MINISTRY OF EDUCATION

AGRICULTURE EDUCATORS &
TRAINERS ASSOCIATION OF GHANA

# Agricultural Science

## for Senior High Schools

Year 3

Rev. Emmanuel Asare

Stephen Gyempeh

Abdulai S. Gong

MINISTRY OF EDUCATION
AGRICULTURE EDUCATORS & TRAINERS
ASSOCIATION OF GHANA

# Agricultural Science

## for Senior High Schools

Year 3

Rev. Emmanuel Asare
Stephen Gyempeh
Abdulai S. Gong




ISBN:

# ACKNOWLEDGEMENTS

# Table of Contents

# FOREWORD

Ghana's new Senior High School Curriculum aims to ensure that all learners achieve their potential by equipping them with 21st Century skills, knowledge, character qualities and shared Ghanaian values. This will prepare learners to live a responsible adult life, progress to further studies and enter the world of work. This is the first time that Ghana has developed a Senior High School Curriculum which focuses on national values, attempting to educate a generation of Ghanaian youth who are proud of our country and can contribute effectively to its development.

The Ministry of Education is proud to have overseen the production of these Learner Materials which can be used in class and for self-study and revision. These materials have been developed through a partnership between the Ghana Education Service, teacher unions (Ghana National Association of Teachers-GNAT, National Association of Graduate Teacher -NAGRAT and the Coalition of Concerned Teachers- CCT) and National Subject Associations. These materials are informative and of high quality because they have been written by teachers for teachers with the expert backing of each subject association.

I believe that, if used appropriately, these materials will go a long way to transforming our Senior High Schools and developing Ghana so that we become a proud, prosperous and values-driven nation where our people are our greatest national asset.

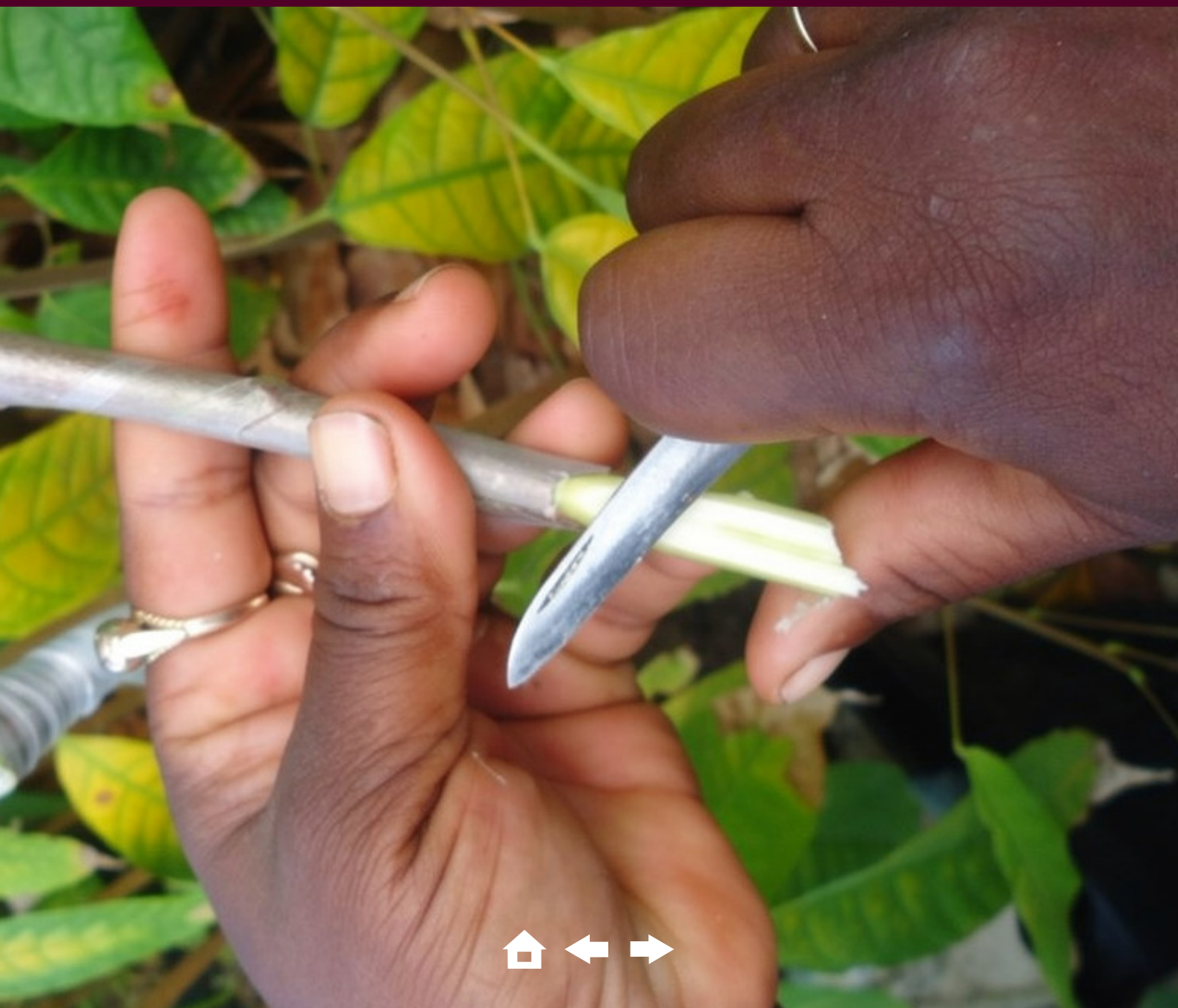
**Haruna Iddrisu MP**

*Minister for Education*

SECTION

1

# BUDDING AND GRAFTING IN TREE FRUIT CROP PRODUCTION



# EMERGING TECHNOLOGIES IN AGRICULTURE

## Introduction & Recap

Hello learner, welcome to Year Three of your Agricultural Science journey! In this section, you will be exploring exciting new ways of growing fruit trees such as mango, citrus, and avocado using modern techniques called budding and grafting. These methods help farmers grow strong, healthy trees more quickly and even develop new fruit varieties that are resistant to pests and diseases. You will learn the steps for budding and grafting, understand why they are important, and get hands-on practice to build your skills. These skills can help you grow your own trees or even start a small business. This learning builds on what you did in Year One (growing vegetables and ornamental plants with new technology) and Year Two (using technology in arable crop production). Get ready to learn, explore, and grow!

### KEY IDEAS

- **Alignment of cambium layers** is the precise positioning of the growth tissues (cambium) of the scion and rootstock during budding or grafting to ensure successful fusion and nutrient flow.
- **Budding and grafting techniques** refer to the step-by-step methods used to join parts of two plants, including methods such as cleft, whip-and-tongue, side, and veneer grafting, and procedures such as insertion, alignment, and securing of plant tissues.
- **Clonal propagation and uniformity** refer to the process of producing genetically identical plants through budding or grafting, resulting in consistent fruit quality, growth habit, and disease resistance.
- **The importance of budding and grafting** includes faster fruiting, improved disease resistance, uniform fruit quality, and rejuvenation of trees.
- **Practical skill acquisition** is the hands-on training learners receive in performing budding and grafting using tree crops like mango, citrus, and avocado under guided supervision.
- **Selection and preparation of materials** deal with the careful choice and readiness of compatible scions and rootstocks, ensuring healthy, proper cuts, and cambium alignment for a successful graft or bud.

# BUDDING AND GRAFTING OF TREE FRUIT CROPS

## Meaning and Differences Between Budding and Grafting

### Budding

Budding is a horticultural technique used for vegetative or asexual plant propagation. In this technique, a bud (the scion) (Figure 1.1) from one plant is inserted into the bark of another plant (the rootstock). This allows the scion to grow and develop into a new shoot or plant, incorporating the desirable traits of the donor plant. This method allows the transfer of specific characteristics, such as flower colour, fruit quality, or disease resistance, into a different plant.

### Purpose

Budding is commonly used for fruit trees and ornamental plants because it is efficient and preserves specific desirable traits. Its main purpose is to produce new plants without using seeds or sexual reproduction.

### Common examples of budded plants

1. **Roses:** Often budded to combine different varieties for better blooms and disease resistance.
2. **Citrus trees:** Varieties like oranges and lemons are frequently propagated using budding techniques.
3. **Apple trees:** Used to propagate specific cultivars and improve fruit quality.

## Grafting

Grafting is a technique in which tissues (scion) from one plant are joined to another plant (the rootstock) to grow together as a single plant. This method is commonly used to combine desirable traits from both plants, such as disease resistance, fruit quality, flower colour, or growth habits.

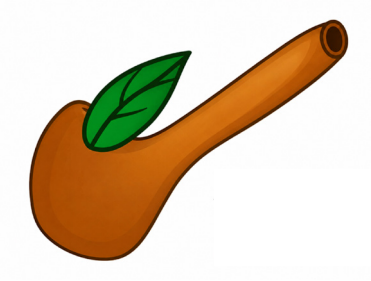


**Figure 1.1:** An excised bud

# Differences Between Budding and Grafting

While both techniques are used for plant propagation, budding focuses on a single bud insertion, whereas grafting involves joining larger plant sections. Each method has its applications, advantages and challenges. (Table 1.2 gives a summary of the differences between the two methods).

**Table1. 2:** Differences between budding and grafting

| Feature | Budding | Grafting |
|---|---|---|
| Plant part | Involves only a single bud | Involves a larger piece eg stem |
| Application | Primarily used for certain fruit trees and ornamental plants | Widely used for a variety of plants, including fruit trees, vegetables, and ornamentals |
| Success rate | Often high due to the smaller size and fewer tissues involved | Can be low due to the complexity of joining larger tissues |
| Scion type | Uses only a bud | Uses a stem section containing multiple buds |

# Importance of Budding and Grafting in Fruit Trees

Both budding and grafting have benefits that help the crop stay healthy, produce more, and last longer. Budding and grafting contribute to the sustainability of commercial and home orchards.

## Importance of Budding

1. **Clonal reproduction:** Budding produces clones of the parent tree, ensuring uniformity in fruit quality and tree characteristics. This consistency is important for commercial fruit production, where uniformity in size, taste, and appearance is desired.
2. **Propagation of desired varieties:** Budding allows for the propagation of specific fruit tree varieties that exhibit desirable traits, such as improved fruit quality, disease resistance, or enhanced yield. By using a bud from a parent tree with these traits, growers can ensure that new trees will produce fruit with the same qualities.
3. **Early maturity:** Trees grown from budding often reach fruit-bearing age more quickly than seeds.
4. **Disease resistance:** Budding susceptible but high-yielding varieties onto resistant rootstocks can solve specific soil-borne disease or pest problems and improve the overall health and productivity of orchards.

## Importance of Grafting

1. **Improved tree health and productivity:** Grafting a scion from a desirable fruit variety onto a rootstock well-adapted to local soil and climate conditions

enhances the tree's overall health, increases resistance to pests and diseases, and improves productivity.

2. **Variety development:** Grafting allows growers to experiment with and develop new fruit varieties. By combining different scions and rootstocks, new cultivars with unique characteristics can be created, leading to a wider range of fruit options and potentially new market opportunities.
3. **Repair and maintenance:** Grafting can repair damaged trees or rejuvenate older, less productive trees, hence extending their productive life.
4. **Space efficiency:** Grafting allows for the propagation of multiple varieties on a single rootstock, which is particularly useful for small spaces or speciality orchards, diversifying the types of fruit produced.

# PROCEDURE OF BUDDING AND GRAFTING

## Budding

### Selection of scion and rootstock

**Rootstock**: Select a vigorously growing and healthy rootstock to provide the growth base and root system.

**Scion:** The part of the plant that will become the new shoot (usually a bud from a desirable variety). Choose the scion from a healthy desired plant/shoot.

#### Preparation

1. *Scion preparation:* Using a budding knife, carefully remove the bud from the shoot, typically with a small portion of wood (See ***Figure 1.2***).
2. *Rootstock preparation*: Cut the bark of the rootstock where the bud will be inserted in a T-shape, inverted T or a vertical slit.

#### Insertion

Lift to separate the bark from the rootstock and insert the bud into the cut, ensuring good contact with the cambium layer (the growth tissues).

#### Securing

The bud and the rootstock are wrapped with tape or another binding material to hold them in place and prevent moisture loss.

#### Healing

Over time, the tissues of the rootstock and bud will grow together and become one plant. Once the bud has successfully taken root and is growing well, the binding material can be removed

### Aftercare

The plant is monitored for growth and health. Any shoots growing from the rootstock below the bud should be pruned.

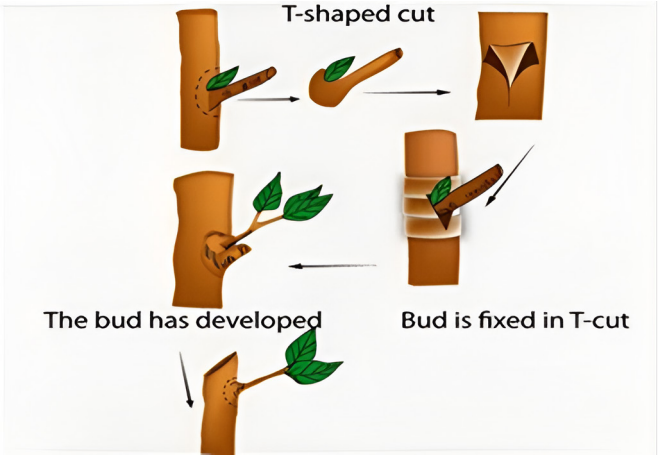



**Figure 1.2**: Diagram of the budding process

## Grafting

### Types of Grafting

There are various types of grafting, but there are four common forms: Cleft/wedge grafting, Whip-and-tongue grafting, Side grafting and Veneer grafting.

1. Cleft grafting is used to join a scion to a rootstock. The process involves splitting the rootstock, inserting the scion, and securing them together to allow for fusion and growth. It is commonly used for top-working fruit trees, changing varieties, or propagating trees that are difficult to root from cuttings (***Figure 1.3A***).
2. **Whip-and-tongue grafting:** a plant graft made by locking a small tongue and notch in the obliquely cut base of the scion with corresponding cuts in the stock (***Figure 1.3B***).
3. **Side grafting:** A wedge-shaped cut is made into the rootstock, removing a section of wood and bark. The rootstock may be decapitated, depending on the specific side grafting technique. The scion is usually a wedge-shaped piece of wood, designed to fit into the cut on the rootstock. The main advantage of side grafting is that it can be used with scions of varying sizes and may offer a larger surface area for vascular fusion (***Figure 1.3C***).
4. **Veneer grafting:** It is a type of side grafting but also called inlay grafting. A thin, almost superficial cut is made on the rootstock, creating a "veneer" of bark and wood. The rootstock is usually not decapitated, allowing plant growth to continue above the graft. The scion is a wedge-shaped piece of branch, designed to fit into the veneer cut on the rootstock. Veneer grafting is used for stocks larger than 2.5 centimetres. The cut is made on the side of

the stock and not on top. Its main advantage is that it is easier to perform than cleft grafting, and can be used with rootstocks of different sizes (***Figure 1.3D***).

## Selection of scion and rootstock

Choose a compatible rootstock and scion; the scion should be the same girth as the rootstock at the grafting point.

### Preparation

Cut the rootstock and scion to fit together, according to the grafting technique.

### Joining

The scion and rootstock are joined, ensuring the cambium layers (the growth tissues) are aligned. Proper alignment is crucial for successful grafting.

### Securing

The joined parts are secured with grafting tape, rubber bands, or string. The graft union should be protected from infection, sometimes with wax or a grafting compound.

### Healing

The graft union is covered with a grafting compound or wax to prevent desiccation (drying out) and infection. Over time, the tissues of the scion and rootstock fuse.

### Aftercare

The grafted plant is monitored for healthy growth. Any new shoots from the rootstock below the graft are removed. Over time, the tissues will unite and form a single plant.

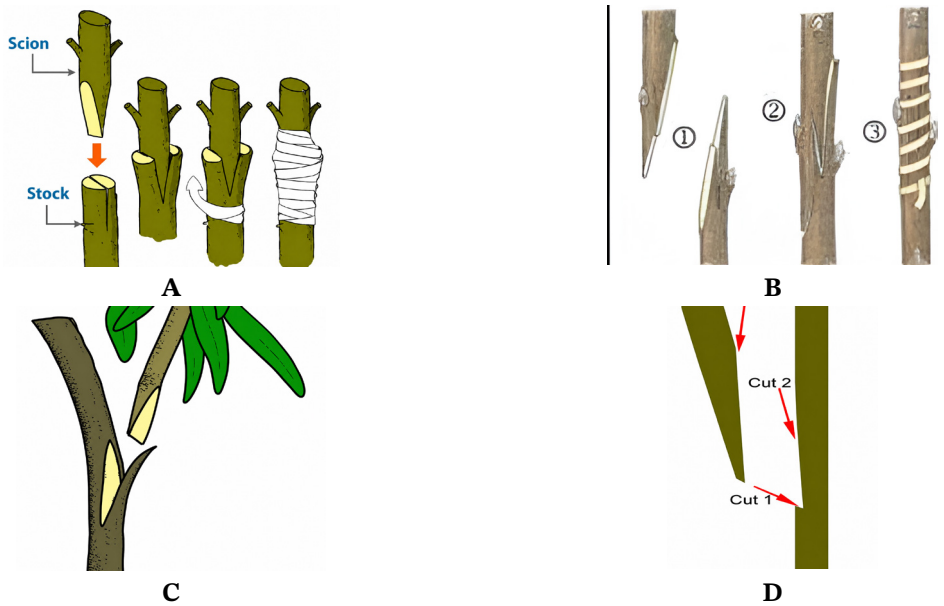



**Figure 1.3:** Diagram of the grafting types. "A" = Cleft/Wedge grafting, "B" = Whip-and-tongue grafting, "C" = Veneer grafting and "D" = Side grafting

## Activity 1.1 Exploring Budding and Grafting in Modern Agriculture

1. Pair up with a classmate and conduct an online (or from textbooks) search to find information on:
   - **a.** The meaning of budding and grafting.
   - **b.** The importance or relevance of these techniques in modern agriculture.
2. As you research, focus on:
   - **a.** Types of plants or trees that are commonly used.
   - **b.** Benefits such as improved crop yield, faster growth, or disease resistance.
   - **c.** Any challenges or limitations farmers may face when using them.
3. Prepare a short summary (in writing or as a poster/presentation) that includes:
   - **a.** Clear definitions of budding and grafting.
   - **b.** At least three reasons why these techniques are important today.
   - **c.** A simple diagram or labelled drawing showing how either budding or grafting is done.
4. Present your work to the class. Be prepared to explain your findings in your own words and answer any questions from your peers or teacher.

## Activity 1.2 Budding and Grafting Fruit Trees (Practical & Inclusive)

1. Watch a video tutorial or observe a live demonstration on budding and grafting fruit trees. (https://www.youtube.com/watch?v=aqbuI05WgIU and https://www.youtube.com/shorts/D18Ppdto-HQ )
2. Pair up in groups and discuss what you observed, focusing on:
   - **a.** Tools needed
   - **b.** The steps involved
   - **c.** Safety precautions
3. Practise each method under supervision or using a model:
   - **a.** Budding (e.g. T-budding or chip budding)
   - **b.** Grafting (e.g. whip-and-tongue or cleft grafting)
4. Apply what you have learned:
   - **a.** Try budding or grafting with local fruit trees like mango, citrus, or avocado.
   - **b.** If materials or tools are not available, create a model, diagram, or flow chart showing the steps.

