RIDGE TO REEF PROJECT

SUSTAINABLE LAND MANAGEMENT

A TRAINING MANUAL

for local farmers in Tuvalu

FORWARD

Climate change impacts and increasing population pressures on the islands of Tuvalu, put many external pressures on the livelihood of people and the environment. Climate change bring uncertainties weather conditions creates great challenges for our people way of life especially in food production. This leads to many environmental problems such as Land degradation. Land degradation pose a significant challenge toward the implementation of sustainable development in Tuvalu.

Sustainable Land Management (SLM) can provide help in assisting local people with the urgent need to minimizes and control land degradation. This manual helps to provide a methodology for our local people to adapt to the impact of climate change and achieve increased environment resilience in Tuvalu.

This manual include modules that will introduces you to the problem of climate change and its potential threats to our vulnerable islands. Then more modules focus on how you can practice sustainable land management techniques, looking at nutrient management, soil and water conservation, agronomic practices, tillage and residue management, land restoration and rehabilitation, and integrated pest management. Each module simply guides through practices with detailed descriptions on how to implement the specific techniques.

These practices in this training manual can help build the knowledge of our local people on new techniques and also existing techniques that our people have been used over many years but have not been able to document.

The project hope that this manual will improve the ability of our local people and stakeholders especially Kaupule in all the islands to implement SLM practices to improve the livelihoods of our people and a safe and healthy environment for future generations.

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INTRODUCTION

This training manual aims to broaden our understanding in Sustainable Land Management (SLM), identify some of the common sustainable land management practices, explain the importance of these practices and hope to link our understanding on these practices to climate change. Climate change is one of the factors that affect agricultural production. It is very important for us to have a broad understanding of the concept of climate change, and some of the activities that we can do to reduce its impact on the livelihood of our people.

What is climate change?

Climate change refers to a broad array of alterations in climatic and weather conditions. It is characterised by the shifts in average conditions such as rainfall, temperature, winds, humidity and in the frequency and severity of extreme conditions including droughts, cyclones, etc. In simple terms, climate change refers to changes in long-term weather patterns.

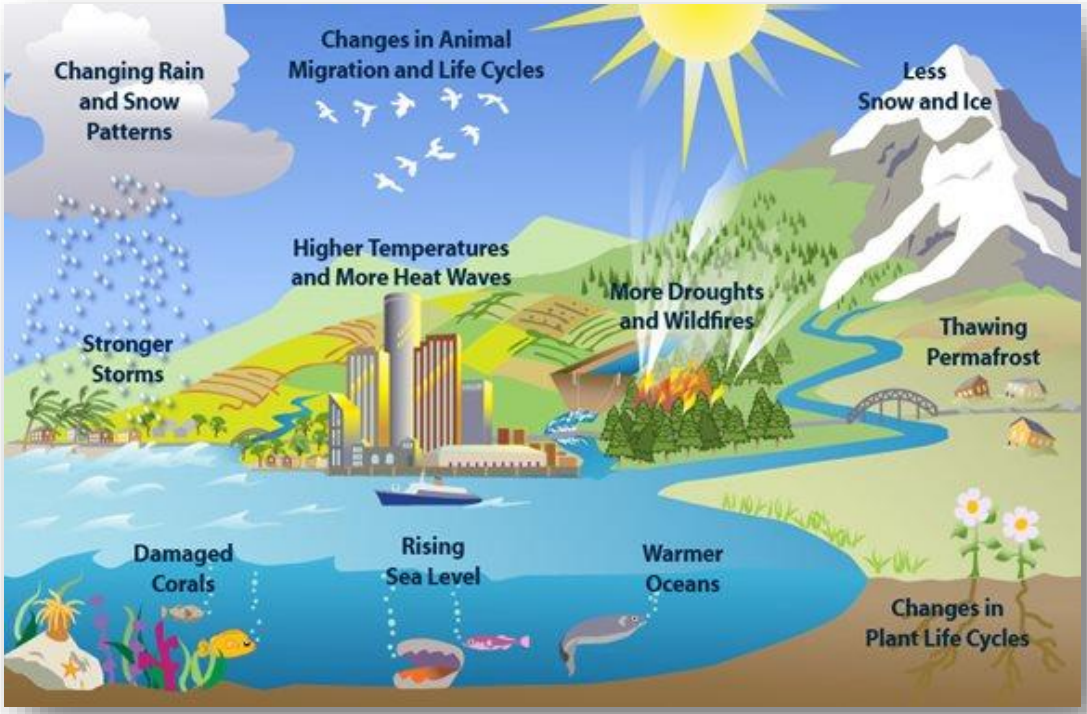

Fig 1. Climate change. Source: https://thisgreenearth.files.wordpress.com/2015/02/scientists-clues-print.jpg

What causes climate change?

Climate change is predominantly caused, directly or indirectly, by both natural processes and human activities that lead to the accumulation of greenhouse gases (GHGs) in the atmosphere. These are some of the major human activities that causes these gases; industrialisation, deforestation, destruction of ecosystems (wetlands, oceans, lakes, wildlife), agriculture and livestock production, transport, energy production, waste, urbanisation, building and changes in land use.

Here are some of the most common greenhouse gases;

- Water vapour
- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous Oxide (N_2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulphur hexafluoride (SF_6)

These increased concentration of greenhouse gases makes our atmosphere store more heat from the sun thereby increasing the temperature on earth, which results in global warming. The higher the temperature, the more severe the weather conditions become.

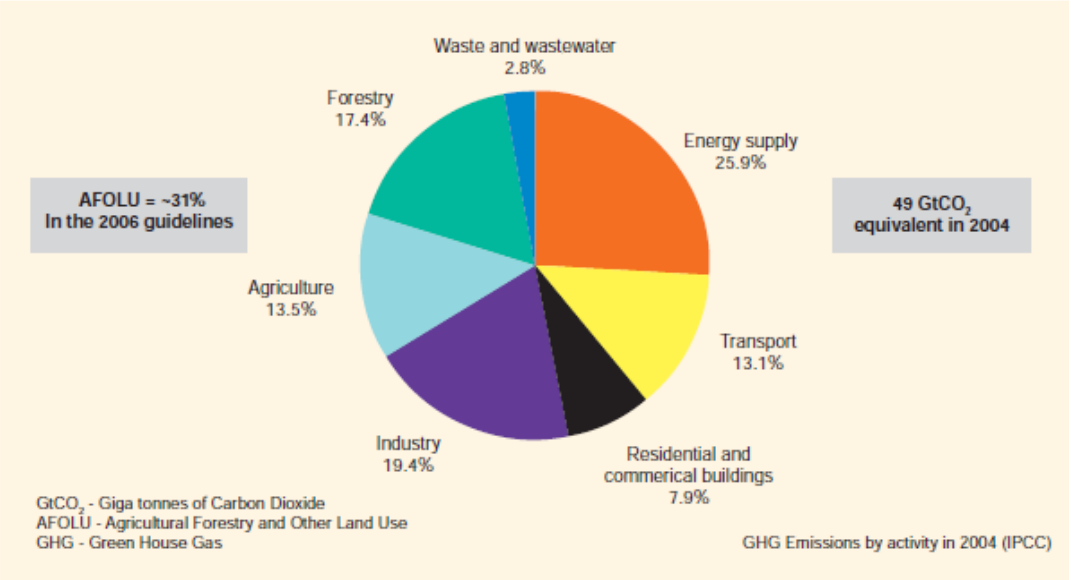

Illustration: Contribution per sector to climate change

Fig 2: Percentage of GHG's released from human activities. Source: We SALM effect

Climate Change adaptation and mitigation

Our people as small holder's famers have been struggling with the impacts of changing climatic conditions on animals and plants for example, animals (pigs & chicken) suffers from heat stress, our land become drier, underground water becomes brackish, affecting local trees and our ecosystem. To ensure food security and sustain livelihoods, it is becoming increasingly important for farmers and people to find ways of adapting to and/or reducing the negative impacts of the changing weather patterns, hence improving their farming practices through Sustainable Land Management activities.

