdin.org/DRIP%20tech%20manual.pdf

6. Food Security

Climate change will reduce food security across Kenya. It will make common food items less available due to crop failures and reduced productivity, it will increase the cost of food and it will change utilisation patterns. This will likely have an impact on human health, livelihoods, food production and distribution networks, as well as changing purchasing power and market flows. The impacts of climate change on food security will be both short term, resulting from more frequent and more intense extreme weather events, and long term, caused by changing temperatures and precipitation patterns.

People who are already vulnerable and food insecure are likely to be the first affected. Specifically smallholder tea farmers are facing an immediate risk of increased crop failure, new patterns of pests and diseases and a lack of appropriate seeds and planting material that performs well under the changing environmental conditions. It is thus important to strengthen the resilience of smallholder tea farmers by increasing their food security so that they can continue to feed themselves and their families in coming years.

Food security can be defined as ensuring that people are free from hunger and can access the food they need for an active and healthy life.

Food security can be addressed in a number of different ways:

- Increasing the productive output from kitchen gardens
- Increasing the range of food products produced in kitchen gardens (diversification)
- Producing hardy indigenous and drought tolerant food crops e.g. cassava, arrow roots
- Increasing the intake of nutritional food

Key adaptation options covered in this chapter:

- Increasing the productivity of kitchen gardens
  - → Adaptation option 1: Efficient planting (page 63)
  - → Adaptation option 2: Multi-storey Gardens (page 64)
- Increasing the intake of nutritional food
  - → Adaptation option 3: Learning about highly nutritious foods (page 67)

Kitchen Gardens role in food security

A kitchen garden is an important tool to reduce the likelihood of tea farmers experiencing hunger. Kitchen gardens enable a family to maintain a sufficient food supply that is high in nutritional value. In addition, families can reduce their need to purchase food from local markets and can instead generate income by selling the surplus, providing a secondary source of income to supplement that from tea, especially during the dry season when harvests are low.

It is thus recommended that every household learns how to establish and maintain a Kitchen garden. The kitchen garden should contain a diverse mix of crops including indigenous vegetables, cereals and root crops designed to provide a balanced diet to the family.

A key problem for Kenyan tea farmers is the scarcity of land for kitchen gardens and it is thus important to work to increase **productivity** to ensure that the maximum crop output is being produced from the available land. There are a number of ways in which this can be achieved. First it is important to ensure that the soil is in the best condition possible so that it can provide the plants with nutrients and water for growth. Techniques to maintain and improve soils are detailed in chapter 4 of this manual. Next, water harvesting and irrigation provide useful means to extend the growing season during dry months and are thus also useful ways to increase crop productivity (chapter 5). In addition to these techniques this section of the manual discusses efficient planting and multi-storey gardens as further approaches to increasing the productive output from kitchen gardens.

Facilitating with Farmers

Ask the farmers to discuss the importance of kitchen gardens.

- What do they currently grow in their kitchen gardens?
- Do they provide their families with a highly nutritious and healthy diet?
- What are the benefits and disadvantages of increasing the diversity of crops in their kitchen gardens?
- What other crops will they consider growing?

6.1 Food Security: Adaptation Option 1 - Efficient planting

A key way to increase the productivity in a kitchen garden is to use efficient/intensive planting techniques so that the maximum number of plants can be cultivated on any given piece of land. The first step in developing an efficient bed is to prepare the bed properly before planting. To do this, farmers can use the double digging technique detailed on page 38 and add compost to the soil to increase the soil's ability to provide nutrients and water to the new plants. It is recommended that beds are approximately 4 feet wide as this enables easy access from either side of the bed for watering and weeding.

KEY POINT: It is important to never walk on a prepared bed as this will compact the soil and reduce root growth.

