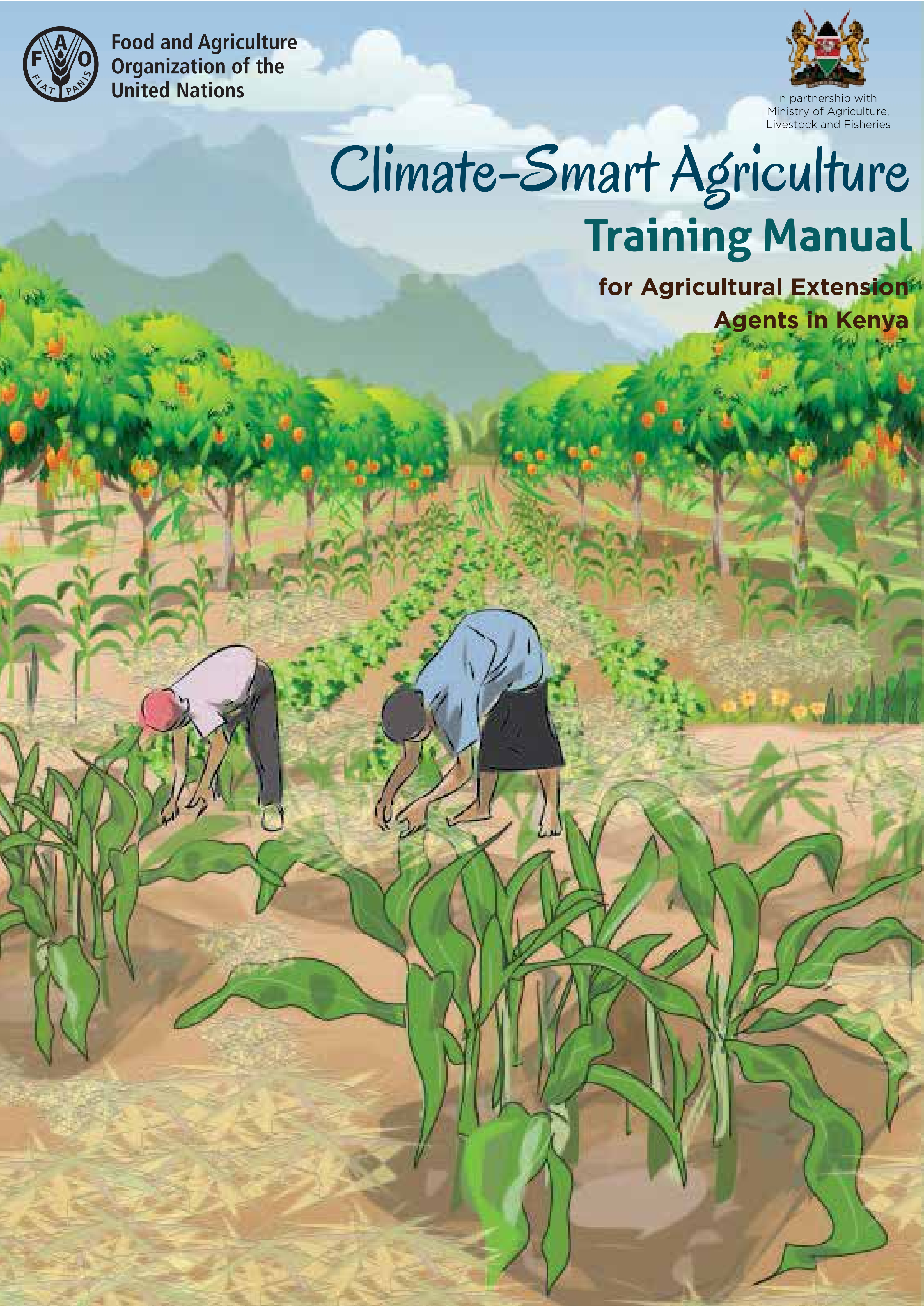
Food and Agriculture Organization of the United Nations

In partnership with Ministry of Agriculture, Livestock and Fisheries

Climate-Smart Agriculture

Training Manual

for Agricultural Extension Agents in Kenya



CLIMATE-SMART AGRICULTURE

TRAINING MANUAL FOR AGRICULTURAL EXTENSION AGENTS IN KENYA

Author:
BarrackO. Okoba

MINISTRY OF AGRICULTURE LIVESTOCK AND FISHERIES

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

KENYA, 2018

Required Citation:

FAO, Ministry of Agriculture, Livestock and Fisheries, 2018. Climate Smart Agriculture - Training Manual for Extension Agents in Kenya.

ISBN 978-92-5-130780-9

CREDITS

Photos: ©FAO/Barack Okoba, Eric Kimani, Christena Dowsett

Illustrations: ©FAO/John Nyaga

Table of Contents

Foreword

The current need to support the food demand of our growing population, which primarily relies on the world's natural resources, is more pressing now than it was ever before. At the same time, people and communities who are dependent on agriculture for their livelihoods are more threatened by and vulnerable to widespread changes in rainfall and temperature patterns. It is a known fact that agriculture is very sensitive and highly vulnerable to weather variability and climate change and is already experiencing serious negative consequences of droughts, floods and other extreme events on food production and development.

The consequences are compounded by the widespread poor agricultural infrastructure, lag in technology adoption and the low adaptive capacity of smallholder farmers in developing countries such as Kenya. For instance, in Kenya, which is largely semi-arid, rising temperatures and frequent rainfall variability have been observed to negatively impact on the productivity of crops, livestock, forestry, fisheries and aquaculture investments, and it's likely that their productions are likely to drop by more than 30% by 2030.

Climate change phenomena can be tackled by increasing the adaptive capacity and resilience of agriculture as well as increasing resource use efficiency in agricultural production systems. Building the capacity of farmers and institutions towards effective promotion, adoption and implementation of improved technologies that can adapt to and mitigate against the effects of climate change/variability is recommended. FAO believes that the best way to achieve this is through adopting farming principles that adhere to the climate-smart agriculture (CSA) approach.

CSA aims at transforming and reorienting all forms of agricultural systems (crops, livestock and fisheries) to support food security in the context of a changing climate. It is an approach that emphasizes improved food security by helping communities to adapt to climate change while ensuring agricultural activities contribute to the reduction of greenhouse gasses. CSA is a concept, originally put forth in 2010 by the UN's Food and Agriculture Organization, in response to the realities of climate change impact on agriculture and it's potential to increase greenhouse gas (GHG) emissions. CSA could be the way to feed our planet as climate change makes it impossible for us to farm the way we do now.

This manual presents a comprehensive package of general and practical illustrations of a set of agricultural technologies targeting both the smallholder farmers as well as Ward-level Agricultural Extension Agents in supporting climate-smart investments in the counties. It is our expectation that the suggested technologies in this manual, when implemented in an integrated approach, may trigger improved farm-level financial and landscape-level ecological benefits that will affect local and national economies besides achieving sustainable agricultural production.

Also we expect that the Lead farmers and County and National Extension Officers that were trained in the course of developing this manual will influence widespread adoption of the CSA technologies.

FAO will continue to support development, publication and dissemination of simplified CSA materials (leaflets, banners, etc.) that will enhance widespread access and understanding of CSA practices by the majority of smallholder farmers, community lead farmers and Ward front-line extension agents across the country. FAO will continue to work with the Government of Kenya in the adoption and effective implementation of the CSA approach, which addresses the effects of climate change and environmental degradation in agriculture.

Luca Allinovi, PhD
FAO Representative to Kenya

Acknowledgements

The production of this Climate-Smart Agriculture manual was made possible through active participation, support and cooperation of numerous organizations and individuals whose efforts deserve to be acknowledged.

Appreciation is given to the United States Department of Agriculture (USDA) for financing the process of FAO to provide technical knowledge in developing a training manual and consequently build the capacity of Ministry of Agriculture, Livestock and Fisheries' Extension officers on Climate Smart Agriculture (CSA) concepts as well as raise awareness of National and County Policy makers on the need to consider investments that support CSA principles.

Much appreciation goes to the FAO, Regional Initiative (Outcome 2 - Integrated Management of Agriclutural Landscapes) for providing complementary funding to the USDA financial support in order to include extra Counties governments and to include champion/lead farmers during CSA trainings. Later, other complementary financial support was provided through FAO - Rome, the Mitigation of Climate Change in Agriculture (MICCA) project that is funded by the Finnish Government, to the development of simplified dissemination materials based on this manual for wider accessibility and understanding by smallholder farmers in the targeted Counties.

Special appreciation goes to a dedicated project management team and experts in the various components of CSA, who contributed to the development of this manual. The compilation of the technologies in this manual was through a process that included: holding workshops and meetings in various venues, aimed at consolidating and validating the identified materials; visiting various Counties to meet County policy makers; and finally conducting trainings in 13 Counties with an aim of building capacity of Champion/lead farmers and the County extension officers on the CSA approach.

This was actualized by a dedicated team of National Agricultural Officers drawn from the three state departments of the Ministry of Agriculture, Livestock and Fisheries of Kenya, as follows:

Contributor	Duty station
Michael Okumu	State Department of Agriculture, Climate Change Unit. Kilimo House, Hqt.
Veronica Ndutu	State Department of Agriculture, Crops Directorate. Kilimo House, Hqt
Robin Mbae	State Department of Livestock, Apiculture and Climate Change Unit. Hill Plaza, Hqt.
Luke Kessei	State Department of Livestock, Dairy Services. Hill Plaza, Hqt
Evans Makokha	State Department of Livestock, Head Non-ruminant Section. Hill Plaza, Hqt
Maurice Ouma	State Department of Livestock, Range Management Division. Hill Plaza, Hqt
Jared Mochorwa	State Department of Livestock, National Bee keeping station. Lenana, Nairobi
Bernard Kimoro	State Department of Livestock, Programme Coordination Unit, SDCP. Nakuru County
Bethuel Omolo	National Aquaculture Research Development and Training Center station, Sagana
Vincent Ogwang	State Department of Fisheries, National Museums of Kenya, Nairobi.
Beatrice Akunga	Climate Change Unit, State Department of Fisheries, National Museums of Kenya, Nairobi.

The overall conceptualization and production of this manual was coordinated by Dr. Barrack Okoba, FAO Kenya CSA Expert and greatly supported by the Natural Resource Sector team: Philip Kisoyan, Nina C. Lande, Phylis Obayo and Francisco Carranza (NRM Head of Sector).

Special acknowledgement is to Judith Mulinge, FAO Kenya Communication Officer, for providing graphic design and editorial support in the production of the manual.

Executive Summary

The effects of climate change and climate variability on agriculture pose the greatest challenge for Kenya to realize its Vision 2030 and specifically of becoming a prosperous country.

Agriculture is sensitive and highly vulnerable to climate change and climate variability, whose effects are already being experienced in ways such as prolonged dry spells, droughts, floods and other extreme events directly affecting food production and development.

Given the high dependency on rain-fed agriculture amongst farmers in Kenya, people and communities whose livelihoods is conditional on agricultural sector are at higher risk of these climatic extremes. These consequences are compounded by the widespread lack of agricultural infrastructure, modest technology adoption and low adaptive capacity of smallholder farmers.

However, the challenges posed by climate change can be tackled by increasing the adaptive capacity and resilience of agriculture to climate change impacts. Building the capacity of land users (farmers), influencing policy makers and relevant institutions towards effective promotion and implementation of appropriate technologies and systems that can adapt to and mitigate the effects of climate change and weather variability is recommended.

This manual has been prepared to assist extension officers, both formal and informal, and community leaders/champion farmers in disseminating a list of Climate–Smart Agriculture (CSA) practices. These set of practices when implemented in an integrated farm approach and in context of the local social and physical ecology should ensure increased production and profitability, enhance resilience and adaptation to climate change effects but also promote low greenhouse gas emission development.

Though the list of practices are not exhaustive, sections of the manual attempt to demonstrate possible effective combination of set practices that are suitable for most of the Kenyan farming systems and which simultaneously achieve a farming approach that is productive, adaptive and with resultant opportunities for carbon sinks. Each chapter describes a CSA practice and tries to respond to the three questions of any proposed technology: What?, Why? and How? The format of writing this manual was intended to make it easy for the user to understand and be able to apply the synergistic implementation of selected practices.

This manual will be complemented by other manuals and policy guidelines prepared by FAO and the Government of Kenya to support policy makers in integrating climate change concerns in other development areas while achieving food and nutrition security in a secure environment.

Climate - Smart Agriculture

Chapter 1

Introduction

The agriculture sector in Kenya is highly vulnerable to the impact of climate change. Current evidence shows that climate change is expected to influence the state of food production both directly and indirectly. These impacts are due to the increases in mean temperature; changes in rainfall patterns and amounts; decreases in water availability; frequency and intensity of extreme events - notably droughts and floods; and a rise in the sea level with the attendant salinisation of coastal soils.

Agricultural activities account for 10 -12 percent of global greenhouse gas (GHG) emissions besides being the key driver of deforestation and land degradation, which account for an additional 12 -14 percent of GHG emissions. However, the agricultural sector can be an important part of the solution to climate change by capturing synergies that exist among its activities to improve natural resource management while developing more productive food systems. An ecosystem approach will be required to sustainably utilise natural resources.

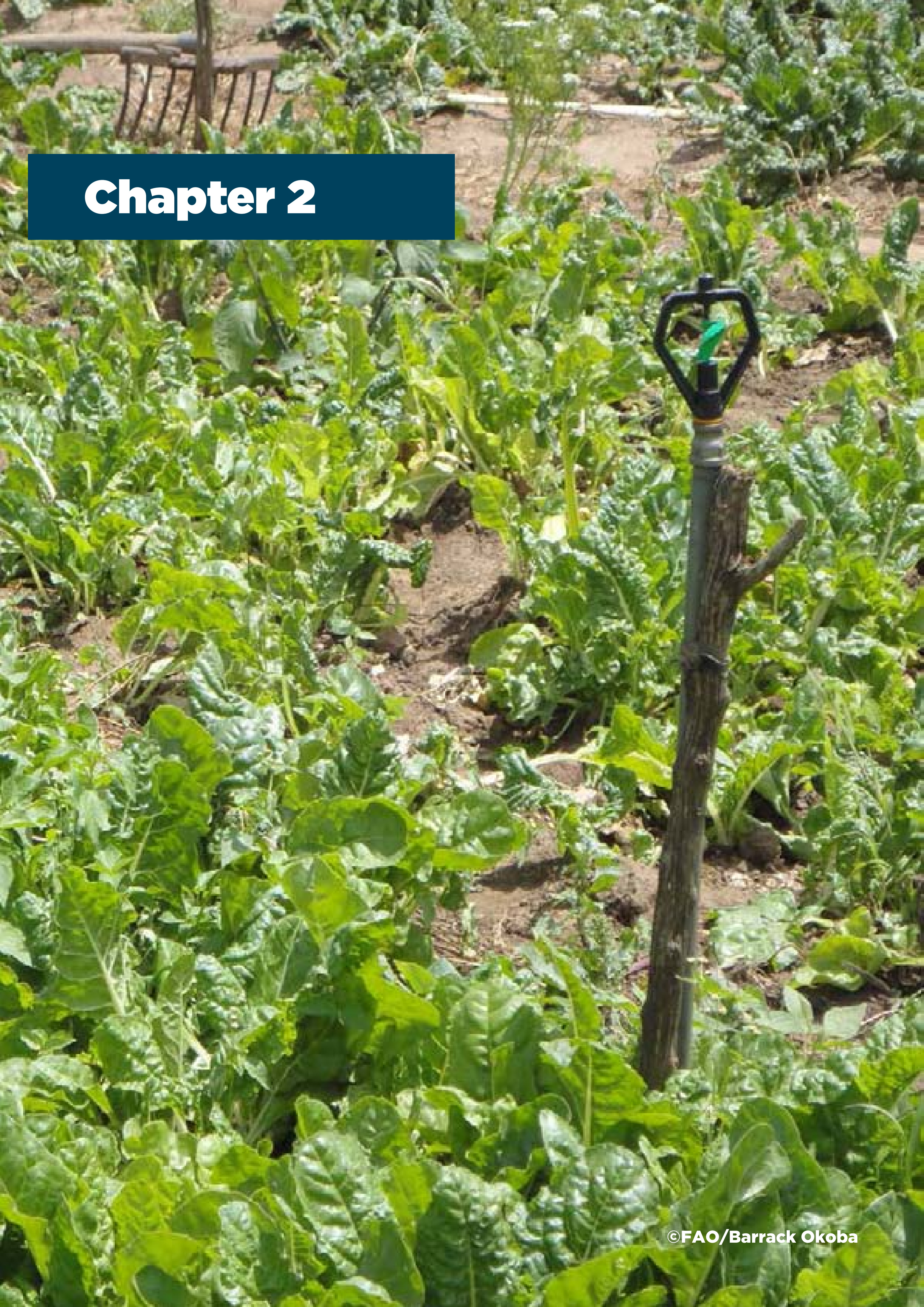
The Climate-Smart Agriculture (CSA) approach is anchored in the principles of sustainable intensification of agricultural production (crops, livestock and fisheries) that is working on landscape level with an ecosystem approach that aims at reducing and removing GHG emissions from the atmosphere.

Sustainable intensification means a productive agriculture that conserves and enhances natural resources. It uses an ecosystem approach that draws on nature's contribution to crop growth - soil organic matter, water flow regulation, pollination and natural predation of pests.

It applies appropriate external inputs at the right time and in the right amounts to improved crop varieties that are resilient to climate change and use nutrients, water, and external inputs more efficiently, without causing harm to the fish and livestock ecosystems. Both the sustainable intensification and ecosystem approaches are meant to enhance resilience of livelihoods towards fodder and food insecurity as a result of climate change.

CSA is composed of basket of sustainable practices that are applied in an integrated landscape approach, and that are coordinated across agricultural sectors, ensuring they capitalize on potential synergies, reducing trade-offs and optimizes the use of natural resources and ecosystem services.

Chapter 2



Definition of basic concepts

2.1 What is climate change?

Climate change is the long-term or permanent shift, either upwards or downwards, of the average climatic condition

These changes are seen in:

- The onset and cessation dates of rainfall,
- The duration and intensity of dry and rainy seasons,
- The amounts of seasonal rainfall,
- The rainfall intensity,
- The strength and direction of winds,
- Outbreak of diseases and pests; and
- The abnormal frequency of floods and droughts.

2.2 What causes climate change?

Climate change is directly or indirectly caused by human activities that alter the composition of the global atmosphere which forms a blanket of gases over the earth. Long-term production of these gases makes the natural climate warmer than usual.

The gases include:

- Carbon dioxide (CO_2), which is the gas from organic and industrial firewood, industry and vehicle engines and factories;
- Nitrous oxide (N_2O), a gas from fertilisers that are exposed to the sun's heat;
- Methane (CH_4), a gas produced primarily under oxygen-deficient (anaerobic) conditions such as those that occur when animal by-products are fermented or rice paddies are put under a complete water cover;
- Ozone (O_3), a gas from aerosol sprays such as perfumes, cosmetics, and household sprays; and
- Water vapour from open, natural water bodies such as lakes and oceans.

Some of the activities that amplify effects of climate change are:

- Clearing land and burning plant biomass for farming exposes the soil and releases the carbon stored in the soil into the atmosphere
- Burning of wood as firewood or for charcoal releases the carbon stored in the trees into the atmosphere
- Tillage practices that turn and expose the soil release the carbon stored in the soil into the atmosphere
- Poorly managed manure leads to more biogas (methane) escaping into the atmosphere
- Overstocking of livestock leads to land degradation and hence causes soils to emit GHGs
- Inefficient energy use in the poultry value chain leads to increased carbon emissions to the atmosphere
- Indiscriminative use of agro-chemicals interferes with maintenance of a sustainable ecosystem
- Fishing in depleted waters requires more fuel per kilo landed hence increasing GHG emissions.

2.3 What is Climate-Smart Agriculture?

It is a pathway towards development and food security built on three principles/pillars:

- Increasing productivity and income
- Enhancing resilience or adaptation of livelihood and ecosystems
- Reducing and removing greenhouse gas emission from the atmosphere

In a real landscape level situation the use of natural resources for productive food systems when capturing the synergies among the three pillars may demand some tradeoffs while ensuring ecosystem services are not compromised, e.g. through dry season river flows, air and water quality, land degradation, and animal and human health.

	Term	Definition	Key Indicators
1.	Climate Resilience	Capacity of a socio-ecological system or land user is able to cope with a hazardous event or disturbance, responding or reorganising in ways that maintain its essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation	Socio-ecological system or lifestyle that demonstrates ability to recover after climatic shock or disturbance
2.	Land Degradation	Reduction in the capacity of the land to provide ecosystem goods and services, over a period of time, for its beneficiaries	Vegetation cover; soil organic matter and related soil factors decreasing/ decreased compared with stable conditions
3.	Agroforestry	Land-use systems and technologies where woody perennials are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence	Significant number of multipurpose trees deliberately grown in association with crops or pastures
4.	Conservation Agriculture - adoption	CA is characterized by three linked principles, namely: (1) Continuous minimum mechanical soil disturbance.; (2) Permanent soil cover and (3) Diversification of crop species grown in sequences and/ or associations	A farmer can be considered to be an 'adopter' if s/he reports to practice consistently 2-3 principles
5.	Conservation Agriculture with Trees (CAWT)	The combination of CA principles within same land with a form of deliberately arranged multipurpose trees and shrubs. CA enterprises could be food crops while Agroforestry enterprises could be fruit/nuts, timber, fodder and fertilizer trees and shrubs.	System that offers mutual benefit to both the food crops and economical/social purpose trees/shrubs while minimizing impact of food production on the environment and increasing resilience on other farm enterprises

	Term	Definition	Key Indicators
6.	Water Harvesting	The collection and concentration of rainfall runoff, or floodwaters for plant, fisheries and livestock production, and domestic purposes.	System designed to capture and use rainfall runoff from roofs, path, rocks or other catchments – and use productively
7.	Road Runoff Harvesting	The collection and concentration of road drainage waters for crop and fisheries production or other purposes.	System designed to capture and use rainfall runoff from roads – and use productively
8.	Household resilient to climate change	Household with socio-economic system that demonstrates climate resilience [see climate resilience above]	Household fulfils the above definition of being food secure and has increased both its absolute income and the variety of sources of income, improved its access to markets and has adopted integrated agricultural practices that are aligned to CSA approach
9.	Sustainable increase in production	An increase in production of crops or other vegetation/ livestock per unit area that is stable and sustained over time	Increase in production is achieved regularly and in the long term through the use of CSA technologies in watershed management around the productive sites
10.	Productivity increase	An increase in production of crops or other vegetation/ livestock per unit area	Productivity increase is measured by comparing the various crop yields of the treatment group with that of a non-treatment group for the same season.