APPROACHES TO CLIMATE CHANGE

There are two approaches to climate change: adaptation and mitigation. Climate change adaptation refers to activities to managing the social, environmental and economic impacts of climate change, whereas climate change mitigation involves activities implemented to reduce the emissions of greenhouse gases

What is Sustainable Land Management (SLM)?

Sustainable Land Management is a collection of activities that could be practiced by local people to adapt to the impacts of climate change and achieved increased environmental resilience in Tuvalu. It involved the use of terrestrial resources and ecosystems (e.g. soils and plants) to provide goods and services such as food, drinking water, fuel, timber, without detriment to the long-term productive potential of these resources and their environmental functions.

Sustainable practices can be divided into the following categories;

1. Nutrient management.
2. Soil and water conservation.
3. Agronomic practices.
4. Agroforestry.
5. Tillage and residue management.
6. Restoration and rehabilitation.
7. Integrated Pest Management.

Sustainable land management practices are essential as it minimises and rehabilitate the effect of land degradation, and ensuring optimal use of resources for sustainable development and poverty alleviation.

CHAPTER 1: NUTRIENT MANAGEMENT

This topic will help to enhance skills in some of the common soil nutrients, explain the importance of these nutrients, and discover ways through which you can increase and/or maintain the nutrients in the soil for food production. Our soils are one of the poorest in the world. Tuvalu soils like all other atolls are largely derived from materials which are mostly made of calcium carbonate, these are like corals, reef materials, etc. These types of soils are mostly alkaline, immature and very poor fertility (Macleans *et al*. 1983). There are a lot of phosphate soils found in some sites but very poor in nitrogen and potassium, only soils in pulaka pits which are compost and man-made soils are very rich in humus and moist from underground water. The soil tests shown high phosphate contents while trace in Nitrogen and Potassium in most areas. Sites with lots of canopies and shrubs covers shows medium nitrogen and potassium and high in phosphorus.

1.1 What are nutrients?

Plants need nutrients to grow and reproduce. Without sufficient nutrients plants, can become stunted, struggle to flower and produce fruit, become discoloured, or simply wither and die.

Below is the list of nutrients:

- Potassium (K)
- Magnesium (Mg)
- Nitrogen (N)
- Phosphorus (P)
- Carbon (C)
- Calcium (Ca)
- Sulphur (S)
- Iron (Fe)
- Zinc (Zn)

Exercise

1. List five abnormal changes you have observed in your crops.
2. Do you remember when or why your crops were looking or behaving strangely.

Nutrient Deficiencies in Plant

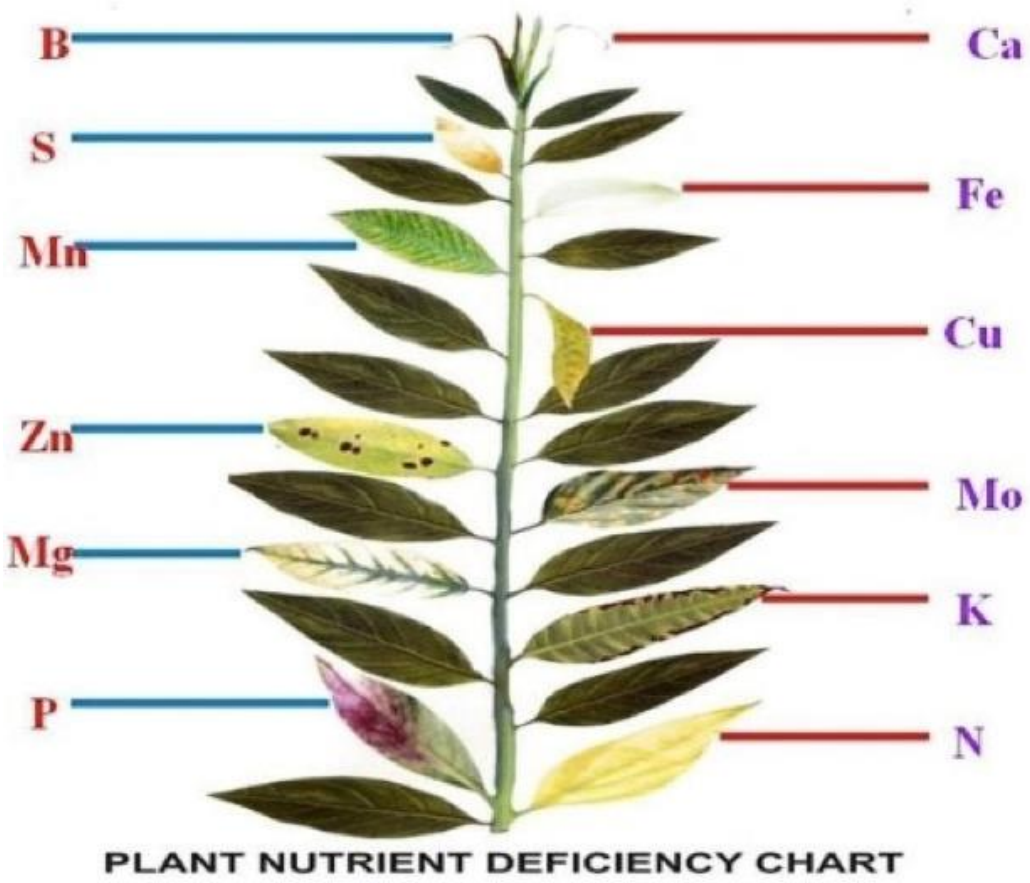

Fig 3: Nutrient deficiency chart Source: https://directcompostsolutions.com/nutrient-deficiencies/

It is very important to have knowledge about nutrient deficiency to know the soil status. The amount of nutrient in the soil will be shown on leaves of plants indicating a shortage of a nutrient in the soil.

It is important to be able to identify a nutrient deficiency and diseases or a climatic condition. If not sure of a symptom on plants, please inform the agriculture extension officer on the island and the Agriculture Department on Funafuti.

When you experience nutrient deficiencies, you will need enrich your soil to increase the fertility status nutrient management.

1.2 What is nutrient management?

A fertile soil is a type of soil that can supply different forms and amounts of nutrients to plants in a balanced way. Nutrient management is the process of maintaining and/or enhancing soil fertility, and it is done using the nutrients already in the soil or by adding nutrients through organic fertilizers (compost). The purpose of nutrient management is to increase soil and crop productivity, and increase climate resilience. Good examples of nutrient management are: use of manure, application of fertilizer and composting.

1.2.1 Use of animal manure

Animal manure can be obtained from different animals in your farm, or from a friend's farm. These animal manure can be used as an organic fertilizer, on different crops and trees.

The different forms of animal manures are such as chicken manure, pig manures, and human water and urine.

How to use animal manures;

- You can use one type of animal manure or a mixture of all the available ones (pigs/chickens).
- Dry the manure and mix with composted organic matter before mixing it to the soil where crops are to be grown. Be careful using wet manures (fresh ones) as they can burn the crops and damage the crops.

When applying to crops, you can apply as much as 1-2 wheelbarrow of these mixture around a tree crop (e.g. breadfruit) of about one meter around a tree. For vegetables and seedlings of trees place the mixture around the root stems.