5. Give a short presentation to your classmates, explaining:
   a. The technique you tried or modelled
   b. Why it worked
   c. Any difficulties or safety issues encountered

## EXTENDED READING

- Watch or examine this video on Budding and Grafting Fruit Trees
  https://youtu.be/RQLPR4soTco

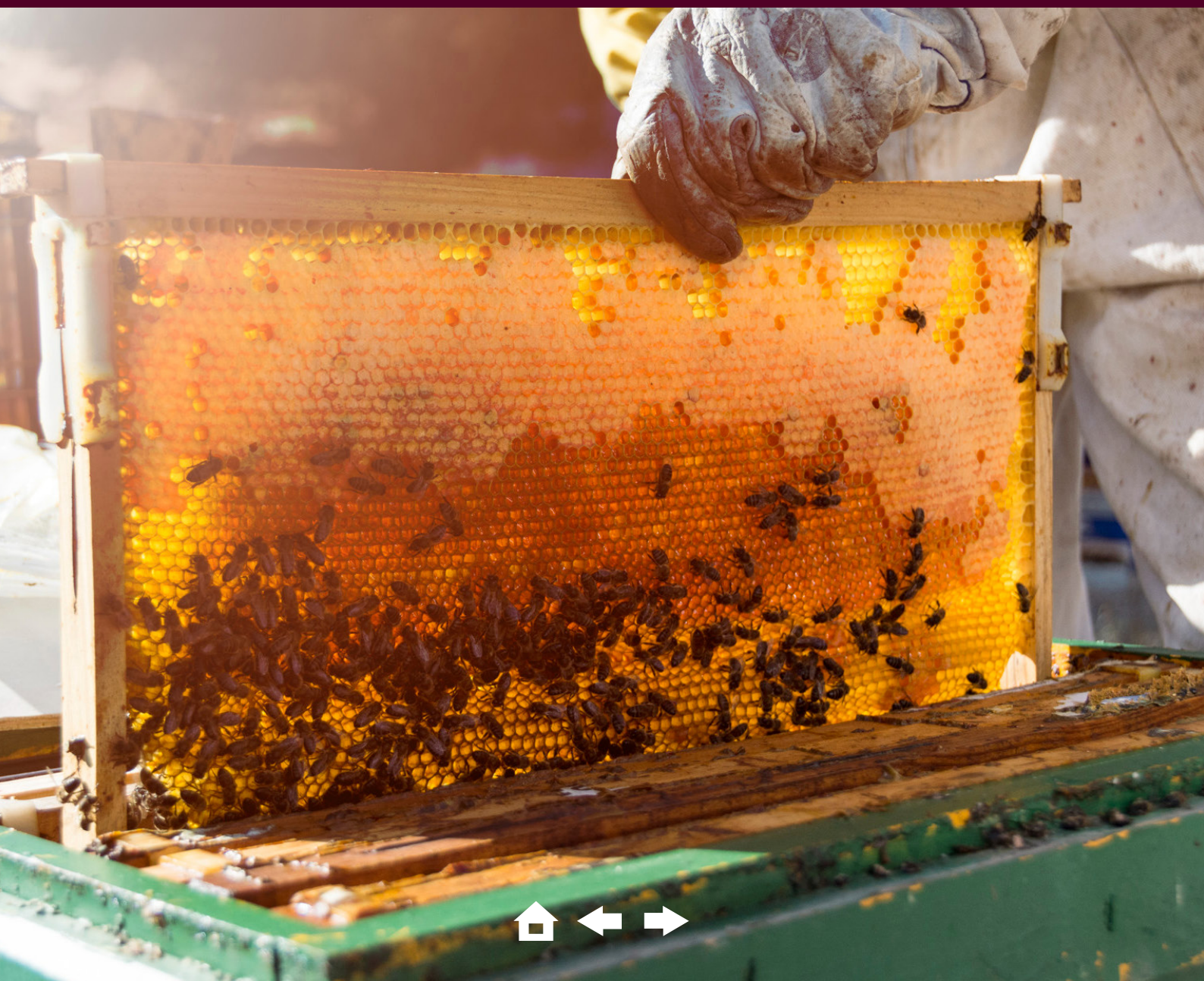
# REVIEW QUESTIONS

1. Describe the steps involved in performing a successful grafting operation on a fruit tree crop.
2. How are budding and grafting different from the mini-sett technique? Compare them based on:
   a. How each method is done (procedure),
   b. The types of crops they are used for, and
   c. How well they improve crop yield and quality.

SECTION

2

# BEE-KEEPING AND ITS ROLE IN PROMOTING TREE FRUIT CROP PRODUCTION



# EMERGING TECHNOLOGIES IN AGRICULTURE

## Introduction

Hello learner! Welcome to Section 2 of the Third Year Agricultural Science Learning Material. In this section, you will be evaluating the role of bees and beekeeping in tree fruit crop enterprises. Fruit tree plants rely largely on bees for pollination. Therefore, encouraging bees naturally or strategically placing beehives in orchards will enhance pollination and increase fruit production. In years one and two, vegetable and ornamental plants production, as well as arable crops production, were discussed in detail. However, the focus in this section will be on the roles bees play in tree fruit crop enterprises. At the end of this section, you should be able to explain the importance of beekeeping in tree fruit crop enterprises.

**KEY IDEAS**

- **Apiculture** is the practice of maintaining honeybee colonies, usually in artificial hives, for various purposes. Apiculture is also known as beekeeping.
- **A beehive** is a structure naturally built by honeybees or artificially constructed by humans that serves as the dwelling place for a colony of honey bees.
- **A fruit crop** is a crop/tree that bears fruits that are consumed by animals or humans. They are mostly flowering plants.
- **The honeybee** is a flying insect of the largest bee family. They are naturally good
- pollinators.
- **Orchard:** an enclosed area of land planted with fruit trees/ an intentional plantation of trees or shrubs that is maintained for food production.
- **Pollination** is the act of transferring pollen grains from the anther (male part) to the stigma (female part) of a flower.

# THE ROLE OF BEE-KEEPING IN PROMOTING TREE FRUIT CROP PRODUCTION

## Importance of Bees in Agriculture

Bees are very important in growing fruit trees because they help with pollination, which helps fruits to form.

An adult bee is a flying insect in the order Hymenoptera. Honeybees are specific to the genus *Apis*. Bees are very important to agriculture because they pollinate many crops.

About 35 % of the global food crops depend on pollinators, and bees are one of the most effective and reliable pollinators. Their pollination contributes to greater yields and higher-quality produce.

Beekeeping, also known as apiculture, is the practice of maintaining bee colonies, usually of the species *Apis mellifera* (the Western honey bee), primarily for products like honey, beeswax, royal jelly and propolis (bee glue). But one of its most vital contributions is pollination, which is the transfer of pollen from one flower to another. Many plants, especially fruit-bearing trees, need pollination to reproduce.

Beekeeping involves hive management, bee health monitoring, and seasonal care, e.g.

1. feeding honey bees when there is a scarcity of nectar and pollen sources available in the environment, because few plants are blooming or
2. preventing them from swarming.

Beekeepers (Apiarists) may keep their hives in one place (stationary hives), or they can move them to different orchards as particular plants begin to flower.

## Importance of Bees in Fruit Tree Production

1. **Pollination (natural hybridisation) services:** Bees carry pollen from one flower to another on the same tree or a different tree or in another orchard. The resultant seeds may have varied genetic makeup, which may produce different varieties.
2. **Yield improvement:** Fruit crops like citrus, mango, guava, avocado, passion fruit, pumpkins, melons and cucumbers depend heavily (or entirely) on bee pollination for optimal yields.
3. **Biodiversity support:** Managed bees can complement native pollinators and help maintain floral biodiversity in orchards.
4. **Economic value:** Bee pollination service is often worth more than honey production, accounting for billions of dollars in agricultural value worldwide.

## Role of Beekeeping in Tree Fruit Cultivation

Beekeeping helps tree fruit crops grow better by pollinating them. Honey bees are among the most effective pollinators, and their managed colonies can be placed strategically near orchards to boost the quantity and quality of fruit yields. Beekeeping helps tree fruit production in the following ways:

1. **Enhanced pollination:** Honey bees transfer pollen as they move from flower to flower, ensuring cross-pollination, which is critical for fruit set in many tree crops. Inadequate pollination could lead to some fruit trees producing smaller, deformed fruits or not bearing fruit at all.

2. **Increased fruit yield:** Research has shown that the presence of honey bees can significantly increase fruit yield. For instance, apples, pears, plums and cherries rely heavily on pollinators for larger yields. Honey bee pollination boosts the number of flowers that develop into fruits, ultimately increasing the total crop yield.
3. **Improved fruit quality:** Well-pollinated flowers develop into fruits with better shape, bigger and uniform sizes.
4. **Extended pollination season:** Beekeeping provides a steady and reliable source of pollinators over the flowering period, supporting consistent pollination even during adverse weather conditions. Honey bee hives can be relocated to orchards during peak bloom times, ensuring the flowers receive ample pollination.
5. **Economic benefits:** Increased fruit production leads to higher profitability for orchard growers. Larger yields and better fruit quality reduce the need for thinning, minimise production waste, and boost revenue. Honey and other bee products also provide an additional income.
6. **Biodiversity and ecosystem health:** Honey bees promote biodiversity by supporting the reproduction of flowering plants in the ecosystem surrounding orchards. This, in turn, enhances the habitat for other beneficial insects and wildlife, contributing to healthier, more resilient agro-ecosystems.
7. **Sustainability and reduced reliance on synthetic pollination alternatives:** Beekeeping reduces the need for artificial pollination, which can be costly and less effective.

## Key Benefits of Bees in Agriculture

1. **Increased crop yields**: Bees enhance the productivity of many crops by improving the fertilisation process. Crops such as apples and tomatoes benefit significantly from bee pollination, which boosts both quantity and quality of the produce.
2. **Improved food quality:** Pollination by bees leads to better-sized and more uniformly shaped fruits and vegetables. This significantly impacts the market value and nutritional quality of the produce. In other words, well-pollinated crops often have higher nutritional content.
3. **Support of biodiversity:** Bees contribute to plant species diversity by pollinating wild plants around farms. This diversity creates habitats for other organisms, promoting ecological health and resilience.
4. **Economic value:** Bee pollination contributes billions of dollars annually to the global economy by improving crop productivity. This economic impact is of particular importance in areas dependent heavily on agriculture.

# BIOLOGY OF BEES

## Classification and Diversity of Bees

Bees belong to the order **Hymenoptera**, family **Apidae**, which includes honey bees, bumble bees and stingless bees. There are over 20,000 known species globally. Many bee species, including the honey bee, are social insects and live together in large, well organised colonies. A honey bee colony typically consists of three adult bees: workers, drones and a queen. Several thousand worker bees work together to build nests, gather food and brood rearing. A colony usually has one queen and a few drones, as well as worker bees.

## Different Castes of Bees and Their Roles

1. The queen bee is the sole fertile egg-laying female in a hive and regulates the colony. It develops from a fertilised egg and is fed in the larval stages with royal jelly**.** When matured, she mates once and stores sperm for life. The queen lives a maximum of five years.
2. Drones are male bees that develop from unfertilised eggs. Their sole role is to mate with the virgin queens and die soon after or during mating.
3. Worker bees are sterile females that perform various tasks within the hive. The sub- castes are: scout bees which can travel 18 km away from the hive to locate new food sources; foragers which follow the trail of scout bees to fetch pollen and nectar from fields and blooms located by the scouts; guard bees that guard the hive against intruders and stray foreigners. and nurse bees, which care for the hive with special attention to the developing queens and drones. The workers live for up to three months.

## Bee Morphology

Bees have a three-part body consisting of a head, thorax, and abdomen. The head bears a pair of compound eyes, simple eyes (ocelli), a pair of antennae and the mouthparts. The thorax has three segments (prothorax, mesothorax and the metathorax). In the adult bee, each thoracic segment bears a pair of walking legs, while the mesothorax (middle segment) and metathorax (last segment) bear a pair of wings.

In the honey bees, the majority of adults are sterile, winged females who function as workers and soldiers, defending the colony. All female honey bees have a sting organ at the end of their abdomen used for defence and offense. The workers also have some special organs e.g. proboscis for sucking up nectar and other juices, pollen baskets for transporting pollen and wax glands for building combs.

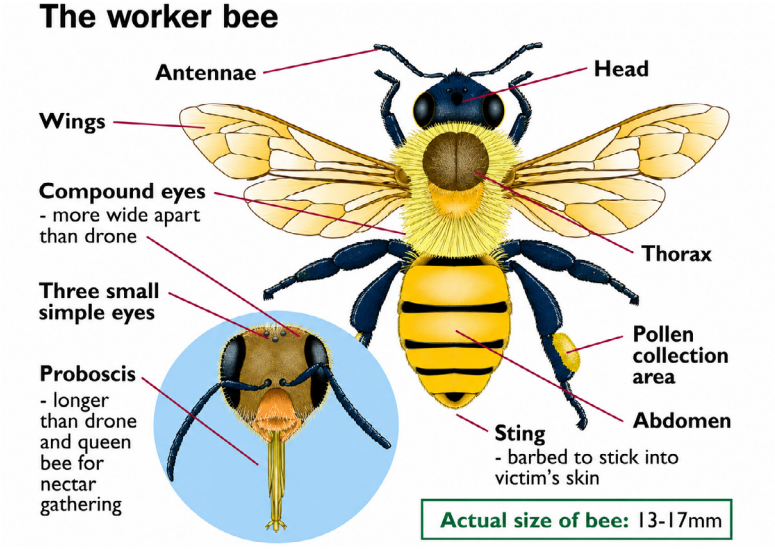



**Figure 2.1:** Morphology of bees

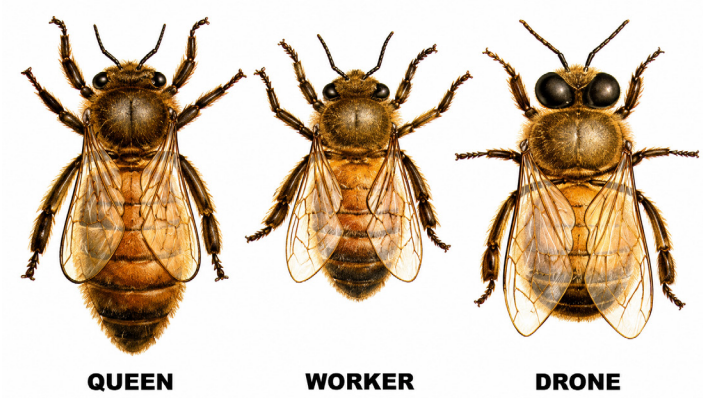



**Figure 2.2:** The main bee castes

## Ecological Role of Bees

Bees are key pollinators, essential for reproduction in 70–80 % of flowering plants. Their decline poses serious threats to biodiversity, agriculture, and food security.

## Threats to the Conservation of Bees

Major threats to honey bees are pesticides (e.g. neonicotinoids), habitat loss, climate change, parasites such as the Varroa mite (*Varroa destructor*) that attacks and feeds on honey bee larvae, the fungal pathogen, *Nosema* sp., and many viruses such as the Sacbrood virus.

# Beekeeping in Ghana

Like in many other parts of the world, beekeeping in Ghana is an increasingly valuable agricultural practice, enhancing income generation, biodiversity, and crop productivity. Ghana's climate and vegetation are well-suited to honeybee activities, making it an ideal environment for honey production.

# The process of beekeeping in Ghana

## 1. Choosing hive types and sites

### Hive types

The most common hives in Ghana include the Kenyan Top-Bar Hive and the Langstroth (***Figure 2.3***), both suited to local beekeeping practices. Top-bar hives are popular for their simplicity, low cost, and ease of maintenance.

**Figure 2.3:** Examples of Langstroth hives (BeesWiki.com)

### Site selection

Hives are ideally placed near water sources and abundant flowering plants, such as farms with flowering crops or areas with wild flora. The site should be away from strong winds and human activity, providing a safe and productive environment for the bees.

## 2. Obtaining and introducing bees

Beekeepers can start colonies by capturing wild swarms, which is common in Ghana, or by purchasing bees from other beekeepers. Swarm capture involves placing an empty hive in a location where swarms are likely to settle or using bait hives to attract bees. Once bees are introduced to the hive, beekeepers must closely monitor the colony to ensure it becomes established and the queen is laying eggs.

## 3. Feeding and colony management

Feeding may be necessary during the dry season when nectar is scarce. A sugar solution can be provided to supplement the bees' diet and maintain colony strength. The farmer should check regularly for brood, honey stores, and signs of disease or pests like the Varroa mite. In Ghana, ants are common pests, so protecting hives from ant infestations is crucial. Coating the stands with grease will prevent ants from climbing into the hive.

## 4. Harvesting honey and other products

Honey harvesting typically occurs during the main flowering seasons, with two major harvest periods each year in Ghana. When the honey cells have been capped or sealed, it means the honey is mature and ready to harvest. Honey is

harvested by removing the frames from the hive and extracting honey, either through manual squeezing or using a honey extractor. Other bee products like beeswax and propolis are also collected for sale.

### 5. Protective clothing in beekeeping

Bees are gentle insects, but when ruffled, they can attack and sting the intruder. Bee venom is highly toxic and can kill if the attack is severe. It is therefore necessary to acquire and wear the appropriate protective clothing when dealing with bees. White colour is preferred, but blue is also acceptable. See ***Figure 2.4***.

**Figure 2.4:** Protective bee gear

### 6. Processing and selling honey

After extraction, honey is filtered to remove impurities and stored in airtight containers to prevent contamination. Local markets and export opportunities exist for high-quality honey, as Ghana has a growing demand for natural and organic products. Ghanaian honey is sought after due to its unique floral flavours, and many beekeepers sell their products at local markets or collaborate with cooperatives to reach larger buyers.

### 7. Training and sustainable practices

Many Ghanaian beekeepers receive training through organisations like the Ghanaian Beekeepers Association, agricultural extension services, and NGOs. Training often covers sustainable practices, pest management, and business skills for profitable beekeeping. Sustainable practices, such as minimising the use of pesticides and providing forage for bees, are emphasised to support healthy colonies and promote biodiversity.

### 8. Challenges and opportunities in beekeeping

#### Challenges

Beekeepers in Ghana contend with bushfires, pesticide drift from nearby farms, pests and difficulties accessing markets. Limited access to resources and knowledge also hampers some beekeepers from scaling up their operations.

### Opportunities

With a strong demand for honey and bee products locally and internationally, beekeeping presents a significant rural income generation and economic empowerment. Support from the government and NGOs helps provide equipment, training, and market access.

Well done for studying the content on the role of bee-keeping in promoting tree fruit crop production! Now, perform ***Activity 2.1*** below.

## Activity 2.1 Make and Display a Simple Beehive

Work in groups of 3: Find two friends and work together to create a simple beehive using local or recycled materials. (You may watch this video on claypot hives first https://www.youtube.com/watch?v=uyJsH6xzYSM )

### What you will need (use what is available)

- Old clay pot, metal can, wooden box, or plastic bucket with a lid
- Small sticks or wooden bars
- Knife or nail for making holes
- Rope, stones, or a stand to lift the hive
- Thatched material, plastic sheet, or cloth to cover it

### Steps

1. Choose your hive container: Use a clean old bucket, clay pot, metal can, or wooden box.
2. Make the hive space: Make small entrance holes near the bottom (about the width of your finger). This is where the bees will enter and exit.
3. Add support for combs (optional): If you are using a box, lay small sticks or bars across the top inside. Bees will build their honeycombs on these.
4. Cover the top: Use a lid, thatch, or plastic sheet to protect the hive from rain and sun.
5. Lift the hive off the ground: Place your hive on a raised platform using stones or a wooden stand, or hang it on a tree to keep it safe from ants and water.
6. Pick a good location: Choose a quiet, shaded area near flowers and water. Bees love flowers and need water to survive.
7. Present your work: Show your finished hive to your teacher. Tell the class how your hive can help support bees and fruit tree farming.

# REVIEW QUESTIONS

1. A major cashew-growing region in Ghana has experienced declining yields over the past three years. Research indicates inadequate pollination as a significant factor, with native pollinator populations reduced by approximately 30 % due to issues such as habitat loss, pesticide use, and climate variability. The Regional Agricultural Office is considering promoting integrated beekeeping as a solution. Drawing on your knowledge in bee-keeping, fruit tree production, ecological principles, and agricultural economics:

   **a.** Critically analyse the potential ecological, economic, and social impacts of integrating bee-keeping with tree fruit production in this region.

   **b.** Evaluate how climate change might affect the proposed bee-keeping integration programme and suggest adaptation strategies that would enhance system resilience.

SECTION

3

# REDUCING DRUDGERY IN AGRICULTURAL PRODUCTION

# AGRICULTURAL MACHINERY

## Introduction

Hello learner! Welcome to Section 3. In agriculture, doing hard work by hand can be tiring and slow. That is why some farmers now use machines and computers to make their work easier and faster. In this section, you will learn how to use machines like tractors, ploughs, harvesters, and planters, and how to use computing tools such as GPS-guided tractors, remote sensors and drones to reduce stress and effort in farming.

Let us quickly recap what we studied earlier. In Year One, Sections 2 and 4, we learnt about different farm tools and their uses, how farm equipment and machines are grouped, and how modern irrigation systems help in growing vegetables and ornamental plants. In Year Two, we looked at different types of machines used in growing crops such as maize and rice. Now, we will build on that knowledge by learning how to use modern machines and computer tools to carry out farm work and help remove the drudgery. Get ready for this exciting journey!

### KEY IDEAS

- **Automated monitoring systems**: These are technology-based systems (such as sensors and IoT devices) used to automatically track weather, soil moisture, crop health, or pest activity.
- **Computing tools**: These are software and related applications (e.g., mobile apps, GPS tools, weather forecasting programs) that help farmers with planning, record-keeping, market access, and decision-making, making farming more data-driven and efficient.
- **Digital agriculture**: This refers to the use of digital technologies (such as data analytics, mobile apps, cloud platforms, and artificial intelligence) to improve all aspects of the farming process, from planting to marketing.
- **Drudgery in agriculture:** This refers to the hard, repetitive, and time-consuming tasks often done by hand, such as weeding, watering, and harvesting.
- **Remote sensing and drones**: These technologies collect real-time data from above the farm, such as crop health, soil conditions, and pest spread. Drones can also be used for spraying, mapping, and monitoring, saving time and labour.
- **Robotics in agriculture**: This involves the use of robots or robotic machines to perform tasks like harvesting, planting, weeding, and spraying.

# REDUCING DRUDGERY IN AGRICULTURE

## Meaning and Common Examples of Drudgery in Agriculture

In agriculture, drudgery refers to the difficult, physically demanding and often repetitive tasks that farmers and agricultural workers endure while producing crops and raising livestock. These tasks typically require significant manual effort, are time-consuming, and can lead to fatigue or health issues over time. Often, drudgery is associated with traditional or low-tech farming systems with limited mechanisation and advanced tools. In agricultural production, common forms of drudgery are:

1. **Manual land preparation:** Using hand tools like hoes and cutlasses for land clearing, tilling, or weeding, which can be physically exhausting.
2. **Human labour for sowing, planting and harvesting:** Tasks like sowing, weeding, and harvesting involve repetitive bending, stooping, and working in hot weather. This can cause fatigue.
3. **Irrigation:** Where mechanised irrigation is lacking, humans carry water to irrigate crops. This activity is labour-intensive.
4. **Post-harvest processing:** Activities such as threshing, winnowing, sorting and drying produce are done manually.
5. **Livestock care:** Carrying heavy feed, cleaning pens, and manually milking animals are laborious and time-consuming.