Chapter 3

Components of Climate-Smart Agriculture (CSA)

3.1 What does taking CSA action mean?

CSA is not a single specific agricultural technology or practice that can be universally applied.

It is an approach that requires site-specific assessments to identify suitable agricultural production technologies and practices. CSA aims to improve food security, help communities adapt to climate change and contribute to climate change mitigation by adopting appropriate practices.

These practices, which may be applied alone or in an integrated approach, include those that:

1. Increase the quantities and qualities of farm yields as well as profitability without destroying the environment;
2. Cushion farmers from the effects of climate extremes such as floods and droughts; and
3. Release of greenhouse gases (CO_2, N_2O, CH_4, O_3) that warm the atmosphere, or trap such gases.

3.2 Why CSA?

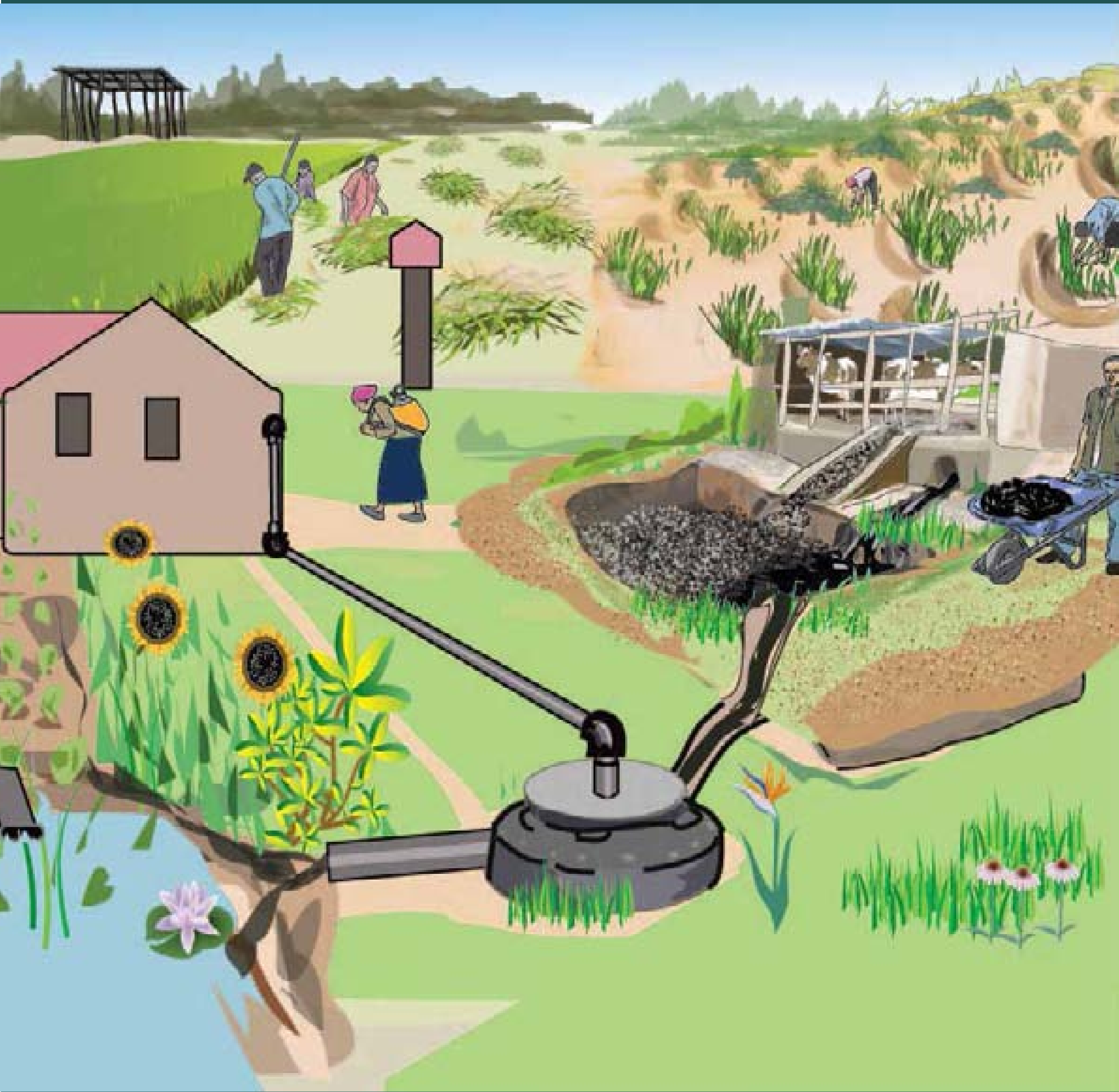
Good farming practices can maintain biodiversity and reduce the quantity of GHGs released to the atmosphere, and instead trap carbon through improved biomass production

1. CSA increases the soil-carbon content, improves fertiliser- and water-use efficiency as well as water-holding capacity, and makes soils easy to work.
2. CSA increases cost-benefit returns.

3.3 How do you implement CSA?

Some farm practices, when implemented in synergy and with care, will limit triggers of climate change and thus qualify to be CSA actions. Such practices include:

1. Choosing appropriate farm enterprises for your area, e.g. growing arrow roots in a flood-prone area, growing drought-tolerant maize varieties in low-rainfall areas, and selecting drought-tolerant livestock species for dry areas,
2. Diversification of farm enterprises so that when the season experiences extreme weather, some enterprises will survive,
3. Proper timing and application of farm operations such as timely placement of appropriate fertilisers to enable the crop to take them up easily and thus reduce losses through leaching or conversion to gaseous forms. Equally importantly, such practices will promote crop growth and early maturation,
4. Implementation of soil and water conservation measures such as construction of water-retention structures and minimum or zero tillage, and planting crops that increase ground cover quickly and use little water,
5. Intercropping and crop rotation involving legumes to improve soil fertility as well as increase the chances of some harvest even in poor seasons,
6. Adopting farmyard manure management through biogas production, and farmyard composting to improve soil fertility and reduce release of methane,
7. Practising beekeeping which conserves the environment and contributes to natural resource enhancement and biodiversity,
8. Promoting climate-efficiency gains in dairy production systems,
9. Promoting pasture land rehabilitation and management,
10. Preserving hay for use during drier seasons,
11. Practising integrated farming so that as much as possible, by-products from one enterprise will be used to promote performance in another enterprise on the farm.



Integrated CSA practices to achieve low GHG emission development pathways in a farming system

CSA Practices shown:

- Pasture establishment
- Dairy
- Biogas Production
- Aquaculture fertilised by slurry products
- Crop field fertilised by slurry products

The following chapters describe most of the CSA actions, which when implemented in an integrated approach can help to achieve the three pillars of CSA.

Chapter 4

©FAO/Barrack Okoba

Conservation Agriculture (CA)

4.1 What is CA?

Conservation agriculture is an approach to farming which can sustainably increase yields from cereal, legume, fodder, and cash crops. The various practices that make up this approach follow key principles that target to conserve the soil, rain-water, and soil-nutrients, and stabilise land production while reducing production costs.

Conservation agriculture principles are:

1. Minimal soil disturbance
2. Permanent ground cover - maintenance of a mulch of carbon-rich organic matter covering and feeding the soil (e.g. straw and/or other crop residues including cover crops)
3. Crop rotation or sequences and associations of crops including trees, which could include nitrogen-fixing legumes
4. Balanced application of chemical inputs

The GHG mitigation potential of minimum tillage management alone is about 0.44-1.89 tCO_2-eq/ha/yr.

4.2 Conservation Agriculture - Principles in Action

Maize field with permanent soil cover (mulch)

Crop rotation between fields; banana and pumpkins

Minimum soil disturbance, planting holes prepared by hoe

Maize field with permanent crop cover (desmodium)

4.3 Why CA?

1. CA offers climate change adaptation and mitigation solutions while improving food security through sustainable production intensification and enhanced productivity of resources.
2. It enables management of soil fertility and organic matter, and improvement of the efficiency of nutrient inputs, helping to produce more with proportionally less fertiliser.
3. It saves on energy-use in farming and reduces emissions from the burning of crop residues, thus helping sequester carbon in the soil.
4. Avoidance of tillage minimises occurrence of net losses of carbon dioxide by microbial respiration and oxidation of the soil organic matter and builds soil structure and biopores through soil biota and roots.
5. Maintenance of a mulch layer provides a substrate for soil-inhabiting microorganisms which help to improve and maintain water and nutrients in the soil. This also contributes to net increase of soil organic matter derived from carbon dioxide captured by photosynthesis in plants, whose residues above and below the surface are subsequently transformed and sequestered by soil biota.
6. Rotations and crop associations that include legumes are capable of hosting nitrogen-fixing bacteria in their roots; this contributes to optimum plant growth without increased GHG emissions induced by fertiliser production.
7. The protective soil cover of leaves, stems and stalks from the previous crop shields the soil surface from heat, wind and rain, keeps the soil cooler and reduces moisture losses by evaporation.
8. CA helps to stabilise yields in years of extreme weather, drought, floods, pests, and diseases.
9. CA reduces production costs on machinery, fuel, fertilisers, and labour, and makes it possible to prepare up to three times as much land in a given duration compared to complete ploughing and weeding.
10. CA helps to reduce soil compaction and plough pans and regenerates degraded lands.

Dying maize crop grown under conventional tillage

Thriving maize crop grown wth conservation agricultural practices

4.4 How do you implement CA?

Before applying CA, you may need to correct some factors in your soil that limit production. The factors are:

1. Soil compaction – this is a dense layer near the soil surface which inhibits infiltration of rain water into the soil, or growth of seedlings in the soil. It is caused by heavy rainfall, animal hooves and wheels of farm equipment. The problem is serious in sandy and clay soils and makes such soils hard to till.
2. Hardpan – this is a dense layer of soil that forms below the soil surface. It makes roots bend side-ways, and results in waterlogging and crop damage. A hard pan results from ploughing or hoeing to the same depth season after season.
3. Compaction and hardpans can be corrected by using a ripper, subsoiler, planting basin, and planting cover crops with strong and deep rooting systems.

You should also ensure that your land is conserved with biological and physical structures against soil erosion due to steep slopes or upstream runoff effects. CA practices will work best where soil and water conservation structures have been implemented. There are several ways of conserving soil and water.

These include:

- Contour planting to trap water and prevent soil from moving downslope
- Retention ditches and cut-off drains will help to trap on-farm runoff water and allow it to infiltrate into the soil
- Growing of grasstrips/agro-forestry trees/shrubs – these vegetative barrier will act as filters to check soil loss and enhance deep water percolation while reduce erosive energy from rain drops
- Construction of terraces (Channel terraces, Bench terraces) and Fanya juu structures that harvest/trap rainwater directly in the soil.

4.5 Implementing CA principles

a) Zero or minimum land tillage

Tillage is confined to the area where the crop is going to be planted, leaving the rest of the area undisturbed and is usually tine based to avoid soil inversion and excessive soil disturbance.
This maintains a good soil structure pores, flow of water into soil profiles and removal of hardpans. Reduced tillage practices sequester carbon only under certain conditions; relatively high precipitation, high productivity, and a large amount of crop residues as carbon input into the soil.

Minimum tillage can be practised using tools and equipment such as rippers, sub-soilers, a chisel plough, a broadcaster, a planting stick or dibbler, a hand jab planter, an animal-drawn planter, and a motorised or tractor planter.

Left: An oxen-drawn frame attached with a sub-soiler
Right: An animal drawn frame attached with a ripper

i) Ripping

Is the opening of a narrow slot or furrow in the soil, about 5-10 cm deep, to improve water storage in the root zone. The slot breaks the developed compaction and thus loosens the soil to allow root penetration and deeper water seepage.

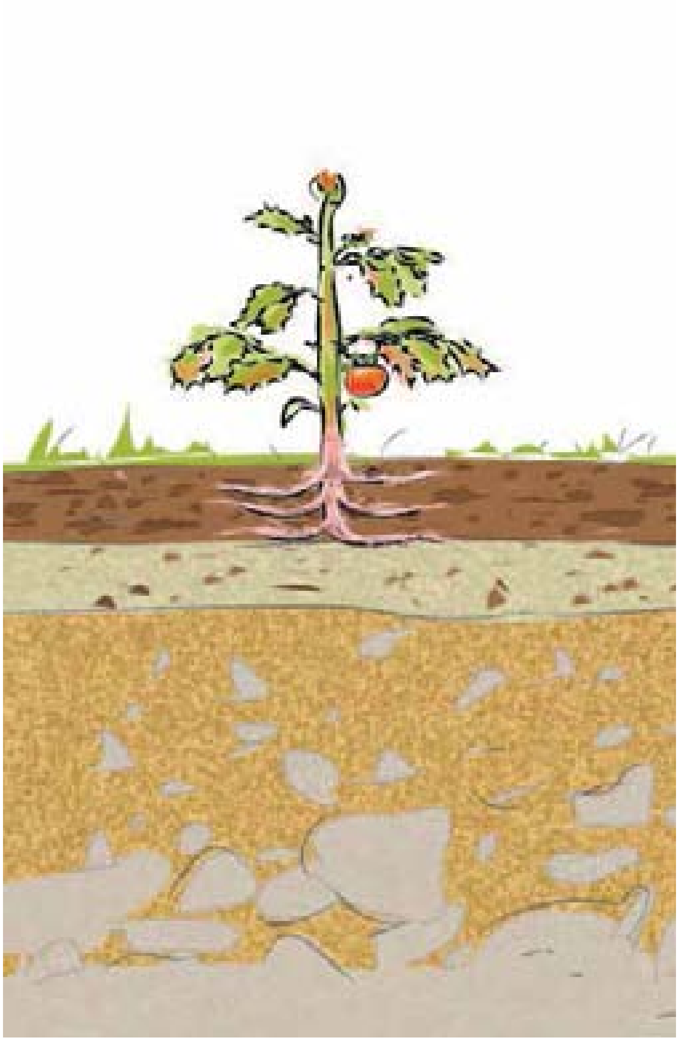
A ripper is a chisel-shaped implement pulled by animals or a tractor. Unlike a victory plow or a mouldboard plow, a ripper does not turn the soil over. Ripping can be done during the dry season or at planting time. In the rip lines you can plant by hand or use a direct hand planter. Most direct animal or tractor planters are attached onto rippers.

Ripping carried out with an oxen-drawn ripper

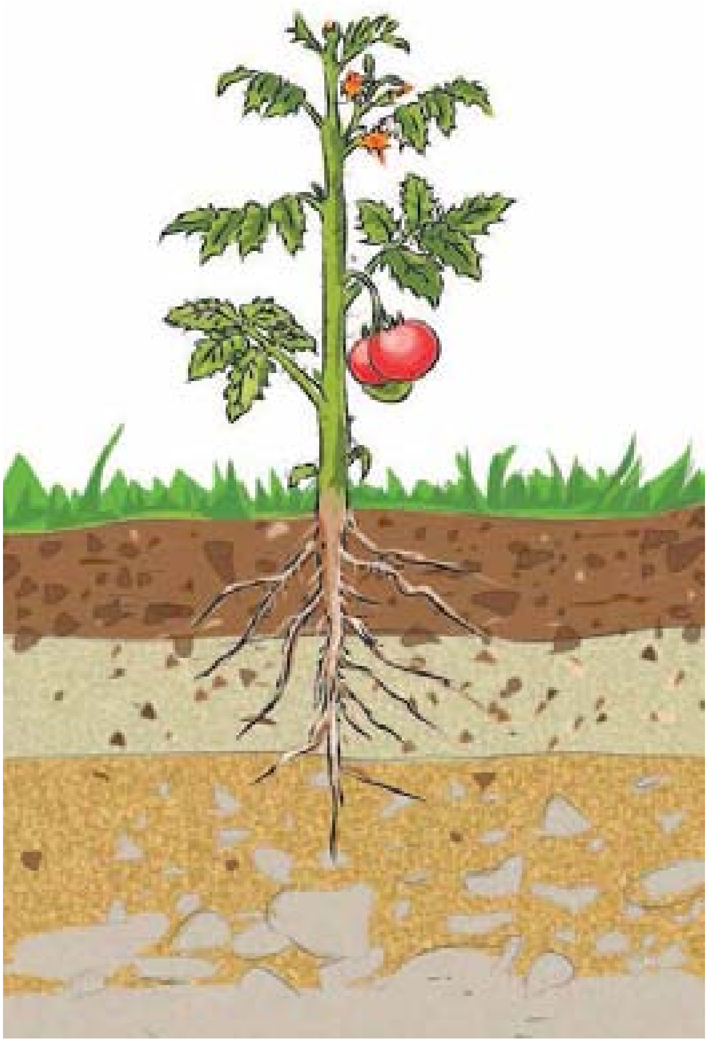
Jab planting in rip lines

ii) Sub-soiling

This is done when a hardpan is deeper than common hard pans or when soils are heavy. A sub-soiler is like a ripper but works at lower depths and has a narrower tine of upto 20 cm long. It can work upto 20-30 cm, just below the level of most common hardpans. A sub-soiler may be mounted on a oxen plow frame or a tractor. Sub-soiling heavy soils generally needs a tractor.



Plant root structure in hardpan soils



Plant root structure in non - hardpan soils

Warning

You do not have to sub-soil every cropping season. It is okay to do it only once when you switch to CA, thereafter do it periodically once every 3 years.

By allowing animals to graze on your field or lack of maintaining soil cover may encourage hardpan formation and therefore frequent sub-soiling may be necessary.

Sub-soiling just after previous season harvest – when there is minimum residual soil-moisture

Sub-soiling of new land using tractor drawn sub-soiler

Women using oxen-drawn sub-soilers.

Tractor-drawn three row direct seeder and animal-drawn seeder ensures minimum soil distrubance when placing seed and fertilizer in rip lines

Use of ordinary hoe for making planting holes then later apply fertilizer/manure then seed

Pick-axe can be useful equipment for making planting holes

Other methods to correct compaction and harpans include:

i. Planting basins for breaking hardpans

These are used in cases where the farmer does not have draught animals or a tractor to break up the hardpan. They are dug slightly deeper than a depth a hoe will attain. The basins are only made where you want to plant the crops, and is thus a form of minimum tillage. Application of fertiliser, manure and lime is critical to ensure plant nutrients are adequately supplied since more than one seed can be sowed. In basins, in situ-harvested rain-water and applied soil-nutient losses are minimised.

ii. Use of cover strong rooted crops or trees for breaking hardpans

Some leguminous cover crops and trees have strong roots that will penetrate through the hardpan and help water infiltration and establishement of crop roots. The crops can be planted after ripping and grow together with main crops as an intercrop, or in rotation to break hard pans. Examples of such crops and trees include: Pigeonpea (Cajanus cajan), sunn hemp (Crotalaria juncea), and Gravelia (Gravelia robusta).

Planting basins can be large enough to have 7-9 plants or small for 1-2 plants.
CA principles applied include minimum tillage, cover crops (mulch and live) and appropriate crop integration ensuring food security , sustainable incomes and livelihoods.

B) Permanent soil cover (cover cropping)

It is the deliberate introduction of live leguminous plant materials and/or dead crop stovers or mulch to the soil surface to protect it from rain, sun, and wind.

Permanent soil cover helps in:

- Building soil structure;
- Improving soil fertility;
- Maintaining soil temperature;
- Improving soil aeration and soil water holding capacity; and
- Decreasing dependence on herbicides for weed control.

Cover crops are commonly grown during the same period of planting main crops or during fallow periods, between harvesting and planting of commercial crops, utilising the residual moisture in the soil. Their growth is interrupted either before or after the next crop is planted, but before competition between the two crops starts.

How to choose the right cover crops

The crops must have multiple purpose services, such as:

- providing edible seeds and vegetables
- improving soil fertility
- serving as animal fodder
- being used as firewood or fencing material
- suppressing weeds and having medicinal properties

The permanent soil cover is provided either by live crops such as beans, pigeon peas and pumpkins within a cereal field or by crop residues left on farm after harvesting (e.g. maize stovers, sorghum stovers and leaf falls).

Soil surface covers include:

- Mulch cover such as the slow breaking/ decomposable crop residues (dead cover) from stalks and leaves/pruning from crops/ trees/shrubs/grasses
- Grown cover crops (live cover) - Green manures that are grown or applied as a cover on the soil surface with the purpose of recovering and reducing soil degradation

i) Mulch as soil cover

Mulch may come from different sources including:

1. Cover crops – from slashed, crashed or after spraying live crops with herbicides
2. Crop residues – from harvested annual crops such as maize or sorghum stalks laid on the surface. Stalks of cereal crops which decompose slower than those from legume crops are preferred.
3. Tree and shrub prunings – leaf fall and twigs can be used to cover the soil as well as for animal fodder. These trees and shrubs can be along the fence and on contours as soil erosion hedges but also within the cropped area as part of CAWT approach.

ii) Live cover crops as soil cover

These can be:

1. Non-legumes – for example pumpkin, sweet potato, etc.
2. Legumes – those that fix nitrogen, evidence of this is seen on the roots – with bumps holding special bacteria, for example Dolichos lab lab, Mucuna, Cowpeas, Pigeon peas, Canavallia, Desmodium, Vetch, Crotalaria (Sunn hemp), Tephrosia, etc.