1.2.2 Use of green manure

The use of green manure refers to plants that are cultivated to improve or protect the soil. These types of plants are inclined to grow fast, cover the ground, and have deep roots, but are not left to flower or harvested for the food. The main idea is for the deep roots plants to bring to the surface nutrients that the plants with shallow roots plants can utilize. There are also some other importance of using green manure. Some of the plants also take nitrogen from the atmosphere and deposit in the soil. In addition, when the ground is covered with plants these may help in preventing the growth or spread of weeds, and can be utilised to break disease cycles; some have beneficial microbes. The plants can also be cut and placed on the compost heap. These crops can also be ploughed back in the soil to be ready for another crop such as vegetables or any other crops to be cultivated. Overall, green manure increases the levels of organic matter in the soil.

Fig 4: Planting cover crops for green manure Source: http://www.saga.co.uk/magazine/home-garden/gardening/advice-tips/soil-improvement/green-manures

1.2.3 Cover crops

Cover crops can be referred to nitrogen-fixing plants that have important relationships that helps enriching the soil. Leguminous plants are known to have the ability to absorb

atmospheric nitrogen and fix it organically into the soil to increase nutrients and conserve soil. A good example of a leguminous cover crop practiced in other Pacific Island countries is mucuna (*Mucuna pruriens*), mucuna is sowed into the soil while the soil is either fallow or at other stages for its many benefits. Mucuna is known for its ability to fix nitrogen to available forms thus increase soil fertility.

Note: cover crops should be ploughed or removed at the flowering stage to prevent the crops from using the nitrogen that has already been fixed.

Some of the common cover crops are;

Alfalfa, beans, cowpeas, mucuna, peanuts, peas, pumpkin, sweet potato.

Fig 5: Mucuna is one of the best cover crops. Source: http://www.pirai.com.br/semente_mucuna_cinza-texto-b105.html

How to plant a cover crop when farming a land.

1. You can grow any cover crops mentioned above into piece of land that you want to farm.
2. Let them grow up to knee length.
3. Cut them using a knife to pieces.
4. Plough them to mix in the soil (mix them with your soil, or as mulch)
5. Leave for 1 week then start planting your crops.

This will help the soil to restore nutrients by adding lots of important nutrients to the soil.

1.2.4 Mulching

The mulching purpose is to conserve soil moisture, reduce runoffs, reduce losses of water through evaporation, reduce wind erosion, prevent weed growth, enhance soil structure, and control soil temperature. Common mulches that we can use includes; cut grass, crop residues, and other plant material.


Fig 6: Organic mulches used in home garden. Photo credit: Elu Tataua

1.2.4 Liquid manure

Liquid manure is a technique of mixing manures (green leaves especially leguminous plants with ash and animal dung) into a fermented or slurry form. It can be applied directly to the soil or crops.

Liquid manure protects crops, prevents pests and diseases, provides nutrients (nitrogen, phosphorus, potassium) and irrigate crops. It can be the substitute from the use of chemical fertilizers.

Fig 7: Liquid manure for home gardening Source: http://www.sacdepkenya.org/sacdep-programs/sector-1-community-direct-reach/production-of-liquid-manure/

Benefits of using liquid manure;

- Improves the soil
- Saves cost
- Helps farmers to self-reliant.
- Uses local resources and knowledge.
- Protects beneficial insects.
- Protects the environment.
- Preserves health by reducing the use of harmful chemicals.
- Reduce, Reuse, and Recycle of wastes.

How to prepare liquid manure:

1. Chop green sappy leaves and young branches of leguminous plants such as *Sesbania. (See: Fig 8a,b for pics of this species)*
2. Mix together with manure, shovels of dried manure, and 2 shovels of ashes.
3. Put these in a sack.
4. Place the sack in a drum with clean water. Mix thoroughly.
5. Cover drum and let contents stand for 21 days.
6. Apply to soil near the crop, do not apply directly to the crop as this will burn it.

Fig 8a. Sesbania sp. Source:https://www.forestryimages.org/brow

Fig 8b. Sesbania sesban(L.) Merr. Source: https://www.feedipedia.org/node/253

1.2.5 Composting

Composting is the natural process of turning organic materials such as crop residues and other wastes with animal manures into plant food or humus. Compost is a cheap and effective organic mulch that can be used as an alternative to commercial fertilizers to improve the soil nutrient status and other properties especially in atoll islands like Tuvalu.

There are many traditional knowledge on how to make composts which have been passed down by our forefathers. There have also many compost techniques from projects which were based on collective knowledges of experts. This technique we are trying to show is one of the Development of Sustainable Agriculture in the Pacific (DSAP) project compost technique.

Figure 9a drum composting. Photos: Elu Tataua; 9b. Compost bin Source: http://www.diynetwork.com/how-to/outdoors/gardening/how-to-compost-and-the-different-types-of-compost-bins

Ingredients:

- Top soil (dark soil)
- Animal manures (sludge – a mixture of animal waste/water)
- Green leaves (legumes, shrubs, trees)
- Brown leaves/wood ashes
- Water

Fig 10: Compost ingredients, banana stalk and soil Photos: Elu Tataua

Steps

1. Choose a site for the compost pit to be in a shaded area or under a tree.
2. Make sure all the ingredients needed for the compost layers are ready.
3. Start piling the ingredients to form a pile.
    - First layer: put the brown leaves to form the layer of 30 cm.
    - Second layer: put 15 cm of wood ashes and grasses, sprinkle some water on these layers
    - Third layer: Add some animal wastes on to the layers.
    - Fourth layer: Form another layer of green leaves.

- Fifth layer: Add some top soil on to the layers
- Sprinkle some water on to the soils
- Add some animal waste on to the layers.

Fig 11: Compost preparations in layers Photo: Elu Tataua

- REPEAT TO FIRST LAYER and follow all the steps until all ingredients are finished.
- Your compost will be ready when the materials are soft and break down like humus.

Figure 12: Steps in compost making Photos: Elu Tataua

Important note:

- Do not over wet your compost otherwise it will become stink.
- Turn your compost weekly and wet parts that looks dry. Turning helps giving air in the compost to speed up the decomposition process.
- When turning, notice that you will feel some heat coming from the compost (which is good). If you do not feel any heat, that means the decomposition process is too slow and not working. Add little amount of water on the compost to dry parts.

CHAPTER 2: SOIL AND WATER CONSERVATION

Introduction

Effective soil and water management practices can improve soil fertility and increase yields in a sustainable way. This session will highlight some of the techniques that conserve soil and water, preserve soil moisture and/or drain water sustainably to avoid soil erosion and the depletion of soil nutrients.

In Tuvalu, soil and water conservation falls into these four broad groups and some of the techniques within these groups.

1. Soil and Moisture conservation techniques.
2. Rain water harvesting techniques
3. Water storage techniques
4. Sustainable sanitation systems.

2.1 Soil moisture conservation techniques.

The use of terracing in pulaka pits is the main method of soil and water conservations that we can use in Tuvalu. The idea is for local farmers to harvest more than one crop when visiting the pulaka pit. The few contours that found on the edges of pulaka pits can be used for growing other tree crops such as bananas, Pawpaw and even vegetables such as cabbages, beans, maize etc.

Steps:

1. One step up of pulaka pits you can grow bananas and integrate with vegetables such as beans, tomatoes.
2. Second contour, grow another tree crop such as pawpaw and integrate with vegetables such as cabbages, and maize.

Figure 13: Pulaka pits and contour planting idea. Photos: Elu Tataua

2.2 Contours/Terracing

The idea of terracing is to grow crops on the terrace to capture water and nutrient runoffs and to have more than one food to harvest. This is a good practice to implement on big vaipulaka pits where more than one crop can grow on the contours.