## Ways of Using Machines to Reduce Drudgery in Agriculture

Having machines that make work easier and being able to use them are important for making agriculture more appealing, especially to young people, and for increasing efficiency and productivity. Mechanisation helps to automate jobs that require a lot of physical work. This saves time and effort while making farm operations more accurate and efficient.

This is how machines are used to cut down on work in agriculture:

1. **Land preparation**
    a. **Tractors and ploughs:** Instead of manual tilling (Figure 3.1A), tractors equipped with ploughs or harrows (Figure 3.1B) can prepare large areas of land quickly and efficiently, reducing physical labour and time spent on land preparation.
    b. **Rotary tillers and cultivators:** These machines help break up soil, remove weeds, and prepare the seedbed, replacing labour-intensive manual work.

*A. Manual land tilling/ridging* *B. Mechanised land tilling*

**Figure 3.1:** Land preparation

2. **Sowing and planting**
   a. **Seed drills and planters:** Machines such as seed drills ensure that seeds are planted at the correct depth and spacing, which is difficult and time-consuming to achieve manually. This saves labour and increases crop yields due to better planting precision.
   b. **Transplanters:** Machines for transplanting seedlings, particularly for crops like rice and vegetables, eliminate manual planting, reduce labour requirements and enhance efficiency.
3. **Weed control**
   a. **Power slashers:** Manual weeding is labour-intensive and time-consuming. Power slashers or mechanised hoes can significantly reduce the effort required to remove weeds from the farm, improving crop growth and reducing the drudgery involved.
   b. **Herbicide sprayers:** Instead of manually controlling weeds, machines like herbicide sprayers ensure quick and effective weed control with minimal physical effort.
4. **Irrigation**

Recall that in Year 1, we learnt about the surface irrigation system (e.g. border irrigation, check basin irrigation, furrow irrigation), subsurface irrigation, and pressurised irrigation (e.g. drip irrigation, sprinkler irrigation). But for the purpose of using machines to reduce drudgery in agriculture, we shall talk about the mechanised irrigation systems and motorised pumps.

a. **Mechanised irrigation systems:** Mechanised irrigation systems such as drip irrigation (***Figure 3.2B***), overhead sprinklers, or centre-pivot irrigation automate water supply to crops. This ensures optimal water usage and conserves resources and labour.

b. **Motorised pumps:** Motorised water pumps eliminate the need for manual water fetching, making irrigation more efficient and less labour-intensive.

*A. Manual irrigation* *B. Drip irrigation*

**Figure 3.2:** Types of irrigation

5. **Harvesting**
   a. **Harvesters:** Machines like combine harvesters can perform multiple tasks (cutting, threshing, and winnowing) in one operation, reducing the manual effort required for crops such as maize, rice and wheat.
   b. **Fruit and vegetable harvesters:** Specialised harvesters for fruits like tomatoes, oranges, or vegetables reduce the backbreaking work of picking by hand, especially when dealing with large farms.
6. **Post-harvest processing**
   a. **Threshers and winnowers:** Threshing and winnowing machines replace traditional manual methods of separating grains from straw, making post-harvest processing faster and less strenuous.
   b. **Grain dryers:** Instead of manually drying grains under the sun, which is labour-intensive and time-consuming, mechanical grain dryers offer a more efficient alternative, especially in regions where weather conditions are unpredictable.
   c. **Milling machines:** For crops like maize, rice, and cassava, milling machines eliminate the need for hand grinding, making food processing faster and easier.
7. **Livestock farming**
   a. **Milking machines:** In dairy farming, milking machines (figure 3.3B) reduce the physical labour of manually milking cows, speeding up the process and improving hygiene.
   b. **Feed mixers and dispensers:** Machines that mix and automatically dispense feed reduce the effort in feeding large numbers of livestock, enhancing efficiency.

c. **Manure collectors and spreaders:** These machines reduce the need for manual labour in cleaning livestock pens and spreading manure in fields.

*A. Manual cow milking* *B. Mechanised cow milking*

**Figure 3.3:** Milking of a cow

8. **Transporting farm produce**
   a. **Farm trucks and carts**: Mechanised transport vehicles, such as farm trucks or motorised carts, reduce the physical effort required to transport produce from the farm to storage or markets.
   b. **Conveyor systems:** For large-scale processing, conveyor belts can move products within processing plants, reducing the manual effort required for handling produce.
9. **Pest and disease control**
   a. **Drones for spraying:** Drones equipped with pesticide sprayers can cover large areas in a short time, reducing the physical labour of manual spraying and minimising human exposure to chemicals.
   b. **Motorised sprayers:** Motorised backpack sprayers or boom sprayers are efficient tools for applying pesticides, herbicides, or fertilisers over large areas, reducing manual labour and increasing precision.
10. **Precision agriculture**
    a. **GPS-guided machinery:** Precision agricultural equipment (like GPS-guided tractors or combines) improves accuracy in planting, spraying, and harvesting, reducing waste and labour while enhancing productivity.
    b. **Automated monitoring systems:** Automated systems (Figure 3.4), including sensors and cameras, help monitor crop health, water levels, and soil conditions, reducing the need for manual labour in crop inspection.

***Figure 3.4**: Crop pest monitoring system*

## Benefits of Using Machines to Reduce Drudgery

1. **Reduced physical fatigue:** Mechanised farming minimises the physical strain associated with labour-intensive tasks, making farming less exhausting and more manageable.
2. **Time savings:** Mechanisation significantly reduces the time required for farm operations, allowing farmers to focus on other aspects of the business or expand their farming operations.
3. **Increased efficiency and productivity:** Machines perform tasks faster and more accurately than manual labour, increasing output per unit of time and per unit of labour input.
4. **Improved precision:** Machines can perform tasks like planting, spraying, and harvesting with greater precision, leading to better crop health, reduced wastage, and larger yields.
5. **Increased cultivation:** Relying on machines can lead to increased areas of cultivation.
6. **Attracting youth to farming:** The introduction of technology and machinery into agriculture makes it more appealing to young people, who are often more tech-savvy and interested in modern, less labour-intensive work.

## Challenges and Solutions to Mechanised Farming

1. *Cost of machinery:* High initial farm machinery cost is a disincentive to farming, especially for smallholdings. Solutions include government subsidies, leasing options, cooperative ownership, and low-interest loans.
2. *Low technical know-how:* Farmers need training on how to operate and maintain agricultural machinery. Extension agents and technicians from large-scale, well-established farms can provide the necessary skills.

3. *Maintenance and repairs:* Access to spare parts and skilled mechanics is essential. Establishing local service centres can address this challenge.

Well done for coming this far! Have you thought of how you could be implementing this knowledge on your farm soon? Now, continue to do the activities below.

## Activity 3.1 Understanding Farm Drudgery

This activity is about coming up with the meaning of drudgery, with some appropriate examples of how it affects agricultural production

### Steps

1. Think about a simple definition of drudgery and some common farming tasks that are hard and tiring when done by hand.
2. Work with one classmate.
3. Discuss together and agree on a simple definition of drudgery based on what you understand.
4. List five of the tasks that you both agree are examples of drudgery in agriculture. Write your findings down.
5. Share your findings with the class.

## Activity 3.2 Ease Farm Work

This activity is about exploring how machines reduce drudgery in planting, growing and harvesting a particular crop.

### Steps

1. Find a friend and choose a crop grown in your locality.
2. Discuss how machines reduce drudgery in the production of the selected crop.
3. List at least five benefits of how drudgery is reduced in the production of your selected crop.
4. Write a report and submit it to your teacher.

*Suggested content for the report*

**a.** Title

**Example**: "How Machines Reduce Drudgery in Maize Production"

**b.** Introduction

**i.** Briefly explain what maize production involves.

**ii.** Define "drudgery" and why it's a challenge in farming.

iii. Mention how machines can help.

c. Main discussion

i. Describe the different machines used in maize production (eg planters, harvesters, shellers).

ii. Explain how each machine helps reduce hard physical labour.

iii. Discuss how these machines improve speed, safety, and comfort for farmers.

d. Benefits of reduced drudgery (List at least five)

i. Improved health and safety

ii. Increased productivity

iii. Time-saving

iv. Higher maize yield

v. Greater interest in farming by young people

e. Conclusion

i. Summarise how machines make maize production easier and more efficient.

ii. Share your opinion on the importance of mechanisation in agriculture.

5. Summarise your findings and make a presentation to your classmates.

# REDUCING DRUDGERY IN AGRICULTURE

## Digital Agriculture

Using computers in agriculture, also known as "digital agriculture" or "smart farming", makes work a lot easier by automating tasks, making better use of resources, and helping people make better decisions. Through the use of Internet of Things (IoT) technologies like data analytics, sensors, drones and software platforms, farmers can reduce the physical and cognitive workload associated with traditional farming practices.

## Ways computing tools reduce drudgery in agriculture

1. **Automation and precision farming**

   Computing tools like GPS-guided tractors (***Figure 3.5***), automated irrigation systems, and drone-based crop monitoring systems reduce the manual labour required for field operations, allowing for more precise and efficient farming. GPS-enabled tractors reduce the need for human operators, thus saving time and effort in planting, fertiliser application and spraying crops. Automated irrigation

systems ensure crops receive the optimal amount of water, reducing the labour-intensive task of hand watering.


**Figure 3.5:** GPS-guided tractor

### 2. Data-driven decision making

Using computing tools such as farm management software, sensors, and big data analytics allows farmers to monitor crop conditions, soil health and weather patterns in real-time. This reduces the drudgery of manual inspections and guesswork. For example, IoT-based sensors and big data analytics help farmers track soil moisture, nutrient levels and pest infestations, minimising the need for labour-intensive fieldwork. These systems inform precise interventions, such as when to irrigate or apply fertilisers, reducing the physical effort and time spent on these activities.

### 3. Remote sensing and drones

Drones equipped with cameras and sensors (***Figure 3.6***) reduce the drudgery associated with field surveillance, crop monitoring and pest control. Remote sensing via drones captures aerial images that provide data on soil status, plant growth and areas affected by pests and diseases. This eliminates the need for manual scouting, a time-consuming and labour-intensive task. Automated drones can also spray pesticides and fertilisers, further reducing the need for manual labour.

**Figure 3.6:** Drone technology in agriculture

### 4. Robotics in harvesting

Agricultural robots (***Figure 3.7***) automate planting, weeding and harvesting. Robotic harvesters, like those used for fruits and vegetables, can pick crops efficiently without human intervention. These robots use machine learning systems to identify ripe produce, reducing the need for manual labour during harvesting. In large-scale farming, such systems eliminate the physical strain associated with harvesting and save time.

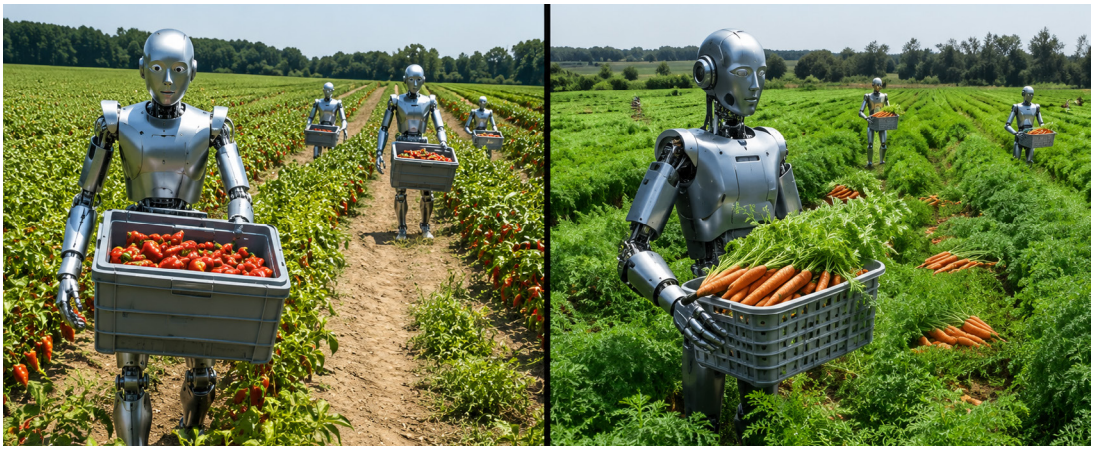


**Figure 3.7:** Robots harvesting crops

### 5. Farm Management Software (FMS)

Farm Management Software simplifies operational planning, record-keeping and financial management, reducing the administrative workload for farmer supervisors. Tools like FarmLogs or Agri-Edge allow farmers to manage inventories, schedule planting and track crop performance and harvesting. These systems reduce the time and effort spent on farm planning and paperwork.

### 6. Supply chain optimisation through Blockchain

Blockchain and cloud-based tools streamline supply chains, reducing the administrative drudgery associated with tracking produce from farm to market. Blockchain platforms allow transparent tracking of agricultural produce from farm to consumer, ensuring quality and reducing the need for time-consuming physical following of produce and manual record-keeping. This system simplifies auditing and certification processes, ensuring compliance with less human effort.

### 7. Cloud computing for collaborative farming

Cloud-based platforms enable collaboration and data sharing among farmers, agronomists and advisors, reducing the time spent on communication and decision-making. Smart farming platforms hosted in the cloud (***Figure 3.8***) allow farmers to upload and analyse data from weather forecasts, soil sensors and crop growth models to make informed decisions collectively and efficiently. Platforms like Climate FieldView enable farmers to share data with experts in real-time for quick insights, advice and recommendations, reducing the need for on-site visits and time-consuming consultations.


**Figure 3.8:** Cloud-based computing platform

8. **Mobile applications and sensors (Pest predictor)**

   Specialises in pest monitoring and prediction, using weather data and pest biology to forecast potential outbreaks. It helps farmers detect early signs of pest infestations through environmental factor analysis and make prompt decisions on pest control. This offers early warning systems that allow farmers to take preventive actions before pests cause economic damage.

9. **Automated livestock health monitoring**

   An Artificial Intelligence (AI) system that uses sensors to monitor livestock health and behaviour. These systems can detect early signs of illness or abnormal activity, allowing farmers to take action without manually inspecting each animal. For example, wearable AI devices for livestock can monitor body temperature, movement and feeding patterns, notifying farmers of any health concerns and eliminating the need for frequent manual checks. AI can control automated feeding systems and robotic milking machines, reducing the time and physical effort required to manage livestock.

## Benefits of Computing Tools in Agriculture

Computer-based tools provide numerous benefits, especially in reducing the drudgery associated with traditional farming practices. These tools improve efficiency, precision, and decision-making, thereby minimising physical labour and enhancing productivity.

Here are some key benefits of using computing tools to reduce drudgery in agriculture:

1. **Reduction of physical strain**

   Computing tools minimise the physical labour associated with tilling, planting, and crop monitoring. Instead of walking fields, farmers can use drones or remote sensing tools to monitor crop health, reducing fatigue and the risk of injury.

2. **Labour savings**

   Computing tools reduce the need for human labour, particularly for planting, weeding and harvesting, freeing up time for other farm activities.

3. **Enhanced precision**

   Precision agriculture uses computing tools like GPS, sensors and drones to apply inputs (seeds, water, fertilisers, pesticides) in a targeted manner, reducing waste and improving yield.

4. **Increased efficiency and productivity**

   Computer-based tools like GPS-guided tractors, automated irrigation systems, and drones enable farmers to carry out tasks more quickly and accurately. By automating repetitive tasks, farmers can cover more land in less time.

5. **Improved decision-making**

   Data analytics, artificial intelligence and farm management software provide farmers with real-time insights into soil conditions, weather patterns and crop health. This information allows for better decision-making and reduces the time spent on guesswork or trial-and-error methods.

6. **Minimised resource waste**

   Precision tools ensure that resources such as water, fertilisers and pesticides are used efficiently. This reduces waste and cuts down on the labour needed for input application.

7. **Cost saving**

   Computing tools reduce operational costs through task automation and improved resource use. Although there is an initial investment in technology, the long-term savings on labour, inputs and time can significantly increase profitability.

8. **Improved farm management**

   Farm management software allows farmers to streamline administrative tasks such as record-keeping, inventory management and financial planning. This reduces the mental workload and time spent on these tasks.

9. **Real-time monitoring and alerts**

   Computing tools like IoT sensors and drones offer real-time monitoring of farm conditions, providing instant feedback on issues such as pest infestations, weather changes, or equipment failures. Farmers can act immediately, reducing the labour required for manual monitoring and damage control.

10. **Sustainability and environmental benefits**

    Computing tools help optimise input usage, leading to more sustainable farming practices. Reduced use of fertilisers, pesticides and water lowers costs and minimises environmental impact, reducing the labour required for managing long-term negative environmental issues.

11. **Enhanced collaboration**

    Cloud-based computing platforms allow for better collaboration between farmers, agronomists, and agricultural advisors. This helps reduce the time and effort spent on decision-making and farm planning.

Now that you have learned how computing can help reduce farm labour, Let us build a low-cost drip irrigation system that makes farming smarter and easier.

## Project Work Activity Build a Low-Cost Drip Irrigation System

**Objective**: In this project, you will work in small groups to design and create a simple drip irrigation system using recycled plastic bottles. You will also prepare a short report and give a class presentation to explain:

1. How the system works
2. How it saves water
3. How it reduces hard manual work (drudgery)
4. Why it is good for the environment

### Materials needed

1. Work with 2–3 classmates to complete the project.
2. Gather materials
3. Collect the following materials (ask your teacher or parents for help if needed):
4. Clean, empty plastic bottles (with caps)
5. Small nails, pins, or needles (for making holes)
6. Hammer (optional)
7. String or wire (for hanging the bottles)
8. Scissors or knife (for cutting)
9. Marker or pen (for marking)
10. Ruler (to measure hole placements)
11. Water
12. Potted plants or garden crops to test the system

### Steps

1. Build the drip irrigation system
    a. Wash the bottles and remove labels.
    b. Use a marker to mark 2 to 4 spots near the bottom of each bottle.

**c.** Carefully make holes at the marked spots using a small, heated nail or pin. Ask for adult help if needed for safety.

**d.** (Optional) Make a tiny hole in the bottle cap to allow air in for smoother dripping.

**e.** Fill each bottle with clean water.

**f.** Turn the bottle upside down and:

**i.** Bury the mouth slightly in the soil near a plant **or**

**ii.** Hang it above the plant with the mouth facing down

**g.** Observe how fast the water drips. Adjust the hole size or number if needed.

**h.** Refill the bottles as needed during the week.

**2.** Prepare a report. Your report should include the following

**a.** Title: e.g. "Low-Cost Drip Irrigation Project"

**b.** Names of group members

**c.** Materials used

**d.** Steps followed (with drawings or photos if possible)

**e.** How the system works

**f.** Benefits (water-saving, reduced drudgery, good for the environment)

**g.** Challenges faced and how you solved them

**3.** Present your work. Each group should give a short presentation to the class. You can use your report or a poster and the real irrigation setup you built

## EXTENDED READING

Use the links below to learn more about how to use plastic bottles to produce a low-cost drip irrigation system

https://www.youtube.com/watch?v=uGHk0CNS2Ys

https://www.youtube.com/watch?v=U1TF1tPlteM

# REVIEW QUESTIONS

1. A youth group in a rural community in Ghana wants to start a vegetable farm. They want to make their work easier by using computers or mobile technology. Suggest one suitable computing tool or app they can use for each of these activities:

   **a.** Measuring and planning the farmland (land mapping)

   **b.** Controlling pests on the farm

   **c.** Selling their vegetables (marketing)

   Explain how each tool or app will help them reduce hard work and improve their farming. Give clear reasons for your choices.

2. Farmers need to know what the weather will be like so they can plan their farming activities well. In your area, most farmers use their experience or look at the sky to guess the weather.

   **a.** Explain how modern tools like weather apps on phones and weather sensors can help farmers carry out better farming.

   **b.** Give examples of farming decisions that would be better with good weather information.

   **c.** Describe how these tools can make farm work easier and reduce stress for farmers.

   **d.** What problems could farmers face when trying to use these tools in rural communities?

SECTION

4

# SOIL SCIENCE

# FARMING FOR JOBS AND INCOMES

## Introduction

Hello learner, welcome to Section 4 of the Year Three Agricultural Science course. This section focuses on the formation of soil and its physical, chemical, and biological properties. You will explore how soil plays a key role in supporting life on Earth, from growing crops to maintaining natural ecosystems. The section also highlights the fragile nature of soil and the importance of avoiding practices that can lead to soil degradation. You will be required to carry out simple experiments to observe and test different soil properties and investigate practical soil conservation methods. These activities will help you develop skills to manage soil properly and apply the knowledge in farming and environmental care. By the end of this section, you are expected to understand how to use soil wisely and protect it for long-term agricultural and environmental sustainability.