Step 1:

Relay the plant cover crop within a growing maize or any other crop

Step 2:

After harvesting of maize crop, leave the cover crop colonize the field

Step 3:

Cut down the cover crop to allow planting of new crop. The residue acts as good mulch as the new crop establishes and repeat the process of sowing in cover crop seven weeks after planting your choice crop

iii) Some tips on the management of cover crops:

During sowing of the cover crop decided on the appropriate spacing/seed rate since it depends on the companion crop (inter-crop), rainfall amounts/season (wet and dry areas)

1. Carry out inoculation for some legume plants that may not make nodules by themselves. Ask expert on how to carry out inoculation or if necessary to do it.
2. You may need to speed up germination in dry areas or during delayed onset of rainfall season.
3. Weeding of cover crops may be necessary before they completely cover the soil surface to suppress weeds.
4. When intercropping, control the climbing nature of some cover crop plants to avoid entangling with companion crops. You can do this by frequent checking and breaking the shoots of the lead tendrils/ climber vines. This mechanical management will encourage crawling rather than climbing growth.
5. To avoid pest and disease infestation, rotate types of cover crops you grow, and in extreme cases, consider the appropriate use chemical spray. Major pests include: Pod-borer (Adisura atkinsoni); Gram caterpillar (Helicoverpa armigera); Plume moth (Exelastis atomosa); Spotted podborer (Maruca vitrata); Bruchid beetles (Callosobruchus spp.); Root-knot nematodes (Meloidogyne spp.);Reniform nematode (Rotylenchus reniformis);Lession nematode (Pratylenchus penetrans); etc.
6. You may need to control the suppressing nature of some cover crops by slashing the fully grown plants to make mulch. This can be done at the end of growing season. Use of herbicide to clear land of the previous season cover crop is recommended too but using a knife roller to crush the vegetation is possible on larger fields.

What you need to know about the principle of permanent soil cover

- At least 30% of the soil surface should be covered by trash or live cover plant materials throughout the year.
- Soil cover materials should have the potential to produce enough biomass to cover the entire soil surface during the growth cycle.
- Cover materials should be slow in decaying so as to allow a gradual process to recover degraded soils, and to allow slow release of nutrients required for crop growth.
- A combination of legumes and grasses provides the best process of slow release of nutrients for crop growth.
- Soil cover material should also be of low carbon to nitrogen ratio (C: N).
- Choose the soil cover crop that can be adapted to a wide range of rotation and intercropping with common crops and livestock needs where applicable.
- Some of the cover crop areas should be specified for seed production to ensure seed availability in all seasons.
- Do not put on so much mulch that you bury the plants or shade them out; and do not incorporate the materials into the soils.

iv) When to plant cover crops with respect to existing cropping system

Intercropping system

- Delayed planting – this is recommended in wetter areas and it ensures reduced competition for light and nutrients at establishment stage.
- At the same time - you plant the main cereal crop and also plant the suitable cover crop but this must be in situations where late planting will face inadequate moisture for germination. The likely problem is that the cover crop may grow so quickly and smother the main crop. In this case, breaking of climbing tendrils may be required during the early growing period.
- Cover crops may not be necessary when cereal crop is already intercropped with beans/other food legumes.

Relay cropping system

This is possible at the end of the vegetative phase or during the first weeding of the main cereal crop. However, when already maize/cereal and beans/other food legumes exist the cover crop can be sowed once the beans/food legumes have been harvested

Rotational/sequential system

The cover crop can be planted after harvesting the main crop(s). The cover crop can be used to provide for extra mulch and livestock feeds as well as maintaining permanent soil cover against wind erosion and stopping livestock from grazing on your land since it can be seen to hold a crop.

In cases where rains are short/one rainy season and a crop after harvest cannot be sustained, sequential cropping is recommended, whereby a drought tolerant cover crop (e.g. Mucuna lablab) can be sown between main crop rows before the end of the rainy season. The cover crop will cover the soil surface and suppress weeds after the harvest of maize/main crop.

Need to note:

The challenges of using crop/plant residues in an extensive livestock system especially in Semi-Arid areas

Crop residues used as mulch can be a big challenge among most livestock farmers. Many will remove all or most of the residue to feed their livestock or allow animals in the field after harvesting to graze on the crop stubbles.

It is recommended that farmers leave as much of the mulch as possible on the land but feed some to livestock. Controlled grazing should be adopted especially where free range grazing is still practised. This will prevent animals from trampling and compacting the soil but also stop them from feeding on all the crop residues.

Conservation Agriculture with trees (CAWT) and establishing wood lots will help in sourcing plant forages from within the farm area to feed animals.

In case of disease and insect pest attack on cover crops farmers should rotate crops rather than resort to burning to control pests and diseases. Use pesticides if only very necessary.

Termites are important because they break down plant materials and help to improve soil organic matter; they also help aerate the soil to improve infiltration by water.

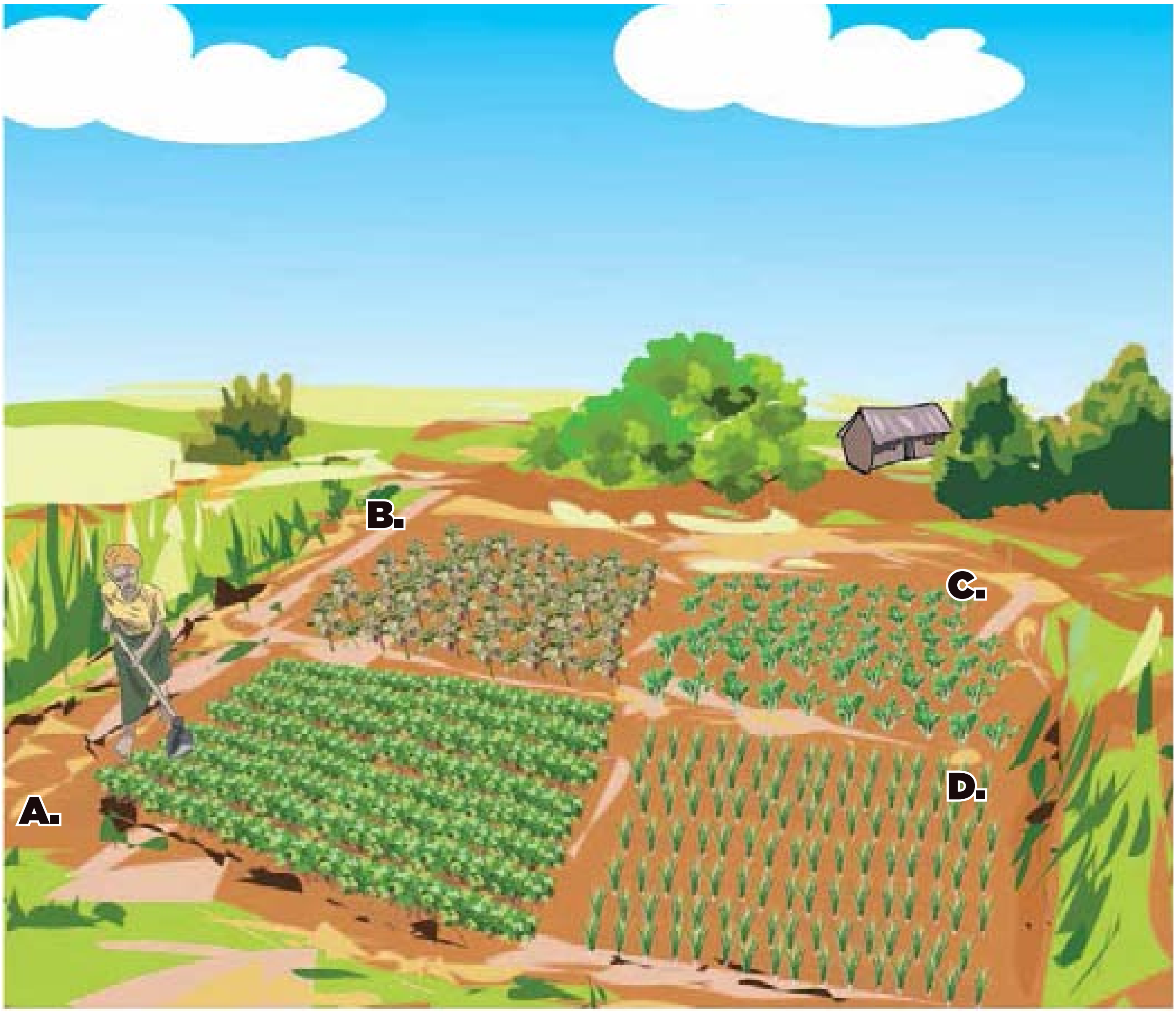
Other farmers have observed

- *Continued mulching eradicates termite infestation due to moisten soils.*
- *Using live fences that are not palatable as fodder and/or spraying them with cattle urine will keep off livestock from your CA farm.*

c) Crop rotation and association

This is the changing of crop sequences (crop rotation) and/or intercropping (association) with leguminous crops. The practice will decrease the occurrence of pests, diseases and weeds as well as protect your soil.

- Rotation/association with legumes improves the soil fertility and structure.
- Deep-rooted crops such as sunflower and pigeon peas have the advantage of utilising the nutrients and moisture below the root zones as well as weakening the hard pan.
- The tap root, when left in the soil after harvesting forms an opening for water and air when it decays. It also acts as a means of preventing formation of a hardpan because it can leave openings in the subsoil layer that will allow roots of other crops to penetrate the soil.
- Crop rotation in conservation tillage can be used to minimise weeds, insect pests, and disease pathogens.



An illustration of stepwise rotation

In the next cropping season, the crop in field A can be planted in field B, crop in field B can be planted in field C, crop in field C can be planted in field D while crop in field D can be planted in field A. Avoid planting the same crop in the same field for more than one season, as is in the case of pure stand cropping.

Other benefits of crop rotation:

For example, Soya bean rotation with cereals will take care of the cereal rust diseases and grass (gramineae) family weeds.

Mucuna or Dolichos will cover the soil and reduce the population of mexican poppy weed when rotated with cereals. Mucuna has also been found to be the best natural means of controlling couch grass weeds.

Rotation of maize with diversified crops like irish potato, sweet potato, beans and vegetables will control spread of Maize Lethal Necrosis Disease (MLND), especially in regions with a practice of growing of maize in two consecutive seasons.

4.6 Conservation Agriculture with Trees (CAWT)

This is a new concept that ensures conservation agriculture includes trees to increase uptake of CA, provides fodder, fuel, construction materials, nutrient cycling/"pumping", fruits among other products and services. Structured inclusion of leguminous trees in a CA system help in fixation of atmospheric nitrogen thus enriching the soil with nitrates.

Appropriate selection of tree species and good management can substantially reduce the requirement of inorganic fertilizers.

Pruning materials leaves a lot of litter in the soil that add carbon and enhance better retention of water and increase the content and efficiency of fertilizer use.

There is need to get correct tree spacing and management in a CAWT system. This will provide necessary nutrients and control pests and weeds to optimize on production and reduce post-harvest losses.

a) Features to consider when choosing trees for an agroforestry system

Ask for advice from the nearest agricultural office if you are unsure of the best tree species for your area. Ask for agroforestry trees that are adaptable in your area and meet the purposes of your production goals.

Confirm that the species can provide fruits, medicine, wood lot (Casuarina (C. equestifolia) and Grevillea (G. Robusta), improve soil fertility, fodder (e.g. Leucaena (L. leucocephala), Sesbania (S. sesban), and Calliandra (C. Calothyrsus), and other annual crops.

Examples of CAWT farm models

4.7 Weed control in CA

Definition of a weed: Any plant/crop that grows where it is not wanted or needed or desired.

If weeds are not controlled early enough they may take over your field and have nothing to harvest. Weeds compete with your target crops on light, water and nutrients. They are major cause/host of pests and diseases. The longer you leave them the harder it is to control them.

Weeds can be clarified as:

- *Annuals:* these are weeds that usually germinates, flowers, and dies in a year or season e.g. black-jack, Macdonald eye, Mexican marigold. They set seed for reproduction.
- *Biannuals:* are weeds that takes two years to complete its biological lifecycle e.g. colic weed, fox glove. Mainly found in temperate areas.
- *Perennials*: are weeds that lives for more than two years. e.g. couch grass, sedges, kikuyu grass. They reproduce vegetatively by use of tubers, bulbs, rhizomes, and crowns.

Weed control can be carried out by using physical and chemical methods to stop them from reaching a mature stage of growth when they could be harmful to crops. Conventional weeding besides being laborious can kill crops when it is carried out during dry periods of the season or when action of weeding disturbs sub-soil and at times rooting system of the target crops.

Conventional weeding can be overwhelming to the old and sickly farmers and the act of weeding damages the roots and kills the plant.

Controlling weeds is vital in CA practice, which must be done at the right time. Do not let weeds become mature enough to produce seeds. In the first couple of years after adopting CA, it may be hard to control weeds but patience is required. When weeds are slashed when still young and left on the soil surface, they can become good mulching material.

Why you should control weeds in CA

- Weeds shade your crops from light and compete with them for water and nutrients, push them out of their living space, and suppress growth, thus causing yield losses.
- Weeds sometimes harbour pests and diseases that attack your crop.

How to control weeds in CA

- Apply pre-emergence and post-emergence herbicides which are easy to apply and do not disturb the soil. Use any of the methods of spraying - weed wiper, knapsack sprayer, hand-pulled sprayer, animal-drawn sprayer
- Plant cover crops and intercrops which spread over the soil and suppress weeds. Use crops that spread quickly and produce much vegetation. Ensure they do not strangle the main crop
- Apply mulch all over the surfaces between rows, and thus make it hard for weeds to grow.
- Practice shallow weeding to minimise soil disturbance at a depth of more than 2.5cm, using a weed scraper or a panga/machete
- Practice rotation to break the life cycle of weeds
- Practice hand weeding by uprooting weeds.

a) Weed control

Weed control while minimally distrubing the top soil can be achieved by shallow weed scraper, herbicide application using a knapsack sprayer and zamwipper. Also use of livecover crop and residue soil cover materials.

CA methods of reducing weeds competition and population

METHOD	TOOLS	BENEFITS
Slashing weeds throughout the season	Slashers, Machetes	Prevents weeds from producing mature seeds
Shallow weeding	Hand hoe, shallow weeders	Avoids disturbance of deeper soil layers and evaporation of soil-water
Application of appropriate herbicides	Knapsack sprayer, Zamwipe	Broad spectrum herbicides such as glyphosate clear the weeds. Selective herbicides enable clearing of weeds within crops
Cover cropping	Creeping crops (e.g. mucuna, desmodium, dolichos lablab, etc)	Introduce when planting main crop or 2-3 weeks after
Hand weeding	Pulling out	Prevents weed from flowering where weed density is low

Weed control methods: Use knapsack sprayer, shallow weeder, contact applicator (zam wipe) and cover crop.

b) Safe use of herbicides:

1. Always read the label carefully before using any herbicide.
2. Check the date on the label to make sure the herbicide you buy is still effective.
3. Buy only from a certified dealers.
4. Mix the herbicide with clean water of drinking quality.
5. Spray from the right height. This depends on the height of the weeds and the type of nozzle.
6. If you are using a hand-pulled or animal-drawn sprayer, adjust the height of the boom so that the spray mist from the nozzles covers the weeds evenly – not too much overlap and no gaps.
7. Do not use the same herbicide year after year, because weeds may become resistant to it.
8. Use protective clothing to protect yourself from harmful effects of the herbicides.
9. Wash your hands, face, body and equipment immediately after handling or using any herbicide.
10. Rinse and clean spray equipment well away from water sources such as wells, ponds or rivers.

c) Integrated pest and disease management

What is climate-smart pest and disease management?

- Safe use of chemicals avoids the destruction of the ecosystem which kills some of the beneficial organisms such as bees and lady birds.
- Some farming practices like mono-cropping encourage the buildup of diseases and pests.

How can you practise climate-smart agriculture?

- Use integrated pest and disease management practices that combine cultural, biological, mechanical, genetic, and chemical methods.
- Use chemicals that are friendly to the environment and do not kill friendly organisms. To avoid killing bees, spray in the afternoon (between 1.00 pm and 3.00 pm) when nectar secretion by flowers is low and bees are not foraging.
- Diversification by planting more than one crop type on the farm reduces the build-up of pests and diseases.
- Use of biological pest and disease control methods in the form of parasites or predators as natural enemies, as well as repellant plants and organic chemicals that are environment friendly.
- Use of cultural pest and disease control methods through crop rotation and mulching in order to break the pest and disease cycle
- Planting of pest- and disease-resistant crop varieties
- Scouting and mechanical destruction of pest and disease infested plants or crops

Parasitic wasps and predators such as predatory mites, ladybird beetles, and lacewings are important in natural control of whiteflies. Spray Neem tree extracts as Neem products inhibit growth and development in the immature stages, repel whitefly adults and reduce egg laying.

In bee keeping areas, crops that are repellant to bees like Mexican marigold are poisonous and should be planted away from bee hives.

Chapter 5

©FAO/Eric Kimani

Practices that improve soil fertility

One of the aims of sustainable land management (climate-smart natural resource management) is to increase productivity and improve livelihood by reducing on production costs, maintaining soil fertility while conserving the water. Practices of burning crop residues, deforestation and continuous ploughing tend to destroy soil structure and contribute to declining soil fertility.

As such soils are compacted, eroded and can hardly produce enough for the family. While use of chemical (inorganic) fertilizers is suggested by others, most smallholder farmers cannot afford recommended rates of chemical fertilisers, despite clear evidence of soil fertility depletion. Also, because of the shrinking land sizes and impact of climate change, adequate quantities of crop residues are not available for farmers to use as fodder and leave some on the land to recycle for soil enrichment.

There is, therefore, a need to develop appropriate soil nutrient management practices that will supplement the small doses of other types of fertilisers the farmers can afford. Besides to stop ploughing (over-turning the soil layers), it is recommended that the farmers should frequently carry out spot disturbance of soils (minimum tillage/no-till) through ripping and sub-soiling, while leaving much of crop residues on soil surface, which ensures insitu water harvesting (all described above). There is need for farmers to add compost and manure to their crop land. These last two methods of soil fertility improvement are recommended for improving soil health status, and are described below in detail.

5.1 Farmyard compost making and management

Composting is an excellent way to avoid both wasting useful, natural resources and creating environmental problems, while at the same time producing a high quality and inexpensive soil amendment. It is a simple way to add nutrient-rich humus which stimulates plant growth and restores vitality to depleted soil. It's also free, easy to make and good for the environment. Compost is a combination of wet and dry plant material and manure that has decomposed together to form a rich plant food. Compost making is a natural process of turning organic material into valuable plant food called humus.

5.1.1 Why Compost

- There is clear evidence of soil fertility depletion in most soils.
- Composting offers a natural alternative to chemical fertilizers. Most smallholder farmers cannot afford to apply chemical fertilisers at recommended rates.
- Compost also helps the soil to hold water and keep plants free from diseases.
- Compost is ready as plant food, without the need to be broken down by soil micro-organisms.
- Compost does not cause a lot of weed growth, like most animal manures do.
- Introduces beneficial organisms to the soil which help to aerate the soil, break down organic material for plant use.
- Recycles kitchen and yard waste by diverting as much as 30 percent of household waste away from the garbage can.
- Compost also helps the soil to hold water and keep plants free from diseases.

5.1.2 Materials needed for compost

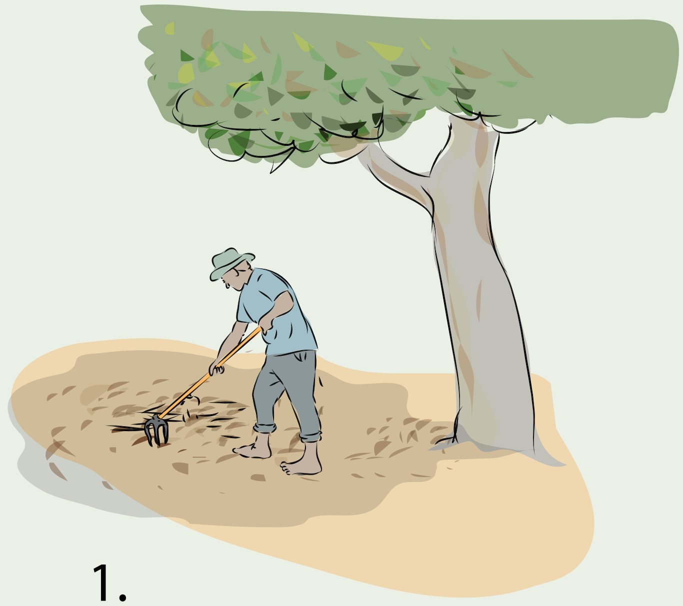
You need to collect a lot of the following:

- Rough matter- twigs or branches.
- Dry organic matter (Nitrogen rich)-Maize stalks or leftovers from other crops, wood shavings, dry weeds, etc.
- Nitrogen rich organic matter- green weeds, grass, shrub cuttings e.g tithonia, stinging nettle, leguminous trees- anything green.
- Fresh animal manure.
- Wood ash.
- Water.
- A pole of 10-15cm diameter and 1.5-2 m length.
- Tools: A panga and pitch fork.

NB: Do not put plastics, glass, metal, wood, old batteries or anything that cannot decompose (break down in soil) in the compost.

5.1.3 How to make compost

1. Choose your site under a shade but not too close to the tree trunk.
2. Choose your site and turn the soil over with a fork or a hoe. The area should be about 1 metre by 2 metres (1 spade length wide and 2 spade lengths long).
3. Collect and bring materials needed for composting and chop them into small pieces to make the composting process go faster.
4. Turn the soil over with a fork or a hoe in an area of about 1 metre by 2 metres (1 spade length wide and 2 spade lengths long).
5. Lay twigs or straw first, a few inches deep. This aids drainage and helps aerate the pile.
6. In the middle, put a pole.
7. Add a layer of nitrogen rich material (green).
8. Add a layer of carbon rich material.
9. Sprinkle some wood ash, lime, bone meal or rock phosphate (2 handfulls per m^2).
10. Spread manure on top of this about 4 cm deep. This is the width of 2 fingers.
11. Cover with some soil on top -about 2 cm deep – the width of 1 finger.
12. Water these layers until the water soaks through at the bottom of the pile.
13. Continue to build the heap, repeating the layers as before, until it reaches the height of 1.5 m (your chest).
14. It is best to cover your pile, either with a thick layer of straw or grass or plastic. This helps to keep the water and heat in and helps your pile to decompose. It also stops animals from scratching in your heap and destroying it. The covering also reduces direct methane release into the atmosphere and leaching during rain seasons. Covering also allows breakdown of organic materials into less harmful gases ensuring nutrient conservation.