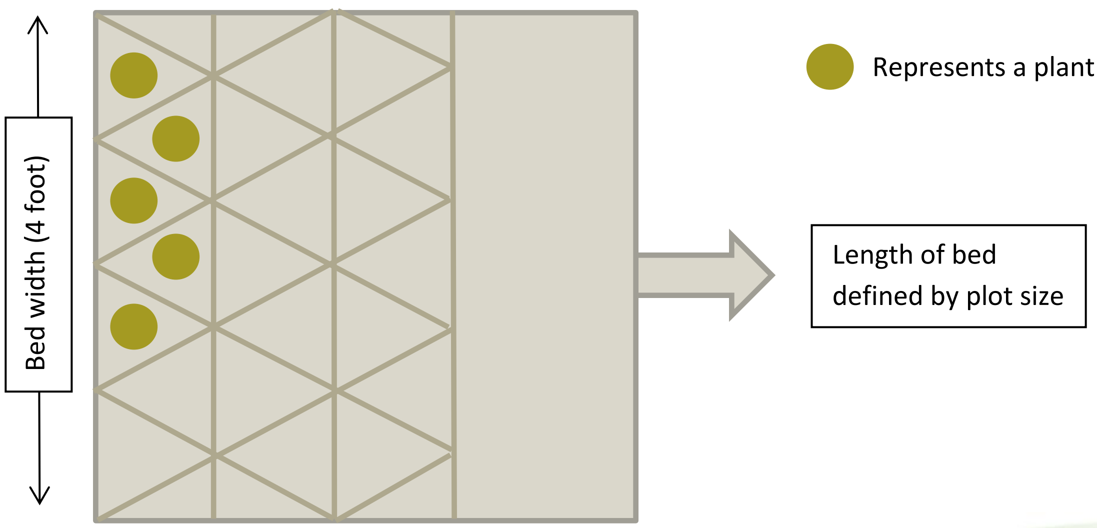
What is efficient planting?

Typically plants are planted in rows, however by shifting each row diagonally, it is possible to plant more efficiently and fit more plants into a bed. This is demonstrated in Figure 22. The advantages of this method of planting is that you maximise the utilisation of available space, water use is more efficient because you are not watering empty ground, and when the plants mature, you have few weeds since the plants fill in and cover the ground. The intensive method works best with plants with larger seeds or with plants that are started ahead of time, then transplanted into the kitchen garden.

Planting method

The easiest way to plant seeds or plants using the efficient planting method is to make a triangle from sticks, bamboo or cardboard with each side of the triangle the same length as the spacing distance. For example, for crops that should be grown at 1 foot spacing, the triangle should measure 1 foot on each side. The triangle is then placed on the prepared bed and used to identify the location of each planting spot.

Figure 22: Efficient planting



6.2 Food Security: Adaptation Option 2 – Multi-storey Gardens

Multi-storey gardens provide a means of increasing food security. Multi-storey gardens are small vegetable gardens that are built in sacks that allow ample food to be grown when there is a limited amount of land available or where land is of poor quality. There are many benefits of multi-storey gardens which include the following:

- They are water efficient and thus useful for growing vegetables in times of drought
- Cheap and easy to construct
- Allow crops to be grown when land is limited
- Many different types of crop can be grown in one sack
- They can be located next to the homestead for easy and quick access.
- Provide opportunities for income diversification

Multi-storey gardens are particularly effective in situations where farmers have little land available for growing vegetables or when available land is dry and not fertile. They are also suitable for extending crop growth into the dry seasons as they are very efficient in terms of water requirements.

Figure 23: Multi-storey Gardens

Constructing a multi-story garden

Multi-storey gardens are easy to construct using easy to access materials which include a 90kg sack, metal oil cans, stones, soil and compost. In a multi-storey garden the sack is filled with soil and manure and then food crops such as leafy vegetables, kales, carrots, tomatoes and traditional vegetables are grown both in the sides and on top of the sack. The sacks have a column of stones in the middle which supports water infiltration ensuring that water reaches all the crops in the sack. The stones also help with aeration and provide a holding point for the plants roots.

Equipment Required

- Tin can (e.g. oil can)
- 90kg sack (e.g. cereal bag or animal feed bag)
- 2 buckets of gravel (small stones)
- 6 buckets of soil
- 6 buckets of manure / compost
- Seeds/ seedlings
- Water

Tools Required

- Jembe - To dig the soil that will be mixed with other components for constructing the garden
- Spade - To collect and mix the soil components
- Tin snip/Knife - To cut off the top and bottom parts of the tin
- Wheelbarrow - To measure and transport the various materials.