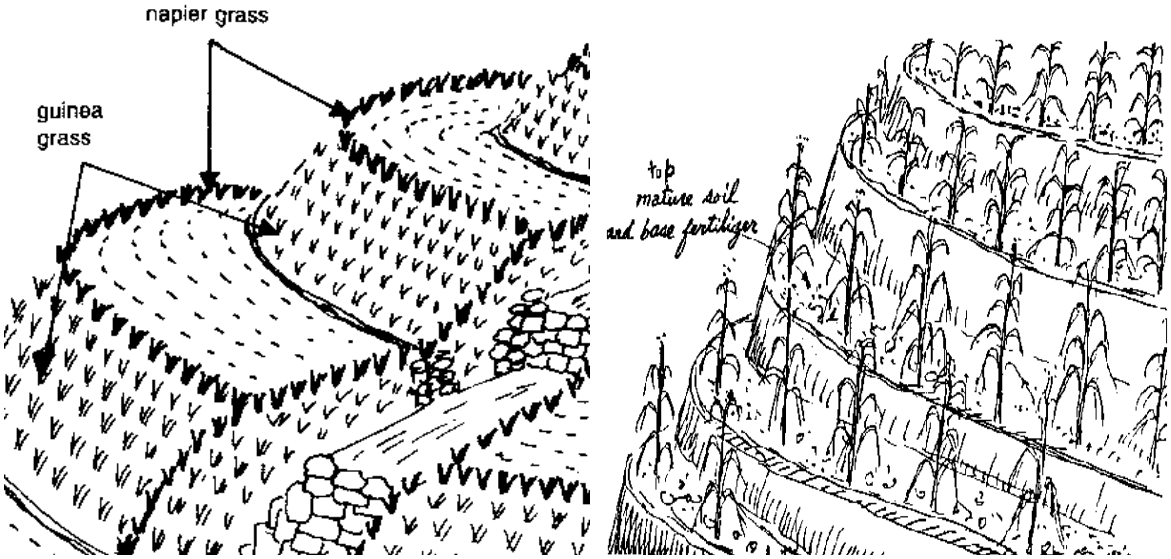

Fig 14: Contour planting Source: http://www.nzdl.org/gsdlmod?

2.3 Irrigation

Irrigation is the use of collected or harvested water for agricultural purposes. The practice improves soil moisture and militate against drought, thus allowing crops to use the available water efficiently. In Tuvalu, it is very important to use water wisely as water is scarce, therefore the method of irrigation system used is vital in the use of water for agricultural purposes.

2.3.1 Drip or trickle irrigation

This is a common method of irrigation system used by small farmers where water is coming out very slowly, drop by drop of a tube or any material to the crop. Common example is Bottle irrigation and bucket irrigation.

Fig 15: Drip irrigation Source: https://www.indiamart.com/proddetail/drip-irrigation-system-2109818433.html

2.4 Rainwater harvesting techniques

Rainwater harvesting is the slowing down, collection and concentration of runoff water for productive purposes such as growing crops, supply livestock or/and for domestic water supply. The purpose is to mitigate the effects of temporal rain shortages, some of which can

be attributed to climate change. Below are some of the harvesting techniques practiced in Tuvalu.

1. Roof catchment.
2. Coconut tree/drum.

2.4.1 Roof catchment

A roof catchment is a system where gutters in the roof drain rain water into a suitable storage system such as a tank or a water cistern. It is especially used in roofs made of galvanised iron.

2.4.2 Coconut tree/drum (Traditional harvesting technique)

This is a common system in places when the water supply is far. A drum can be put closely next to the trunk of a coconut tree. On the trunk, there is coconut leaf weaved into a form that could drain the water that comes down of the tree to be captured into the drum.

Fig 16: Coconut/drum system for water collection. Photo: Elu Tataua

2.5 Water storage approaches

Water storage approaches are practical ways of storing and conserving water, especially during dry season. The water is mainly used for household consumption but can also be used for agricultural purposes, e.g. water harvesting tanks can provide water for drip irrigation.

2.5.1 Tanks.

Tanks can be placed above the ground (surface tanks) or underground (sub-surface tanks) and used to harvest rainwater from roofs. The water can be used at home for household use, livestock and also for crops.

Fig 17: Water tanks from a falevatie on Funafuti Isand. Source: http://www.pacific-iwrm.org/community/showthread.php?24-Photos-of-Composting-Toilets-ECOSAN-in-GEF-Pacific-IWRM-Projects

2.5.2 Water cisterns

Cisterns are large rectangular underground cisterns with concrete on impermeable cement used for harvesting of rainwater from large buildings or houses. It usually community owns reservoir for time of droughts.

Fig 18: A water cistern for water harvesting and storage in Tuvalu. Source: http://www.sprep.org/pacc/tuvalu

2.5.3 Wells

In atoll islands or other regions without surface water resources it is necessary to obtain water from underground sources. A well is commonly used for livestock, and used as water reservoir.

2.6 Sustainable sanitation system

2.6.1 Compost Toilet

The Compost toilet is one of the best solution to water shortage problem and other environmental problems. The Compost toilet (Falevatie) is an ecological sanitation toilet that collects human waste and urine to use as manure/compost for improving crop productivity. Human waste is decomposed and mixed with ash and top soil with leaves then leave to decompose for 6 months and can be used for compost for crops. A compost toilet project (Falevatie) currently implemented on Funafut provides compost toilet units for interested households. The project is funded by the European Union.

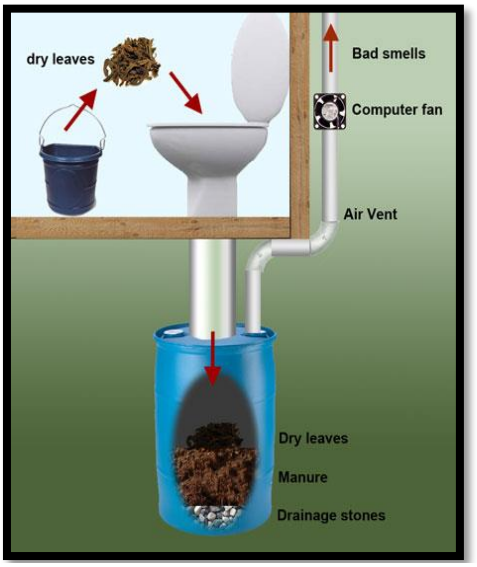

Fig 18: How compost toilet works Source: http://www.ecofilms.com.au/tanias-compost-toilet-tour/

Fig 19: Falevatie project in Tuvalu (compost toilet) Photo credit: Lamese Samu

How to use the Compost toilet.

1. Construct and use the compost toilet.
2. Add 1 handful of soil in the hole for human waste every day to reduce smell and kill germs.
3. Collect urine when needed and dilute with water to use as fertilizer

2.6.2 Kitchen water

Water that has been used in the kitchen or from showers can be treated and used for irrigation gardens. Leave the water in the basin in the sun to kill germs. Let it cool before applying to your garden or crop trees, otherwise it will destroy the plants.

CHAPTER 3: AGRONOMIC PRACTICES

This session will give you an understanding on how to choose the crops best suited for your farm or garden, the most suitable ways to plant different crops in your farm to increase produce, as well as how to adapt to the negative impacts of climate change.

What are agronomic practices?

Agronomic practices are designed to manage crops on croplands to increase yields, productivity, adapt to climate change and increase resilience of the crop land. These are some of the good examples of agronomic practices.

AGRONOMIC PRACTICE	EXAMPLES	BENEFITS
Improved crop varieties	Hybrid maize, grafted mangoes, indigenous vegetable, mosaic resistance cassava, ground nuts, tissue cultured banana	The crops are fast maturing, high yielding, and are generally more tolerant to pests and diseases.
Crop rotation	Maize to groundnuts to root crops.	Controlling the build-up of pests, weeds and diseases, and ensuring that root systems explore the soil to different depths. Recycling nutrients.
Intercropping	Mix maize-beans, maize-groundnuts, maize-potatoes	Nitrogen-fixing, intensification, and increased yields of two crops.