**KEY IDEAS**

- **Soil conservation**: This refers to practices that protect soil from degradation, erosion, and nutrient loss, ensuring its long-term health and productivity.
- **Soil management: This** involves using smart methods—like adding compost, rotating crops, or preventing erosion—to keep the soil in good shape.
- **Soil pH**: It is the measure of the acidity and alkalinity of soil which is a critical factor influencing plant growth.
- **Weathering of rocks**: This is the first step in making soil. Rocks slowly break down through natural processes such as heating and cooling, water penetration, freezing and thawing, and plant root growth and penetration. These weathering processes turn solid rock into loose material that can eventually become soil.

# SOIL FORMATION PROCESSES

## Weathering of Rocks

**Weathering of rocks (parent materials)** is a fundamental process in soil formation, where rocks break down into smaller particles that eventually become soil. This process occurs through a combination of **physical, chemical** and **biological** mechanisms. The parent material refers to the original rock or the mineral subjected to these processes. Over time, the weathering transforms the solid bedrock into a loose layer of particles that mix with organic matter, water and air to form soil.

## Types of Weathering in Soil Formation

1. **Physical (mechanical) weathering**

   Physical weathering is the breakdown of rocks into smaller fragments without any change in the chemical composition of the fragments. This process occurs due to environmental factors such as temperature changes, water, ice, wind, and pressure.

   **a.** *Temperature fluctuations:* Rocks expand and contract due to temperature changes. During the day, the heat causes rocks to expand, but they cool and contract at night. The repeated expansion and contraction cycles cause the rocks' surface to crack and break apart. This process is especially common in desert regions where temperature fluctuations are extreme.

   **b.** *Exfoliation*: In areas where rocks are exposed to intense heat (eg in deserts), the outer layers of rocks may expand and peel off in thin sheets, much like the layers of an onion. This happens because the surface layers heat up faster than the interior.

   **c.** *Pressure release (unloading):* When overlying material (such as soil or another rock layer) is removed by erosion, the underlying rock experiences a decrease in pressure. This pressure release causes the rock to expand and crack, contributing to the breaking up of the parent material.

   **d.** *Frost action (freeze-thaw):* This process occurs more in higher latitudes. Water enters cracks in rocks and freezes and thaws according to temperature fluctuations. Due to the anomalous expansion of water, freezing water expands between 4 0C and 0 0C. This expansion exerts pressure on the rock, causing it to fracture and eventually break apart.

   **e.** *Abrasion:* Wind, water and ice can act as agents of erosion, gradually scraping rock surfaces over time. For example, flowing rivers or glaciers can carry sediments that abrade rocks, gradually wearing them down.

2. **Chemical weathering**

   Chemical weathering involves the alteration of the rock's chemical composition through reactions with water, air, and other chemicals. This process is most effective in warm, humid climates. The processes that contribute to chemical weathering are:

   **a.** *Oxidation*: Oxidation involves the reaction of minerals, particularly those containing iron, with oxygen. Oxidation weakens the rock structure and facilitates further weathering. Example reaction: Iron in minerals reacting with oxygen and water to form iron oxides ($4Fe2+ + O2 + 6H2O \rightarrow 4Fe3+O(OH) + 4H+$ )

   **b.** *Hydrolysis:* Hydrolysis occurs when minerals react with water, resulting in the chemical alteration of the mineral structure. This process

involves the splitting of water molecules ($H_2O$) into hydrogen ($H^+$) and hydroxyl ions ($OH^-$), which then react with minerals, particularly silicates. For example, feldspar, a common rock-forming mineral, undergoes hydrolysis to form clay minerals and releases soluble ions like potassium, calcium, or sodium. This reaction weakens the original rock and promotes further weathering,

$$(KAlSi_3O_8) + H_2O + H^+ \rightarrow (\text{clay}) + K^+ + \text{Silica}\,(SiO_2)$$

***Feldspar*** ***Kaolinite***

**c.** *Carbonation*: Carbon dioxide in the atmosphere dissolves in rainwater, forming a weak carbonic acid. This acid reacts with certain minerals like limestone (calcium carbonate), causing them to dissolve. Over time, this process can create cavities or cracks in rocks, contributing to their breakdown.

**d.** *Dissolution:* Some minerals are directly dissolved by water, especially in areas with high rainfall. Salts like halite (sodium chloride) and gypsum (calcium sulphate) dissolve easily in water and are carried away, leaving behind smaller particles that contribute to soil.

**e.** *Hydration:* Hydration occurs when minerals in rocks absorb water molecules, leading to an expansion and change in their structure. For example, anhydrite ($CaSO_4$) can absorb water and convert into gypsum ($CaSO_4 \cdot 2H_2O$), a softer and more expansive mineral. This process weakens the rock, making it more susceptible to further breakdown. Hydration is common in minerals like clays, where water incorporation causes the minerals to swell and helps initiate other weathering processes.

**f.** *Reduction:* Reduction is the chemical reaction where minerals lose oxygen or gain electrons, often occurring in environments with low oxygen, like waterlogged soils. For example, ferric ($Fe^{3+}$) oxides are reduced to ferrous ($Fe^{2+}$) oxides, which are more soluble and can be leached away from the rock. This process is common in wet and anaerobic environments.

### 3. Biological weathering

Biological weathering occurs when organisms contribute to the breakdown of rocks. Plants, animals and microorganisms play a role in this process.

**a.** *Root growth:* Plant roots grow into cracks and fissures in rocks, exerting pressure as they expand. This can cause the rock to split over time. In addition, roots release organic acids that chemically react with minerals, further breaking down the rock.

**b.** *Microorganisms:* Bacteria, fungi, and lichens can produce acids as part of their metabolic processes, which can chemically weather rocks. Lichens, in particular, are effective at colonising rock surfaces and contributing to the breakdown of minerals.

c. *Burrowing animals:* Animals such as rodents, ants, and earthworms disturb the soil and rocks as they burrow. This physical disturbance brings rock fragments to the surface, exposing them to weathering processes.

# MOVEMENT AND DEPOSITION OF WEATHERED MATERIALS

The movement and deposition of weathered materials is an essential part of soil formation, following the initial weathering of rocks. Once the parent material is broken down into smaller particles through physical, chemical and biological weathering, these materials are transported and deposited by various natural forces. This process helps form different soil horizons and influences the soil's texture, composition and fertility.

## Movement of Weathered Materials

This occurs through erosion and transportation of weathered materials. Weathered materials are often moved by natural forces like water, wind, ice and gravity. These forces transport the particles, sometimes over great distances, to new areas where they are deposited. The key mechanisms of movement include:

1. **Water (Fluvial action)**

   Flowing water is one of the most effective agents for transporting weathered materials. During heavy rainfall, runoffs carry soil particles downhill through sheet erosion. In steeper terrains, rill and gully erosion occurs, carving out small channels or gullies in the soil. Streams and rivers pick up loose sediments, carrying them downstream. Larger particles like sand grains and gravel are deposited closer to the source, while smaller particles such as silt and clay are transported further. Over time, this process leads to the formation of river valleys and floodplains, which are often fertile due to the rich deposits of fine sediments. In coastal areas, ocean currents and waves can also transport weathered materials, contributing to the formation of beaches, sandbars, and deltas.

2. **Wind (Aeolian) action**

   In dry arid environments, wind is a powerful agent of erosion and transportation. Wind lifts fine particles like silt, clay, and fine sand, carrying them over long distances. This process forms dunes in deserts and loess deposits, which are fertile soils formed from wind-deposited dust.

3. **Ice (Glacial) action**

   Glaciers transport large amounts of weathered material as they move across the landscape. They grind and erode rock, carrying the debris along. When the

glaciers melt, they deposit this material, forming features like moraines, which are accumulations of unsorted rock debris.

4. **Gravity action (Mass wasting)**

   Mass wasting is the downward movement of weathered materials under the influence of gravity. This includes landslides, mudslides, rockfalls and soil creep. On steep slopes, gravity pulls weathered materials downhill, where they accumulate at the base of hills or mountains, forming deposits called colluvium.

## Deposition of Weathered Materials

Once transported, weathered materials are eventually deposited in new locations. The process of deposition plays a crucial role in shaping the landscape and forming new soils. The nature of deposition depends on the transporting agent and the size of the particles being moved:

1. **Alluvial deposition**

   When rivers or streams slow down, they lose their energy and begin to deposit the materials they are carrying. Coarser particles like gravel and sand are deposited first, while finer particles such as silt and clay settle out later. This results in the formation of alluvial soils, which are found in river valleys, deltas and floodplains. These soils are often fertile due to the fine texture and abundance of nutrients.

2. **Aeolian deposition**

   Wind-deposited materials form distinctive soil types. For example, loess, a fine, wind-blown sediment, is deposited in thick layers over large areas. Loess deposits are commonly found in regions like China, the American Midwest, and parts of Europe. Soils formed from loess tend to be fertile because of their fine texture and ability to hold moisture.

3. **Glacial deposition**

   As glaciers melt, they leave behind glacial till, a mix of clay, silt, sand, gravel, and boulders. This material is unsorted and forms the base for many soils in regions once covered by glaciers. In addition, glacial meltwater can carry finer materials that are deposited in outwash plains, creating well-sorted soils.

4. **Colluvial deposition**

   Materials moved by gravity, such as from landslides or soil creep, accumulate at the base of slopes in a process called colluviation. Colluvial soils often contain a mix of rock fragments and finer particles. These soils may be less fertile than alluvial soils, but can still support vegetation.

5. **Marine deposition**

   Coastal areas where rivers meet the sea, or in tidal zones, often see the deposition of weathered materials carried by water. This can result in the formation of

coastal plains and deltas, where fine sediments like clay and silt accumulate. These deposits create fertile soils.

## Soil Profile Development

Soil profile development is a critical process in soil formation that involves the layering of distinct horizons within the soil over time. These horizons, which are vertically arranged in a soil profile, reflect the various physical, chemical and biological processes that have acted upon the soil. These processes include weathering, organic matter accumulation, leaching, eluviation and illuviation of materials, and bioturbation. Soil profile development involves several processes that contribute to the formation of different horizons. A typical soil profile (***Figure 4.1***) has the following horizons:

1. **O horizon (Organic horizon)**

   This is the uppermost layer, composed mainly of organic material such as decomposing leaves, twigs, and plant roots (***Figure 4.1***). The O horizon is present in forest or grasslands where organic material accumulates on the soil surface. In cultivated soils, this layer may be absent or very thin.

2. **A horizon (Topsoil)**

   The A horizon, or topsoil, is rich in organic matter and minerals. It is usually darker in colour than the other horizons because of the high humus content. The A horizon is the most fertile layer and is critical for plant growth. It contains a mixture of organic matter and weathered mineral particles. This horizon experiences the eluviation process, which is the removal of clays, iron and organic matter from this horizon, leaving behind a concentration of sand and silt.

3. **B horizon (Subsoil)**

   The subsoil is where materials leached from the upper horizons are deposited and accumulate through illuviation. This horizon often contains higher concentrations of clay, iron, and aluminium oxides, giving it a dense, compact structure. The B horizon may be red or yellow due to the presence of iron oxides (***Figure 4.1***).

4. **C horizon (Weathered parent material)**

   The C horizon comprises partially weathered parent material that has not yet undergone significant soil formation processes. It is typically coarser in texture and less affected by leaching and illuviation. This horizon represents the transition between the soil and the unweathered bedrock below.

5. **D horizon (Bedrock)**

   The D horizon consists of unweathered bedrock, which may be granite, limestone, or other types of rock. Over time, this bedrock weathers to form the parent material for the overlying soil horizons.

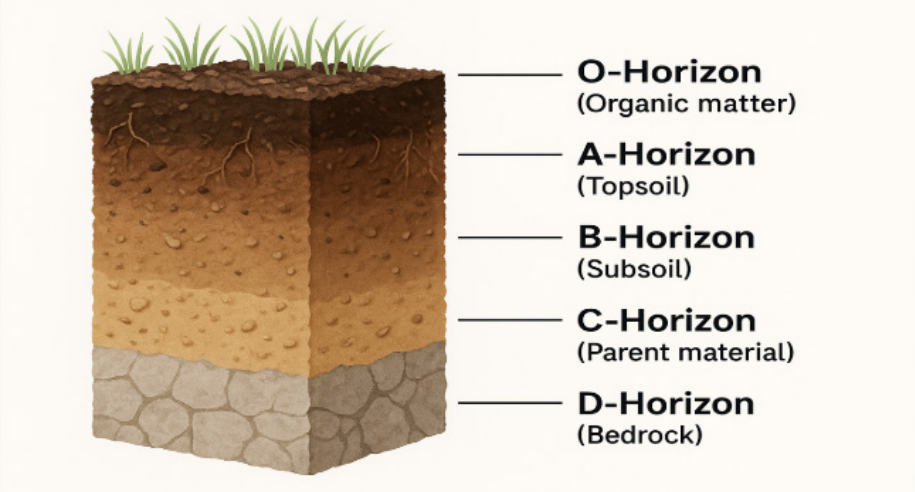



**Figure 4.1:** Diagram of Soil Profile

## Factors That Influence Soil Formation

Several factors influence soil profile development and horizon formation. Among these factors are:

1. *Parent material:* The mineral composition of the parent material influences the soil texture, structure, and nutrient content. Soils derived from volcanic rock, for example, may be rich in nutrients, while soils from quartz-rich rocks may be sandier and less fertile.
2. *Climate:* Temperature and precipitation play a major role in soil formation. In warm, humid climates, chemical weathering and leaching are more intense, leading to thicker, more developed soil profiles. In contrast, soils in cold or dry climates may have less organic matter and fewer distinct horizons.
3. *Organisms:* Plants, animals, and microorganisms contribute to soil formation through organic matter decomposition, bioturbation and root activity. Vegetation, particularly deep-rooted plants, helps stabilise soil and promotes horizon development.
4. *Topography*: The slope of the land influences water movement and erosion. Soils on steep slopes may be thin and poorly developed due to erosion, while soils in low-lying areas may accumulate more organic matter and develop thicker profiles.
5. *Time*: Soil formation is a slow process that takes thousands to millions of years. The age of the soil affects the development of its horizons. Young soils may only have a few horizons, while older soils may have well-developed, distinct horizons.

Congratulations on getting to this point! Please perform ***Activity 4.1***.

### Activity 4.1 Exploring Soil Profile Layers

This activity is about digging a soil pit and observing the different soil layers (horizons), noting their colour, texture, and composition.

#### Steps

1. Pair up with a classmate.
2. Go outside and choose an open area with natural soil (e.g., school garden or farm).
3. **Dig a soil pit:** Measure and dig a pit about 2 m long, 1 m wide, and 1 m deep.
4. Observe the soil layers (Horizons). For each visible layer, record the:
   a. Colour
   b. Texture (sandy, clayey, loamy)
   c. Composition (roots, stones, organic matter, moisture, structure)
5. Take notes and draw/sketch the soil profile and label each horizon.
6. Write a simple report (Include what you saw, the differences between layers, and what those differences might mean).
7. Present your report to your classmates.

# PHYSICAL PROPERTIES OF SOIL (TEXTURE AND STRUCTURE)

## Soil Physical Properties

Soil physical properties are the basic physical characteristics of soil that determine how soil behaves concerning plant growth, water movement, and farming activities. The most important soil physical properties are:

Texture, structure, temperature, colour, aeration and moisture.

## Soil Texture

The soil consists of sand, silt and clay particles, and its texture refers to the relative amounts of sand, silt and clay particles in a soil sample. It describes how fine or coarse the soil is, depending on the sizes of the soil particles present in it (***Table 4.2***).

***Table 4.2***: Properties of soil particles

| Soil Property | Particle characteristics | | |
|---|---|---|---|
| | Sand | Silt | Clay |
| Size of particles (diameter) | 0.02-2.0mm | 0.002-0.02mm | Less than 0.002mm |
| Coarseness | Coarse | Moderate in number and size | Very fine |
| Space between particles | Large and more spaces | Moderate | Small and fewer spaces |
| Drainage | High | Moderate | Low |
| Water holding capacity | Low | Moderate | High |
| Ease of moulding into shapes | Cannot be moulded into shapes | Slightly easy to mould into shapes | Very easy to mould into shapes |
| Condition when wet | Non-sticky grains remain separate | Slightly sticky | Very sticky |
| Condition when dry | Loose and grains remain separate | Slightly compact and hard | Very compact and hard |
| Ease of tillage | Very easy to till (light soils) | Slightly difficult to till | Very difficult to till or work (heavy soils) |

## Soil Texture Determination Using the Feel Method

**Experimental Objective**: To determine the relative proportions of sand, silt, and clay particles in soil samples using touch.

### Materials Required

1. Soil samples (representing different textures if possible)
2. Small containers for soil samples
3. Water spray bottle or dropper
4. Paper towels
5. Hand sanitiser or soap and water for cleaning hands
6. Reference soil texture guide/chart
7. Data recording sheets
8. Plastic gloves (optional)

# Detailed Procedure

## Part A: Sample preparation

1. Obtain soil samples, removing any visible debris (stones, roots, organic matter)
2. Place approximately 2 tablespoons of soil in your palm
3. Add water dropwise to moisten the soil until it reaches a putty-like consistency
4. Mix thoroughly with fingers until uniformly moist but not soggy

## Part B: Tactile assessment techniques

**Step 1**: Initial feel assessment

1. Rub the soil between thumb and forefinger
2. Note the dominant feeling: gritty (sand dominant); silky/floury (silt dominant) and sticky/plastic (clay dominant)

**Step 2**: Ribbon test

1. Form the soil into a ball about 3-4 cm in diameter
2. Compress the ball between your thumb and forefinger, attempting to form a ribbon
3. Measure how long the ribbon extends before breaking:
    a. Less than 2.5 cm: Low clay content
    b. 2.5-5 cm: Medium clay content
    c. Greater than 5 cm: High clay content

**Step 3**: Ball formation and ring test

1. Roll the soil into a cylinder shape about 6-7 cm long
2. Attempt to bend it into a ring
    a. Forms a ring without cracks (high clay)
    b. Forms a ring with cracks (moderate clay)
    c. Cannot form a ring (low clay)

## Part C: Texture determination

Use the combined observations to classify the soil sample according to texture:

1. *Sandy soil:* Gritty feel, will not form a ball or ribbon
2. *Sandy loam:* Gritty feel, forms a ball that crumbles easily, minimal ribbon

3. *Loam:* Equal mixture of gritty/smooth/sticky, forms a short ribbon (1-2 cm)
4. *Clay loam:* Sticky and smooth, forms a medium ribbon (2-5 cm)
5. *Clay:* Very sticky, forms a long ribbon (>5 cm), can form a full solid ring.

### Classification of Soil Based on Texture

Soil can be classified into three main types based on the textural characteristics of the soil. These are:

1. *Sandy soil:* (Large particle size (2.0 - 0.05 mm). Sandy soil is light, dry and gritty to the touch. It consists mainly of large particles and has a loose texture, which allows water to drain quickly. As a result, it tends to dry out rapidly and does not retain nutrients well. While it is easy to till and heats up quickly, it often requires organic matter to improve its fertility and moisture retention. This soil cannot form rolls or rings when moistened.
2. *Clayey soil:* Clay soil is heavy and dense, with very fine particles that pack closely together. It feels sticky when wet and can form hard clumps when dry. Clay soils retain water and nutrients well, but drain poorly and can become waterlogged. They are slow to heat up and difficult to dig, but they can be very fertile when managed properly.
3. *Loamy soil:* (balanced mixture, ideal for farming). Loamy soil is considered ideal for most plants. It is a balanced mixture of sand, silt, and clay, and has a fine, crumbly texture. This soil type retains moisture and nutrients effectively while still draining well. It is soft, rich in organic matter, and easy to cultivate, making it highly suitable for gardening and farming.

## Soil Structure

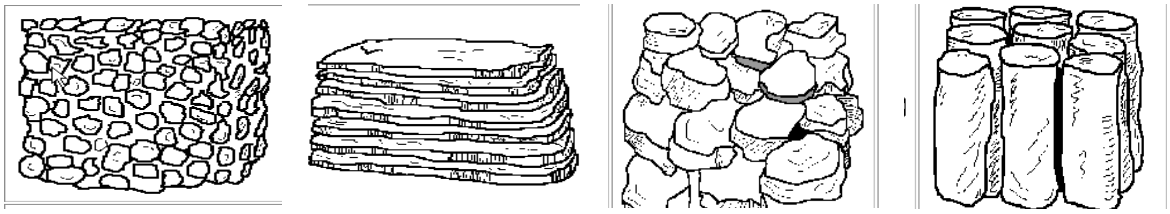
Soil structure refers to the arrangement of the soil particles into aggregates or peds. The aggregates consist mainly of fine soil aggregate particles held in a single mass or cluster, which are separated by pores, cracks, or natural planes of weakness. A good soil structure enhances water infiltration, air circulation and root penetration, while a poor soil structure can cause compaction, waterlogging, and poor plant growth.

### Types of Soil Structures

Based on the way aggregates are arranged in the soil, the following soil structures exist:

1. *Granular (**Figure 4.2A**):* It consists of small, rounded particles which appear in clusters of more or less spherical aggregates with spaces between them. This structure is commonly found in the A horizon (topsoil) and is prevalent in soils rich in organic matter, such as those in grasslands. Granular structure promotes good aeration and water movement, making it ideal for plant growth.