1.

Choose a site under the shade but not too close to the tree trunk

2.

Lay twigs and straw first

3.

Continue to build the heap, repeating the layers as described in step 5 - 13

4.

Cover your pile with a thick layer of straw or grass

Steps to follow in making a compost heap

5.2 Animal manure management

Why animal manure?

When used properly, animal manure can be a valuable source of plant nutrients and organic matter to improve crop production and soil quality.

Nitrous oxide emissions from manure storage and processing, and from the application of manure on crops and pasture, represent about 3 million tonnes of nitrogen.

Animal manure contains most of the nutrients that crops require, including nitrogen, phosphorus, potassium, sulphur, calcium, magnesium, copper, manganese, zinc, boron and iron.

Animal manures can be solid, semi-solid or liquid. Manures differ in their nutrient content depending on the species of livestock. The indicative nutrient value of manure is shown by the Nitrogen (N), Phosphorus (P) and Potassium (K) content.

Nutrient content of manure from different livestock species

Animal Species	Nitrogen(N) - %	Phosphorus(P) - %	Potassium(K) - %
Rabbit	2.4	1.4	0.6
Chicken	1.1	0.8	0.5
Sheep	0.7	0.3	0.6
Horse	0.7	0.3	0.6
Steer	0.7	0.3	0.4
Dairy cow	0.25	0.15	0.25

Within the livestock sector, manure storage and processing is the source of about 10 % in GHGs emissions (FAO, 2014). Manure contains two chemical components that can lead to GHG emissions during storage and processing:

- Organic matter that can be converted into Ammonia (NH_3) and Methane (CH_4(
- Nitrogen (N) that leads to nitrous oxide (N_2O) emissions.

During storage and processing, N is mostly released in the atmosphere as NH_3 (ammonia) and can later be transformed into N_2O (indirect emissions).

5.3 How to manage animal manure

Minimising direct exposure of animal waste prior to proper disposal is critical. This is because the level of GHG emissions from manure (CH_4, N_2O, and NH_3 from liquid manure) depends on the temperature, method and duration of storage. The following are some of the key considerations in manure handling that affect GHG emission intensity:

- Animal waste (dung and urine) should be collected for storage without delay.
- Reducing the duration of storage is essential since long-term storage results in higher GHG emissions.
- Heat levels during manure storage affects the rate of GHG emission at high temperatures, more gas is emitted compared to lower level
- Gas release can be reduced by the use of covered storage facilities;
- Composting ensures reduced direct GHG release into the atmosphere. In this case the manure will be covered and subsequently broken down into less harmful gases.
- Improved application techniques, by rapid incorporation of manure into the soil, are critical to minimise exposure and thus risks of GHG release into atmosphere. The incorporated manure will thereafter contribute to the carbon sequestration process.

Steps of manure collection

Under stall feeding the following steps are followed:

1. The stall should ideally be constructed with a manure pit as one of the components.
2. The dung pat/fresh manure is swept or collected from the walking area in solid form and stored directly into the pit or the collection point.
3. Where the stall is cleaned with water, the manure is swept off as slurry and directed into the manure pit and covered. Where the manure is heaped, it should be covered or kept under shade.

In the extensive system, manure collection is a tedious process but dung pats can be collected, heaped and stored under shade.

Correct manure collection from livestock stall to a collection pit.

1.

2.

Move manure from the collection pit to the compost site

3.

Cover manure heap to allow uniform composting and to reduce GHC (methane) gas losses.

An example of poor manure collection and storage

Chapter 6

Water harvesting for farm production

6.1 What is it?

Water harvesting is the harnessing of rain or groundwater for crop and livestock production and aquaculture.

6.2 Why practise water harvesting?

- Water is normally abundant during the rains and scarce during drier seasons.
- Water is normally the most limiting aspect of crop, livestock, fish or fodder production.
- Water harvesting and irrigation enables crops or fodder to be grown despite inadequate rains, or outside growing seasons.
- Harvesting water for irrigation helps to increase production efficiency (output per unit input) and provide crop/fodder throughout the year.

6.3 Types of water harvesting technologies

There are several water-harvesting technologies such as use of zai pits, retention ditches, road runoff harvesting, rock catchment harvesting, roof catchment harvesting, construction of ponds, dams, and water-pans, among others.

6.3.1 Zai Pits

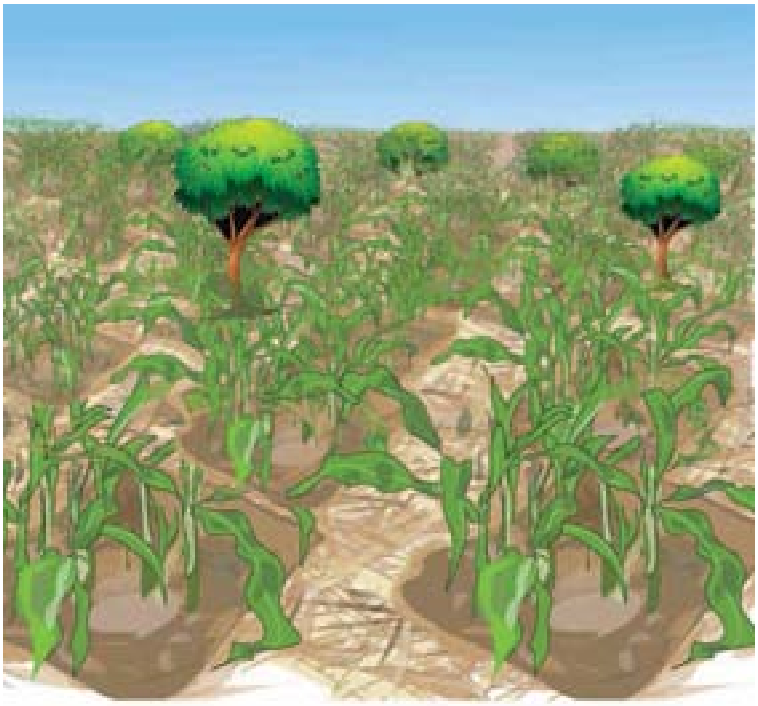
These are shallow, wide, circular pits that combine water harvesting and conservation of both moisture and fertility in the pit, mostly used for growing cereals or fodder in drier areas.

To construct a zai pit:

- Measure a circular diameter of 60 cm;
- Using a hoe, dig within the circle to a depth of 30 cm;
- Apply well-decomposed manure into the pit;
- Plant 4 – 8 seeds of a cereal crop in the pit;

Spacing between the pits depends on the number of seeds per pit, but you should ensure that the correct plant population per acre is achieved.

Zai pits are useful for rehabilitating barren, crusted soils, and gentle clay slopes (below 2%), where infiltration is limited and tillage is difficult. The soils should be fairly deep.



Zai pits can be used for planting crops such as maize, sorghum, millet

6.3.2 Retention ditches and basins

These are ditches about 50 cm wide and 50 cm deep dug along a contour to trap water and enable it to sink laterally into the soil. The bottom of the ditch may be made level to retain a uniform depth of water; if the ditch is long, it may be graded to allow water to flow to the furthest end.


©FAO/Barrack Okoba

Retention ditches are mainly used for growing bananas.

Retention basins are rectangular or square shaped, and measure about 5 x 5 m; they are enclosed by small earth bunds and tap road runoff water for growing of crops, fodder or trees by farmers on flat land.

For trees, the basins should be larger. The design of such a system and the selection of tree species should be done with care to ensure that the depth of water and duration of ponding will not be so great as to damage the trees.

6.3.3 Catch pits

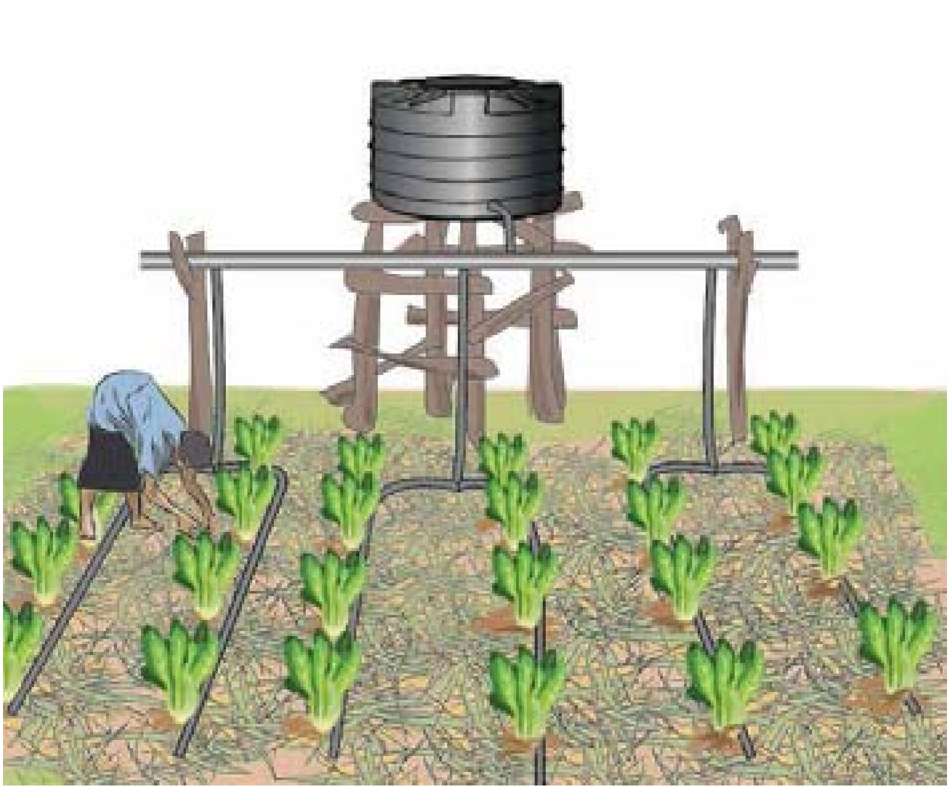

©FAO/Barrack Okoba

In this method pits of size 1 x 2 x 0.25 m are dug at many places in the corners of the fields or at any suitable sites in the slope areas. During the rains, the rain water is collected in the pits along with the silt. This enhances moisture availability to the crops.

6.4 Water harvesting for drip Irrigation

In a changing climate, irrigation technologies that promote efficient use of water are preferred. Drip irrigation is preferred because of the need to conserve the water used and to minimise the drainage problems associated with the other water application methods. Drip kits are normally installed by the suppliers or their agents.

Two types of drip kits are: ***Bucket and Drum.***



Drum drip kit: Water is collected or pumped and stored in the raised tank

Bucket drip kit: Water is collected and put in the buckets

Chapter 7

©FAO/Barrack Okoba

Greenhouse farming as a climate-smart technology

7.1 What is a greenhouse?

Greenhouse is a structure that is able to block out the negative impacts of extreme weather events by creating an artificial climate leading to high productivity. It is able to control to some level the temperature, humidity, light, and air movement, and keep out pests and diseases.

7.2 Why use a greenhouse?

In a changing climate, greenhouse technology enables the farmer to:

- Increase production through modification and stable control of the plant environment, including temperature, light and CO_2.
- To have intensive, highly-productive, year-round growing systems.
- Use valuable unused urban space to produce abundant. crops commercially grown for sale or food consumption.
- Keep pests and diseases out of the crop-growing environment.
- Ensure efficient water and fertiliser utilisation by precision application through the drip irrigation system (fertigation).
- Take advantage of flexibility in market timing.
- Minimal soil disturbance all the time.
- Allow growing of crops normally not suited to the region given outside climatic conditions and soils.

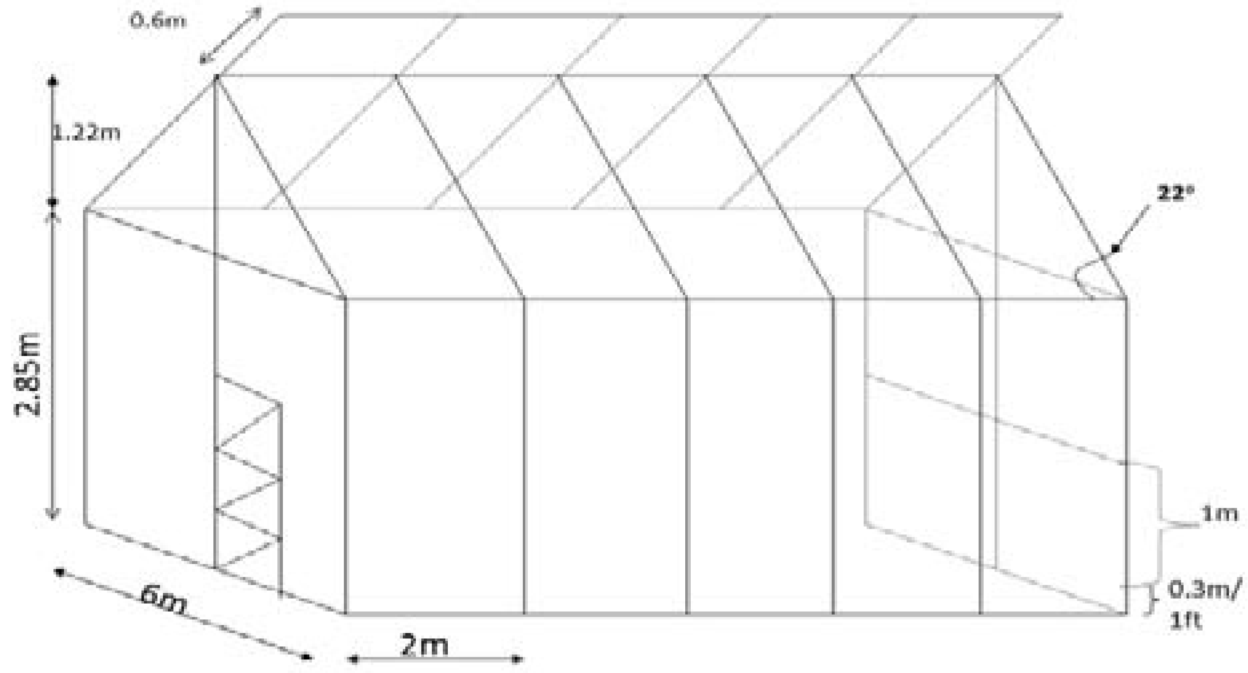
NB: Greenhouse technology has no direct relation to 'greenhouse gasses'. Greenhouse gasses (GHG) is a term used to describe the effect of the gasses that cause global warming by allowing heat energy into the atmosphere and limiting the reflection of the heat energy from the atmosphere (the way the greenhouse polythene does - making the greenhouse temperatures rise), leading to global temperature rise.

Inside a greenhouse: Potted plants on drip irrigation

7.3 Greenhouse farming technology in Kenya

There are various greenhouse sizes made in Kenya. There are about 4 sizes that are normally preferred by small-to-medium scale farmers and also largely supplied by most service providers;

1. 8 x 15 m
2. 8 x 30 m
3. 8 x 60 m



Typical dimension of a greenhouse

7.4 How you may access the greenhouse technology

Various types of greenhouses are available in the market particularly the readily pre-fabricated frame-work types by various companies and local experts. These specialists can also install the greenhouse structures. However while installing a greenhouse the following should be observed:

1. There are a variety of styles and sizes to choose from when designing a greenhouse.
2. The design and construction of a greenhouse is very customizable
3. The right one will depend on your location, space, budget limitations, how you plan to use the greenhouse, and time commitment

7.5 Factors to consider in greenhouse installation

1. Weather and seasonal extremes of your area.
2. Construction and materials: Greenhouse frames (support structure) may be constructed of wood, steel, aluminum or concrete. Modern greenhouses are usually constructed of steel or aluminum. Aluminum is the material of choice since it is light-weight, strong and rust-resistant. For low-cost structures use of wooden poles is preferred.
3. A high structure (traditional A-frame greenhouse with a relatively large roof area compared to the wall area) that:
   - Allows circulation and controls temperature compared to a low structure that gets very hot inside.
   - Prevents pest and disease build up.
   - Has an additional insulation layer of black netting materials inside.

Typical greenhouse

7.6 Orientation of the structure

1. The prevailing wind should always blow perpendicular to the longer truss or roof thus where possible the structure should be oriented such that the longer sides face the east - west direction for optimum radiation and light from the sun.
2. The door should be positioned at the edge of a short wall and a door trap constructed to provide indirect entry into the greenhouse. The trap door should be darkened for purposes of insect control.
3. Vents of up to 50% of the side walls are necessary. However, this is combined with mist sprinklers, roof sprinklers or a pad advance system to lower temperatures in the greenhouse.

7.7 Greenhouse management:

The type of greenhouse and management depends on the environmental conditions of the locality. The following recommendations if adhered to will address the challenges faced by farmers who venture in greenhouse farming.

Recommendations for setting up greenhouses in different environment

Area	Recommendation	Reason
Termite-infested areas	Do not use wood material for construction. If wood is the only possibility, then invest heavily in wood treatment against termites. Burning the 3 feet section of posts before anchoring in the holes not only helps control the termites but also prevents rotting from moisture ingress.	Termites may destroy the wooden structures
Hot areas	Choose structure designs for hotter areas Control temperatures by use of ventilation and humidity	Temperature control to suit the crop being grown in the greenhouse
Cold areas	Structure choice Temperature enhancement	Temperature control to suit the crop being grown in the greenhouse
Areas with strong winds	Consider wind direction Plant windbreaks or construct a site shielded from wind	Stronger winds are expected with climate change
Cloudy areas	Orientation should be such that the longer sides face the east- west direction for optimum radiation and light from the sun	For maximum utilisation of sunlight

Greenhouse needs to be managed properly to maintain a balanced environment and keep off pests and diseases within the greenhouse. Maintenance of the greenhouse throughout the year involves preparing for the hazards of each season such as:

i) Disease management

- The limited air circulation, tight spacing and constant irrigation encourages high humidity providing optimal conditions for reproduction of many fungal and bacterial pathogens.
- Sanitation practices which involves removal of any material that can harbor pathogens prevents spread of pathogens to healthy plants or reduces survival from one cropping cycle to another
- Start with clean material to avoid disease introduction through planting material .
- Remove weeds and volunteer plants to prevent establishment of alternate hosts.
- Familiarization with the most common diseases of the crops grown, scouting to identify and eliminate/manage diseases before build up.

ii) Fumigation

- It is necessary to clear crop pests and diseases.
- Fungicides application if plants are infected.
- Prune or remove infected tissue (flowers, leaves) to eliminate sources for spore production or propagule multiplication before fungicide application.
- Discard prunings and culled plants.
- Do not bring outside soil into greenhouse production areas.
- Do not drag hoses and other tools along floors, where infested soil and plant debris can stick and be moved to clean surfaces.
- Restrict traffic to and from areas, especially if invasive or easily transmissible diseases have been identified in the vicinity.

- Use foot baths containing sanitizers in greenhouses to prevent carrying propagules to clean areas.
- Disinfest pots, benches, floors, and tools to remove spores and propagules.

7.8 Necessary additional practices to keep inside a greenhouse:

- Employ use of horticulture lamps when there is not enough sunlight.
- Place materials that store heat through a phase change inside a greenhouse especially when heat retention is poor. This ensures that heat that enters through the glazing will remain inside the greenhouse. Concrete, rocks and water retain heat for long periods and can be used to keep a greenhouse warm overnight.
- Place chemical compounds such as sodium thiosulfate pentahydrate and calcium chloride hexahydrate, inside the greenhouse where they will melt during the day and absorb heat from the sun. At night, these materials will turn back into solids and release their stored heat into the air inside the greenhouse.
- Always try to maintain greenhouse temperatures in the range 20-25° c. Relative humidity above 60% poses the risk of multiplication of pathogens to plants and humans.
- Ventilators are fitted to most greenhouses to provide artificial movement of air and keep fresh air moving toward the plants so that their respiration cycle can occur normally. Use automated ventilators to ensure that there is always adequate air movement, or construct a greenhouse to receive natural ventilation when its doors or vents are opened.

Chapter 8

Dairy Herd Management

8.1 Improving animal health

Why improve animal health?

Good dairy herd health helps to shrink the herd overhead by ensuring small numbers in the unproductive part of the herd. This means that higher productivity benefits can only be realised from healthy animals. Therefore interventions geared towards alleviating dairy livestock diseases and disease conditions will in the long run reduce greenhouse gas emissions and ensure that there is a higher spread of the green house gas (GHG) over a higher quantity of the product from dairy farming.

Additionally, healthy dairy animals have better adaptation mechanisms to the effects of climate change such as hot temperatures, increased pests including vectors important in diseases that have high economic losses.

How you may improve animal health?

A number of interventions can improve animal health. They include:

- Deworming and vaccination
- Farm level application of bio-security measures
- Selection and appropriate culling policy
- Disease surveillance and early warning systems

8.2 Improving animal nutrition

Why improve animal nutrition?

There is a direct link between GHG emission intensities and the efficiency with which producers use natural resources. For livestock production systems, nitrous oxide (N_2O), methane (CH_4) and carbon dioxide (CO_2) emissions represent losses of nitrogen (N), energy and organic matter that undermine efficiency and productivity. An efficient dairy nutrition system is therefore essential for GHG emission intensity reduction.

How may you improve animal nutrition?

Possible interventions to reduce emissions are, to a large extent, based on technologies and practices that improve production efficiency at animal and herd levels. The composition of feed has some bearing on enteric fermentation and the emission of methane gas from the rumen or hindgut. The volume of feed intake is related to the volume of waste product.

Some of the intervention measures include:

i) The use of good quality feed: This refers to feed that contains adequate nutrients for both maintenance and production. Low quality feeds high in fibre when consumed by dairy cattle are not adequately utilised by rumen microbes and often lead to production of high quantities of methane gases.