Table 1: Agronomic practices suitable for Tuvalu

3.1 Improved crop varieties

Improved crop varieties are crops that have been researched on, bred and tested to have special qualities e.g. fast maturing, dry spell tolerant, high yielding, high quality, and pest and diseases tolerant. Some particular crops can also withstand the effects of climate change and increase organic carbon or residues that can be managed to store carbon in the soil for a long period of time.

Examples of improved crops include hybrid maize, millet, sorghum, pulses and legumes (beans), rice, grafted mangoes, indigenous vegetables, mosaic resistant cassava, groundnut and tissue culture bananas, salt resistant of taros and yams.

High yielding crops also provide more biomass or residues can be returned back to the soil. However, certain improved crop varieties need to be used with caution, not all are suitable for all climates and soils.

It is very important to consult an agriculture extension officer before purchasing and planting the seeds of these improved varieties.

There is a lot to learn in growing these improved varieties especially in sowing, replanting and growing them.

3.2 Crop rotation

Crop rotation is the repetitive planting of a sequence of crops in the same field following a defined order in a year or years in cropping. This practice is necessary in order to avoid the build-up of pests, weeds or diseases, and chemicals, and to ensure that root systems explore the soil to different depths.

Example of crop rotation is the using legumes (nitrogen-fixing) mucuna, root crops (taro), fruit trees (bananas), and maize. The ideas are to have a high feeder to plant first such as maize or sweetcorn's, followed by legumes (nitrogen-fixing) to enrich the soil and then followed by root crops such as taro or cassava, then finally when harvest we can plant bananas.

3.3 Intercropping

Intercropping is the planting of two or more crops in the same field at the same time such as maize and beans, maize and groundnuts or maize and potatoes. Intercropping, also known as interplanting, provides additional income, food and shade, fix nitrogen, and controls weeds and soil erosion. It also provides a lot of biomass to form residues to be returned as organic inputs to the soil in form of mulch and compost.

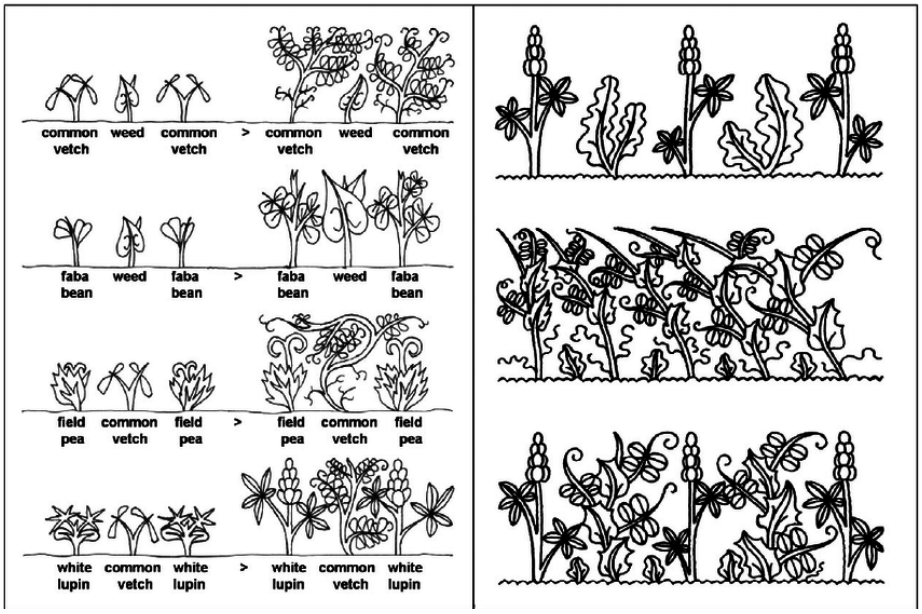

Fig 20: Intercropping practice helps sustainable land management. Source: http://www.sciencedirect.com/science/article/pii/S0254629913002949

When we do intercrop we should take care of the crops to make sure there is no pest and diseases can transmit from one crop to the other. Therefore, we should choose wisely which crops to intercrop, it is better to choose those from different families as there is less likely to have the same pest and diseases.

For example, we cannot inter-cropped yams, pumpkins, watermelon and cucumber with bananas as these serve as alternate hosts for the infectious chlorosis virus that affects bananas.

CHAPTER 4: AGROFORESTRY

This session will introduce the idea of the intentional or deliberate planting of trees in a crop or livestock farm. By the end of this chapter you will be able to know the benefits of agroforestry including climate change mitigation and some of the common methods used.

What is agroforestry?

Agroforestry is the deliberate growing of woody perennials (trees, shrubs) as agricultural crops alongside other crops and/or livestock on the same land. It improved productivity and mitigates the impacts of climate change (adaptation and mitigation). Existing trees can be protected and manages, or/and new ones planted.

The benefits of trees on the impacts of climate change cannot be overstated. Trees capture and absorb carbon dioxide – a significant factor in the climate change equation – and trees use carbon dioxide for photosynthesis or store it in leaves, stems, branches and roots. Trees also release oxygen during photosynthesis. Trees grow faster in tropical regions, absorbing more carbon dioxide than trees that grow in temperate regions. When trees are cut and forests destroyed, the carbon that is trapped is released into the atmosphere, facilitating raises in temperature. Planting trees and maintain forests is therefore essential for climate change mitigation.

Agroforestry has three major attributes: productivity, sustainability, and adaptability. In other works, agroforestry should maintain or increase production (productivity), meeting the needs of the present generation without compromising those of future ones (sustainability) and be culturally acceptable and environmentally friendly (adaptability).

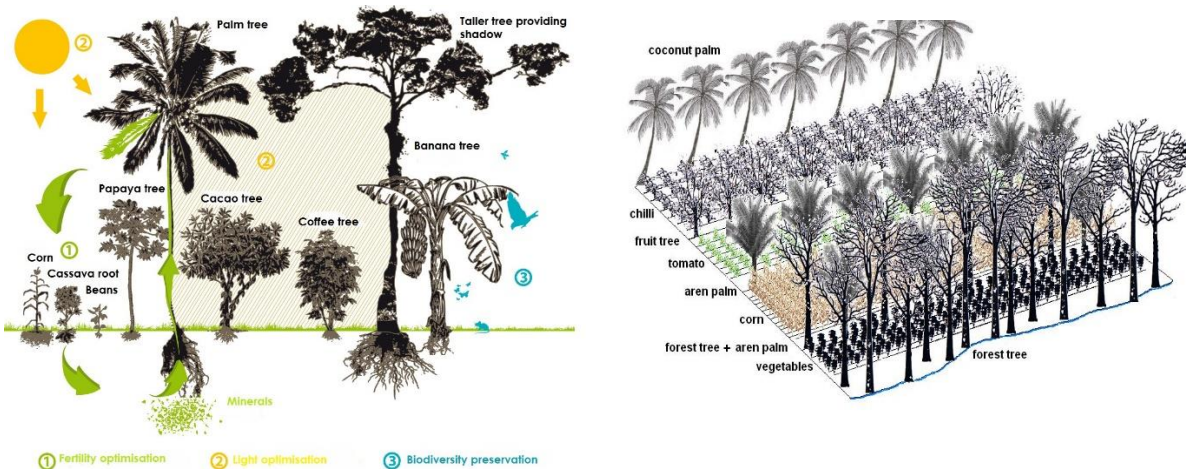

Fig 21: Agroforestry systems Source: http://pertaniandanmanusia2015.blogspot.com/2015/12/agroforestry.html

Table 2: Benefits of agroforestry:

CATEGORY	SPECIFIC BENEFITS
Social	Food and nutrition, shelter, medicine, cultural, psychological.
Economic	Sales of timber, fruits, nuts, poles, medicine.
Environmental	Soil fertility, crop and livestock productivity, firewood energy, biodiversity, reduce deforestation, climate change adaptation and mitigation, wind breakers, beauty, landscape.