2. *Blocky structure* (***Figure 4.2C***): Soil aggregates are shaped like blocks or irregular cubes. The peds (natural soil clumps) have more or less equal dimensions in all directions. It is common in clay-rich subsoils with moderate water movement and root penetration.
3. *Platy structure* (***Figure 4.2B***): The soil aggregates are arranged in thin, flat plates or sheets. These plates are oriented horizontally, often impeding water movement and root growth. Typically found in compacted surface layers or soils with high clay content or poor drainage.
4. *Prismatic structure:* Soil aggregates form vertical columns or pillars with flat or slightly rounded tops. Prismatic soils are found in subsoils, particularly in arid and semi-arid regions with high clay content. It allows vertical water movement but with restricted lateral movement.
5. *Crumb structure:* Similar to granular but has larger, more porous aggregates, with high porosity and excellent drainage. It is ideal for agricultural production as it has fertile topsoil with high biological activity.
6. *Columnar structure* (***Figure 4.2D***): It is characterised by vertical columns with rounded, dome-like tops and high sodium content. It does not support agricultural production because drainage is poor. It is found in sodic soils in arid and semi-arid regions.
7. *Single grain structure:* it has individual particles with no aggregation. It is characterised by excessive drainage and poor water retention, hence limited fertility and drought-prone. It is very common in sandy soils with low organic matter.
8. *Massive structure:* It has large cohesive masses with no visible aggregations. Drainage, aeration and root penetration are all poor. It severely restricts plant growth and is mostly found in compacted subsoils and heavy clay soil.



A. Granular B. Platy C. Blocky D. Columnar

**Figure 4.2:** Diagram of types of soil structure

## Experiment to Assess Soil Structure

### Materials needed

1. Soil samples from different locations
2. Water
3. Hand lens or magnifying glass (optional)

## Procedure

1. Collect moist (not soaking wet) soil samples.
2. Gently break the soil apart by hand.
3. Observe how the soil naturally breaks into lumps (aggregates).
4. Sprinkle a little water on the sample to observe stability.

**Observation**: Note the shape, size and feel of the aggregates — whether crumbly, blocky, or compacted.

**Conclusion**: Relate the observed structure to its ability to allow water and air movement.

## Importance of Knowledge About Soil Texture and Structure to Farmers

Knowing soil texture and structure helps farmers in several practical and impactful ways. These include:

1. Farmers can match crops to soil conditions, hence reducing crop failure
2. Knowledge of soil structure helps farmers to improve soil health and long-term productivity.
3. Farmers can save money and reduce waste by applying the right amount of fertiliser at the right time, in the knowledge that the soil structure supports proper uptake.
4. Farmers can adopt practices like minimum tillage, cover cropping or contour farming based on the structure of their soil to prevent soil loss.
5. Understanding the soil structure helps the farmer to choose the right tillage method in land preparation.
6. Farmers can use this knowledge to plan better irrigation schedules and prevent waterlogging in poorly drained areas.
7. Farmers who understand soil structure can select practices that promote healthy root growth, more vigorous plants and larger yields.

Having gone through the content on the physical properties of soil, perform **Activity 4.2**.

### Activity 4.2 Experiment on soil texture and structure

Find a classmate and carry out experiments to determine the texture and structure of the soil on your school farm or home, and present your findings to the class.

#### Hint

For steps to complete **Activity 4.2**, refer to the content on determining soil texture and structure. Use the instructions to experiment on soil structure.

# PHYSICAL PROPERTIES OF SOIL (TEMPERATURE, COLOUR AND MOISTURE)

## Soil Temperature

Soil temperature is a measure of how hot or cold the soil is at a specific depth. It influences seed germination, root development, microbial activity, and nutrient uptake.

## Factors Affecting Soil Temperature

Several factors influence soil temperature and affect seed germination, root activity, microbial processes, and plant growth. The key factors include:

1. **Solar radiation (Sunlight):** Solar radiation is the primary source of heat for the soil. Soils receive more heat when days are longer and sunlight is more intense, typically in summer or in tropical regions.
2. **Soil colour:** Dark-coloured soils absorb more heat and become warmer than light-coloured soils, which reflect more sunlight.
3. **Soil moisture content:** Wet soils heat up and cool down more slowly than dry soils due to water's high heat capacity. Moist soils may stay cooler during the day and warmer at night than dry soils.
4. **Soil texture:** Sandy soils heat up and cool down faster than clay or loamy soils due to lower water retention and fewer fine particles.
5. **Soil structure and porosity:** Well-aerated soils with larger pores allow better heat transfer, while compacted soils resist temperature changes.
6. **Vegetative cover:** Plants and mulch act as insulation, reducing the amount of sunlight that reaches the soil and slowing temperature changes.
7. **Topography (Slope and aspect):** South-facing slopes (in the northern hemisphere) receive more direct sunlight and tend to be warmer. Flat or shaded areas receive less sunlight and may remain cooler.

8. **Atmospheric temperature:** The ambient temperature affects soil temperature; warmer air tends to warm the soil and vice versa.

## Importance of Soil Temperature in Agriculture

1. Many crops germinate within an optimal soil temperature range, outside of which they fail to germinate or experience a very low germination rate.
2. Soil temperature influences root growth and nutrient availability.
3. The rate of microbial activity in the soil is dependent on the soil temperature. This is important for decomposition and nutrient recycling.

## Experiment to Investigate Soil Temperature

**Objective**: To measure and compare soil temperatures at different depths and locations.

**Materials**: Soil thermometer, ruler, notebook, soils from different sites (E.g shaded vs. open).

### Method

1. Insert the thermometer 5cm and 10cm deep into the soil at selected sites.
2. Record the temperature at the same time of day for 5 to 7 days.
3. Compare results across depths and locations.

**Observation**: Shaded soils are cooler; deeper layers fluctuate less.

## How Farmers Apply the Knowledge of Soil Temperature In Farming

1. Knowing the right temperature helps farmers plant at the most favourable time for optimum and uniform germination.
2. Knowledge of soil temperature helps in selecting suitable crops or using mulches to modify temperature for better root growth.
3. Understanding soil temperature allows farmers to make informed decisions that increase efficiency, reduce waste and improve crop yields.
4. Some soil-borne pests and diseases thrive at specific temperatures. Monitoring soil temperature helps in predicting and managing outbreaks.
5. Soil temperature helps determine the best time for ploughing and other mechanical operations.
6. Farmers growing crops in controlled environments use soil temperature data to adjust heating and improve seedling growth.

7. Soil temperature affects evaporation rates and how water moves in the soil. It helps in scheduling irrigation to maintain adequate moisture.

# Soil Colour

Soil colour refers to the appearance of the soil due to three main pigments: black – from organic matter, red – from iron and aluminium oxides, and pale colour – due to silicates and salts.

## Determination of Soil Type Based on Soil Colour

1. **Dark brown/black soil** (***Figure 4.3***)
   - **a.** Rich in organic matter, especially humus, giving it a dark colour.
   - **b.** Often found in fertile regions, ideal for crop farming.
   - **c.** Has good moisture retention and structure.
2. **Red/yellow soil**
   - **a.** The colour is due to the presence of iron and aluminium oxides.
   - **b.** Found in tropical and subtropical regions.
   - **c.** Usually, well-drained but low in fertility unless managed.
   - **d.** Often requires lime and fertilisers for productive farming.
3. **Grey/blue soil**
   - **a.** Indicates poor drainage and waterlogging.
   - **b.** The grey or bluish colour is due to reduced iron under anaerobic conditions.
   - **c.** Common in swamps or poorly drained lowlands.
   - **d.** Not ideal for most crops unless drainage is improved.
4. **White soil**
   - **a.** Light coloured due to high silica, salt or lime content.
   - **b.** Often sandy and infertile, with poor nutrient and water retention.
   - **c.** Found in arid or semi-arid regions.
   - **d.** May support only limited vegetation unless amended.

**Dark Brown/Black** **Red/Yellow** **Grey/Blue Soil** **Pale/White**

**Figure 4.3:** Images of Soil Types Based on Soil Colour

## Importance of Soil Colour in Agriculture

1. Indicates fertility status and organic matter content of the soil.
2. Provides clues about drainage conditions and mineral content of the soil.
3. Assists in soil classification and crop suitability decision-making.

## Farmers' use of knowledge of soil colour in farming

1. *It helps to predict soil fertility:* Dark soils (black or dark brown) often contain more organic matter and nutrients, indicating higher fertility. Light-coloured soils (grey or white) may have low organic matter and nutrients.
2. *Helps assess drainage and aeration:* Red or yellow soils usually indicate good drainage and aeration, often due to iron and aluminium oxides. Grey or bluish soils suggest poor drainage or waterlogging, which hinders root growth.
3. *Guides crop selection:* Soil colour can hint at suitability for certain crops. For example, crops sensitive to waterlogging may not perform well in grey, poorly drained soils.
4. *Assists in land management practices:* Farmers can decide where to apply organic matter, lime, or drainage improvements based on the soil colour.
5. Helps in planning for erosion control, as certain colours may indicate erosion-prone soils.
6. *Provides clues to soil temperature:* Dark soils absorb more heat, heating up faster and supporting earlier planting. Light soils reflect more sunlight and stay cooler, affecting crop growth timing. This applies in the cooler regions.
7. *Helps identify soil types and layers:* Colour differences in soil horizons (layers) help farmers understand soil depth, composition and structure, important for root development and nutrient management.

# Soil Moisture

Soil moisture refers to the water present in the soil. It exists in different forms based on how it is held within the soil particles, hence available or not for plant use

## Types of Soil Moisture

The main types of soil water are:

1. **Gravitational water**

   This drains through the soil due to the force of gravity. It occupies the large pores (macropores) in the soil after heavy rainfall or irrigation. It is generally not available to plants because it moves too quickly through the root zone.

2. **Capillary water**

   This water is held in the soil micropores (small pores). It moves slowly and is the most important source of water for plants. It is available to plants because it is held loosely around soil particles and can be absorbed by roots.

3. **Hygroscopic water**

   Forms a thin film tightly bound around soil particles. It is unavailable to plants because it is held too tightly and cannot be absorbed by plant roots. It remains in the soil even when very dry.

## Importance of Soil Moisture in Agriculture

1. Essential for plant growth and development.
2. Affects soil temperature and microbial activity.
3. Dissolves soil nutrients for plant uptake.
4. Essential for seed germination.

## Experiment to Determine Soil Moisture Content

**Objective**: To measure the moisture content of different soil samples.

**Materials**: Soil samples, weighing scale, oven, containers.

### Method

1. Weigh a fresh soil sample (wet weight).
2. Dry it in an oven at 105°C for 24 hours.
3. Weigh the dried sample (dry weight).
4. Use the formula: Moisture content (%) = (Wet weight – Dry weight)/Dry weight) × 100

**Observation**: Soils with higher moisture retain water better, hence will support longer plant growth during dry periods.

## Application of Knowledge in Soil Moisture in Farming

1. Farmers can apply the right amount of water at the right time, avoiding overwatering and underwatering. Saves water and reduces irrigation costs.
2. It helps with better timing of farm operations. Soil moisture levels influence when to plough, plant, or harvest
3. Farmers can adjust fertiliser application based on moisture levels to enhance nutrient efficiency.

4. It helps farmers to maintain long-term soil health by avoiding erosion, salinisation, or degradation due to improper water management
5. It helps farmers prepare for or mitigate the effects of droughts or excessive rainfall by choosing appropriate crops or soil conservation practices.

Now perform the **Activity 4.3**.

## Activity 4.3 Experiment on Soil Colour, Moisture and Temperature

This activity is about understanding the importance of soil colour, moisture and temperature in agricultural production by conducting simple experiments to investigate soil colour, moisture and temperature

### Steps

1. Team up with a classmate.
2. Use the Internet or learner material to help understand:
   a. What soil temperature, colour, and moisture mean
   b. Why each is important in farming
3. Gather soil from 2–3 different places (E.g school garden, roadside, wet area).
4. Observe the colour of the soil samples
   a. Look closely at each soil sample
   b. Compare their colours (dark, light, reddish)
   c. Record your observations
5. Test the soil moisture

### Hint

Follow the steps listed in the content, which describe how to determine soil moisture content, then record your results

6. Check the soil temperature

### Hint

Follow the steps in the content which describe how to measure soil temperature at different depths and locations, then write down the temperatures.

7. Analyse your results
   a. Compare the temperature, colour, and moisture of each sample
   b. Think about how these can affect plant growth
8. Write a brief report
   a. Describe what you did
   b. Present your findings

   c. Include drawings or photos if possible
9. Present your report to your other classmates.

# CHEMICAL AND BIOLOGICAL PROPERTIES OF SOIL

## Soil pH

Soil pH is the acidity or alkalinity of the soil solution, expressed on a scale from 0 to 14. A pH of 7 is neutral; values below 7 indicate acidic soils, and values above 7 indicate alkaline soils.

## Importance of Soil pH in Agriculture

1. **Nutrient availability:** Soil pH directly affects the solubility and availability of essential nutrients. For example, phosphorus is most available in the pH range of 6.0–7.0, while iron and manganese are more soluble under acidic conditions.
2. **Microbial activity:** Many beneficial microorganisms thrive in neutral to slightly acidic soils (pH 6–7). Strongly acidic or alkaline soils suppress microbial activity, which slows organic matter decomposition and nitrogen fixation.
3. **Toxic elements:** At low pH, toxic elements like aluminium and manganese may become more soluble, making the soil harmful to plant roots (Brady & Weil, 2016).

## Factors Influencing Soil pH

1. Parent material (basic rocks yield higher pH soils)
2. Rainfall and leaching (more rainfall tends to lower pH)
3. Fertiliser use (eg ammonium-based fertilisers acidify the soil)
4. Organic matter decomposition

## Causes of Soil Acidity

Soil acidity occurs when hydrogen ions ($H^+$) and aluminium ions ($Al^{3+}$) dominate the soil's exchange sites, leading to a low pH (usually below 6.5). Several natural and human-induced factors contribute to the development of acidic soils. Some of these are:

1. **High rainfall and leaching:** Heavy and consistent rains leach away basic cations such as calcium ($Ca^{2+}$), magnesium ($Mg^{2+}$), potassium ($K^{+}$), and sodium ($Na^{+}$). These are replaced by hydrogen ($H^{+}$) and aluminium ($Al^{3+}$) ions, increasing soil acidity.
2. **Use of acid-forming fertilisers:** Ammonium-based fertilisers (eg ammonium sulphate, urea) are converted to nitrate ($NO_3^{-}$) by soil microbes, releasing hydrogen ions into the soil. This acidifies the soil over time.
3. **Organic matter decomposition:** Decomposition of organic matter produces organic acids (e.g. fulvic and humic acids) that can increase soil acidity, especially in poorly buffered soils.
4. **Crop uptake of basic cations:** Plants absorb more cations (e.g. $Ca^{2+}$, $Mg^{2+}$) than anions (e.g. $NO_3^{-}$), and in exchange, roots release $H^{+}$ ions into the soil, contributing to acidification.
5. **Parent material:** Soils formed from acidic rocks (e.g., granite, sandstone) tend to be more acidic than those formed from basic rocks (e.g., basalt, limestone).
6. **Acid rain:** Rain containing sulphuric ($H_2SO_4$) and nitric ($HNO_3$) acids from industrial emissions releases large amounts of H+ ions in the soil, which can lower soil pH over time, leading to soil acidity.
7. **Poor drainage and waterlogging:** Anaerobic conditions in poorly drained soils cause the accumulation of organic acids and the reduction of iron and manganese, leading to acidification.

## Correcting Soil Acidity

1. **Application of liming materials:** The most effective method to neutralise soil acidity is by applying liming materials to the soil. They are alkaline in nature and help to raise the soil pH and reduce toxic levels of aluminium and manganese. Some common liming materials include:
   a. Calcitic lime (Calcium carbonate – $CaCO_3$)
   b. Dolomitic lime (Calcium magnesium carbonate – $CaMg(CO_3)_2$)
   c. Quicklime (Calcium oxide – CaO)
   d. Hydrated lime (Calcium hydroxide – $Ca(OH)_2$
2. **Use of gypsum (in certain cases):** Calcium sulphate (gypsum**)** is not a liming material, but can supply calcium without significantly altering pH. The calcium ions displace aluminium ions from the root zone in acidic subsoils. It is useful in acidic subsoils where lime incorporation is difficult.
3. **Organic amendments:** Compost, manure, and green manure can help buffer soil pH. Organic matter improves soil structure and microbial activity, which can reduce acidity over time.

4. **Acid-tolerant crops:** Sowing/planting crops that thrive in low-pH soils can be an interim strategy to improve the soil. Examples of acid-tolerant crops are sweet potato, pineapple, cowpea and millet. This is very useful in areas where liming is not immediately feasible.
5. **Improved drainage:** Waterlogged soils can accumulate organic acids, increasing acidity; therefore, proper drainage reduces acidity buildup, especially in clayey soils.
6. **Controlled use of fertilisers:** Minimised use of acid-forming fertilisers (e.g. ammonium sulphate, urea) and neutral or alkaline fertilisers (e.g. calcium nitrate, potassium nitrate) will reduce soil acidity. Fertiliser application should be based on soil test results.
7. **Crop rotation and cover cropping:** Rotating deep-rooted crops with surface feeders improves pH balance. Cover crops can prevent nutrient leaching and build organic matter.

## An Experiment to Test Soil Acidity Using Litmus Paper

**Title**: Litmus paper determination of soil acidity

**Objective**: To determine whether a soil sample is acidic, neutral, or alkaline using litmus paper.

### Materials needed

1. Soil samples (from different locations/sites)
2. Distilled water
3. Clean beakers or plastic cups (1 for each sample)
4. Stirring stick or spoon
5. Filter paper or coffee filter
6. Funnel (optional)
7. Blue and red litmus papers
8. Pen and notebook for recording results.

### Procedure

1. Label each cup or beaker according to the soil sample location or number.
2. Place two tablespoons of soil into each cup. (Either heaped or flat).
3. Add 50 ml of distilled water to each soil sample to make a slurry.

4. Stir thoroughly for about one minute and leave for 15–30 minutes.
5. Filter the mixture through filter paper into another clean container.
6. Test with litmus paper:
   a. Dip a strip of blue litmus paper into the filtrate and note the colour change.
   b. Dip a strip of red litmus paper into the filtrate and note the colour change.
7. Record the observations and interpret the results (Table 4.3).

***Table 4.3***: Soil acidity test results

| Soil Sample | Blue Litmus Paper Result | Red Litmus Paper Result | Conclusion |
|---|---|---|---|
| A | Turns red | No change | Acidic Soil |
| B | No change | Turns blue | Alkaline Soil |
| C | No change | No change | Neutral Soil |

**Conclusion**: This experiment shows whether a soil is acidic, neutral, or alkaline based on litmus paper reactions, which helps in determining soil suitability for different crops.

# Soil Organic Matter and Fertility

Soil organic matter comprises all organic components in the soil, including plant and animal residues at various stages of decomposition, cells and tissues, and substances/chemicals produced by the soil organisms.

## Components of Soil Organic Matter

1. *Fresh residues:* Recently added plant materials
2. *Particulate organic matter:* Partially decomposed organic materials
3. *Humus:* Stable, fully decomposed organic matter resistant to further rapid decomposition
4. *Living biomass:* All microorganisms and soil fauna (macro-organisms).

## Experiment to Determine Organic Matter Content of Soil: Combustion Method

**Objective**: To determine the percentage organic matter content of a soil sample.

### Materials needed/Apparatus

1. Soil sample (air-dried and sieved)

2. Crucible or heat-resistant container
3. Oven (for drying)
4. Muffle furnace or open flame source (for heating)
5. Balance (accurate to 0.01 g)
6. Tongs or heatproof gloves

### Procedure

1. Weigh about 100 g of air-dried, sieved soil into a clean, dry crucible.
2. Dry in an oven at 105°C for 24 hours to remove moisture.
3. Cool in a desiccator and weigh accurately (Weight 1).
4. Place the crucible with the dried soil in a muffle furnace at 360–400°C for two hours, or heat carefully over an open flame until the soil turns greyish (indicating organic matter is burned off).
5. Cool in a desiccator and weigh again (Weight 2).
6. Calculate organic matter content: Organic Matter Content (%) = (W1 - W2)/(W1) × 100.
7. Weight of dry soil before combustion (W1) = 120 g
8. Weight of soil after combustion (W2) = 90 g
9. Organic matter Content =120 − 90/120 × 100 = 25 %.

## The Role of Organic Matter in The Soil

1. **Improves soil structure:** It enhances soil aggregation, thereby increasing porosity, aeration and facilitating root penetration.
2. **Increases water retention:** Organic matter acts like a sponge, holding water. This helps soils retain moisture during dry periods.
3. **Enhances nutrient availability:** Serves as a reservoir of essential nutrients (eg nitrogen, phosphorus, sulphur), releasing nutrients slowly through decomposition.
4. **Boosts Cation Exchange Capacity (CEC):** Increases the soil's ability to hold and exchange positively charged ions (e.g. $K^+$, $Ca^{2+}$, $Mg^{2+}$), which improves nutrient retention and reduces leaching.
5. **Promotes soil microbial activity:** Provides food and energy for soil microorganisms, which supports beneficial organisms involved in decomposition and nutrient cycling.

6. **Buffers soil pH:** Helps neutralise acids and bases, stabilising soil pH levels and helping reduce the harmful effects of extreme soil pH.
7. **Suppresses soil-borne diseases:** Supports populations of beneficial microbes that compete with or suppress pathogens.
8. **Regulates soil temperature:** Improves soil insulation, reducing temperature extremes.
9. **Reduces soil erosion:** Improves soil cohesion and reduces susceptibility to wind and water erosion.
10. **Sequesters carbon:** Plays a vital role in climate change mitigation by storing carbon in the soil.