Multi-storey gardens are simple to make using the following steps:

1. Mix the soil and the well rotted manure or compost thoroughly
2. Cut off the bottom of a 4 litre oil can
3. Tie the bottom of the sack so that it makes a round shape
4. Fold back the bag and place the can in the bottom at the centre of the bag.
5. Fill the can with small stones(3-5cm diameter)
6. Fill the area between the oil can and the bag with the soil-manure mixture up to the can level.
7. Pull up the can to the level of the soil compost mixture with a tilting motion carefully leaving the stones intact. Then fill the oil can once again with stones and add soil compost mixture as before.
8. Repeat steps 5, 6 and 7 until the bag is full and a central core of stones is formed leaving the tin at the top of the bag garden.
9. Pour water into the tin through the central core till the soil is soaked.

In areas where water is in short supply, this is a very economical way to utilise extremely limited resources. Each bag only needs to be watered twice daily with 5 litres of water. The water is poured into the tin at the centre of the bag and drains through the stones down through to the bottom of the bag of soil, irrigating all the plants throughout the depth of the bag. It is recommended to use household waste water after rinsing out clothes or bathing, and also waste water from around water points. However, it is important to incorporate and integrate waste management into the programme so as not to further limit water resources necessary for other activities. A standard kitchen garden requires much more water than that used in the MSG approach.

Suitable vegetables for growth in a multi-storey garden include green leafy vegetables such as spinach and kale, capsicums, cabbage, tomatoes, okra and amaranthus.

Figure 24: Building a multi-storey garden

Additional sources of information:

- Multi-storey garden training manual: http://www.unhcr.org/4b7becf99.pdf

6.3 Food Security: Adaptation Option 3 – High Nutrition Foods

Food insecurity is usually associated with malnutrition because the diets of people who are unable to satisfy all of their food needs usually contain a high proportion of staple foods and lack the variety needed to satisfy nutritional requirements. Climate change is likely to increase the number of people who are food insecure due to a decline in the availability of wild foods, limits on small-scale horticultural production due to the scarcity of water and increasing food prices at markets making people increasingly reliant on a small range of food crops. It is therefore important to encourage farmers to grow a range of crops in their kitchen gardens to ensure that they can have continued access to foods that will provide them with a healthy and nutritionally balanced diet.

A nutritionally balanced diet is a diet that contains the right proportions of macronutrients (proteins, carbohydrates and fats) and micronutrients (vitamins and minerals). It requires eating a variety of foods from each food group because no single food can supply all the nutrients our bodies need.

The important components of diet

Food contains a range of nutrients; proteins, carbohydrates, fats, fibre, vitamins and minerals. These nutrients are vital for the body to help it to move, think and work. Food also contains important substances which keep our bodies strong and healthy, help to boost our immune system and protect us from infections. When we eat, our bodies absorb useful nutrients into the blood system where they are transported to areas where they are needed. These include the bones, the muscles, the brain and the organs.

To remain healthy it is important to have a diet that contains the following core elements:

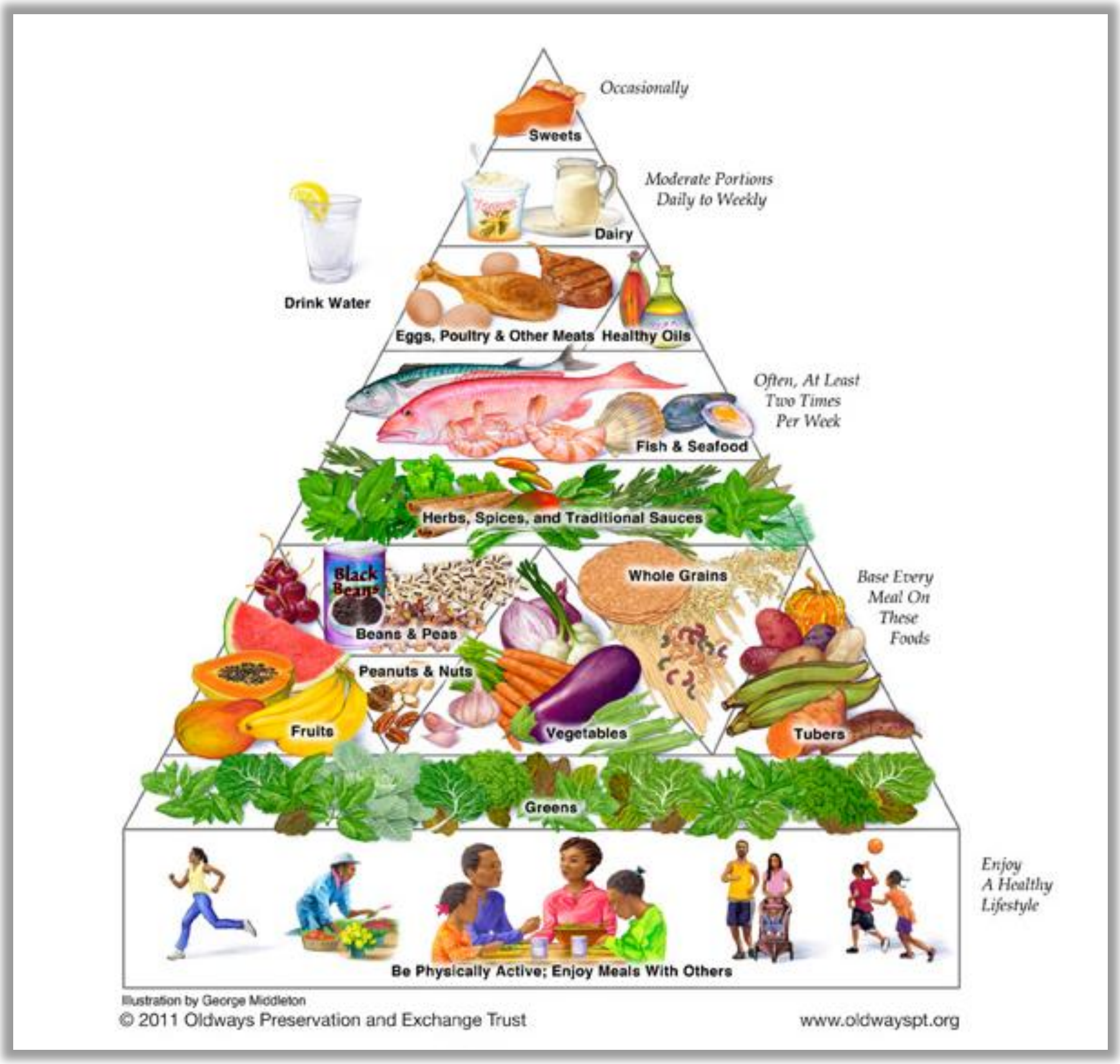
1. Proteins

Proteins help our bodies to grow, maintain and repair themselves. Also called body-building foods, they come from leguminous plants including all peas, beans and pulses (e.g. green beans and other legumes, cow peas, pigeon peas, shelled peas, sugar beans, soya beans, ground nuts, lentils, chick peas), processed leguminous plant products (peanut butter and soya mince), processed animal products (cheese, sour milk and yoghurt) and animals (eggs, red meat, white meat, milk, insects).

2. Carbohydrates

Carbohydrates give our bodies energy to move, work and think. They also help to keep us warm. We get most carbohydrates from grain crops such as wheat, maize, sorghum, millet and rice, and root crops such as potatoes, sweet potatoes, yam and cassava. Carbohydrate that is not used immediately by our bodies is stored as fat. Too much stored fat can be unhealthy for the body.

Figure 25: The food pyramid (Oldways 2011)[5]



Eating large amounts of refined carbohydrate such as refined maize meal, white bread, white rice and white sugar is unhealthy. Refined foods are processed in factories to make them look tastier. Unfortunately, the refining process removes most of the important fibre, protein, minerals and vitamins these foods naturally contain. It is much better to eat unrefined staple foods with every meal as a cheap, healthy source of energy and fibre, as well as some protein, vitamins and minerals.

3. Fats

Fats can come from animal products such as milk, butter, meat and fish or processed plant products such as seeds and nuts (sunflower oil, sunflower, pumpkin and sesame seeds and peanut butter). They provide the body with energy. Avocadoes are also a good source of fat and contain energy and vitamins. Eating food with too much fat/oil is unhealthy for the body.

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[5] Oldways (2011) 'African Heritage Food Pyramid', http://oldwayspt.org/sites/default/files/images/African_pyramid_flyer.jpg

4. Vitamins and minerals

Our bodies need small amounts of Vitamins and minerals to help different parts such as the blood, eyes, bones, skin, body organs and hair work properly. Many of these substances help to strengthen the body's immune system and keep us strong and healthy so that we resist infections and diseases. Vitamins and minerals come primarily from eating fresh fruits and vegetables so it is important to eat a range of these each day.