Agroforestry and how it works.

- Leaves from the trees enrich the soil and help keep it moist.
- Trees increase biodiversity, reduce deforestation, and enable climate change adaptation.
- Trees provides shelter and act as windbreakers, and have a cultural and psychological value.
- Trees absorb carbon dioxide from the air and enables climate change mitigation.
- Trees provide firewood, timber, fruits, nuts, poles and sometimes have medicinal properties.
- Trees provide fodder for the animals and increase livestock productivity.
- Manure from animals is used for crops and trees.
- The farmer gets milk, fruit and other food from the farm.
- Trees stabilises the ground and reduce soil erosion.
- Nitrogen fixed by the trees benefits the crops.
- Trees improves soil fertility and crop productivity.

Common agroforestry systems

An agroforestry system is a distinct use of different agroforestry practices in different location and over a certain period of time. Here are the most common systems discussed below.

1. **Agrisilvicultural system (Crops + Trees)**

The system is the planting of trees among crops known practices such as dispersed interplanting, trees with perennial crops and alley cropping.

a. Alley cropping

Alley cropping is the growing of annual crops or forage between rows of trees or shrubs to form hedgerows. This practice improves soil characteristics and fertility, alley cropping can be done in areas with flat to gently rolling terrain.

Examples of shrubs to be grown with crops include *Sesbania sesban, Gliricidia sepium* or *Calliandra* species.

The benefits of alley cropping include:

- Controls soil erosion
- Trees shelter crops from wind damage
- Trees sequester carbon dioxide

b. Trees with perennial crops

Trees can be grown in combination with other perennial crops such as coffee, sugarcane and tea. This system provides land use with strong build up soil, organic matter, multiple or intercropping, mulch and extended rotation, because crops are permanent there is little re-

planting. Hence there is minimal disturbance of soil and thereby, more carbon is sequestered in the soil.

c. Wind trees

Wind trees, also known as wind breaks or shelter, are planted to slow down wind speed. The trees should be of different heights, and should be planted alongside bushes and grasses. Wind trees should not have gaps as wind can be channelled through the gaps creating a destructive tunnel of high winds.

A good knowledge of your farm wind direction is important so that you can plant your windbreaks to make sure you protect fruit trees and vegetables.

d. Home gardens

A home garden is a piece of land with various trees (fruit, fodder, timber and medicinal trees) and crops planted together. It is usually located close to the homestead or a nearby cropland to provide different plant and animal products. The trees sequester carbon, provide shelter, provide products, and improve soil fertility.

Most of the home-gardens in our islands are for vegetables only, however, we can also introduce small fruit tree species to increase the variety of our harvest. There are also benefits of trees to the home gardens such as windbreaks, their leaves can contribute as mulch and also as organic matter thus enriching our soil.

Home gardens not only provide useful vitamins and minerals to the family but also a good source of income if the surplus is sold to local market vendors.

Fig 22: Vegetables in a home garden Source: http://js-diabetes.com/2017/12/26/container-vegetable-gardening-in-buckets-net/how-to-start-a-vegetable-garden-in-your-backyard-for-beginners/

Benefits of home gardens with some trees.

- You can grow the desired tree species and varieties of vegetables.
- Income generation opportunities from selling surpluses and seedlings.
- Cost efficient – cheap too establish and manage.
- Possibility of using locally available materials for planting.

Location of home gardens

The location of the home garden is a very important factor to consider. It should be;

- Close to a reliable water supply
- Accessibility and near the house
- Availability of good soils.
- Protection from strong wind, direct sunlight (shade) and livestock
- Area free for expansion.

Soil Preparation for garden

Gardening soil should be fertile and well-drained. It should also be collected preferably, from some identified part of the farm such as under some trees as it is very rich in organic matter in the top soil. Before digging topsoil for nursery use, clear the surface to remove all plants and litter. Dig using a hoe and then sieve the soil to remove undesirable materials such as stones and sticks. Mix two portions of the sieved soil with one portion of sand and one portion of manure. The soil will be used in the next step, potting.

Seed Sowing

Seed comes in different sizes, big seeds such as water melons, cucumbers, beans can be sown directly in transplanted bed, and they do not have to be potted first or sown in the nursery. However, sometimes cucumbers are better off planting in nursery before transplanting.

It is important that fine seeds are mixed with sand and uniformly spread on the seed bed to avoid overcrowding as overcrowding leads to diseases. Do not sow the seed too deep in the soil as this is likely to affect seed germination.

Seed germination bed preparation

A seed germination bed is a place where seed are sown for purposes of germination, there are several types of beds: sunken beds, raised beds, and other containers.

a) Sunken beds

A sunken bed is a baisin like excavation, 1 m wide and 5cm deep, in which seeds are planted, such a structure holds the seedlings together, and help to conserve moisture. Sunken beds are commonly used in dry areas.

Fig 23: Sunken bed and raised bed for seed germination. Source: https://www.change-making.com/raised-beds-vs-sunken-beds/

b) Raised beds

A raised bed is a structure of soil in which the soil is held in place using materials like banana stems. The width of a raised bed is 1m, the height 10 cm. A raised bed is preferable in high rainfall areas. The bed enables you to manage the roots so that they don't grow too deep.

Pricking out

Pricking out is the process of transferring young and tender seedlings from seedbeds into the garden.

1. Water the seedbed properly before pricking out.
2. Take an empty basin and fill with water to ¾ level.
3. Hold the leaves of the seedlings and insert a sharp tool (pencil or small stick) underneath the root system to loosen the soil.
4. Pull out the seedlings gently and immediately put them in to the basin with water.
5. Water the pots before transplanting the seedlings.
6. Make a hole at the centre of the pot using sharp tool (pencil or stick).
7. If the roots are too long clip off the tip, insert the root system gently in the hole while holding the seedlings by the leaves. Do not hold the stem of the seedlings because they are tender and feeble – this may injure the seedlings.
8. Hold the sharp tool (pencil or small stick) in the tilling position and insert it in the soil about one centimetre away from the seedling to the same depth as the hole.
9. Push the soil towards the seedling to hold it tightly. This ensures that all the air pockets around the roots are closed, using your fingers cover the hole you made; water the pots properly and shade the seedlings.

Shade and watering.

Both during germination period and raising the seedling, shading is necessary. Use locally available materials such as grass, mats, or banana fibres for shade construction.

Water seeds and seedlings twice a day, early in the morning and evening, when the sun is not hot. Watering may be done once or skipped altogether during the rainy season. Take care not to under-water or over-water the plants. Use an adequate amount of water, i.e. 20 litres for 1,000 seedlings. Use a watering can which doesn't damage the seedlings. Avoid the direct use of hosepipes while watering the seedlings as this may wash away the soil.

Weeding

Weeds are a threat to healthy seedlings development as they compete with seedlings for nutrients, water and light. Weeds also cause diseases to the seedlings. Control weeds by gentle pulling out of the unwanted growth (roughing) whenever the weeds are observed sprouting from the pots. You can also use your fingers to weed by gently disturbing the soil, or a small stick.

How to plant a tree (breadfruit/banana

For most trees, the right time to plant is during the long rainy season. Get a note book to record every detail of the tree and make sure you have all the materials and requirement available before planting.