Leguminous fodder crop – Desmodium

Processing crop residue

Concentrate feed

ii. Feed balancing – This has a positive effect of lowering enteric and methane emissions as a result of an effective supply of requisite nutrients to the microbes. This subsequently ensures that microbial anabolic processes minimise nutrient loss in form of methane and nitrous oxide. In addition, balanced feeds will also minimise disease conditions that arise as a result of nutrient deficiencies.

iii.Increasing the proportion of concentrate in the diet – under normal circumstances, microbial breakdown of fibrous feed materials result in a higher output of methane. Without concomitant supplemental protein and energy sources, effective conjugation of released methane will not take place. This will then be a sure source of GHG released during the eructation process by the cattle.

iv. Dietary manipulation and utilisation of feed additives – this includes nitrates and dietary lipids and helps to address the large volume of methane by improving the rumen microbial efficiency.

v. Pathogen-free feeds - Provision of adequate and disease-free feeds and water to the cattle will minimise introduction of diseases through the feed.

vi. Optimal stocking rates – this ensures that livestock units (LUs) are matched with available feed resources for sustained dairy cattle productivity.

vii. Feed conservation – conservation through low-cost technologies of silage and hay making is part of the feed planning process that creates resilience of the cattle operations.

viii. Use of improved forage species - the use of improved grass species and forage legumes results in increased animal productivity. Biomass feeds that are high yielding per unit area and which are highly digestible will in the long run reduce land size for feed production and reduce enteric inefficiencies. This can be used as a basis for reduction in animal numbers from increased feed conversion efficiency, which has a positive effect on GHG emissions.

ix. Rotational grazing – Rotational grazing allows for maintenance of forages at a relatively higher growth stage. This enhances the quality and digestibility of the forage, improves the productivity of the system and reduces CH_4 emissions per unit of live weight gain (LWG). Rotational grazing is more suited to managed pasture systems, where investment costs for fencing and watering points, additional labour and more intensive management are more likely to be recouped.

Rotational grazing for better forage quality and incresed animal productivity.

8.3 Improving animal breeds

Why?

The objective of animal breed improvement is to enhance the efficiency of production and the quality of the product through planned genetic change.

Fast growing dairy breeds are more efficient in converting energy from feed into production. Improved breeds have lower enteric based losses as the extraction of nutrients from the feed materials is higher resulting in less waste excreted as dung and hence less release of GHGs from manure.

Healthy calf - a product of good breeding

How?

a) Cross-breeding programmes – In the context of climate change cross breeding could be considered as an upgrading programme. This is because it provides a strategy in which cattle breeds that are adaptable to climate change effects such as heat tolerance, disease resistance, fitness and reproductive traits can be developed. Ultimately, this has the possibility to deliver simultaneous adaptation, food security and mitigation benefits.

Cross breeding can be done in a number of ways as follows:

1. Two-way crossing - this is a simple system whereby a bull of one breed is joined to straight bred cows of another breed. The cross breeding may involve exotic dairy breeds (Friesians x Jerseys, etc) or indigenous and exotic breeds (e.g. Friesians x Borans);
2. Three-way crossing – in this cross breeding programme, 3 breeds are mated. This is the most productive system, as F1 females of the right breed groups can maximise maternal heterosis for fertility, milking ability and longevity. The resultant breed can then be selected for environmental adaptation;
3. Four-way crossing – in this case, four breeds are used in a cross breeding programme.

Both the three and four way crossing, may be used to develop a composite breed. The composite breed is then subjected to selection in order to retain only a population with desirable traits (such as low feed requirement, heat tolerance, high fertility, etc). An example of such a breed in Kenya is the dual purpose Sahiwal.

b) Introduction of adaptable dairy breeds – Kenyan dairy cattle originated from the temperate regions of Europe. This implies that these animals thrive well in cooler parts of the country or in places where temperatures are regulated through proper housing and shelters. Success of any dairy enterprise depends on selection of dairy breeds suitable to the local environmental conditions .

In the context of climate change, it is important to identify and import only those breeds of animals that have shown adaptability to climate change effects. This is critical in that such breeds will maintain productivity due to their adaptation capacity even in the changed climate. In Kenya, some cattle breeds have shown useful adaptation mechanisms as follows:

- Sahiwal breed – Dual purpose with good adaptability to poor feeds and high temperatures
- Ndama breed – trypanotolerant
- Fleckvien breed– adaptable to poor feeds

c) Selection of indigenous cattle breeds – this will involve identifying and strengthening indigenous breeds that are adapted to local climatic stress and feed sources. There is always a challenge of introducing relatively higher producing cattle breeds in environments they are not well adapted to as they face constant risks of survival.

High producing indigenous cattle

Bearing this in mind, it is therefore important that selection of adaptable animals in undertaken from the already existing population. This will involve identifying and retaining individual cattle that show good productivity compared to their peers.

In breed improvement, selection is the most rigorous and intensive exercise. If undertaken successfully, it will have an outcome of ensuring complementarity between animal potential (genotype) and the environment. Selection therefore fits the animal genes (genotypes) to the environments within which animal performance in terms of survival, production and reproduction will be at their optimal levels.

The selection process

Selection can be done using either visual assessment (for subjectively measured traits) or genetic assessment (for objectively measured traits).

Subjective, visual assessment

Visual assessment is an assessment of an animal based on what can be physically seen. The traits to look for when visually assessing livestock include:

- The conformation or shape of the animal e.g. muscling.
- Structure of the animal e.g. whether the mouth is overshot or undershot.

Objective genetic assessment

Objective assessment uses actual measurements to assess the relative worth of an animal within its environment. One form of objective assessment is genetic evaluation which provides an insight into the genetic makeup of animals. This is particularly useful when sires are being acquired to improve a herd or flock according to the enterprises breeding objectives.

Simple selection criteria for dairy cattle

Irrespective of the selection process that can be used, farmers can select good dairy cattle using the following parameters:

- Milk production potential (can be measured from the performance of ancestors by looking at the conformational traits - udder size, pelvic width, teat size, neck size and shape, wither height, body length and dewlap size)
- Growth rate to weaning and yearling (the growth phase)
- Age at first heat, conception and calving
- Reproductive efficiency – as measured in terms of number of services per conception
- Mothering ability
- Calving difficulty

8.4 Improving milk production

Why?

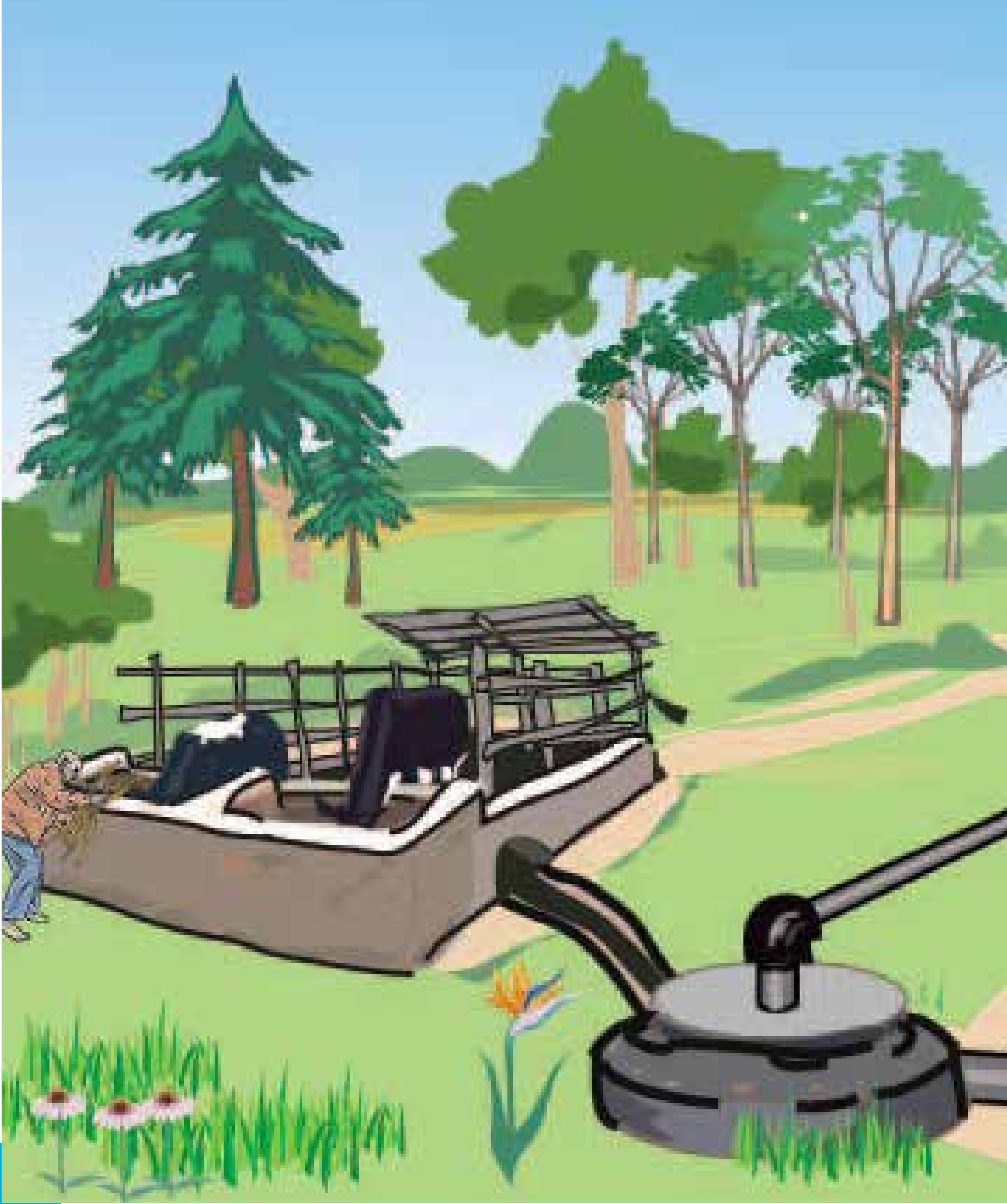
High-yielding dairy cattle producing more milk per lactation generally exhibit lower emission intensities. Improved productivity at the animal and herd level can lead to a reduction of emission intensities while at the same time increasing milk output. This is because emissions are spread over more units of milk, thus diluting emissions relative to the maintenance requirements of the animals.

How?

1. Improving practices and technologies which also contribute to emissions reduction, such as high quality feed and high performance dairy cattle genetics. It is a well known fact that cattle grow more quickly and produce more milk when provided with rations that are energy-rich such as grain supplements or improved forages. Consequently, more cattle can be raised on less land, and with fewer emissions per unit of milk produced.
2. Better herd management, animal health and husbandry practices that increase the proportion of resources utilized for productive purposes rather than simply being used to maintain the animals.
3. Reducing standing biomass (both in lactating and in replacement herds) per unit of milk produced. The impact per unit of milk is therefore reduced at both the individual cow and dairy herd level.

High yielding dairy cows

Chapter 9



Biogas production from livestock manure

9.1 Manure management for biogas production

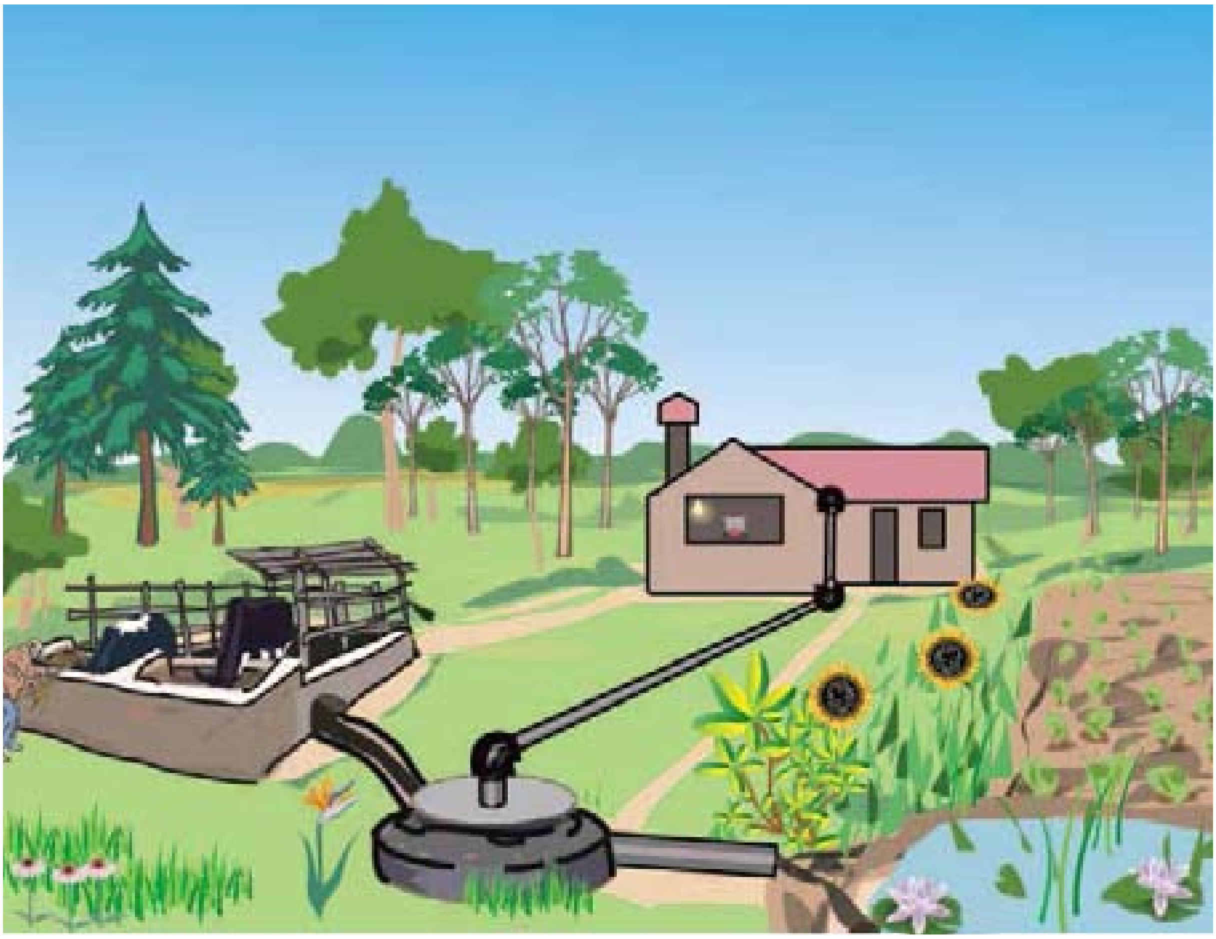
Why manage manure for biogas production?

Greenhouse gas emissions from manure are a form of energy loss that can be recovered when manure is fed into a biogas digester and is a form of clean energy source that is based on CSA principles. Dairy cattle and other livestock generate N_2O and CH_4 which is released from manure, causing 7 percent of agriculture's emission of greenhouse gases. It is possible not only to mitigate GHG emissions but also to create an opportunity for renewable energy through the generation of biogas from dairy production systems.

9.2 How can one manage manure for biogas production?

A number of issues need to be addressed in order to mitigate climate change effects through use of the biogas technology. Some of these factors are:

1. Efficient manure collection systems at production level such as through intensification and confinement of animals;
2. Creating awareness on the potential of utilising manure as a renewable source and its potential to conserve the environment and foster health through reduced air pollution from the wood-based fuels;
3. Training households on design, construction, efficiency and maintenance requirements and fuel cost-effectiveness of the available biogas systems; and
4. Biogas-derived bio slurry provide organic fertiliser that is of reasonably better quality compared to unprocessed manure.



Slurry flow from cowshed unit to digester to storage (types- flexi, floating drum, etc) to kitchen and then slurry-by product directed to crop land and fishponds and into pastures.

Chapter 10

©FAO/Eric Kimani

Improved Pasture and Fodder Management

10.1 Why improved pasture and fodder management?

Pasture management is critical in ensuring good quality and quantity forage is available at all times, while soil is covered by vegetation adequately. Poor management of pasture results in loss of land surface cover that leads to soil erosion and reduction in productivity of livestock. The removal of vegetative cover reduces the pastureland's capability of sequestration of carbon dioxide.

The ensuing soil erosion results in further release of soil-carbon to the atmosphere. The improved soil cover and availability of high-yielding quality pastures contributes to livestock productivity while reducing emissions of GHG from ruminants. Additionally, it contributes to building resilience of livestock keepers to droughts that are predicted to increase as a result of climate change.

Rhodes grass

Sudan grass

Common grazing land management mistakes

- Not matching stocking rates with expected forage yield and maintaining historical stocking rates. Projected annual precipitation is a good guide to adjusting stock numbers, increasing when expected rains are above normal and decreasing when expected rains are below normal. Overgrazing results in an increase of bare ground, reduced water infiltration, and soil erosion.
- Adhering to "Take half and leave half". Not leaving sufficient carbohydrate reserves in the lower stems and roots impedes regrowth and eventually leads to death of the plant. Harvesting too close to the ground results in minimal CHO to initiate regrowth in the subsequent year. If this is repeated, the plant loses the ability to regrow and dies.
- Half is not necessarily the half of annual production, as 25 percent is lost to insect herbivory, trampling and grazing by wild animals. Therefore aim at 25 percent of annual dry matter (DM) production.
- Stocking rates should be area specific and avoid generalised recommendations.
- Drought must be factored into stocking rates. Water development and adjustment of stocking rates are key to surviving droughts. A possible approach to destock is in the following sequence: dry, open cows with no calf, non-pregnant cows, animals with defects, steers, young replacement females, old cows, thin female and finally good condition cows.
- Not managing for toxic plants whose consumption leads to illness or death. Generally an increase in toxic plants indicates poor management.

Seven steps for successful pasture establishment:

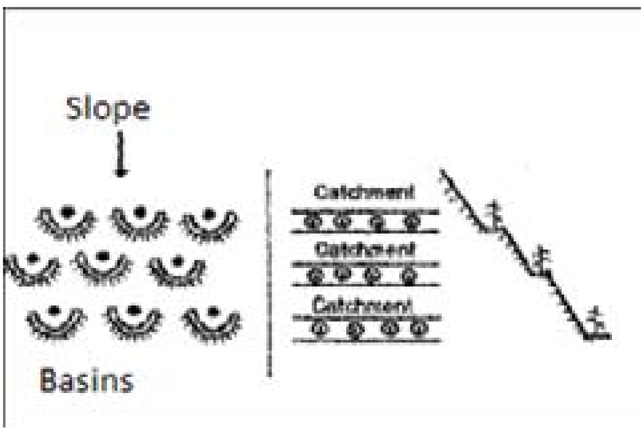
- Choose varieties with care - When selecting pasture varieties to grow, there are several factors to consider such as climate, yield (productivity), persistency, nutritive value, and animal health concerns. Determine the forage requirements, the size of land required and availability of finances, as well as machinery and labour requirements.
- Control weeds – start with a clean field and ensure perennial weeds are controlled before seeding. In addition, consider other hazards such as pests and ensure control at the earliest time.
- Choose seeds wisely – whenever possible use clean, pedigreed seeds at recommended seed rates. Apply appropriate fertiliser, or if legumes inoculate the seeds before sowing.
- Ensure soil moisture is adequate - sow into a moist seedbed when follow up rains are reasonably assured.
- Prepare the seedbed – aim at a fine, firm, weed-free seedbed and ensure that the seed is covered.
- Minimise competition with other crops – when mixing with other crops, consider aspects of competition for nutrients, light and water.

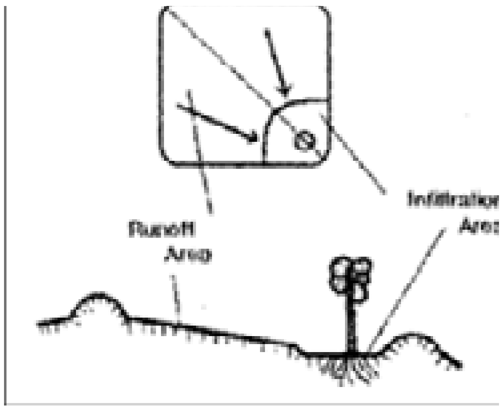
10.2 How to rehabilitate denuded pasture land?

i. Deferment is a management strategy that either postpones or delays grazing or harvesting to achieve a specific goal e.g. plant reproduction, establishment of new plants or natural regeneration for accumulation of forage for later use. This is an option for rehabilitation, when the soil seed bank is considered adequate and all that is needed is removal of grazing animals to give plants a chance to rejuvenate.

ii. Reseeding –when soil erosion has been extensive resulting in loss of soil seed bank or where selection pressure due to heavy grazing has eliminated desired palatable grass species, reseeding is a viable option. In a heavily degraded pasture land the first practical step is to undertake physical land surface manipulation in the form of making micro-catchments.

The basic micro-catchment consists of two parts, the catchment area and the infiltration basin. Rainfall runoff is collected from a small catchment area that has been cleared or otherwise lacking vegetation. The slopes and bunds are designed to increase runoff from rain and concentrate it in a planting basin where it infiltrates and is effectively “stored” in the soil profile (see illustration below). The aim is to have a mosaic of pits covering the denuded land and in the process 20 percent of the land is disturbed.





Micro catchment and infiltration basins with established grass species

Land rehabilitation using micro catchment

Within the pits, over sowing at a rate of 8 kg/ha with productive grasses such as Cenchrusciliaris, Chloris-roxburghiana, Entoropogommacrostachyus, and Eragrostissuperba is recommended. These grasses are known to have good grazing value, are easy to establish, drought tolerant and able to survive and perpetuate by producing adequate amounts of viable seed. It is also advisable to incorporate forage legumes such as:

- *Macroptiliumatropurpureum* (Siratro) with suggested seed rate of for 2-m square (in grammess),
- *Macrotylomaaxillare* with suggested seed rate of 1.6 for 2-m square (in grams);
- *Cassia rotundifolia*, with suggested seed rate of 1.0 for 2-m square (in grams);
- *Stylosanthesguinensis*, with suggested seed rate of 1.4 for 2-m square (in grams); and
- *Stylonthee hamate* with suggested seed rate of 1.4 for 2-m square (in grams).

10.3 How do you conserve and store pastures?

Animal demand is relatively constant despite temporal production of pasture that is wholly dependent on rainfall patterns, thus there are periods of scarcity and surplus of forage and the need to conserve pasture.

Why conserve pasture?

Conservation aims to avail good-quality forage during scarcity by harvesting surplus herbage. Utilisation of poor-quality pastures in the dry season contributes to enhanced methane emissions due to inefficient enteric fermentation.

How to conserve pasture

The main operations in haymaking are highlighted below.