# Cation Exchange Capacity (CEC) Of the Soil

CEC refers to the soil's ability to hold and exchange positively charged ions (cations) such as potassium ($K^+$), calcium ($Ca^{2+}$), magnesium ($Mg^{2+}$), and ammonium ($NH_4^+$) ions. It is measured in centimoles of charge per kilogram of soil (cmol (+)/kg).

## Importance of Cation Exchange Capacity (CEC) of the soil

Cation Exchange Capacity (CEC) is a key indicator of soil fertility and health. It refers to the soil's ability to hold and exchange cations in the soil. Some of the importance of CEC are:

1. **Enhances nutrient retention:** Soils with high CEC hold more essential nutrients such as Potassium ($K^+$), Calcium ($Ca^{2+}$), and Magnesium ($Mg^{2+}$). This prevents nutrients from being easily leached by rain or irrigation water.
2. **Improves soil fertility:** Higher CEC means greater nutrient-holding capacity, contributing to better plant growth. It also supports sustained nutrient supply throughout the growing season.
3. **Regulates soil pH:** CEC contributes to soil buffering, helping to resist rapid changes in soil acidity. This helps maintain a stable chemical environment for plant roots and microbes.
4. **Supports efficient fertiliser use:** Soils with higher CEC retain applied fertilisers better, increasing efficiency and reducing costs.
5. **Indicates soil type and quality:** Sandy soils have low CEC and tend to be less fertile, while clay and organic-rich soils have higher CEC and better nutrient-holding potential.
6. **Enhances microbial activity:** A stable nutrient environment promotes microbial growth and biological activity.
7. **Aids in soil amendment decisions:** It helps guide the application of lime or fertilisers based on nutrient-holding capacity.

## Factors Affecting CEC of Soils

Cation Exchange Capacity varies from one soil to another based on several physical and chemical characteristics. The major factors that influence CEC:

1. *Soil texture:* Clayey soils have higher CEC due to the large surface area and presence of negatively charged clay particles, while sandy soils have low CEC because of their coarse texture and small surface area.
2. *Organic matter content:* Organic matter (especially humus) has a very high CEC, therefore, soils rich in organic matter can retain more nutrients and have a higher total CEC.
3. *Soil pH:* As soil pH increases, the negative charge on soil particles (especially organic matter and variably-charged clays like kaolinite) increases, raising CEC. Acidic soils tend to have lower effective CEC.
4. *Soil moisture:* Soil moisture affects the mobility of cations and their ability to interact with exchange sites; therefore, well-hydrated soils allow for better cation exchange.
5. *Type and concentration of cations present:* Polyvalent cations (e.g. $Ca^{2+}$, $Mg^{2+}$) can affect how strongly cations are held and exchanged. Sodium-dominated soils may have a lower effective CEC due to the dispersion of clays.
6. *Soil temperature:* High soil temperatures can accelerate organic matter decomposition, potentially lowering CEC over time.

### Activity 4.4 Experiment on the Chemical Properties of Soil

#### Steps

1. Work with a classmate.
2. Talk about soil acidity and organic matter, using the content in your learner material as a guide.
3. Decide who will lead each experiment.
4. Measure the pH of soils from a number of different locations - Mix soil + water, dip litmus/pH paper, record the pH in your book. (Hint: the procedure can be found in the content of an experiment to test soil acidity using litmus paper).
5. **Measure the organic matter content of a soil sample** – Use the combustion method (Hint: the procedure can be found in the content on an experiment to determine the organic matter content of soil: Combustion method).
6. Record your findings
7. Make a short presentation on:

   a. Soil acidity and organic matter
   b. Talk about the results of your experiment on organic matter determination and what they mean for soil health.
8. Share with the class.

# PRINCIPLES OF SOIL CONSERVATION

## Introduction to Soil Conservation

Soil conservation is the application of sustainable practices to protect soil from degradation. Soil is a finite resource that forms over extremely long periods, hundreds to thousands of years, yet can be degraded rapidly through erosion, compaction, contamination and other processes. The need for soil conservation arises from several critical factors such as:

1. Topsoil is lost at rates 10-40 times faster than it forms naturally.
2. Over 33 % of global soils are moderately to highly degraded.
3. Soil degradation directly threatens food security and ecosystem functions.
4. Once severely degraded, soil restoration becomes extremely difficult, costly and time-consuming.

## Fundamental Principles of Soil Conservation

Effective soil conservation requires understanding the principles that guide conservation efforts and the specific practices implemented in different agricultural contexts. Some of these principles include:

1. **Principle of soil surface cover**

   Maintaining vegetative or residue cover on the soil surface is fundamental to soil protection. This helps to:

   a. Intercept raindrops, reducing their erosive impact.
   b. Slow surface water flow allowing greater infiltration.
   c. Reduces wind velocity at the soil surface.
   d. Provides organic material for soil building.

2. **Principle of minimum disturbance**

   Minimising soil disturbance helps maintain soil structure and biological functions by:

   a. Preserving natural soil aggregation and porosity.
   b. Maintaining root channels and earthworm burrows for water infiltration.

**c.** Preventing the rapid decomposition of organic matter.

**d.** Reducing oxidation of soil carbon to $CO_2$.

3. **Principle of biodiversity**

   Enhancing biological diversity above and below ground promotes soil health through:

   **a.** Diverse root structures that explore different soil depths.

   **b.** Varying nutrient demands that prevent single-element depletion.

   **c.** Enhanced resilience against pests and diseases.

   **d.** Greater microbial diversity supporting nutrient cycling.

4. **Principle of continuous living roots**

   Maintaining living roots in the soil throughout the year provides continuous food for soil microorganisms and stabilises soil aggregates through root exudates. It also creates channels for water infiltration and captures nutrients that might otherwise leach.

5. **Principle of integrated soil management**

   This principle combines multiple approaches that adapt to local conditions. This approach recognises that no single practice is sufficient for all situations. This principle can be achieved by:

   **a.** Adapting conservation methods to local soil types, topography and climate.

   **b.** Combining cultural and mechanical approaches for comprehensive protection.

   **c.** Monitoring outcomes and adjusting strategies accordingly.

# Cultural Methods of Soil Conservation

Cultural methods focus on agronomic and biological approaches to soil management that enhance soil protection while maintaining agricultural productivity. These methods include:

## Crop rotation

Crop rotation is the systematic and sequential planting of different crops on the same land across many growing seasons. The aim is to improve soil fertility, reduce pest and disease cycles, control weeds, and enhance overall crop productivity.

### The benefits of crop rotation

1. Improves soil fertility – legumes such as cowpea fix nitrogen.
2. Reduces pest and disease build-up – rotating crops breaks life cycles.

3. Prevents nutrient depletion – different crops use different nutrients.
4. Improves soil structure – deep-rooted and shallow-rooted crops alternate.
5. Enhances yield and income stability

## 4-Year crop rotation programme (Table 4.4)

***Crops**:* Maize, tomato, cowpea, cassava

***Land size:*** Let us assume 4 plots of equal size (Plots A, B, C, D), one crop per plot per year.

***Table 4.4*:** Four-year crop rotation plan involving four crops

| Plot/Year | Plot A | Plot B | Plot C | Plot D |
|---|---|---|---|---|
| **Year 1** | Maize | Tomato | Cowpea | Cassava |
| **Year 2** | Tomato | Cowpea | Cassava | Maize |
| **Year 3** | Cowpea | Cassava | Maize | Tomato |
| **Year 4** | Cassava | Maize | Tomato | Cowpea |

## Guide to implement the rotation

1. *Sequence crops wisely:* Follow heavy feeders with legumes (e.g. maize → cowpea), avoid planting crops from the same family consecutively and alternate deep- and shallow-rooted crops (e.g. cassava → tomato).
2. *Soil fertility management:* Let legumes like cowpea build nitrogen naturally, add compost/manure before heavy feeders like maize and tomato, test soil annually and add lime or fertiliser as needed.
3. *Pest and disease control:* Avoid planting crops from the same family consecutively to reduce the build-up of specific pests/diseases. Monitor regularly and use integrated pest management **(**IPM).
4. *Record keeping:* Keep a rotation calendar or farm map and track yields, pest issues and soil amendments.

# Cover Cropping

Growing plants to cover and protect the soil when main crops are not growing. This can be achieved by:

1. Planting immediately after harvesting the main crop.
2. Selecting species based on specific conservation goals.
3. Terminating before planting the next main crop.

4. Considering mixtures of multiple species for enhanced benefits.

## Benefits of cover cropping

1. *Prevents erosion during fallow periods:* Cover crops act like a living blanket, holding soil in place so wind and rain can't wash it away.
2. *Captures and recycles nutrients:* Their roots grab leftover nutrients in the soil and store them, ready for the next crop to use.
3. *Suppresses weeds:* Thick cover crop growth blocks sunlight, making it hard for weeds to sprout and grow.
4. *Builds organic matter:* When cover crops decompose, they add rich, crumbly material that improves soil structure.
5. *Enhances soil biology:* The roots of cover crops feed earthworms and helpful microbes, creating a lively, healthy soil community.

# Windbreak Establishment

Windbreaks are rows of trees or shrubs planted to block or reduce wind speed over the soil surface (***Figure 4.4***). Trees or tall plants are planted strategically, often at right angles to prevailing winds. The foliage and branches lessen the force of the wind, reducing its ability to carry away topsoil.

## Its benefits for soil conservation are

1. Reduces wind erosion, especially in dry, sandy, or bare soils.
2. Protects crops from wind damage and moisture loss.
3. Improves microclimate by reducing evaporation and providing shade.
4. Enhances biodiversity and adds organic matter through fallen leaves.

**Figure 4.4:** Windbreak in arable farmland.

## Strip Cropping

Growing strips of different crops in alternating bands across a field, typically along contours (***Figure 4.5***). It is achieved by alternating erosion-reducing crops (grasses, forages) with erosion-susceptible crops (maize, soybeans). The width of strips depends on slope steepness, erosion risk and equipment size.

### The benefits of strip cropping

1. *Reduces the rate of soil erosion:* The crop strips slow down rainwater and wind, so they cannot carry away the topsoil.
2. *Creates a diversified habitat for beneficial insects:* Different crops bring in bees, ladybirds, and other "good bugs" that pollinate plants and eat pests.
3. *Reduces pest movement between susceptible crops:* Pests have a harder time moving across different crop strips, so they cannot quickly damage the whole field.
4. *Combines the benefits of crop rotation and contour farming:* You get the soil protection of contour farming and the soil health boost of crop rotation all in one method.

**Figure 4.5:** Strip-cropped land

## Mulching

Applying plant materials, compost, or other suitable materials to the soil surface.

### Its benefits are:

a. *Reduces raindrop impact on the soil:* The mulch layer softens the force of falling rain, so it does not splash and wash the soil away.

b. *Suppresses weeds:* Mulch blocks sunlight, making it hard for weed seeds to sprout and grow.

c. *Moderates soil temperature:* It keeps the soil cooler on hot days and warmer on cold days, protecting plant roots.

d. *Conserves soil moisture:* Mulch slows down water evaporation, so the soil stays moist for longer.

e. *Adds organic matter as mulch decomposes:* As mulch breaks down, it feeds the soil with nutrients and improves its structure.

## Conservation tillage systems

Tillage approaches that maintain at least 30 % residue cover after planting. Types include:

1. **No-tillage:** Planting directly into undisturbed residue with specialised equipment, after herbicidal or mechanical destruction of weeds/vegetation, or slashing and burning vegetation.
2. **Strip-tillage:** Tilling only narrow strips where seeds will be planted.
3. **Ridge-tillage:** Creating permanent ridges and planting on ridge tops.
4. **Mulch-tillage:** Incorporating some residue into the soil while leaving significant amounts on the surface.

### Benefits of conservation tillage

1. *Dramatically reduces erosion rates:* Leaving crop residues on the soil surface protects the topsoil from being washed or blown away.
2. *Improves soil organic matter:* Plant leftovers from previous crops break down and enrich the soil with nutrients.
3. *Enhances soil biological activity:* Earthworms and beneficial microbes thrive under the protective cover, making the soil healthier.
4. *Reduces fuel and labour requirements:* Because the soil is tilled less often, machines like tractors are used fewer times. This saves fuel, reduces costs, and means less time and effort spent working in the field.
5. *Improves water infiltration and retention:* Rainwater soaks in more easily and stays in the soil longer, helping crops grow better.

# Agroforestry

Integrating trees and shrubs into agricultural systems. Types include:

1. **Alley cropping:** Planting rows of trees or shrubs (the “alleys”) and growing crops in the spaces between them. The trees can improve soil fertility, reduce erosion, and provide additional income (e.g. from fruit or timber).
2. **Silvopasture:** Integrating trees, forage (grasses) and livestock on the same land. It improves pasture quality, provides shade for animals, and allows for timber or fruit cultivation alongside livestock farming.

3. **Riparian buffers:** These are planted areas usually with trees and shrubs along waterways. They help filter runoff, reduce erosion, improve water quality, and provide habitat for wildlife.
4. **Windbreaks/shelterbelts:** These are rows of trees or shrubs planted to protect crops, livestock, or buildings from strong winds. They reduce wind erosion, improve microclimates, and can serve as a wildlife sanctuary.

# Mechanical Soil Conservation

Mechanical soil conservation involves physical structures or earth-moving operations that control water flow and soil movement.

## Common Types in Agriculture

1. **Terracing**

   A soil conservation practice where sloped land is transformed into a series of flat, step-like platforms or "terraces" (***Figure 4.6***). These structures reduce water runoff, minimise soil erosion and make it easier to cultivate crops on hilly or mountainous terrain. Terracing helps retain moisture and improves soil fertility, making it suitable for farming on steep slopes.

## The types of terracing

**a.** *Bench terraces:* These are step-like platforms cut into steep slopes. The land is levelled or gently sloped for farming, with vertical or slightly sloped risers between them. They are common in hilly areas and help control erosion and water runoff.

**b.** *Broad-based terraces:* These are wide terraces with gentle slopes on both sides, suitable for use with machinery. They are designed for areas with moderate slopes and are often used for large-scale farming to manage water and reduce erosion.

**c.** *Narrow-based terraces:* These are narrow ridges with steep slopes, mainly used for erosion control rather than crop production. They are built on steeper lands and are usually planted with grasses or other cover crops.

**Figure 4.6:** Bench terraces (Utopia.org)

**2. Contour ploughing**

Contour ploughing is the practice of ploughing along the natural contours of a slope, rather than up and down the slope. The ploughing lines follow the shape of the land's elevation, forming ridges and furrows across the slope. These ridges act as barriers to slow down the runoff speed during rainfall. Its benefits for soil conservation are:

**a.** Reduces soil erosion by preventing water from gaining speed as it moves down the slope.

**b.** Improves water infiltration into the soil, allowing more water to be absorbed rather than running off.

**c.** Prevents nutrient loss since runoff speed is slow.

**3. Diversion ditches and bunds**

Channels with supporting ridges designed to intercept and divert water before it gains erosive velocity. It can be implemented by:

**a.** Constructing across slopes or around vulnerable areas.

**b.** Ensuring proper gradient for water flow without causing erosion.

**c.** Directing water to stable outlets or storage structures.

**d.** Ensuring regular maintenance to prevent breaches.

**4. Check dams**

Small, temporary or permanent dams constructed across drainage ditches or small watercourses. The benefits of check dams are:

**a.** Reduces water velocity in channels

**b.** Traps sediment behind structures

**c.** Creates a step-like gradient in channels

**d.** Relatively inexpensive and simple to construct

**5. Contour bunding**

This is a soil and water conservation technique where small earthen embankments (bunds) are constructed along the contour lines of a slope. These bunds help slow down the flow of rainwater, allowing it to soak into the soil rather than washing it away. This reduces soil erosion, conserves moisture, and improves crop productivity, especially in hilly or semi-arid areas

**6. Gabion structures**

They are wire mesh boxes or cages filled with stones, used to control erosion and stabilise slopes, riverbanks, or stream channels. They reduce the speed of flowing water, prevent soil from being washed away and support weakened landscapes. Gabions are durable, flexible and allow water to pass through, making them effective for long-term soil and water conservation.

## Integration of Conservation Methods

Effective soil conservation typically requires combining multiple approaches into integrated systems:

1. **Conservation Farming Systems**

   Comprehensive approaches that combine multiple conservation practices:

   a. *Conservation agriculture:* A farming system based on three key principles—minimal soil disturbance (no-till), permanent soil cover (using crop residues or cover crops) and crop rotation. It improves soil health, reduces erosion, conserves water and ensures long-term productivity.

   b. *Regenerative agriculture:* A holistic approach to restoring and enhancing soil health, biodiversity, and ecosystem functions. It includes composting, cover cropping, reduced tillage, and rotational grazing to regenerate the land and capture carbon.

   c. *Agroecological systems:* These integrate ecological principles into farming, combining traditional knowledge with modern science. They promote biodiversity, sustainability and resilience by mimicking natural ecosystems and using locally adapted practices.

2. **Watershed Approach**

   The watershed approach in soil conservation involves managing the entire land that drains into a common water body (like a river or lake) to conserve soil and water resources. It treats the land and water as a connected system, implementing measures like afforestation, terracing, check dams, contour bunding and water harvesting structures. This approach helps reduce soil erosion, improves water availability and enhances agricultural productivity across the whole watershed area.

### Activity 4.5 Cultural and Mechanical Methods of Soil Conservation

This activity is about discussing the various cultural and mechanical methods of soil conservation so that you clearly understand how these methods help in soil conservation. In addition, you should design a suitable crop rotation plan and, where possible, practise crop rotation in your school farm or garden as a soil conservation method

#### Steps

1. Join two classmates to make a group of three.
2. Discuss the various cultural and mechanical methods that can be used to help conserve soil:

   a. Talk about cultural methods (e.g. mulching, cover cropping, crop rotation).
   b. Talk about mechanical methods (e.g. terracing, contour ploughing, bunds).
   c. Discuss how each method prevents erosion, retains moisture, and improves soil fertility.
   d. Write down relevant notes.
3. Design a four-year crop rotation plan:
   a. Choose four crops (e.g. maize, beans, tomatoes, cabbage).
   b. Provide clear reasons for your crop selection and sequence, based on scientific principles.
4. Write a report: Summarise your discussion, and include your crop plan.
5. Share your findings and experience through an oral presentation to the class.
6. Practice on the farm: where possible, use your school farm or garden to carry out a crop rotation plan.

# ROLE OF SOIL ORGANISMS IN NUTRIENT CYCLING

## Introduction to Soil Organisms

Soil is more than just a medium for plant growth – it is an ecosystem filled with organisms that perform critical functions. These soil organisms play vital roles in nutrient cycling and maintaining or improving soil fertility, which directly influences agricultural productivity and environmental sustainability. Soil organisms are living organisms found in the soil. They include microorganisms (too small to be seen with the unaided eye), e.g. bacteria, fungi, protozoa, and macro-organisms (large and visible), e.g. insects, mites, nematodes, earthworms, centipedes and millipedes.

## Types of Soil Organisms Involved in Nutrient Cycling

1. **Bacteria**

   These are microscopic, single-celled organisms. Some bacteria decompose organic matter (dead plants and animals), releasing nutrients into the soil. Nitrogen-fixing bacteria like *Rhizobium* live in the root nodules of legume plants and convert nitrogen gas from the air into a form that plants can use (nitrates). Nitrifying bacteria change ammonia into nitrites and then nitrates. Denitrifying bacteria convert nitrates back into nitrogen gas, completing the nitrogen cycle.

2. **Fungi**

   Fungi also decompose organic matter. Mycorrhizal fungi form partnerships with plant roots and help plants absorb nutrients like phosphorus in exchange for sugars from the plant.

3. **Earthworms**

   Earthworms eat soil and dead plant material. They digest the materials and excrete them as nutrient-rich waste (worm casts). Their excavation and movement through the soil also mixes the soil, improving its structure and allowing air and water to move more easily.

4. **Protozoa and nematodes**

   These are tiny animals that attack crop roots and feed on bacteria and fungi. When they eat these microbes, they release nutrients in forms that plants can absorb. They also help control the population of bacteria and fungi in the soil.

5. **Arthropods**

   These organisms, for example, ants, beetles, and mites, feed on and break down large pieces of organic matter into smaller parts, making it easier for bacteria and fungi to continue the decomposition process.

## Role of Soil Organisms in Nutrient Cycling

Nutrient cycling refers to the movement and transformation of essential elements (like nitrogen, phosphorus, and carbon) through the soil, plants and atmosphere. Soil organisms are key players in this process.

1. **Decomposition of organic matter:** Bacteria and fungi break down dead plants, animals, and organic materials into simpler compounds. This decomposition releases nutrients like nitrogen, phosphorus, and potassium into the soil, making them available for plant uptake.

2. **Nitrogen fixation:** Certain bacteria (e.g. *Rhizobium***)** form symbiotic relationships with legume roots and convert atmospheric nitrogen ($N_2$) into ammonia ($NH_3$), a form plants can use. Free-living bacteria like *Azotobacter* also fix nitrogen independently in the soil for plant use.

3. **Nitrification and denitrification:** Nitrifying bacteria convert ammonia into nitrites and then into nitrates, which plants absorb. Denitrifying bacteria (e.g. *Pseudomonas*) convert excess nitrates into nitrogen gas, completing the nitrogen cycle and preventing nutrient buildup.