1. Choose a suitable species for the area. Select healthy seedlings.
2. Choose the agroforestry system/practice you want to have on your farm.
3. Prepare the holes:
    - For soft soils dig a round hole: 20 cm in diameter wide and 30 cm deep.

- For hard soils, dig a rectangular hole, to let roots penetrate through the corners: 50 cm width, 50 cm deep.
  Note: if you plant a seed (spot planting), dig a small rectangular hole (30cm deep and 20 cm wide). If you want to plant a cutting with a bud, dig 30 cm deep. Follow the instructions below regarding soil preparations.
- Separate top soils (10 cm depth) from sub soils.
- Leave the holes to stay for 7 days – 3 months depending on tree species.

4. Prepare the soil and manure:
   - Mix top soil and subsoil (ratio 2:1), make a fine mix by crushing crumbs.
   - Mix the soil mixture with well composted manure or compost (ratio 1:2)
   - Fill the hole completely with the mixture.
   - Leave the filled soil hole 1-3 days.
5. Plant the seedling:
   - Time the rains onset well, plant 1-7 days before raining.
   - Water the hole with slow flow of water (20 l) in the morning or evening.
   - Open a hole depending on the size of the seedling and species.
   - If your seedling is on a black polyethylene bag, cut of the bottom if closed. Be careful not to destroy the roots.
   - Place the seedling gently in the hole, half down the stem.
     Note: plant seeds 5-10 cm deep. Plant cuttings 30 cm apart and 10 cm deep.

   - Return the soil to cover the hole and flatten.
   - Water the seedling until it is saturated.

6. Managing the growing planted tree:
   - Spread compost/manure around the plant.
   - Mulch with dried residues.
   - Shade the plant against the sun.
   - Weed the plant regularly.
   - Prune if necessary.
   - Water twice a day if rain is not falling
   - Spread ash around to scare away ants and termites.

CHAPTER 5: TILLAGE AND RESIDUE MANAGEMENT.

Introduction

This chapter demonstrates how the integration of residue management and reduced tillage can sustainably manage agricultural lands to increase productivity, resilience to effects of climate change and increase soil organic matter. As a farmer, you have a significant amount of crop residues and litter from trees that you can use to mulch the farm. By the end of this chapter you will understand different tillage operation as well as the importance of residues in supporting tillage.

Conservation agriculture

Conservation agriculture is the way in which crops can be grown in a sustainable way while conserving the environment. Conservation agriculture is based on three core principles.

1. Permanent soil cover with mulch or crops residues (residue management), to protect the soil.
2. Minimal soil disturbance during tillage.
3. Crop rotation

5.1 Crop and residue management and correct tillage.

- Increase crop productivity.
- Reduce weeds
- Reduce cost of production
- Improve soil conditions such as structure and nutrients.
- Enhance soil moisture retention and infiltration
- Reduce soil disturbance and hence reduce soil erosion.
- Increase climate resilience.
- Increase soil organic matter (carbon sequestration).

5.2 Residue management.

Residue management refers to the proper handling and using of plant and crop residues. When we re-use the wastes (plant residues and animal wasters) we are simply using good agricultural practices that combines mulching, composting, integrative manure and livestock management. Plant residues are a major source of carbon in soil. These residues can be used as trash lines or mulch. Manure from the livestock can then be collected and used on the farm.

Benefits of crop residues:

- Improve soil nutrients.
- Improve soil structure and moisture-holding capacity
- Increase soil organic matter
- Control soil erosion
- Control of pests, weeds and diseases.

Note: residues can be used without burning. The burning of residues increases the emission of particles (aerosols) and greenhouse gases, and should be avoided. Burning residues also

increases soil temperature, depletes nutrients from the cropland and interfere with micro-organisms activities.

Fig 24: Organic mulching as an example of residue management. Photo: Elu Tataua

5.3 Tillage

Tillage is the preparation of soil conditions by digging, stirring, overturning and/or any other appropriate method to facilitate seed germination, root development, weed eradication, and crop growth. Tillage in Tuvalu can be achieved by using hand tools, and machines such as tractors in bigger size lands, however, most of the lands in Tuvalu are too small for machines. The using of a hoe is the common tillage tool used.

Fig 25: tillage practice Source: http://growerstools.com/garden-tools/hoes/falci-specialist-grub-hoe

CHAPTER 6: LAND RESTORATION AND REHABILITATION

Introduction

The land is degraded when it is infertile, saline, acidic, eroded, weedy, and low in organic soil matter. Degraded land can decrease productivity and increase the cost of crop production. By the end of this chapter you will understand how you can restore the land on your farm by returning lost nutrients, improving soil structure, and finding alternative nature-based land uses such as bee-keeping or planting fodder plants.

6.1 What is land degradation?

The cause of land degradation varies, but it is often a results of population pressure, unsustainable land practices and poor farming practices such as:

- Land clearance.
- Agriculture depletion of soil nutrients.
- Overgrazing.
- Excessive use of inorganic fertilizers and/or agrochemicals.
- Mono cropping
- Conventional tillage
- Deforestation.
- Droughts, fire and flooding also cause land degradation.

Land that has become unproductive can be restored and/or rehabilitated using the following methods:

- Natural regeneration
- Assisted natural regeneration
- Enrichment planting
- Fire management.

6.2 Natural regeneration

Natural regeneration is the deliberate re-establishment of healthy vegetation and biomass on degraded land by accelerating or enhancing the way the vegetation naturally changes (ecological succession). Bee-keeping, if suitable, can be also introduced. The bees will help to pollinate the crops. Alternatively, silt can be poured onto the affected land and tree seedlings planted to create a woodlot. Over the time the forests and the land on it will be restored.

6.3 Assisted natural regeneration/replanting

Assisted natural regeneration involves promoting tree seedlings and favourable species that were once destroyed. This is a very good activity as we replant trees we are not only helping our degraded land, we are also helping the environment (greenhouse effect).

If we plant any type of trees, fruit trees, flowering plants, vegetables, and with time the quality of the soil on the land improves, and the land becomes more productive.

Note: Avoid weeding grasses, as we are contributing to the degradation of the land by exposing it and destroying micro-organisms habitat.

6.4 Fire management

Fire in agriculture and forest sectors has caused land and environmental degradation. It is therefore important with fire management to control fires. Reducing the frequency and intensity of fires typically leads to increased tree and shrub cover and increasing the levels of carbon in the soil and biomass.

Note: there are severe dangers with burning, such as the risk of spread of the fire (from controlled to uncontrolled fire), deforestation, damage crops, soils and biodiversity. There is also the human risk of getting burned or hurt by smoke.

CHAPTER 7: INTEGRATED PEST MANAGEMENT

Introduction

This session will teach you how to control pests and diseases using a variety of methods whilst minimising economic losses, without harming yourself, your farm and the environment.

7.1 What is integrated pest management?

Integrated Pest Management (IPM) is a system of crop production and protection. It uses a variety of methods to prevent pathogens, insects and weeds from causing economic crop losses whilst ensuring cost-effectiveness and preserving the environment. In other words, it is a long-term technique to reduce/stop pests and diseases from multiplying.

This is done by:

- Introducing beneficial insects (biological control).
- Using crop-resistant varieties.
- Improving cleanliness.
- Using alternative agricultural practices such as pruning, spraying organic pesticides and using organic fertilizers.

Note: in some instances, chemical pesticides and fertilizers can be applied to complement other practices. But overuse can cause low soil fertility, depleted and toxic soil.

Examples of crop pests and diseases include: the striga weed, maize stalk borer, white flies, coffee berry diseases, leaf rust and white coffee borers.