- Mow down grasses.
- Turn to allow even drying, help dissipate heat and reduce the danger of mould development and fermentation.
- Windrow, i.e., put the cut herbage into rows for further handling and collection. In hot arid conditions, this protects the crop against shattering and bleaching.
- Trussing or putting into small heaps is an intermediate stage of drying used in some manual systems.
- Cart and store, with or without baling.

Harvesting and baling of fodder grass

Losses in haymaking

- Fermentation causes beginning of losses as soon as the crop is mown. It is as a result of enzymatic oxidation of the sap and the activity of bacteria and moulds on the crop surface.
- Mechanical leaf loss occurs during field handling, collection, transport and baling.
- Leaching losses occur if rain falls on the crop during the curing process.

High roof hay store

10.4 How to make silage

This is conservation of high moisture fodder material through fermentation in the absence of oxygen. Fodder material with a high content of water-soluble sugar content and have moisture ranging between 20 and 70% are considered suitable for ensiling.

However, materials that are too dry or wet can still be used as long as they are subjected to pre-treatment aimed at reducing or adding water content. Likewise, materials low in sugar content can be ensiled by adding water-soluble sugars such as molasses.


Step 1: Select a waterproof tube and tie the bottom


Step 2: Pack tightly the fodder material into the tube


Step 3: Cover the tube and safely store the tube silage

Basics of silage preparation steps

1. Get fodder material with moisture content between 20% and 70% moisture content.
2. Chop the material to lengths of 2 to 2.5 cm.
3. Add water-soluble sugar if necessary to the raw material and mix efficiently.
4. Fill the material in the silo, ensuring the process takes a short duration.
5. Compact the material while filling.
6. Seal the material ensuring extraction of air from the silo.
7. Store in a cool place.

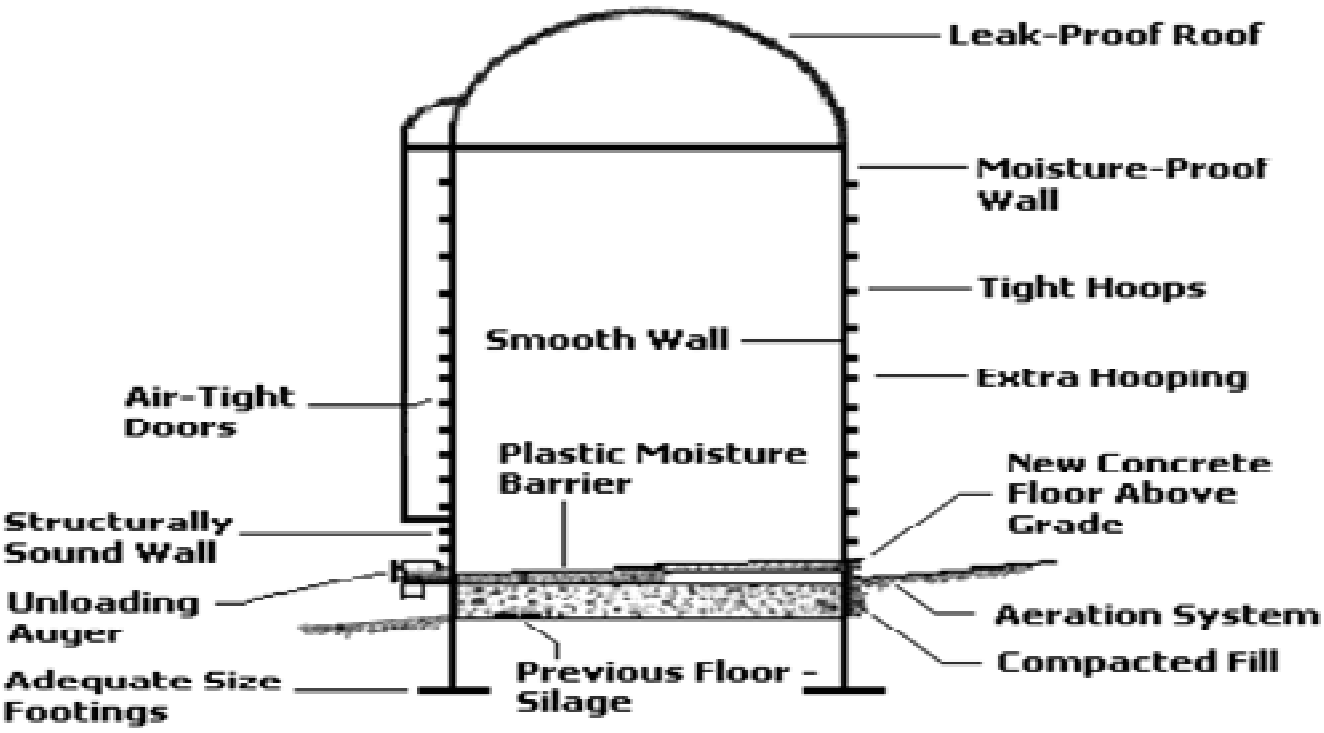


Illustration of Tower Silo

Tube Silo

Pit Silo

Chapter 11

©FAO/Barrack Okoba

Beekeeping

Keeping of honeybees is not only rewarding, but provides many benefits such as honey (food, remedy to various human ailments and income). In addition, honeybees are pollinators for many of our plants, fruits and crops and help increase yields and biodiversity of these plants. Pollination ensures productivity, causing biodiversity and continuity of genetic succession. Through pollination, soil cover is guaranteed by crops, trees and shrubs. Pollination contributes greatly to carbon sink by ensuring existence of plants in the ecosystem. For pollination to occur, a bee colony is important in ensuring the availability of biodiversity, productivity and pollination. Therefore mechanisms for bee multiplication need to be ensured for sustainable succession of genetic biodiversity.

11.1 The link between Climate-Smart beekeeping and forest conservation

Climate change is caused by increase of greenhouse gases into the atmosphere. Beekeeping essentially involves keeping bees for production of honey and wax. Through the practice of Api-agro forestry, apiculture can be integrated in a system where trees are intercropped with food/cash crops. The inter-relationship between the three is that, bees are good pollinators of trees, while trees offset carbon thus reducing the impact of climate change.

Through this integration, beekeepers also derive their livelihoods from the crops and natural forests. It is therefore important for beekeepers to conserve these forests by reducing on the destructive activities.


©FAO/Barrack Okoba

11.2 Integrating beekeeping in CSA and natural forest resource conservation

Why?

It is important to conserve natural forest resources because they act as sinks for greenhouse gases. On the other hand, beekeepers need to appreciate the importance of natural forests and conserve them, as they provide beneficial bee products which can help them derive valuable livelihood.

How?

Conservation of natural forest resources can be achieved by making the communities appreciate the importance of forests by using them to get benefits. Beekeepers should identify, propagate and conserve for the production of honey and other products and this will contribute to environment conservation as they obtain valuable livelihoods.

In order to get sustained benefits from natural forest resources, communities should learn good practices on propagating and conserving forests. This will entail reduced destruction and degradation, and thus making them owners of such resources.

11.3 Climate-Smart beekeeping practices that support crop production and natural forest conservation

What?

It is important to effectively integrate both climate-smart beekeeping and natural resource conservation for enhanced livelihoods and increased productivity.

How?

- Identification of suitable tree species for production of nectar and pollen
- Knowledge of plants that are toxic to bees and man
- Understanding of the blooming period so as to time honey flow seasons
- Identification of attractant plant species such as Oscimum
- Knowledge of plants that have adverse effects on bee products, such as Aloe, Euphorbia, and Sisal.

Nursery establishment is important because it enhances bee plants and shrubs for bees to collect nectar and pollen

Multiple use of beehives: Langstroth hives used as a fence against the elephants entering the farms next to national game parks.

11.4 Establishment of bee apiaries as part of CSA

An apiary is a place where honeybees are kept either for domestic or commercial purposes. In an apiary, there can be as few as a single hive to hundreds of hives. Before establishing an apiary, beekeepers require both skills and equipment to manage their enterprise efficiently and effectively. Before selecting the apiary site, a beekeeper should have knowledge and skills in a number of aspects.

- **Knowledge of bee plants –** this will provide information on the duration and pattern of flowering in plants. An abundance of flowers to attract the bees and knowledge of the period between budding and actual flowering will be useful for good beekeeping. Plants selected should be high nectar and pollen producers. Among the best beekeeping vegetation areas are forest woodlands, grasslands with dense covers of flowering herbs/shrubs, thickets, agricultural crops yielding nectar in abundance can be good beekeeping sites e.g. sunflower, coffee, sisal estates legumes, bananas, citrus, passion fruits etc.

Bottle brush (Nectar and pollen)

Acacia (ssp) pollen

- **Source of water -** Bees requires water for various uses in the hive, cooling, feeding larvae, and own use. Apiary section can be close to the source of water. If there is no permanent source, water can be supplied in containers with floating sticks for bees to step on to avoid drowning.
- **Bee / Human conflicts -** apiary location should be away from public places, away from cultivated fields where large number of people work often. Schools, highways and estates should be avoided so that bees do not become a nuisance to people.

Beehives can also be stored in house structure

- **Fence/hedge** - Trees and bushes to surround the apiary will make bees to fly high when leaving and returning to the apiary, thus reducing the risk of becoming a nuisance to the nearby firm activities. The area should be fenced to exclude livestock and other animals that might disturb bees.
- **Shelter** - Colonies should be sheltered from the scourging sun, frost, wind and floods. Wind cause drifting of bees and poor communication. Artificial or natural shade is necessary.
- **Drainage -** a well-drained place is recommended to avoid absconding due to high humidity. Water-logged soils cause rotting of hives and posts.
- **Accessibility -** Area must be accessible to both motorists and beekeepers commercial apiary and human traffic.
- **Pests -** an apiary should be free from areas with frequent attacks by pests (honey badger, ants and man).
- **Fire hazard -** avoid locations with frequent bush fires, alternatively cut the grass short in the apiary to minimize fire hazard.

Warning:

Use of agro-chemicals (pesticides and herbicides) in crops to eradicate pests and weeds kills bees. It is important that farmers appreciate the role bees play to maintain biodiversity.

If all the bees are cleared by the use of agro-chemicals, no pollination can take place. Because of non-selective applications on the target pest or herb, bees are mostly killed during their foraging periods. Continued use of such chemicals will lead to degradation of the ecosystem.

11.5 Equipments and accessories used in bee keeping

Bee hive

A beehive is the primary equipment that houses the bee colony. Modern hives are standardised with measurements that befits the ideal colony environment for productivity.

Protective Kit

This comprises of the overall, the veil and hand gloves. The overall is made of heavy-duty light coloured drill cotton with a zipper front.

It is fitted to fit loosely and it should always be worn when working bees. The veil is designed to protect the head, neck and face from bee stings.

It should always be tucked inside the bee suit. Gloves protect the hands from bee stings. They should be made of smooth flexible leather.

They fit over the sleeves of the bee suit. Gumboots should always be worn and should be covered by the overall while working bees. The legs of the overall should not be tucked into the boots.

Bee suit

The Smoker: This is equipment for providing smoke, which subdues the bees and makes working hives easier. Never work bees without a smoker. Make sure you have enough fuel to smoke e.g. old cloth rags, grass or wood shavings.

Hive tool: This is a knifelike iron bar. It is used for prying top bars apart. It can also be used for scrapping propolis from top bars or for cutting honeycombs while harvesting honey.

Bee brush: This is made of soft sisal fibres and is used to sweep off the bees from the combs when harvesting honey.

11.6 Carrying capacity and apiary distance

Apiary distance

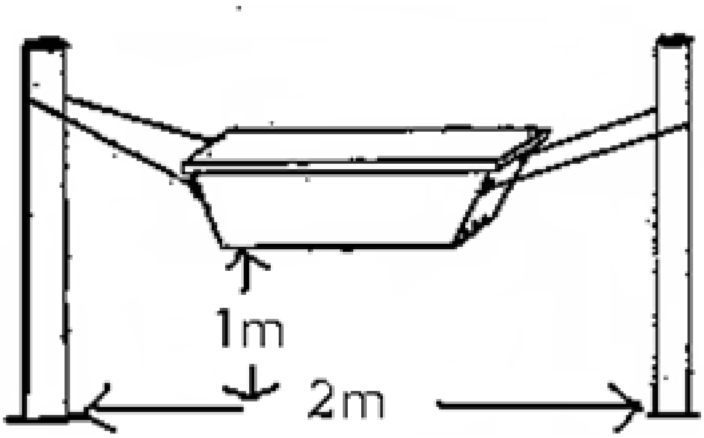
This depends on the acreage of floral sources and the number of colonies within an area. To avoid spread of diseases commercial apiaries should be at least a radius of 2-3Km square.

Carrying capacity

In one acre of good forest woodland an average of 60 hives can be comfortably established without any problem. In areas with sparse vegetation like grassland it can be less than this figure - survey of bee plants is necessary before final figure is established.

Hive setting and hanging

Hives are hanged so as to offer a convenient working height and to prevent pest and predator attack. Usually hives are suspended between two posts at least one metre above the ground. Entrances should face outwards and the posts should be fixed firmly to the ground to avoid sagging when the hive is heavy with honey.



The ideal position of hanging a Kenya Top Bar Hive

There exists various hive hanging patterns;

i) Single Pattern: This is whereby a single hive is hang between two posts at a distance of two metres apart. It uses many posts and a lot of space, thus it is uneconomical when hanging many hives.

ii) Line Pattern: This is where hives are hang on a straight line. It is good especially for a narrow strip of land

Plate : KTBH in a Line Pattern

iii) T. Pattern:

Hives are hung to form a T-shape pattern.

iv) Cross Pattern:

Hives are hung in a cross-like pattern with one post at the centre being shared by four hives. It is a very economical pattern as it saves on posts and space.

KTBH hang on a T- pattern

KTBH hang in a Cross Pattern

11.7 Manamemegnt of Apiaries

a) Honeybee colonies should be inspected at least once a month.

Why?

- To know your bees well,
- To know the colonies that are of good temperament, honey producers, hardworking and less tendency to swarming in order to keep multiplying/increasing the number of colonies in the apiaries.

b) Keep the apiary clean by slashing all the weeds in the apiary.

Why?

- This puts away pests, which might attack the bees such as ants and beetles.

c) Grease the hanging wires often.

Why?

- To avoid other insects from crawling into the hives.
- During inspection, check the inside of the hives for any insects or pests, which might disturb the bees, e.g. ants, rats, snakes, spiders, beetles, etc.

d) Check for any abnormal behavior of bees at the entrance.

Why?

- Behavior can tell you what might be inside of the hive e.g. clusters along the entrance might be an indication of too much heat or bees want to swarm or, a lack of space due to over population and un-harvested honey.

Note: Check if hive is stable, standing well or if any nail is coming out and replace it.

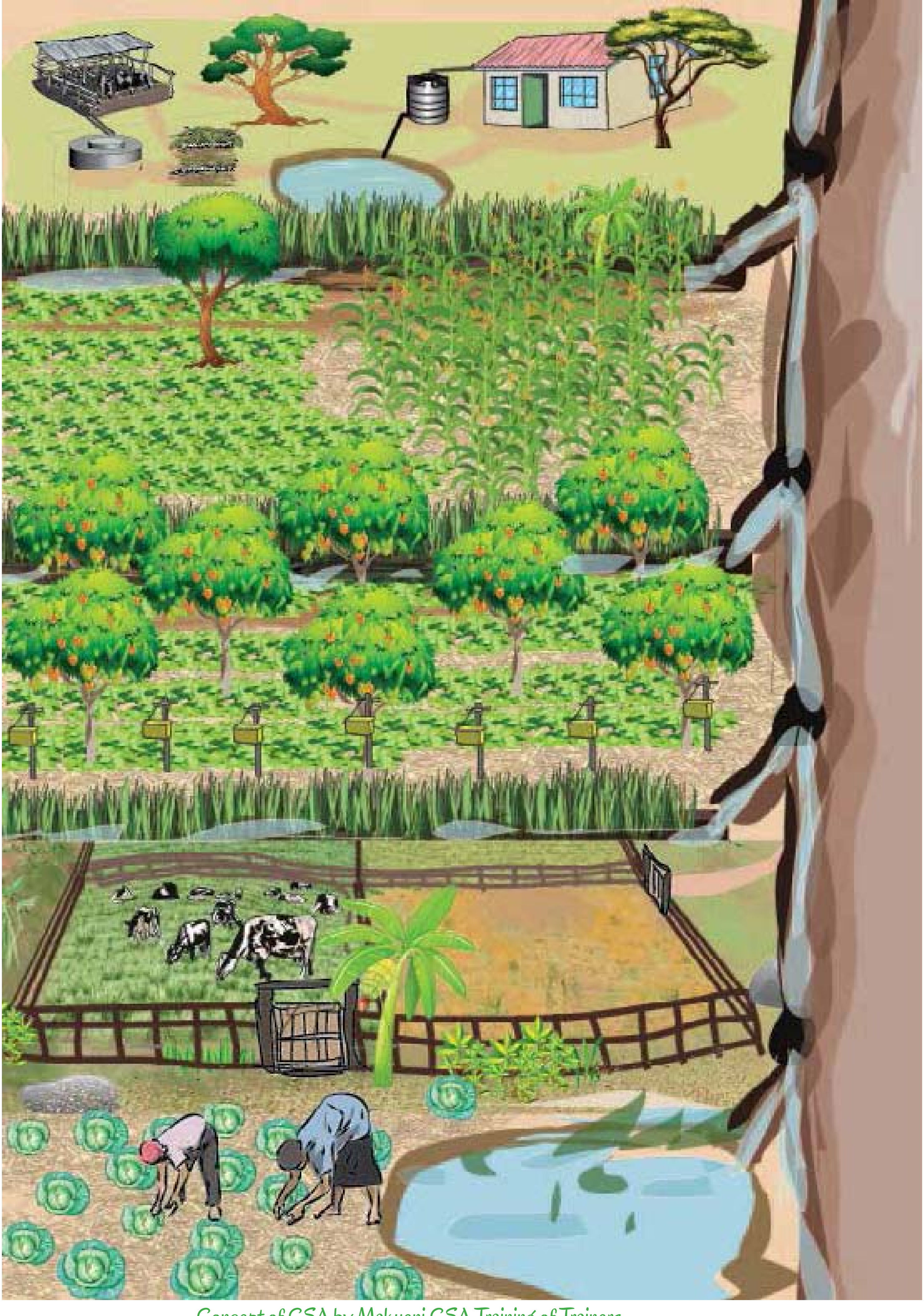
Sometimes complete repair of the hive might be necessary.

11.8 Record keeping

Record keeping is an important farm activity by any farmer.

Why?

- The record helps track some of the characteristics, which might be of a benefit in correcting some situations.
- A beekeeper may use such information to identify high yielding colonies, docile ones with good temperament, aggressiveness and swarming.
- Number all your hives and record any information after inspection, on the amount of honey harvested, pests, repairs, subdivisions, condition of the colony, colony behavior, etc.



Concept of CSA by Makueni CSA Training of Trainers

Chapter 12

Poultry Management

Chicken rearing is a viable enterprise in view of the diminishing land sizes and the increasing demand for eggs and white meat, coupled with the fact that it requires much less labour compared to several other farm enterprises. Globally, chicken supply chains produce GHG emissions of 606 million tons of CO_2, representing 8% of emissions from the livestock sector.

12.1 Climate-smart poultry production systems

Why use climate-smart production systems?

There are three types of chicken production systems: backyard systems for both meat and eggs, commercial layers, and commercial broilers.

(i) Backyard system

In the backyard system, birds are kept in small units, grow at more slowly and produce eggs at a slower rate than in commercial systems. Chickens in backyard systems have poor feed conversion ratios because of the relatively low quality of feeds, and because birds spend more energy on scavenging for feed. In backyard systems, the intensity of manure N_2O emissions is higher due to poor feed conversion.

Indigenous chicken in a run: use of run protects chicken against predation, ensures improved feeding hence increased growth rates and incomes

Management of chicks in basket: This protects chicks from predation and increases survival and enhances flock productivity

Movable poultry structure: It is moved daily from place to place within the compound to ensure chicken are protected from predation and also control scavenging and foraging. This also increases productivity.

(ii) Commercial layers and broilers systems

Broilers make up to 90 % of meat production but have lowest emission intensities, while intensively managed laying hens represent 85 % output and have lower emission intensity than production of eggs in back yard systems. This is due to high productivity in both the broiler and layers production systems have better feed conversion and have few unproductive birds in the flock. Both the commercial layer and broilers systems have much lower (GHG) emission intensities compared to egg and meat-production systems in the backyard.

Broiler raised in deep litter system

Layers raised in a slatted floor system

12.2 How you may use climate-smart production systems

Increasing productivity of birds reduces emissions per unit of product. Unhealthy birds and poor producing birds are not efficient producers.
By improving animal health and use of highly productive breeds will lead to reduced GHG emissions. Also, standardisation of production systems and technology improvement will reduce emissions through better animal and flock efficiency.

i) Poultry feeding

Why poultry feeding

Feeding has a direct link with GHG emissions. In intensive commercial poultry production, GHGs are emitted mainly during farming of feed ingredients as a result of opening up land and use of chemical fertilizer and manufacturing processes to produce feeds. Efficient utilization of feeds while feeding chicken will reduce emissions by minimising wastage and improve flock productivity.

How

This is done by feeding birds on high quality and well balanced feeds.

- Feed birds when it's cool to reduce energy consumption especially early in the morning and late evening.
- Use of homemade feed rations will reduce reliance on commercial feeds.
- Keep chicken in well ventilated houses to control room temperature.

ii) Sources of local protein-rich feeds and home-made rations

Worms and termites are excellent sources of cheap protein and best for small chicks; they also supplement proteins that would otherwise be sourced from commercial feeds. Worms and termites can easily be grown or trapped.

a) Feeding chickens on worms: Worms are high in protein content, which improves the nutritional value of feeds and increases productivity.

How to grow worms:

To grow worms you will require, the following input materials:

- Cow manure
- Fish meal dust
- Kitchen waste

Steps in preparing media for growth of worms:

- Step 1: Mix cow manure, fish meal dust and chicken waste in a large open pot or other suitable container.
- Step 2: Add water into the pot until it is one-third full so that flies lay eggs in the mixture. The eggs will hatch into worms after some hours.
- Step 3: The pot should then be left open during day-time and closed at night.
- Step 4: The mixture is left for 5- 10 days to allow the worms to grow to suitable size.
- Step 5: Once worms grow to the right size, more water is poured into the pot to allow the worms to float so that they are collected and fed to chickens.