4. **Mineralisation:** Soil organisms convert organic forms of nutrients into inorganic forms (e.g. converting organic phosphorus into phosphate ions), making them accessible to plants.

5. **Mycorrhizal associations:** Mycorrhizal fungi form symbiotic relationships with plant roots, extending their network and helping with phosphorus and water absorption.

## Role of Soil Organisms in Soil Fertility

Soil fertility refers to the ability of soil to provide essential nutrients to plants in adequate amounts.

1. *Improving soil structure:* Earthworms and other macro-organisms burrow through soil, mixing it and creating air spaces. Their movement improves aeration, drainage, and root penetration.
2. *Enhancing soil organic matter:* Through decomposition, soil organisms increase the amount of humus, which improves the soil's ability to retain nutrients and water.
3. *Controlling soil-borne diseases:* Some soil microorganisms produce antibiotics or outcompete harmful pathogens, protecting plant roots from disease.
4. *Recycling plant nutrients:* Soil organisms continuously recycle nutrients tied up in plant residues and animal wastes, keeping the soil fertile over time.

## Experiment to Determine the Population of Macro-organisms in Selected Soils

**Title: An experiment to detect macro-organisms in the soil**

**Objective:** To observe, collect, and identify **macro-organisms** present in soil samples.

### Materials required

1. Small garden trowel or spoon
2. Transparent plastic trays or containers
3. Sieve or mesh screen (optional)
4. Magnifying glass
5. White paper sheets or cloth (to spread soil on)
6. Ruler or measuring tape
7. Gloves (for hygiene)
8. Pencil and notebook for recording observations

### Procedure

**Step 1: Choose the sampling site**

a. Select **3 different locations** within the school grounds or nearby (e.g. under a tree, garden soil, bare ground).

b. Ensure the locations are safe and accessible.

**Step 2: Collect soil samples**

**a.** Dig a small hole about **15–20 cm deep** using a trowel or spoon.

**b.** Remove a sample of the soil (about a bowlful) and place it in a tray.

**c.** Label each tray based on the sample location.

**Step 3: Spread and examine the soil**

**a.** Pour the soil onto a white sheet or cloth to easily spot organisms.

**b.** Carefully observe the soil using the unaided **eye and then a magnifying glass.**

**c.** Use a **sieve or mesh screen** to separate larger particles and reveal hidden organisms.

**Step 4: Identify macro-organisms**

**a.** Look for the following:

**i.** Earthworms

**ii.** Ants

**iii.** Beetles

**iv.** Millipedes

**v.** Termites

**vi.** Spiders

**vii.** Centipedes

**viii.** Snails

**b.** Record each type and **count how many** you find.

## Activity 4.6 Role of Soil Organisms

Find two classmates to form a group and discuss the role of soil organisms in nutrient cycling and soil fertility. Present your findings to the larger class.

**Hint**: Follow the steps provided in the content to achieve this activity

## Activity 4.7 Detection of Soil Macro-Organisms

Using the same group as in **Activity 4.6**, carry out an experiment to detect macro-organisms in the soil. Write a report indicating what you found in your sample sites and present your findings to the class.

**Hint**: Follow the steps provided in the content to detect soil macro-organisms

# IMPACT OF HUMAN ACTIVITIES ON SOIL EROSION AND DEGRADATION

## Impact of Human Activities on Soil Erosion

Soil erosion is the removal of the fertile topsoil layer by water, wind, or other natural forces. This reduces soil fertility, affects crop productivity and contributes to land degradation. The process is greatly accelerated by human activities such as deforestation, farming, urbanisation, and surface mining.

1. **Deforestation**

   Removal of trees and vegetation, through logging, agriculture or urban expansion, exposes the soil surface to the agents of erosion. The vegetation protects the soil from the direct impact of raindrops, runoff and wind, reducing soil vulnerability to erosion.

2. **Unsustainable farming practices**

   Practices like frequent ploughing, especially along the slope, disturb the soil, making it more prone to being washed or blown away. Overgrazing removes ground cover and exposes the topsoil to potential loss. Monoculture reduces ground cover and increases the risk of erosion. Slash-and-burn land preparation removes protective vegetation and leaves the topsoil bare.

3. **Urbanisation and infrastructure development**

   Construction activities and land development remove vegetation cover and disturb the soil.

4. **Mining activities**

   Strip mining and open-pit or excavation mining remove and disturb large areas of soil cover. Loose, disturbed soil is highly susceptible to wind and water erosion and disrupts natural drainage.

5. **Poor irrigation water management**

   Supplying too much irrigation water can lead to runoff and soil erosion. Sprinkler or overhead irrigation on slopes, without contour ploughing or terracing, increases erosion.

6. **Climate change (indirect human impact)**

   Human-induced climate change leads to more intense rainfall and droughts, which increase erosion risks.

## Consequences of Soil Erosion

1. *Loss of fertile topsoil:* The top layer of soil, which has most of the nutrients, is washed or blown away. This makes it hard for crops to grow well.
2. *Reduced agricultural productivity:* When the good soil is gone, crops don't get enough nutrients. Farmers harvest less food, and farming becomes harder.
3. *Sedimentation in rivers and dams:* Eroded soil ends up in rivers and dams, making them dirty and shallow. This reduces water flow and storage.
4. *Desertification in extreme cases:* If erosion continues for a long time, land becomes dry and lifeless—like a desert. It can no longer support farming or vegetation.
5. Decline in water quality due to soil particles and agrochemicals (fertiliser and pesticides) entering waterways: Soil, fertilisers, and pesticides are carried into rivers and streams, polluting the water. This harms fish, people, and other animals.

# Role of Human Activity in Soil Degradation

Soil degradation is the decline in soil quality and productivity due to various factors, many of which are human-induced, reducing fertility, structure, and biodiversity of the soil. It threatens sustainable land use, food security and environmental health.

## Types of Soil Degradation

1. Chemical degradation due to nutrient loss, pollution and acidification.
1. Physical degradation due to erosion, compaction and crusting.
2. Biological degradation due to loss of organic matter and soil organisms.

## Main Ways Human Activities Contribute to Soil Degradation

1. *Agrochemical pollution:* Agrochemical overuse – synthetic fertilisers, pesticides (including herbicides), contaminates the soil and disrupts soil pH, causes chemical build-up and nutrient imbalance and kills beneficial organisms.
2. *Over-irrigation and poor drainage:* Excessive watering leads to waterlogging and salinisation (salt build-up), especially in poorly drained soils. This damages plant roots, hardens or destroys soil structure, reduces fertility and lowers productivity.
3. *Intensive Agriculture:* Continuous cropping without allowing soil to recover depletes nutrients. Use of heavy machinery compacts soil, reducing air and

water infiltration and root growth, leading to loss of soil structure and reduced agricultural productivity. Overuse of fertilisers and pesticides depletes soil nutrients and pollutes the soil. Continuous cropping exhausts soil fertility and biological life.

4. *Industrial waste disposal:* Dumping industrial waste can introduce heavy metals (e.g. lead and mercury) and toxic substances into the soil, making it unfit for agriculture.
5. *Deforestation:* This removes trees that protect and enrich the soil. The soil becomes vulnerable to erosion, loses organic matter, and reduces its ability to retain water and nutrients.
6. *Urbanisation and industrialisation:* Construction, paving, and pollution occur during urbanisation, all of which cause soil compaction, sealing with concrete/asphalt, and contamination with heavy metals and waste.
7. *Mining activities:* Surface mining disturbs large areas of the soil, as the land is often stripped of nutrients and structure.
8. *Climate change (indirect human impact or human-induced):* Altered rainfall patterns and increasing temperatures and droughts or floods affect soil moisture and structure, disrupting soil water retention and fertility (Table 9).

***Table 4.5*:** Summary of human activity and the type of degradation and specific effects

| Human Activity | Type of Degradation | Specific Effects |
|---|---|---|
| Overuse of agrochemicals | Chemical | Soil toxicity, reduced fertility |
| Intensive farming | Chemical/Biological | Nutrient depletion, loss of microorganisms |
| Urbanisation/Industry | Physical/Chemical | Soil compaction, pollution |
| Mining | Physical/Chemical | Topsoil loss, heavy metal contamination |
| Climate change | Physical/Biological | Droughts, reduced soil moisture and reduced soil organisms |
| Over-irrigation | Physical/Chemical | Waterlogging, salinisation |
| Deforestation | Physical/Biological | Erosion, loss of organic matter |

**A** **B**

**Figure 4.7:** Effect of minimal (A) and significant (B) human disturbance on land degradation

## How Human Activity Impacts Soil Degradation and Erosion Rates

1. *Farming practices (agriculture):* Unsustainable farming leads to both accelerated erosion and degradation by depleting, polluting, and physically damaging the soil (***Figure 4.7A***).
2. *Deforestation*: It significantly increases both erosion rates and long-term soil degradation, especially on slopes or in tropical regions.
3. *Urbanisation*: Urbanisation contributes more to physical degradation and runoff-induced localised erosion, often permanently altering soil functions (Figure 4.7 B).
4. *Mining*: Mining creates severe, often irreversible soil degradation and highly erodible landscapes.
5. *Over-irrigation:* Poor irrigation practices lead to chemical and physical soil degradation more than erosion.

## Case Study

Conservation strategies have been successfully implemented in Ghana to address human-caused soil erosion, due to deforestation, farming, and overgrazing.

**Topic**: Soil conservation in the Upper East Region of Ghana.

**Background**: The Upper East Region of Ghana is a semi-arid area with fragile soils, severe land degradation challenges and erratic rainfall. Over the years, the region has experienced:

1. Severe soil erosion due to deforestation (for fuel wood and farming),
2. Overgrazing by livestock,
3. Slash-and-burn agriculture, and
4. Climate variability (long dry seasons and heavy storms).

These factors led to: gully erosion, declining soil fertility, loss of agricultural productivity, and increased poverty among farming communities.

## Conservation Strategies Implemented

1. **Stone bunds (Stone lines)**
   - **a.** *What was done:* Farmers placed lines of stones along the contours of sloped farmland.
   - **b.** *How it worked:* Slowed water runoff, captured soil and organic matter.

**c.** *Impact*:

**i.** Reduced erosion by over 40 % in some areas.

**ii.** Improved crop yields by 20–30 %**.**

## Scientific principles involved

**a.** Reduced runoff velocity by up to 60 %

**b.** Trapped sediment moving downslope (15-25 tons/hectare/year)

**c.** Created favourable microenvironments for crop growth

**d.** Progressive terrace formation through sediment accumulation

1. **Zai pits and half-moon basins**

**a.** *What was done:* Small pits or basins were dug into the ground to collect rainwater and debris/compost.

**b.** *How it worked:* Concentrated water and nutrients around plants.

**c.** *Impact:* Revived degraded land and increased soil fertility.

## Scientific principles involved

**a.** Concentrated water and nutrients where plants needed them

**b.** Improved water infiltration by breaking surface crusting

**c.** Enhanced organic matter in specific growing zones

**d.** Facilitated microbial activity in otherwise hostile soil conditions

2. **Agro-forestry and Farmer-Managed Natural Regeneration (FMNR)**

**a.** *What was done:* Farmers protected and managed naturally sprouting trees on their land.

**b.** *How it worked:* Encouraged tree growth to reduce wind and water erosion.

**c.** *Impact*: Increased ground cover, reduced wind erosion and improved microclimate for crops.

## Scientific principles involved

**a.** Utilised existing seed bank and root systems for rapid revegetation.

**b.** Created multi-functional agroforestry landscapes.

**c.** Improved soil structure through diverse root systems.

**d.** Reduced wind erosion and moderated the microclimate.

3. **Contour ploughing and mulching**

**a.** *What was done:* Farmers ploughed along contour lines and covered the soil with crop residues.

**b.** *How it worked:* Prevented water runoff and maintained moisture.

**c.** *Impact*: Reduced soil erosion, improved organic matter and moisture retention.

### Scientific principles involved

**a.** Concentrated water and nutrients where plants needed them.

**b.** Improved water infiltration by breaking surface crusting

**c.** Increased organic matter in specific growing zones

**d.** Facilitated microbial activity in otherwise hostile soil conditions

## Implementation Process

1. **Community engagement**
   - **a.** Mobilisation through traditional authority structures (chiefs, elders and opinion leaders)
   - **b.** Formation of community land management committees
   - **c.** Training of local "conservation champions" to demonstrate techniques
   - d. "Farmer Field Forums" were instituted for experiential learning.
2. **Technical support**
   - **a.** Collaboration between the Ministry of Food and Agriculture and NGOs (including CARE Ghana and World Vision)
   - **b.** Provision of simple measuring tools for contour layout
   - **c.** Training in compost production using locally available materials iv. Regular field visits from extension agents during critical implementation phases
3. **Financial mechanisms**
   - **a.** Introduction of "food for work" during the initial labour-intensive phases
   - **b.** Community savings groups established to finance conservation inputs
   - **c.** Gender-inclusive microcredit schemes set up for conservation agriculture
   - **d.** Creation of community-based tree nurseries as micro-enterprises
4. **Results and success factors**
   - **a.** Over 10,000 hectares of degraded land rehabilitated in communities like Bawku West, Garu-Tempane, and Talensi.
   - **b.** Improved resilience to droughts and food security.
   - **c.** Community participation and training from NGOs (like CIKOD and CARE Ghana) were key.

## Activity 4.8 Soil Conservation Strategies

This activity is about practising two soil conservation strategies—such as mulching and contour planting—on the school farm or a selected plot and observing their impact in reducing soil erosion.

### Steps

1. Choose two strategies (e.g., mulching and contour planting).
2. Mark two small plots on the school farm or a garden area.
3. Apply the following strategies
   a. On one plot, apply mulch (dry grass or leaves).
   b. On the second, plant crops along the contour lines.
5. Simulate rain – Gently pour water from a watering can to observe how each method helps reduce erosion.
6. Note which plot is better at reducing runoff. Share your observations.

# EXTENDED READING

- Access this video on Soil Profile and Soil Horizons: https://youtu.be/nEShY_S_KGc
- Access the link below and read on Soil Physical Properties and processes: https://stormwater.pca.state.mn.us/index.php?title=Soil_physical_properties_and_processes
- Access the link below on Physical properties of soil (temperature, colour and moisture): https://youtu.be/Hm-TupAJMAM
- Access the link below on the methods of soil conservation: https://www.youtube.com/watch?v=D_xmab47L9k

# REVIEW QUESTIONS

1. Explain three natural processes that contribute to the formation of soil from rocks.
2. Describe the steps involved in conducting a field investigation of a soil profile and how each soil horizon is identified.
3. Analyse how the five factors of soil formation—parent material, climate, organisms, topography, and time—interact to influence the development of soil profiles in different environments.
4. Explain the three main soil textures and how the size of soil particles affects drainage and water-holding capacity.
5. Describe the steps involved in using the feel method and ribbon test to determine soil texture. What do your observations indicate about the type of soil?
6. Analyse how the structure and texture of soil influence a farmer's decision-making in land preparation, irrigation, and crop selection. Provide examples from different soil types.

**Questions 7 to 16 are multiple – choice questions.**

7. Which soil texture typically provides the slowest water infiltration and highest water retention?
   - **A.** Clay soil
   - **B.** Loamy soil
   - **C.** Sandy soil
   - **D.** Silty soil
8. What does a granular soil structure primarily support in crop production?
   - **A.** Improved aeration and root penetration
   - **B.** Soil acidity
   - **C.** Reduced microbial activity
   - **D.** Waterlogging and compaction
9. Which factor causes dark-coloured soil to heat faster than light-coloured soil?
   - **A.** Compact structure
   - **B.** Greater reflection of sunlight
   - **C.** High clay content
   - **D.** High organic matter absorption

**10.** Why might a farmer prefer loamy soil over clay soil for vegetable production?

**A.** It is rich in salts and requires no fertiliser

**B.** It resists compaction in all weather conditions

**C.** It retains more water and resists erosion

**D.** It supports both good drainage and nutrient retention

**11.** Which of the following structural soil types is most prone to erosion on sloping land?

**A.** Blocky

**B.** Crumb

**C.** Granular

**D.** Platy

**12.** Which type of soil moisture is most accessible for plant uptake?

**A.** Capillary water

**B.** Gravitational water

**C.** Hygroscopic water

**D.** Surface runoff

**13.** A field with red/yellow soil likely indicates which of the following?

**A.** Anaerobic conditions and waterlogging

**B.** High organic matter and fertility

**C.** Presence of iron oxides and good drainage

**D.** Salt-affected soil

**14.** Which soil property most directly influences microbial activity and seed germination in early spring?

**A.** Soil moisture

**B.** Soil pH

**C.** Soil structure

**D.** Soil temperature

**15.** A farmer preparing for early-season planting tests the soil at 5 cm and 10 cm depths. The purpose of doing this is to ...

**A.** Check soil texture

**B.** Compare soil pH at different layers

**C.** Evaluate soil colour

**D.** Measure soil temperature variability

**16.** Which of the following practices can improve water movement in compacted soils?

**A.** Adding organic matter or compost

**B.** Avoiding any tillage

**C.** Increasing fertiliser application

**D.** Reducing soil moisture

**17.** Sandy soil loses water and nutrients quickly. Adding organic matter can help fix this problem. Analyse how soil organic matter influences nutrient availability in a sandy soil to promote plant growth.

**18.** Your school's Agriculture Club wants to find out which part of the school farm has the healthiest soil based on the number and types of macro-organisms living in it. You and your team are assigned to lead the investigation. You have to compare the population of macro-organisms in the following three different soil areas.

**A.** Near the compost heap

**B.** In the vegetable garden

**C.** In a dry, unused corner of the farm

## Task

**Design and carry out a detailed plan to determine the population of macro-organisms in each soil type. Your plan should include**

**i.** The method for sampling the soil

**ii.** Tools and materials you will use

**iii.** How you will identify and count the organisms

**iv.** How you will organise and present your findings

**v.** Your interpretation of which area has the healthiest soil and why

Present your results in a report or class presentation.

**19.** Koforidua in Ghana's Eastern Region is facing rising soil erosion problems, mainly caused by deforestation, over-farming, and changing weather patterns. As an agricultural expert, you have been asked to suggest practical solutions. Critically assess three soil conservation methods that can help reduce human-induced erosion in the area.

SECTION

5

# PRINCIPLES OF PLANTATION TREE CROP PRODUCTION

# ECONOMIC PRODUCTION OF CROPS

## Introduction

Hello learner, welcome to Section 5 of your Year Three Agricultural Science studies! In this section, you will explore how to grow and manage tree crops such as mango, cocoa, citrus, and cashew using modern and sustainable techniques. You will learn the principles of tree crop production—from nursery management and land preparation to planting, pruning, pest control, and harvesting. You will also discover the environmental, nutritional, and economic benefits of fruit trees in Ghanaian communities and gain practical knowledge in cultivating a fruit tree from start to finish. This includes understanding site selection, seedling care, and key farm maintenance practices. This section builds on your experiences in Year One (vegetable and ornamental crop production) and Year Two (arable crop production and use of technology). Get ready to expand your knowledge and apply new farming skills that support food security, income generation, and environmental protection.

### KEY IDEAS

- **Agro-environmental suitability**: Involves selecting appropriate fruit tree species by evaluating climate, soil conditions, and landscape features to ensure healthy establishment and high yield.
- **Cultural and agronomic practices**: Encompass key operations such as pruning, mulching, fertilisation, pest control, and watering that sustain tree health, enhance productivity, and prolong the lifespan of fruit trees.
- **Economic and nutritional contributions of fruit trees**: Highlights how fruit trees provide steady income through fruit sales, support food and nutrition security, and generate employment in rural economies.
- **Environmental services of fruit trees**: Describes how fruit trees improve ecological resilience by sequestering carbon, enhancing biodiversity, controlling soil erosion, and regulating microclimates.
- **Fruit tree establishment and site preparation**: Covers the selection of disease-free seedlings, preparation of planting holes, soil enrichment with organic matter, and proper planting techniques to ensure optimal growth.
- **Sustainable land use in tree crop systems**: Refers to integrated practices such as agroforestry, intercropping, and soil conservation that enhance long-term productivity while protecting natural resources.

# PRINCIPLES OF TREE CROP PRODUCTION

## Principles of Tree Crop Production

This refers to the fundamental concepts and practices necessary for the successful cultivation, management and harvesting of perennial woody plants that produce fruits, nuts, oils or other economically valuable products. It involves applying a comprehensive, scientific approach to cultivate trees for various purposes, including fruit, timber and other products. It includes understanding tree agronomy, physiology and soil science and, optimising practices like pre-planting preparations, planting, post-planting care, harvesting and post-harvest handling. The key principles also involve developing good agricultural practices, promoting agribusiness and ensuring environmental sustainability.

## Understanding the crop and its environment

1. **Crop physiology:** It is crucial to understand how trees grow, their nutrient needs and response to environmental factors.
2. **Soil science:** For successful tree crop production, it is essential to understand soil types, fertility and drainage.
3. **Agronomy:** Applying scientific principles to optimise planting, spacing, fertiliser application, irrigation and pest/disease management.