7.2 Effects of pests (pathogens, insects and weeds) on a small-holder farm:

- Reduced on-farm yields due to damage by pests.
- Low quality of agricultural produce/products.
- Loss of human/livestock health and life through hunger/starvation and food poisoning.
- Malnutrition
- Loss of income.
- Loss of jobs that are based on agricultural production/produce.
- Rural-urban migration
- Loss of crop diversity.
- High costs of production due to investment in control measures
- Environmental pollution due to use of pesticides.
- Loss of international trade quotas.
- Inability to access new markets.

7.3 Goals of Integrated Pest Management programmes:

1. To eliminate or reduce initial pests.
2. Reduce effectiveness of initial pests.
3. Increase resistance of host plants (genetic or induced resistance).
4. Delay onset of a pest situation/attack.
5. Slow down pest spread and secondary pest cycles.

7.4 How to control pests and diseases?

7.4.1 Pests

A pest is any organism that associates with/or prevents the health or the potential of a plant, crop or animal; it is considered an enemy.

There are four major categories of pests:

1. Arthropods (e.g. invertebrates such as insects)
2. Pathogens (e.g. fungi, bacteria, viruses and nematodes)
3. Plants (e.g weeds, parasites)
4. Vertebrates (e.g. rats)

7.4.2 Plant diseases

A disease is any deviations from the normal health conditions of plant or crop. Diseases are caused by living organisms (pests) and environmental factors (e.g. frost). The disease-causing agents if caused by living organisms are referred to as biotic agents (e.g. bacteria while environmental agents are abiotic agents).

Disease symptoms are expressions of a plant's reaction to the cause of a disease. Signs of diseases are visible disease-causing organisms or parts of a disease-causing organism. Examples of symptoms: spots, lesions, blights, cankers, diebacks, damping off, mildews, rots, rusts, scab, smuts, moulds, wilts, mosaic, chlorosis, galls, streaking, dwarfing/stunting, crinkling, leaf curling/rolling, resetting, enations, vein clearing and vein banding.

There are three broad diseases symptoms categorised as;

- Necrotic: associated with death of cells, tissues or organs
- Hyperplastic: associated with overgrowth of tissues
- Hypoplastic: associated with retarded growth.

7.4.3 Pest Management principles

There are five basic pest management principles: exclusion, eradication, protection, therapy, and hots resistance (see table below)

Table 3: Basic Pest Management Principles

No.	Basic pest management principles	Details
1	Exclusion	Prevents entrance and establishment of pests (e.g. use of pest-free/certified seed or planting material quarantine practices).
2	Eradication	Eliminating/removing a pest that is established on plant, e.g. by: • Removing/roguing and destruction of affected plant or plant parts. • Chemical treatment of affected plant or plant parts: 'pesticides'. • Physical treatment of affected plant or plant parts. • Crop rotation.
3	Protection	Application of a protective barrier on a host before the arrival of a pest, e.g. use of:

		• Windbreaks • Physical walls • Chemicals to kill pests or their transmitting agents 'pesticides'. • Biotechnical control: - Biological control agents e.g. microbial antagonists, predators, parasites and parasitoids. These can be formulated and availed as biopesticides. - Biological cycles manipulations e,g. creating low humidity conditions to reduce spore formation by a fungus. - Utilisation of natural reactions – pheromones, repellents and attractants. - Plant extracts with biogenic substances.
4	Therapy	Treating a plant in order to inactivate a pest, e.g. by using: • Chemicals (chemotherapy): 'pesticides'. • Heat (thermotherapy).
5	Host resistance	Planting cultivars that tolerate or resist invasion or attack by pests: • Identification of resistant/tolerant materials involves breeding and selection. • Conventional or biotechnological techniques may be used in breeding.

IPM can only be successful and economical when all relevant information is available and taken into account. The relevant information includes:

- Crop or range of crops.
- Pest or range of pests.
- History of pest in the areas.
- Host susceptibility/tolerance/resistance.
- Prevailing environmental conditions.
- Locality/affected area.
- Available materials.
- Labour
- Costs.

7.4.4 Pest management advice:

- Accurate and timely diagnoses of a pest situation is an important aspect of successful management.
- Applying management measures to an unknown pest or any other causal agent can lead to failure, more damage, and unnecessary costs.
- It is important to seek advice on diagnosis and management from reliable sources.
- Understanding a pest problem is a process, which may be brief or may unfold over a period of time.

7.4.5 Biological pest control

Biological control is the use of beneficial arthropods or pathogens to keep pest populations down. Biological control also extends to the use of biological cycles of stages of growth to control pests directly or indirectly e.g. time of planting and time of harvesting to increase a plant's resistance capacity to a pest or to escape a pest situation. Pests are controlled by natural agents.

Farmers can manage their fields to provide habitats for species that eat and live on pest insects. This can be accomplished through conserving and augmenting beneficial populations. Using beneficial insects such as ladybirds (predator) which feed on a large number of mites, beetles and aphids control insect affecting crops. Other examples include digger wasps (parasite) and bacteria (pathogen) which kill larvae.

7.4.6 Mechanical pest control

Pests are controlled by non-chemical direct physical measures. Examples include: hand-picking to remove insects, tilling to remove weeds and trapping to catch insects or rodents.

7.4.7 Management of pests using pesticides

Pesticides are agents, substances or mixtures of substances that are deliberately released to the environment to prevent, destroy, repel, mitigate, harm or kill organisms which are considered to be pests. Pesticides may be chemical, biological or physical agents. This is contrary to the common mentality that pesticides are only chemical in nature.

Table 4: Categories of substances for controlling weeds.

NO	Common categories	HARMS OR KILLS
1	Insecticides	Insects
2	Acaricides	Ticks
3	Herbicides	Weeds
4	Fungicides	Fungi
5	Rodenticides	Rodents (rats, moles, squirrel and porcupine)
6	Molluscicides	Snails (aquatic or water pests in the fishpond)
7	Bactericides	Bacteria
8	Nematicides	Nematodes
9	Virocides	Virus
10	Algicides	Algae
11	Miticides	Mites

Note: Consider using pesticides that are effective on the target pest only – avoid indiscriminate application! For instance, a fungicide may not have any effect on a mite problem and not all fungal problems can be controlled by a randomly-picked fungicide.

7.4.8 Pesticides application

Mixing

- Accurately mixing pesticides and calibrating equipment is critical to successful pest management.

- Mixing and diluting of pesticides is usually the first step in pest control operations.
- All recommended and registered pesticides are availed to consumers with instructions on the rates to be applied to the quantity of commodity to be treated.

Calculation

- The area of a given tract is determined by applying the formula that fits the shape of the tract.
- In mixing a finished spray it is important to put the correct amount of pesticide in the water.
- Too little will result in poor job while too much may result in injury to the surface being sprayed or the operator.
- Instructions for mixing are often given on the label hence only simple calculations.

7.4.9 Cultural methods

Pests can be prevented or reduced by using methods to alter the plant environment.

Examples include:

1. Irrigation and fertilization schedules
2. Early planting
3. Sanitation practices
4. Intercropping (crop rotation, relay)
5. Use of improved varieties.

Intercropping

Intercropping is an effective weed control technique. It involves growing legumes as cover crops. The legumes act by: restricting the access of weeds to light, suppressing the weeds and disposing of trap roots. The legumes dispose of trap roots, stimulating for examples striga seeds to germinate. However, unlike cereal crops, striga cannot attach its roots to the roots of the legumes. The germinated striga seeds die. Other examples of trap crops that can be grown as intercrops are: tobacco, sesame and cotton.

How to intercrop legumes with cereals:

1. Grow separate rows of legumes and cereals with close spacing, e.g. one row with sorghum followed by two rows of soybean.
2. Apply organic and mineral fertilizer on the soil.
   Note: it will take approximately six weeks for the legumes to cover the ground.
3. Apply compost to the soil.

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