Feeding on worms: worms are high in protein content and this improves the nutritional value to feeds and increases productivity

b) Feeding chickens on termites

Termites are a rich source of protein and can be trapped in any environment to help feed poultry.

How to trap termites

Steps in trapping termites are outlined below.

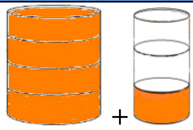
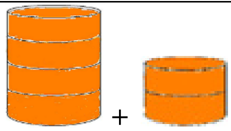
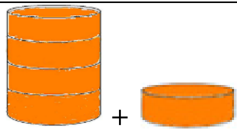
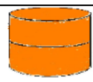
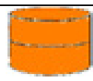
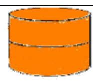
- Step 1: Mix dry cow dung with straw and sprinkle the mixture with a little water then place it on the ground.
- Step 2: Leave it for about 24 hours to attract termites.
- Step 3: The termites can then be harvested and either fed directly or dried and stored for feeding later.

Feeding using termites: increases supply of protein content in the feed improves nutrition of chicken

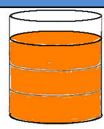
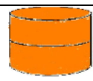
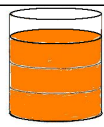
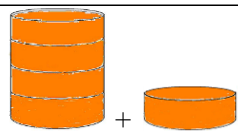
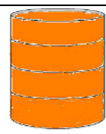
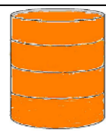
iii) The following homemade ration is recommended for feeding chickens

Ingredients of a 10-kg quantity of chicken feed (source feed supplementation manual)

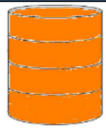
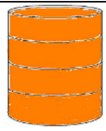
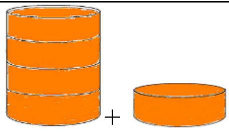
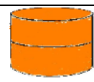
Chick feed ration with 10 kg and local measurements expressed in Swahili

Feed ingredient	Weight in kilogrammes	Local measure	Pictorial
Fish meal	1.7	Kasuku moja na thuluthi (one 2-kg tin and a third)	 1+1/3
Maize	3.0	Kasuku moja na nusu (one 2-kg tin and a half)	 1+1/2
Sorghum	2.2	Kasuku moja na robo (one 2-kg tin and a quarter)	 1+1/4
Millet	1.1	Nusu kasuku Half 2-kg tin or 1 kg	 1/2
Sunflower seed cake	1.1	Nusu kasuku Half 2-kg tin or 1 kg	 1/2
Maize germ	0.7	Kasuku nusu Half 2-kg tin	 1/2
Lime stone	0.1	Pinch / *tone*	

Growers feed ration with 10 kg and local measurements expressed in Swahili

Feed ingredient	Weight in Kilos	Local measure	Pictorial
Cotton seed cake	1.3 Kg	Kasuku kasorobo	 3/4
Fish meal	0.7Kg	Kasuku nusu	 1/2
Copra cake	1.6Kg	Kasuku kasorobo	 3/4
Maize	2.4 kg	Kasuku narobo	 1+1/4
Cassava	1.9kg	Kasuku moja	 1
Maize bran	2.1kg	Kasuku moja	 1
Lime	0.01	Pinch/ *tone*	

Layers' feed ration with 10 kg and local measurements expressed in Swahili

Feed ingredient	Weight in Kilos	Local measure	Pictorial
Maize	2.1	Kasuku moja	 1
Maize germ	1.7	Kasuku moja	 1
Sorghum	2.6	Kasuku moja narobo	 1+1/4
Millet	0.8	Kasuku nusu	 1/2
Sunflower cake	1.9	Kasuku moja	 1
Fish meal	0.3	Kasuku robo	 1/4
Lime stone	0.6	Kasuku robo	 1/4

Mixing of rations: Once the specified feed ingredients have been weighed, they should be mixed thoroughly in a feed mixer (a cylindrical drum with rotating blades) as shown below. If the drum mixer is not available, thorough mixing can be done on a flat surface, ensuring no contamination from undesirable materials.

The mixed feed should be fed to the mature chickens at the rate of 50 grammes per bird per day split into two portions and offered in the morning and evening as supplementary feeding.

For chicks, full confinement is recommended with free access to feeds.

iv) Benefits of home-made rations to free range chicken:

- They are cheaper than commercial feeds.
- They improve growth rate and reduce age at first laying.
- They increase egg production.
- Birds achieve mature body weight faster, thus reaching market weight in a shorter time.
- Chicks from hens fed on home-made rations are bigger and stronger at hatching than those from free range hens.

12.3 Improved poultry manure management

Why you should manage poultry manure

Poor manure storage and processing can be a major source of methane gas emissions. Emissions from egg production poultry systems are higher than those from broiler systems. This is because manure from egg production systems is kept for longer periods before disposal compared to manure from broiler systems.

How to manage poultry manure

- Drying manure reduces GHG emissions and makes it easy to store for long periods.
- Composting ensures reduced direct GHG release into the atmosphere. In this case the manure will be covered and subsequently broken down into less harmful gases.
- When manure is used as organic fertiliser, it should be covered after application on the farm.
- Poultry manure can also be used to fertilise fish ponds.

Dairy unit with manure slurry freely draining into a fish pond and vegetable garden. Note the chicken house constructed over the fish pond, allowing poultry droppings into the fish pond.

4) Energy-saving brooding

Why use energy-saving brooding

Energy is used during incubation of eggs and brooding of chicks. Brooders use charcoal jikos, which produce CO_2.

How to use energy-saving brooding

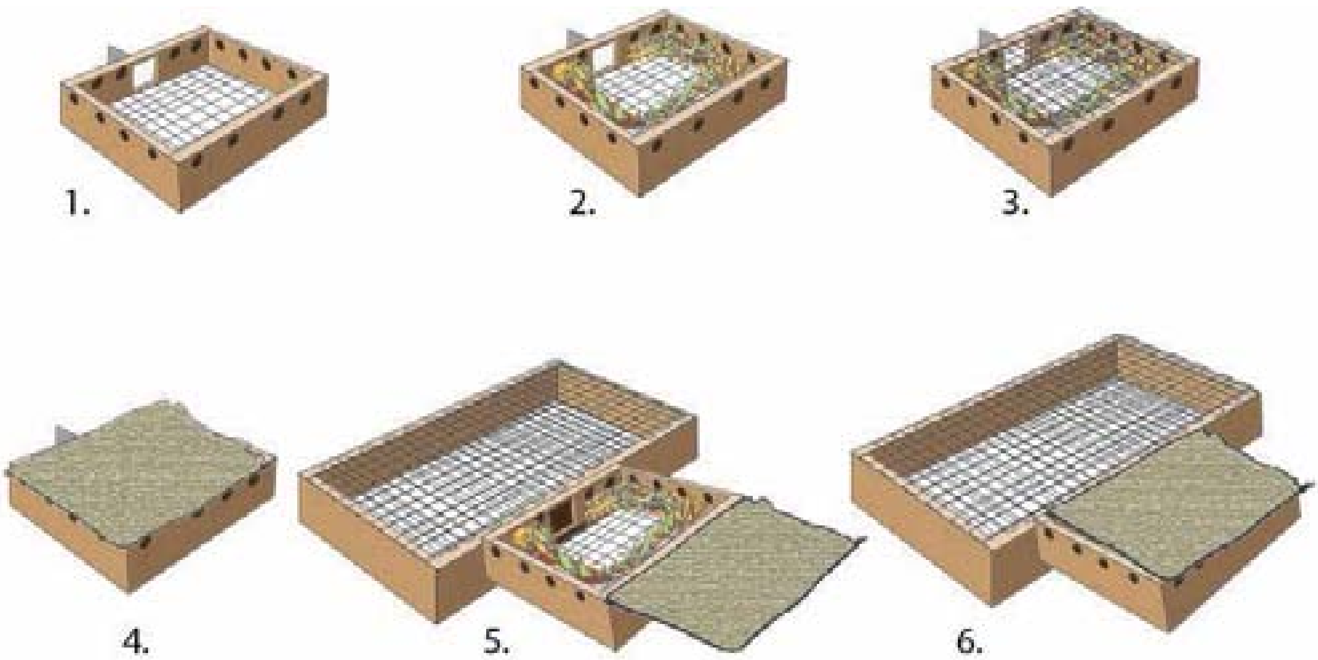
Feed birds when temperatures are low especially early in the morning and late in the afternoon.
Use technologies that require little energy. Use of hay box brooders reduces energy required during brooding and releases the hen to go back into laying. It also increases survival of chicks from 30% to 80%, thus increasing productivity of the flock.

Procedures for constructing and designing the hay-box and run

The box is made of;

- A simple square box consisting of four outer framing wooden boards 30 cm high and 2 cm thick and a door of appropriate dimensions;
- Four small ventilation holes of 2.5 cm diameter drilled at the upper side of each frame board for air circulation; and
- A wooden or wire mesh floor which is durable, smooth, and easy to clean and disinfect.
- The dimensions of the run are 2 m long x 1 m wide x 40 cm high.

Hay box and run



Key to haybox and run

1. Haybox with wiremesh floor and ventilation holes at the upper side.
2. Haybox packed with insulating material eg. hay alongside its wall.
3. Haybox with stuffed hay and wire mesh on the upper side.
4. Haybox covered with removable sack filled with hay or left empty.
5. Haybox (opened) and run covered with a wire mesh at the bottom and upperside. Note the door connecting the haybox and run.
6. Haybox and run complete assembly.

Chapter 13

©FAO/Eric Kimani

Fisheries

13. 1 The significance of fisheries

In Kenya the fisheries sector supports about a million people directly and indirectly, working as fishers, traders, processors, suppliers and merchants of fishing accessories and employees and their dependants. Majority of Kenya's fisheries sector (about 90%) relies on freshwater bodies, particularly Lake Victoria. Marine fishing activities primarily occur inshore, with an estimated 6,500 artisanal fishermen harvesting about 4% of Kenya's national fish production.

Aquaculture is the source of about 12% of Kenya's total national fish production and is undertaken primarily at the subsistence level; few commercial fish farms have been established in Kenya. It is likely that more poor people will turn to fishing and other common-pool resources in future as a result of the negative impacts of climate change on agriculture and other sectors, which have been a major source of livelihood. This is also because fish provides not only protein but minerals and is also an important source of other nutrients such as vitamins A, B and D, calcium, iron and iodine. It provides essential amino acids which have a positive effect on nutritional status.

However, climate change-induced degradation of both freshwater and marine environments is likely to have significant implications for the associated biodiversity and fisheries. Increasing water temperatures and decreasing water levels are likely to have a negative impact on fish stocks, with detrimental consequences for the rural communities.

Some of the impacts of drought on fishing activities are:

- Loss of livelihood due to drying up of fish ponds;
- Receding lake levels affecting fish breeding areas and landing facilities;
- Drying of inland lakes (Elementaita, Naivasha, etc) has increased distances of landing sites from lake shores thus causing fishermen to incur extra costs in paying for transportation of the fish to the landing site;
- Reduced levels of the jetties (Lake Victoria) thus disrupting offloading of fish;
- Increased fishing effort and illegalities in the lakes because of the influx of crop and livestock farmers seeking alternative livelihoods in fishing

13.2 Capture fisheries activities that contribute to GHG emission

Large amounts of fuel are used for activities such as:

- Onboard processing,
- Refrigeration and freezing
- Vessel propulsion
- Using heavy gears and excess weights of boats
- Fishing in depleted waters - requires more fuel per kg landed
- Low levels of fish force fishers to search longer and use heavy gears.

13.3 Aquaculture activities that contribute to GHG emissions

When an aquaculture system moves from being extensive (untreated or partially fertilised), to semi-intensive (fertilised and/or partially fed) to intensive (completely fed and fertilised).

In aquaculture, feed is considered to be the primary determining factor for emission levels; fertilisers are a secondary factor.

13.4 Fish stock enhancement strategies

In order to increase fish population in natural and man-made freshwater ecosystems the following strategies are recommended.

13.4.1 Restocking of large water bodies and rivers

Why restock large water bodies and rivers?

Dams/checkdams/riparian areas have been identified as important inland water bodies which play a vital role to boost fish production in addressing food security, employment and wealth creation. Dams are used by riparian communities for purposes including fishing, recreational fisheries, and irrigation. Most of the capture fisheries resources are under intense fishing pressure, which has significantly affected fish production, hence utilisation of dams as an alternative source of fish production will greatly sustain fish supply.

i) How to restock large water bodies and rivers

Restocking Procedure:

1. Surveying and identifying potential dams and rivers for stocking or restocking
2. Organization of the riparian community as a common interest group to spearhead the activities of the dams or rivers
3. Once rivers or dams are identified, priority fingerlings are identified (Tilapia, Catfish, Rainbow Trout), and procured from a hatchery for supply. The cost of fingerlings depends on the source.
4. Procedure for packaging fingerlings for stocking

    i. The fingerlings are separated from the main pond a day before and put in another container or *hapas* (holding nets for fingerlings) in readiness for transportation.

    ii. Fingerlings are transported in the morning or evening when temperatures are low and the environment is cool.

    iii. Plastic bags with water are used for packaging.

    iv. Quantified fingerlings in volumes are measured into the plastic bags and oxygen is added into them using oxygen cylinders.

    v. Once packed, the fingerlings have to be transported as soon as possible to the dams and rivers identified for stocking.

    vi. Once at the river or dam, the plastic containers are opened and water is allowed into the bags slowly to bring the temperature and pH conditions in the bag to those of the water in which the fingerlings are about to be released.

    vii. The fingerlings are then allowed to swim out gently and slowly into their new environment.

5. After stocking the pond or river, the fingerlings are monitored and records kept ensuring proper management. Measures are taken to prevent poaching and predators to ensure a good harvest at the end of the rearing period.

The following pictures illustrate how rivers and dams are stocked.

1. Fingerlings arrive in plastic bags

2. The plastic containers are opened and pond water is allowed into the bags slowly to bring the temperature and pH conditions in which the fingerlings are about to be released

3. The fingerlings are allowed into the dam

13.4.2 Culture–based fisheries/Aquaculture (CBF/CBA)

Why culture-based fisheries/aquaculture?

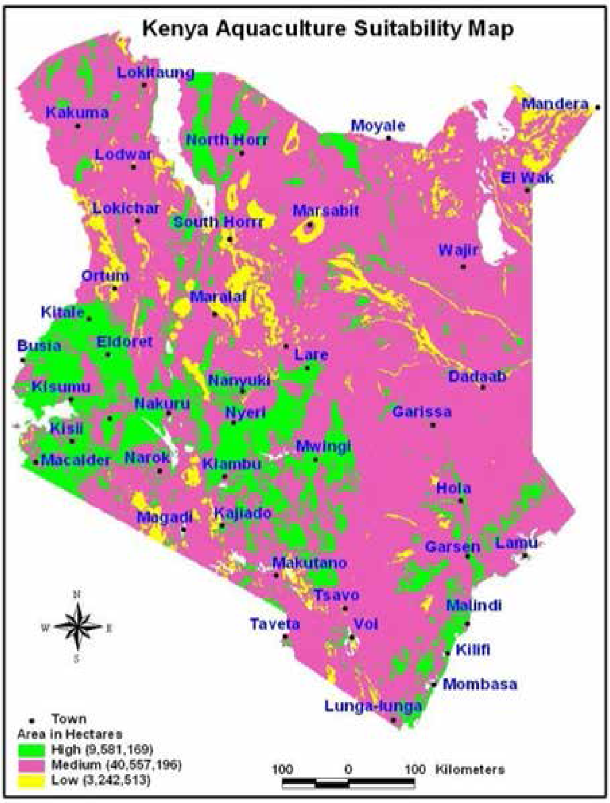
Aquaculture is the rearing of water-based plants and animals under controlled conditions for human benefit. It includes both freshwater, salt water and brackish aquatic environments and refers to fin fishes, amphibians, crustaceans, snails, and even microscopic aquatic animals and plants.

In Kenya, the popular freshwater fish species for aquaculture farming have been the Nile tilapia (Orechromis niloticus) and African catfish (Clarias gariepinus). Others are the exotic species: rainbow trout (Onchornchus mykiss) and common carp (Cyprinus carpio). In the marine environment, sea weeds and crustaceans (Indian and Jumbo shrimps, spiny lobsters and crabs) are reared on a small scale.

Fish species	Fish characteristics	Fish Illustration
NILE TILAPIA (*Oreochromis niloticus*)	Tilapia: • are indigenous to Africa, but have been introduced in many parts around the world; • are disease resistant; • are prolific breeders and reproduce easily under culture conditions; they lay few eggs which enjoy good maternal care and therefore have a high survival rate; • feed on a wide variety of foods and tolerate poor water quality with low dissolved oxygen levels; • can grow in brackish water and some will adapt to sea water; • mainly grow under semi-intensive systems as monoculture, males only monoculture or polyculture with African catfish; • have an optimum temperature range of 27-30^{0}C; • are very popular in Kenya and have a good market in the world; and • fillets yield is from 30% to 37%, depending on fillet size and final trim.	
AFRICAN CATFISH (*Clarias gariepinus*)	The African catfish: is indigenous to Africa; • can be described as omnivorous, eating vegetable matter, zooplankton, insects, snails, tadpoles, leeches, small fish among others; • is very hardy, can survive in low-oxygen waters and are adapted to extreme weather conditions; • can grow in brackish water in salinities of 10ppm; • has ability to breath atmospheric oxygen; • does not breed in captivity and artificial spawning is used; • grows very quickly if adequate high protein feed is available.	

Fish species	Fish characteristics	Fish Illustration
cont'd AFRICAN CATFISH (Clarias Glariepinus)	• has few bones; has higher fillet percentage than tilapia • is mainly grown in semi- intensive polyculture systems with tilapia • has an optimum temperature range of 25-27^{0}C; and • is a good candidate for rural aquaculture in developing countries.	
RAINBOW TROUT (*Oncorhyncus mykiss)*	Rainbow trout: • is native of North America but has been introduced and farmed all over the world; • is a carnivorous fish which in natural waters consumes insects, crustaceans and other small animals; • grows well in cool, fast- flowing waters, 10-18°C, with high oxygen content • requires a flow rate of 1 L/min/kg under culture conditions; • will not spawn naturally in aquaculture systems and artificial spawning is used; • can be produced in intensive systems in tanks and raceways; • is restricted to highland areas in tropical regions where favourable conditions allow its growth; • requires high quality feed, >40% protein; • Has a high market price, especially when fresh; • has fine bones, high fillet percentage and is excellent when smoked; • measures to develop varieties that can withstand higher temperatures and lower oxygen levels can widen its range.	

Fish species	Fish characteristics	Fish Illustration
COMMON CARP (*Cyprinus carpio*)	Common carp: • Is an exotic species that has established itself in natural water bodies in Kenya; • is an omnivore feeding on both plant and animal matter; • has a habit of feeding on organisms in mud at the pond bottom, which makes the pond water muddy; • eats a variety of supplementary foods including common grain brans; • has very limited aquaculture production in Kenya where it is grown under semi intensive systems; and • attains a large size and does not usually overpopulate a pond • has an optimum temperature range of 23-26 ^{0}C • has a poor market demand in Kenya due to intramuscular bones but is popular in Asia	



13.5: Advantages of fish rearing in ponds

These are some of the advantages of fish rearing:-

- Keeping fish is a sure way of having a ready source of protein in the family in the form of fresh fish; the fish can also be sold for income.
- Fish ponds often become the last storage sites for water in times of severe drought and therefore help rural communities obtain their water for domestic use or irrigation.
- You can still keep fish even if the climate may have changed if you plan well and seek advice from your nearest extension service provider.
- Fish ponds help to improve ground water and delay movement of water downstream.
- Fish are cold blooded and therefore do not generate heat as mammals do.
- More biomass can be produced by animals in a water environment per cubic metre than by land-based animals.

Typical actions to take on impacts of climate change

Climatic events	Effects of climate change	Action to take
Decrease in rainfall quantity	Reduced quantities of surface and underground water regimes	-Use re-circulating fish-rearing systems using solar or wind power to reduce water demands and competition for water resources -A fish farmer seizes the opportunity to grow fish only during periods of sufficient water to fill the ponds as in the rainy season. -Use liner ponds to reduce seepage and make smaller rearing units using plastic sheeting (PVC) which cannot let water pass through (photo below) -Where there is a nearby river that is prone to seasonal flooding, dig depressions as shallow as 1.5 m deep where fish from flooding rivers can grow for 1-2 months. -Roof catchment can be channelled in a small pond or fish-rearing unit located next to the homestead if rainfall is sufficient but surface and ground water sources are stressed.
Change in rainfall patterns	Flooding	-Fish may be put in places where water collects and collects and stands for at least 3 months after a flood. Some of this fish will be ready for eating when the place dries up. -A farmer can make better use of a small land area and farm waste by adding fish to other enterprises such as chicken rearing and vegetable farming.

Climatic events	Effects of climate change	Action to take
Rise in sea and lakes	Brackish water zones inundated by full strength sea water of higher salinities	-People rearing fish can move further inland if the sea or lake sites rise. You may need to find a different way of getting water such as using underground water This strategy also applies to situations where fish pens are covered with water.
Reduced precipitation	Reduced crop-based feed	-Fish feed ingredients obtained as by products such as cotton seed cake, sunflower seed cake, cassava and Mexican marigold leaves, and sweet potato vines that require moderate to minimal rainfall should be encouraged.
El nino manifestation	Reduced fish meal available in the world market	-Utilise locally available sardines and crustacean species such as Omena (*Engraulocypris spp*) and freshwater shrimp (*Caradina spp*) from L. Victoria and L. Turkana.

13.6 AQUACULTURE SYSTEMS

One way of describing a fish farming enterprise is by describing the materials used to hold water. A fish-rearing 'system' helps us to describe the design, form or intensity of a specific kind of rearing facility. Common systems that can be utilised for climate-smart fish farming practices are:-

1. Earthen ponds;
2. Earthen ponds with PVC lining;
3. Timber frames with inner PVC lining;
4. Fibre glass tanks;
5. Concrete tanks ; and
6. Aquaponic systems.