5. Fibre

Apart from nutrients in food, the body also needs other substances. Among these is fibre. Fresh fruit, vegetables and unrefined grains and legumes contain fibre. It is important for helping our bodies to digest food and remove waste. It is important to eat fibre with plenty of water.

6. Water

Our bodies contain more water than any other substance. All chemical processes and body functions use water. We need to drink at least eight glasses of fresh, clean water every day to stay healthy.

Facilitating with Farmers

- Why do some families eat the same type of food every day (for example, ugali and vegetables)?
- What problems arise if we do not have different types of ingredients in our meals?
- How can we encourage families to have a more varied diet?
- What does your family eat in a typical day? How can this diet be made more nutritionally balanced so that it contains all the food groups?

Increasing the diversity in kitchen gardens

To ensure that farmers have a nutritionally balanced diet it is recommended that farmers grow a range of crops including traditional high nutritional value crops that allow the farmers to meet their nutritional requirements. These crops can include sorghum, millet, sweet potatoes, cassava, pigeon peas, cowpeas, green grams and dolichos. These crops can easily be grown and perform well under drought conditions.

Through increasing the diversity of crops grown in a kitchen garden it is possible to ensure that farmers and their families have healthy, balanced diets for optimum health and growth. They also allow farmers to save money and provide the potential for extra income generation.

While good quality seeds and fertiliser are major inputs in crop production, farmers often plant poor quality seeds and purchase their seeds from the informal seed sector and often continue to recycle seed that have declined in quality through generations of cultivation. Use

of poor quality seeds leads to low yields, food insecurity, poor nutrition and low household incomes.

TOP TIP: The ministry of Agriculture provides advice on the best crops and seed varieties to use that are tolerant of drought and other changing climate conditions in each location.

Cereal (Carbohydrate): sorghum and millets

It is important to choose the right cereal crops to grow and eat. Maize is a crop from South America that was introduced by traders about 200 years ago but became widespread only about 100 years ago. Before the introduction of maize, most people in Kenya ate sorghum and millet as their staples. These crops are indigenous. Maize is a good source of energy but it contains less protein, vitamins and minerals than millet or sorghum. Maize needs plenty of water and rich soils in which to grow. Thus, as climate change impacts negatively on water supply it may not be so easy to grow maize in the future. It is also susceptible to pests and diseases. Sorghum and millet are tough, nutritious crops that are well suited to the Kenyan climate and are more drought-tolerant, pest tolerant and disease tolerant than maize.

Dry land cereals, sorghum and millets, are recognized as important food security crops. Both crops require less water than maize thus offering great potential for supplementing food and feed resources while both can be consumed by farm household as “ugali”.

Roots/tubers (Carbohydrates): cassava, sweet potatoes,

Cassava is important in the economy of households and is mainly a subsistence crop grown for food by small-scale farmers. It adapts well in adverse and diverse agro-ecological zones with limited labour requirements. It provides food security during harsh seasons since it conveniently grows underground. Cassava could be intercropped with vegetables, mangoes, papaya, sweet potatoes, maize, millet, sorghum and other pulses. Sweet potato grows in marginal conditions, requiring little labour and chemical fertilisers. It is a cheap, nutritious solution in terms of growing more food on less area, and also provides high-protein fodder for animals. Cassava is also contributing significantly to consumption of subsistence farm households where the crop is mainly grown by small-scale farmers, with minimal inputs.

Pulses (proteins): pigeon peas, cowpeas, green grams

Pigeon pea is usually planted at the onset of October/November short rains. Farmers normally do not apply fertiliser for this crop although occasionally they use manure. Cowpea is another important legume grown in the study area. It is highly adaptable to different types of soil and intercropping systems. It is resistant to drought and its ability to improve soil fertility and prevent erosion makes it an important economic crop. The other important pulses include green gram and beans. The majority of grain legumes fixes nitrogen from the atmosphere, thus contributing significantly to the sustainability of soil fertility in the land cropping systems and hence reduces the requirements for inorganic commercial fertilisers.

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