1. Earthen ponds

These are water-holding ponds constructed or built up from the ground with adequate compaction to ensure an impervious character. Also called levee ponds and usually rectangular or square, they are about 4 ft deep with inlets directing water inwards and outlet (optional) pipes in the deepest part to drain the ponds when necessary, e.g when preparing to harvest the fish.

Site selection

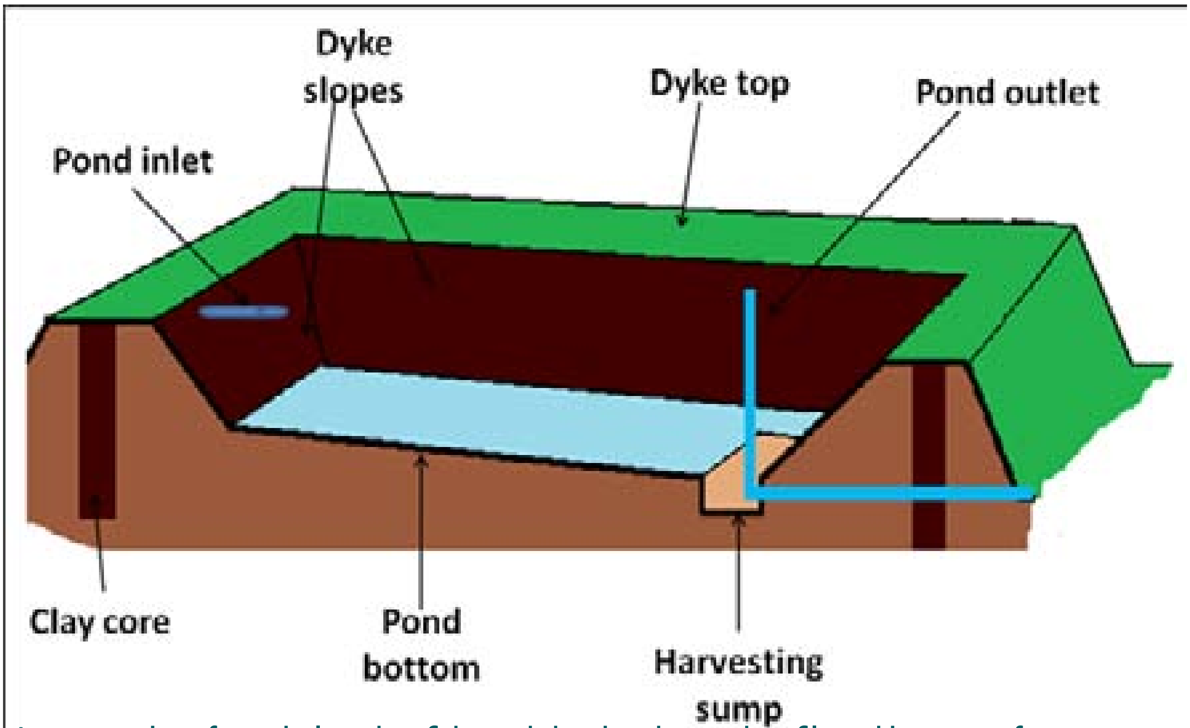
Select a suitable site – slight slope recommended to easily control the water entering and leaving the pond.

Water availability

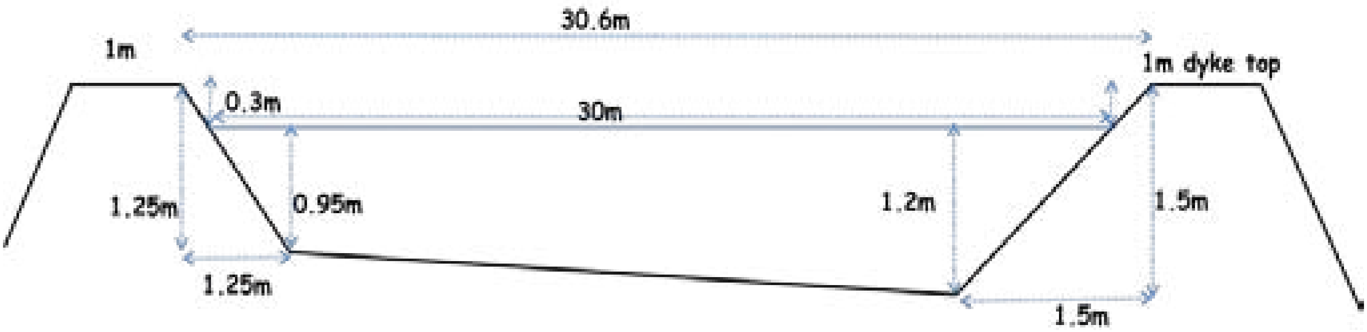
- Water should be sufficient to fill the pond and for adding into the pond as pond water is lost through evaporation.
- Water should not be polluted with pesticides or sediments from upstream.
- You may use rain water from the roof for small holding systems measuring 3 cu m or less.

Climate

- Most tropical fishes grow well in warm weather, preferably with a temperature range of 23 -29oC.



A cross section of a typical earthen fish pond showing the pond profile and important features (Sketch by: Mbugua Mwangi)



Length-wise section of the pond showing the various measurements

Steps in the construction of an earthen pond

- Select a suitable site.
- Insert pegs to mark the edges of the outer and inner corners of proposed pond.
- Remove 4 inches of topsoil.
- Undertake core trenches on all four sides if necessary.
- Begin to excavate from inside to create four walls; compact every 10 inches of moist soil.
- Shape sides (dykes) narrowing from base to the ridge top.
- Compact all sides on a slope of 1:1 or 1:2 and insert inlets and outlet pipes on shallow and deeper sides respectively.

2. Polythene-lined pond

In areas with sandy or stony surfaces and where water is often not available throughout the year, seepage is a major challenge and therefore to minimise water loss it is advisable to line the inner sides of the pond with a PVC liner when it is completed.

Lined earthen pond

These are earth ponds that are covered with sheets of heavy duty PVC sheet (poly vinyl chloride) to avoid water seepage.

3. Concrete fish-rearing tanks

Concrete ponds or tanks - constructed on all sides with bricks, which may be reinforced with cement. The ponds are usually rectangular, square or circular and 4- 8 ft deep. Construction should be as in normal tanks but a water-proof cement mix is used for brick layering and plastering.

Starting a concrete fish pond

Finished concrete fish pond

4. Fabricated raised wooden and polythene catfish tanks

PVC lined wooden frame for intensive catfish rearing unit

Catfish 4 x4 x1 m Tank- Construction

In this system, the fish would have to be cultured in tanks

List of required materials:-

- 13 pieces of cedar posts measuring 1.5 meters each.
- 30 pieces of 6x1 timber measuring 4 meters each.
- 3 kilogrammes of asorted nails (3", 4" and 5").
- Inlet and outlet pipes and valves.
- Pond liner (heavy gauge - 5 millimeter, UV treated) .

Construction procedure

The tanks would be made up of a square pond liner (heavy polythene) that is already designed with specifications of 4x4x1m.

- This liner is fitted within a timber foam work.
- Each side of the foam work has four erected poles measuring 1.5 meters each.
- On the sides, 6x1 timber planks are nailed onto the erected poles. The planks are placed one on top of the other and this is what holds the liner.
- The tank height is 1m.
- The holding tank has an in-let through which water enters the tank and an out-let which is at the lower part.

Note:

The water in the tank is drained regularly (after every 4 days) to rid the tank of ammonia, un-eaten feeds and wastes which would otherwise be toxic to the fish if left to accumulate. The ammonia usually accumulates at the bottom of the tank. When the outlet is opened to remove dirty water from the tank, the inlet should be opened to allow in fresh water.

5. Fibre glass tanks

Fish can be reared in enclosed tanks as small as 500 litres made of plastic fibre glass containers using continuous recycled water, which is purified and returnedto the system

6. Fish cages

Fish cages in a body of water can ensure better fish populations that a farmer can easily monitor as he feeds them daily. This provides better results.

Materials needed

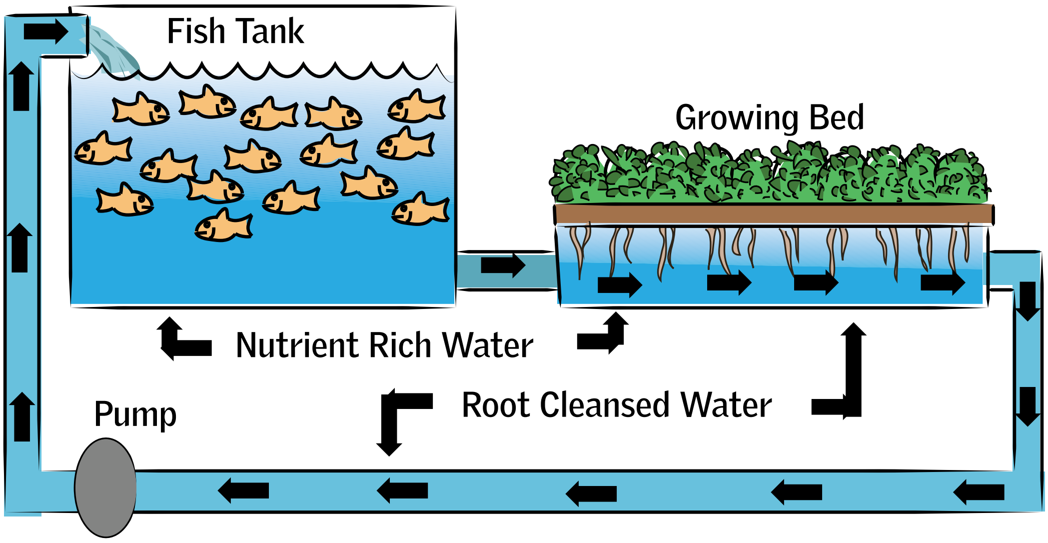
- Wire mesh
- 20-litre plastic water cans
- Roping material
- Netting material

Requirement for selected fish culture systems

System description	Dimensions (length, width and depth)	Level of intensity	Purpose	Species of fish	Stocking rate	Feed and fertilisation, and water management
Earthen	20m,16m ,1m	Semi-intensive	Rearing	Tilapia and catfish at 10:1 (1,000 fishes)	3 fish/m^2	DAP or NPK fertilisers applied with 26% crude protein supplementary diet given at 3% body weight of fish stock. No water exchange until harvest.
Concrete	6ms 4m, 2m	Intensive	Rearing	Tilapia, catfish, ornamental fish	10 fish/m^3	No fertilisation, feed complete diet of 35% or more crude protein daily at 3% body weight of existing stock
Fibreglass tank	2m diameter, 1m depth	Intensive	Rearing or temporary holding	-Tilapia, catfish fingerlings	250 fry per m^3 (2,000 fishes)	Utilise recirculation technology, No fertilisation, feed complete diet of 35% crude protein (or pure fishmeal) 6 times a day
Fabricated timber frames with polythene	4m, 2m, 1.5m	Intensive	Rearing	-Catfish	50 fish per m^3 (600 fishes)	-Total change water every 2 weeks
Raceway	15m, 8m, 0.75m	Intensive	Rearing	Trout	30 fish per m^2 or 2,700 fishes	Water intake and removal is continuous at about 0.08m^3 per second; feed on complete diet. No fertilisation and maintain high oxygen levels and temp of less than 18°C

7. Aquaponic system

Fish can be reared in conjunction with growing of a high value crop which utilises effluent from the system. The extractive action of plant roots helps to purify the system, enabling water to be pumped back into the fish-rearing tank.



By integrating a farm system, you ensure more efficient utilisation of farm resources. For instance, waste from a livestock-rearing unit (e.g. poultry) can be used to fertilise fish ponds or crops. It makes economic sense for farm operations not to rely on inputs that have to be purchased.

- Cultured species such as tilapia are omnivores and can utilise naturally occurring feed such as algae.
- Combinations of tilapia (omnivore), catfish (carnivore) and common carp (detritus feeding) is another strategy that ensures better utilisation of different trophic levels of the aquatic ecosystem under extensive aquaculture.
- By utilising manure from livestock directly or as fertiliser, you reduce ammonia, methane, carbon dioxide and nitrous oxide that escape.

Possible integrated systems and their advantages and disadvantages

Farm Enterprises	Description	Advantage	Disadvantage
Fish and poultry	Poultry houses constructed at edge or inside fish pond	-Poultry (e.g. duck, chicken) droppings fertilise pond water -Cost of inputs reduced -Farmer benefits from sale of poultry and fish products -Uneaten feed droppings from poultry house are eaten by fish such as tilapia	-May require substantial capital to set up -Over-fertilisation can affect water quality
Fish and pig	Pig housing constructed next to or on top of fish pond	-Pig waste is used for fertilising pond water -Farmer benefits from selling fish and pork	-Excessive fertilisation can be released as undesirable effluent during harvesting
Fish and rice	Rice paddies designed with one deep end to serve as fish refuge when rice crop matures	-Farmer gains from fish and rice crops	-Rice crop cannot be sprayed due to fish presence -Clay soils crumble, causing poor penetration of sunlight -Rice may not dry well on maturity
Hydroponic system	-Fish is integrated with high value horticultural crop.	-Fish and high value crops are reared under intensive and clean environment	-Is expensive to set up and is often not profitable

13.7 Feed Management in Fish Farming using the CSA approach

Types of feed

a) Natural feed - their growth is encouraged for use by the fish stock:

- Algae (plankton)- Add DAP, NPK, SSP or dry animal manure in recommended amounts to bring about algal growth. This can be confirmed by a green appearance of water.
- Inorganic fertiliser is applied at 5 g/m2 for semi-intensive pond systems. For empty ponds it may be spread on the pond floor or mixed with water and the solution spread on the pond water surface.
- Animal manure can also be applied on pond water at a rate of 50 g/m2 to boost algal production.

Application of fertilizers in a pond after forming a solution

Simple feed formulation for farmers:

Objective is to mix a 100 kg of feed having 28% protein using 3 combinations of dry milled ingredients:

- Maize bran 60kg
- Cotton seed cake 15kg
- Fish meal 25kg
- Total wt 100kg
- Also add 50g vitamin mix

b) Artificial feed –formulated dry agricultural products given as pellets or powder

- Artificial feed can be acquired from recommended millers and distributers.
- Farmers can also learn to make their own feed using grains and oil crops.
- Feed ration given is calculated as 3% bodyweight per day of dry weight.
- Feed for grow-out fish is usually given twice daily for semi intensive practices and 3-4 times daily for intensive setups, between 9 am and 4 pm for best results.

How to manage pollutants in fish farming

- Avoid excessive feeding and wastage from feeding practices.
- Feed millers to undertake climate-smart operations to minimize heat.
- Closely monitor ammonia emanating from fish feed within ponds.
- Stop fertilisation one month and feeding 3 days before harvesting.

13.8 HYGIENIC HANDLING OF FISH AND FISHERY PRODUCTS

13.8.1 What is post-harvest fish processing?

After the fish is harvested, it must be handled appropriately so that it does not get spoilt since it is perishable. The fish must be kept under ice or in a cold store. Usually, some of the harvested fish is processed in order to add value to it. Another reason for processing is to lengthen the shelf life of the fish. Various forms of processing such as deep-frying, smoking, fermenting and sun-drying are generally done by the artisanal fishers and fish farmers.

13.8.2 Why carry out post-harvest fish processing?

Processing of fish and fish products preserves the quality of the fish. Some of the processing techniques add flavour and of course value to the fish products. In some cases, processing methods such as sun-drying, smoking and deep-frying help prolong the shelf-life of the fish.

During the rainy season, usually a lot of fish is caught but sometimes means of transport to the markets is unavailable. This results in fish being sold at throw-away prices. However, processing helps the fishermen stabilise the market prices because they do not have to sell the fish immediately.

How is the processing done?

Source of energy:

i) We encourage artisanal fish processors to use sources of energy that are environment friendly. Nile perch offals (fish stomach and intestinal content) have been used as a source of fuel for fish frying. This ensures that the fish processing refuses do not litter the environment.
ii) Sugar-cane chewing is rampant along the beaches. The resulting bagasse usually makes the environment very dirty. Some fish processors became smart enough to start using it as an alternative source of fuel for fish smoking or deep frying.
iii) Saw-dust from carpentry workshops is also used as a source of fuel for fish processing.
iv) Energy-efficient cooking stoves (jikos) are recommended for use in fish-processing. These include ***Upesi jiko*** and ***Jiko kisasa***.

Upesi Jiko   Jiko Kisasa

13.9 Steps in fish smoking

Generally, fish smoking has always been done using a lot of wood fuel. This is not climate smart because it emits a lot of GHG gases (Co_2 / Co_3)

In order to ensure climate-smart fish smoking, jikos and ovens that use less fuel, and especially that from bagasse, such as chorkor are recommended. Use of fuelwood in energy-saving stoves is also recommended. Farmers in fishing communities are advised to plant many trees, which become a sustainable source of fuelwood.

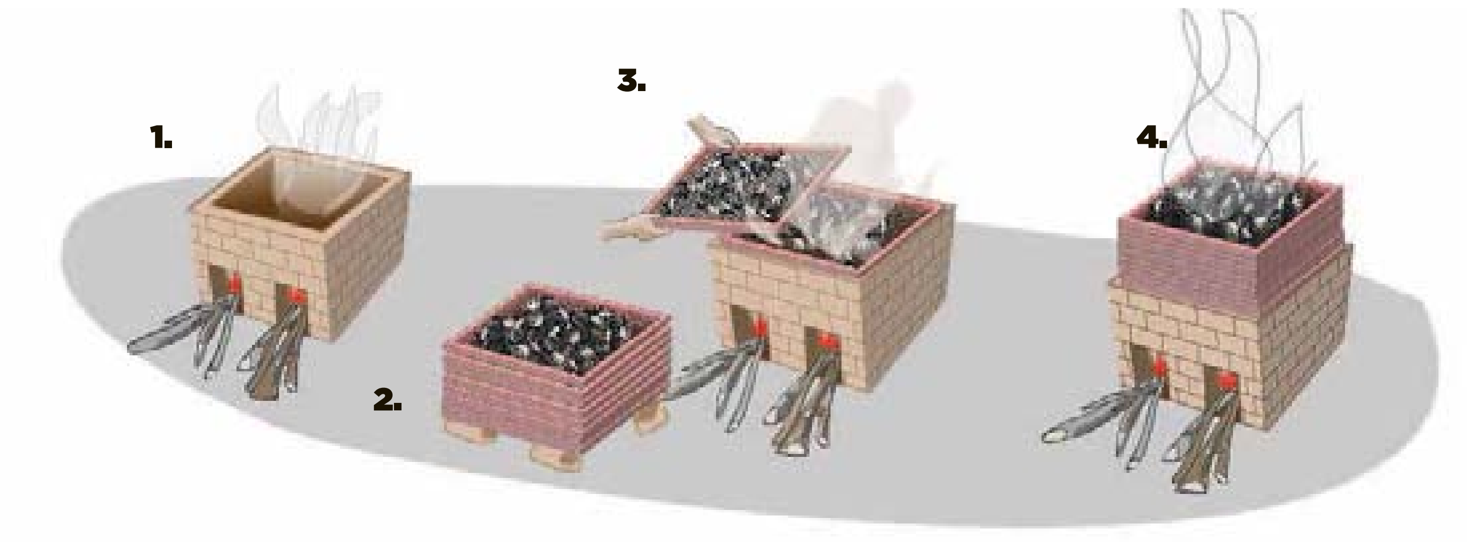
Steps to follow when smoking fishes like Tilapia, Nile perch (Lates niloticus) or Cat fish (Clarias spp.)

1. Wash the fish with clean water (away from the shoreline).
2. Remove the scales, where applicable, and fish offal from the fish and then wash the fish.
3. Apply salt in scours (cuts on the fish body).
4. Place the fish on the tray rack for all the water to drip off.
5. Select suitable fire wood to start a fire.
6. Light the fire in the middle of the smoking kiln.
7. Stack the trays on the chorkor kiln as shown in the illustration below.
8. Control the temperatures. This is done by dampening the fire with water or sand or ash and closing the fireplace, and raising it by opening the arch for air to enter the kiln.
9. Exchange the trays after the fish in the bottom tray turns golden brown by taking up the bottom tray and replacing it with the second-to-bottom tray.
10. Repeat this process until all the fish in the trays have attained a golden brown colour.
11. Remove the trays and allow the fish to cool.

Stacking for smoking fish

1. Stack the trays filled with fish on top of each other on the ovens (resulting in a smoking chamber or chimney).
2. Up to 10 trays may be used for one smoking cycle (with a total of 100-160 kg of wet fish).

Stepwise placing of fish trays on Chorkor oven



1. Kiln with firewood
2. Stack of trays filled with fish on top of each other
3. Placing trays on kiln
4. Complete stack of fish-filled trays on a kiln

13.10 Steps in sun-drying salted Omena

Dry Salting

1. Weigh 1 kg of salt for every 20 kg of Omena.
2. Allow sufficient time for salt to take action.
3. Then spread sparsely on drying rack.
4. Leave Omena to dry sufficiently.

Dry salting

Wet salting

1. Add salt to Omena in a bucket or vat.
2. Add 10 litres of clean water.
3. Mix thoroughly.
4. Allow sufficient time for salt to penetrate the Omena muscles.

Wet salting

Sun drying on raised racks

1. Drain the brine from the Omena
2. Spread it on a drying rack covered with a mat or old mosquito fishing net.
3. Dry for 6-8 hours on a hot day or 2 days when it is cool or raining.

Points to note

- The racks should be at least 1 m from the ground to hasten the drying process.
- They should be slanted to avoid water pools that would otherwise affect the drying rate.
- The racks may be overlaid with old mosquito nets or hessian sheets that have been stitched together from ripped bags.
- If wire mesh is overlaid on racks, salted products should not be allowed to come in contact with it because of the corrosive effect of salt.
- If poles have been treated with some form of preservative, Omena products should not be allowed to come in contact with it.

Good handling practice – dried on perforated trays placed on raised rack

Bad fish handling practice – dried on the ground

ISBN 978-92-5-130780-9
9 789251 307809
CA0299EN/1/06.18