## Pre-planting and Planting

### Site selection and land preparation

1. **Climate suitability:** The crop should be adapted to local temperature, rainfall and humidity conditions.
2. **Soil type, soil testing and analysis:** Deep, well-drained soils with adequate fertility. Waterlogged or highly acidic/alkaline soils should be avoided. Soil fertility and pH should be determined to select appropriate tree species and amend the soil as needed.
3. **Topography:** Gentle slopes are preferred to reduce erosion and improve drainage.
4. **Land preparation**: Land preparation involves clearing, ploughing and digging planting holes to prepare for tree establishment.
5. **Seed/seedling selection:** High-quality, disease-free planting material suitable for the local climate and soil should be chosen.
6. **Spacing and planting techniques:** The recommended planting space should be used to optimise sunlight penetration and resource utilisation.

## Selection of suitable tree crop species and varieties

Tree crop species that are adapted to the local environment and in demand (e.g. mango, cocoa, cashew, oil palm) should be chosen. Improved or grafted varieties that offer greater yields, are disease-resistant and of better quality should be selected.

### Propagation techniques

Tree crops can be propagated by seeds (eg mango, citrus), or by vegetative methods such as grafting, budding and cuttings, for uniformity and early maturity.

### Spacing and planting

1. Proper plant spacing ensures adequate sunlight, air circulation and ease of maintenance.
2. Planting should be done during the rainy season to reduce water stress.
3. Use organic or inorganic fertilisers in the planting hole where necessary.

# Post-Planting Care

1. **Nutrient management:** Apply fertilisers (organic or inorganic) based on soil test results, tree growth stage and nutrient requirements.
2. **Water management:** Irrigate effectively during dry periods, especially young trees, and ensure proper drainage. Mulching helps retain soil moisture and reduce weed competition.
3. **Pruning and training:** This helps to control tree growth, improve fruit quality and ensure structural integrity. Pruning maintains tree shape, removes dead or diseased branches, and improves sunlight penetration, whereas training young trees helps form a strong framework for fruit production.
4. **Weed, pest and disease management:** Preventive and control measures should be implemented as needed. Regular weeding is necessary to reduce competition for nutrients and water. The use of Integrated Pest Management (IPM), a holistic approach to pest control that combines various methods, should supersede synthetic pesticide use. Monitor for diseases and pests and apply control measures promptly.
5. **Monitoring crop progress:** Tree health and development should be assessed regularly.
6. **Intercropping and soil conservation:** Intercropping with compatible crops (e.g. legumes) improves yield, soil fertility and income. Cover crops and terracing help to prevent erosion, especially on sloped land.

## Harvesting and Post-Harvest Handling

1. **Timing and technique:** Harvest at the optimal/correct maturity stage to maximise fruit quality and quantity. The use of proper tools avoids damaging trees or fruits.
2. **Handling and storage:** Proper handling and storage methods are crucial to maintain quality and reduce post-harvest losses.
3. **Record keeping:** Systematically document planting, fertilisation, pest control, and harvest data. Accurate records of planting, inputs, yield, labour and sales should be kept.
4. **Marketing:** Market opportunities need to be identified and value added to products through processing or packaging.
5. **Sustainability and environmental considerations:** Sustainable practices minimise environmental impact through water conservation, reduced fertiliser use and integrated pest management.
6. **Crop diversification:** Introduce a variety of tree crops to diversify income and reduce risk.
7. **Agroforestry:** Integrate trees into farming systems to enhance soil health and improve biodiversity.

# Importance of Tree Crops in Agriculture

Tree crops are woody perennial plants that are cultivated mainly for their fruits, nuts, oils, or other economically useful parts. They play a vital role in both ecological sustainability and human livelihoods. Their importance includes:

## Environmental benefits

1. **Soil conservation:** Tree roots hold soil together, thereby reducing erosion.
2. **Climate regulation:** Many fruit trees provide shade and also absorb carbon dioxide, which helps to mitigate climate change.
3. **Biodiversity support:** Tree crops provide habitats for wildlife.
4. **Water cycle maintenance:** Trees reduce runoff and enhance groundwater recharge.

## Economic benefit

1. **Income generation:** Many tree crops are cash crops that provide income for farmers (e.g. cocoa, coffee).
2. **Export revenue:** Countries earn foreign exchange through the export of tree produce and products.

3. **Employment opportunities:** People can be employed in farming, processing and marketing industries.

## Food and nutrition

1. **Edible fruits and nuts:** These provide essential vitamins, minerals and fats (e.g. mango, cashew).
2. **Fodder for animals:** Some trees (e.g. moringa, leucaena) are used as animal feed.

## Medicinal and cultural uses

1. Many tree crops (e.g. neem) have medicinal properties.
2. Trees are used in traditional ceremonies and beliefs in many communities.

***Table 5.1***: Examples of tree crops, growing areas and main uses

| Tree Crop | Major Growing Countries | Major Uses |
|---|---|---|
| Cocoa | Ivory Coast, Ghana, Nigeria, Brazil | Chocolate production, beverages, and butter |
| Oil Palm | Nigeria, Indonesia, Malaysia | Palm oil (used in cooking, cosmetics, industry) |
| Coconut | Coastal areas in Asia and Africa | Oil, water, fibre (coir), milk |
| Mango | Tropical and subtropical regions | Consumed fresh or processed |
| Cashew | India, Ghana, Nigeria, Brazil | Roasted nut and fruit juice and wine |
| Rubber | Southeast Asia, West Africa | Natural rubber (latex) production |
| Shea | Savanna region of Africa | Shea butter (cosmetics, food) |
| Avocado | Central America, Kenya, South Africa | Nutrient-rich fruit |
| Banana/ Plantain | Africa, South America, Asia | Staple food crop |

# Nursery Practices in Tree Crop Production

Nursery practices are the processes and techniques used to raise seedlings before they are transplanted. Proper nursery management is essential for ensuring healthy, vigorous plants that establish well in the field. These practices are important in the production of tree crops such as cocoa, oil palm, mango, citrus, avocado and cashew. They ensure healthy, uniform, and vigorous seedlings. They also increase the field survival rate and allow early detection and management of problems.

## Site selection for nursery

The site should have good drainage, adequate sunlight and protected from strong winds. It should be accessible and close to a water source for irrigation. The area should not be prone to flooding or erosion.

### Types of nursery

1. *Temporary nursery:* This is set up for short-term use, often in polythene bags or seedbeds.
2. *Permanent nursery:* These are larger and more structured, with facilities like shade nets, and water tanks.

## Growing media preparation

The ideal medium should be loamy, well-drained and rich in organic matter. A common mix is a mixture of topsoil + compost + sand (in ratios like 3:2:1). The soil needs to be sterilised (solarisation or heat) to prevent pests and diseases.

## Seedling containers

These may be polythene bags (black, with holes for drainage), seed trays or pots in more structured nurseries.

**Figure 5.1:** Small-scale tree nursery

*A* *B*

**Figure 5.2:** Permanent tree seedling nurseries

**Figure 5.3:** Oil palm seedlings in polythene bags

## Sowing and planting

Seeds should be sown at the right depth and spacing. In vegetative propagation, ensure the cuttings/grafts are properly placed and cared for. It is important to label plants to keep track of varieties and dates.

## Watering and irrigation

Watering should be done regularly to keep the soil moist but not waterlogged. Watering cans, hosepipes or drip systems can be used for efficiency.

## Shade management

Young seedlings often need protection from direct sunlight. Shade nets, palm fronds or grass thatch could be used to provide partial shade. Shading should be gradually reduced as seedlings mature (hardening off).

## Weed, pest and disease control

Regular weeding is essential to reduce competition for nutrients and water. Organic or chemical controls should be used judiciously for pests and diseases. Sanitation and monitoring are key to their early detection and control.

### Nutrient management

Organic manure or balanced NPK fertilisers should only be applied when necessary. Over-fertilisation can damage young plants and should be avoided.

### Hardening off

To prepare seedlings for transplanting, watering and shade should be reduced gradually. Helps improve survival in the field.

## Planting/Transplanting of Tree Crops Seedlings

Planting or transplanting of tree crops refers to the process of moving young tree seedlings from a nursery to their permanent field location. Seedlings are transplanted when they have developed enough roots and are healthy. Seedlings need to be watered immediately after transplanting. Proper planting techniques are essential for the healthy establishment, early growth and long-term productivity of the tree crop.

### Importance of Proper transplanting

1. Promotes healthy root establishment: Planting the seedling at the right depth and firmly in the soil helps roots spread and hold well.
2. Enhances early growth and survival: A well-planted seedling grows faster and is more likely to survive.
3. Reduces transplant shock: Careful handling prevents damage to roots and leaves, helping the plant adjust quickly to its new place.
4. Increases long-term productivity: Healthy seedlings grow into stronger plants that produce more in the long run.

### Site preparation

The following could be done before planting

1. Clear the land of weeds, stumps, and debris.
2. Plough or dig the soil to loosen it for better root penetration.
3. Mark the planting spots using the recommended spacing for the crop (e.g. 10 m × 10 m for mango, 9 m × 9 m x 9 m or 9 m triangular pattern for oil palm) (Table 5.2).
4. Dig planting holes (usually 30–60 cm deep and wide) depending on the root ball or seedling bag size.
5. Backfill holes with topsoil mixed with organic matter (e.g. compost or well-cured manure)

***Table 5.2***: Some common tree crops and their recommended spacing

| Tree Crop | Recommended Spacing |
|---|---|
| Avocado | 7 m × 7 m |
| Cashew | 7 m × 7 m or 8 m × 8 m |
| Cocoa | 3 m × 3 m |
| Citrus | 6 m × 6 m |
| Mango | 9 m × 9 m |
| Oil Palm | 9m × 9m (triangular) |

### Selection of planting materials

1. Use healthy, disease-free and well-hardened seedlings.
2. Avoid seedlings that are too young or have damaged roots.

### Timing of transplanting

The best time to transplant is at the onset of the rainy season. early morning or evening to reduce transplant shock.

### The planting process (Steps for transplanting seedlings)

1. Water the seedling in the nursery before removal to reduce stress.
2. Carefully remove the seedling from its container to avoid root damage.
3. Place it upright in the centre of the planting hole.
4. Backfill with soil and gently firm the soil around the base to eliminate air pockets.
5. Water the seedling immediately after planting.

## Mulching

Apply organic mulch (e.g. dry grass, leaves) around the base of the seedling to retain soil moisture, suppress weeds and regulate soil temperature.

### Protection of young plants

Different methods are employed to protect the young plants. These include using stakes to support tall seedlings or applying pesticides or repellents for pests. Protective fencing or tree guards can also be used to prevent damage from animals or strong winds.

### Aftercare

Watering should be done regularly, especially during dry spells. There is a need for weed control around the base to reduce competition. It is necessary to monitor for pests and diseases so that they can be controlled early. Based on the fertility of the soil, the appropriate fertiliser should be applied.

## Cultural Practices in Tree Crop Production

Cultural practices are all the routine care and management activities carried out to ensure the healthy growth, high yield, and longevity of tree crops. These practices begin after transplanting and continue throughout the life of the tree. They boost growth and productivity, extend tree lifespan, prevent crop failure and enhance fruit quality.

1. **Weed control:** This reduces competition for nutrients, water, and light. It can be done manually using hoes, cutlasses or hand pulling. Organic material can be applied around the base to suppress weeds. The use of appropriate chemicals, e.g. herbicides, should be done with caution to avoid damaging the young trees.
2. **Watering/irrigation:** This maintains plant vigour and supports fruit development. It is essential in dry seasons or drought-prone areas. Watering cans, drip irrigation and sprinklers may be used.
3. **Mulching:** This is done to conserve soil moisture, suppress weeds and improve soil fertility as it decomposes. Materials like dry grass, leaves, or sawdust are applied around the base of trees.
4. **Pest and disease control:** This is to prevent yield loss and tree death. To prevent their occurrence, infected parts or fallen fruits should be removed (good sanitation). There should be regular inspections of trees for early detection. They can be controlled by using approved pesticides or biological control.
5. **Pruning:** It enhances fruit quality and reduces pest problems. It involves the removal of dead, diseased, overcrowded or unproductive branches, which encourages air circulation, light penetration and shaping of the tree.
6. **Fertiliser application:** This supports vigorous growth and high fruit yield. Organic manure (compost, poultry droppings) or inorganic fertilisers (NPK) may be used depending on crop needs.
7. **Thinning and spacing maintenance:** This is done to reduce competition and improve access to sunlight. Removing excess or poorly positioned trees helps maintain the right population and spacing.
8. **Intercropping:** Where applicable, short-duration crops like maize, beans, or vegetables can be grown between young tree crops. This maximises land use, controls erosion and provides early income while trees mature.

9. **Staking and windbreaks:** Staking young trees helps to keep them upright while windbreaks (e.g. tall grasses or shrubs) are planted to reduce wind damage.
10. **Training and canopy management:** Training involves shaping the growth of young trees to encourage a strong framework. The canopy is managed for optimal light exposure.

## Pest and Disease Management in Tree Crop Production

Tree crops such as cocoa, mango, citrus, oil palm, cashew, and coffee are vital for food, income, and industry. However, they are susceptible to various pests (insects, mites, rodents) and diseases (fungal, bacterial, viral), which can severely reduce productivity. Pest and disease management is a critical component of successful tree crop production, ensuring healthy growth, high yields, and long-term sustainability.

### Common Insect Pests of Tree Crops

***Table 5.3***: Some common pests of tree crops

| Crop | Major insect pests | Damage |
|---|---|---|
| Cocoa | Cocoa mirids, cocoa mealybugs, stink bugs | Pod lesions, premature cherelle drop, cocoa dieback |
| Mango | Fruit flies, mango stone weevil | Fruit rot, seed damage |
| Citrus | Citrus psyllid, swallowtail butterfly, fruit borers | Leaf damage, reduced photosynthesis, fruit yield loss |
| Oil Palm | Palm weevil, rhinoceros beetle, bagworms | Crown damage, defoliation |
| Cashew | Tea mosquito, cashew stem borer, thrips | Dieback, stem tunnelling, flower drop |

### Common diseases of tree crops

***Table 5.4***: Common diseases of tree crops

| Crop | Major Disease | Symptoms |
|---|---|---|
| Cocoa | Black pod disease | Brown-black pods, fruit rot |
| Mango | Anthracnose | Leaf spots, fruits lesions |
| Citrus | Citrus canker, greening disease | Leaf spotting, fruit drop |
| Oil Palm | Ganoderma basal stem rot | Wilting, trunk decay |
| Cashew | Coffee leaf rust | Yellow-orange spots on leaves |

## Integrated Pest and Disease Management (IPDM) Strategies

1. **Monitoring and early detection**
   a. The field should be scouted regularly for signs of pests and diseases.

**b.** Traps (pheromone, sticky traps) can also be used for early detection.

2. **Cultural practices**
   - **a.** Pruning to improve air circulation and reduce humidity
   - **b.** Removal of diseased plant parts (sanitation)
   - **c.** Intercropping with non-host species
3. **Biological control**
   - **a.** Use of natural enemies (e.g. ladybird beetles prey on aphids; parasitic wasps control mealybugs).
   - **b.** Application of biopesticides (e.g. *Bacillus thuringiensis*, neem extracts)
4. **Resistant varieties**

   Planting pest and disease-resistant/tolerant tree crop varieties
5. **Chemical control**
   - **a.** Judicious use of pesticides and fungicides
   - **b.** Following recommended doses and pre-harvest intervals
   - **c.** Use of selective, less persistent chemicals
6. **Environmental considerations**
   - **a.** Avoid overuse of persistent synthetic chemicals to protect beneficial insects and soil health
   - **b.** Promote agroecological approaches and organic farming principles
   - **c.** Encourage farmer field schools for participatory learning

## Activity 5.1 Exploring Tree Crop Production Systems

This activity is about exploring a selected tree crop production in your locality to understand how it is cultivated. The purpose of this activity is to bridge classroom knowledge with actual farming practices.

### Steps: Option A

1. Select one economic tree crop grown in your locality.
2. Identify how the following key principles of the selected tree crop have been applied:
   - **a.** Site conditions (climate, soil type, drainage, slope)
   - **b.** Propagation methods (seeds, grafting, budding)
   - **c.** Spacing (distance between trees)
   - **d.** Pest management (biological, cultural, or chemical control used)

3. Record your findings in a simple table

**Table template (*Hint*:** Use the template below for cocoa as a guide)

| Principle | What was done on the farm | Why it is important for success | Comments/ observations |
|---|---|---|---|
| Site selection | E.g. Deep, well-drained loamy soil; gentle slope | Ensures healthy root growth and good drainage | |
| Propagation method | E.g. Budding from high-yield parent plants | Produces uniform and high-quality trees | |
| Spacing | E.g. 3 m × 3 m between cocoa trees | Reduces overcrowding and competition | |
| Pest management | E.g. Regular spraying and removal of diseased pods | Prevents crop loss and improves yield | |

4. Use the information from your table to design a clear and attractive poster. Show each principle, what was done on the farm, and why it is important.
5. Display your poster on the classroom wall for everyone to see.

## Option B (Farm visit)

Visit a nearby tree crop farm to assess nursery practices, planting/transplanting, cultural practices, pest and disease management, and take notes for discussion in class.

## Steps

1. Prepare a questionnaire that could be used on your visit. The list of questions should include
   a. **Nursery practices:** What methods are used to raise seedlings in the nursery, and how is seedling health monitored or maintained before transplanting?
   b. **Planting and transplanting techniques:** What tools and techniques are used for transplanting seedlings, and how is proper spacing ensured on the farm?
   c. **Cultural practices:** Which daily or seasonal activities (such as pruning, mulching, or watering) are carried out to maintain healthy tree crops?
   d. **Pest and disease management:** What pests or diseases are common on the farm, and how are they controlled using natural or chemical methods?
2. Record or write the responses given by the tree crop farmer on nursery practices, transplanting, cultural methods, and pest management techniques.
3. Prepare a report on the application of the key principles of tree crop production used by the farmer to present in class.
4. Share your findings with your classmates.

# BENEFITS OF FRUIT TREES

## Benefits of Fruit Trees

Fruit trees offer a wide range of benefits – environmental, economic, nutritional and social. Fruit trees are a nutritious food source, enhance biodiversity, improve air quality and the aesthetic value of the landscape. Once established, fruit trees require relatively little maintenance compared to other types of food crops, resulting in a low production cost. Some varieties are even adaptable to different climates.

### Environmental Benefits

1. **Soil erosion and conservation:** Deep roots of crops help prevent soil erosion and improve soil structure.
2. **Carbon sequestration:** They absorb carbon dioxide, helping to reduce climate change effects.
3. **Biodiversity**: Trees provide habitat and food for birds, insects (including pollinators) and other wildlife, contributing to a healthy ecosystem.
4. **Microclimate regulation:** They provide shade and shelter, which reduce temperatures and increase humidity and are valuable in warm climates.
5. **Water retention:** Trees reduce runoff, improve infiltration and promote groundwater recharge.
6. **Air quality improvement:** Trees absorb carbon dioxide and release oxygen, thus helping to improve air quality.

### Economic Benefits

1. **Income generation:** The sale of seedlings, fruits and processed products (eg juices, jams) generates income for the farmer.
2. **Employment opportunities:** Fruit farming, processing and marketing provide jobs,
3. **Long-term engagement:** Perennial fruit cropping provides long-term employment.
4. **Cottage industry evolution:** Fruit tree cropping on large scale and expanse leads to the establishment of small-scale factories to produce fruit juices, jams, dried fruits, oils and cosmetics.

### Nutritional Benefits

1. **Health benefits**: Fruits contain roughage, vitamins, minerals and antioxidants that reduce the risk of diseases like diabetes, heart disease and certain cancers.

2. **Diet diversification:** Fruits increase food choices in many homes and cultures.
3. **Food security:** This is due to a year-round or seasonal supply of fruits for families.

## Social and Educational Benefits

1. **Community greening/aesthetic benefits:** Fruit trees beautify landscapes, parks, schools and roadsides.
2. **Educational value:** School gardens can be used to teach sustainability, biology and nutrition.
3. **Cultural importance:** Fruit trees and fruits are used for festivals and traditions.
4. **Shade and shelter:** Fruit trees can provide shade and shelter, which can be valuable in warm climates.

## Agroforestry Integration

Fruit trees can be grown with food crops to reduce soil erosion, enhance water percolation, as wind breaks to enhance land use efficiency.

### Activity 5.2 Investigating the Benefits of Fruit Trees

This activity is about investigating the benefits of fruit trees in rural communities.

1. Search online and list at least five economic, environmental, social, financial, and health benefits of fruit trees in rural communities.
2. Organise the information in five sections in your book: economic, environmental, social, financial, and health.

**Sample fact sheet:** Benefits of fruit trees in rural communities

| Economic benefits | Environmental benefits | Social benefits | Financial benefits | Health benefits |
|---|---|---|---|---|
| | | | | |
| | | | | |

3. Keep each point short and clear – like quick facts
4. Share your fact sheet with the class

# CULTIVATING A FRUIT TREE

## Cultivating a Fruit Tree

1. **Planning and site selection**
   - **a.** *Selecting the fruit tree species:* Choose the right tree species for your agroecological zone (e.g. mango, orange, guava, pawpaw).
   - **b.** *Soil type:* Most fruit trees prefer well-drained loamy soil with a pH of 5.5 – 7.0.
   - **c.** *Sunlight*: Ensure the site receives at least 6 hours of direct sunlight daily.
   - **d.** *Spacing*: Depends on species, e.g. mango is planted at 10 m x 10 m spacing.
2. **Land preparation**
   - **a.** Clear the land of weeds and debris.
   - **b.** Dig planting holes: Usually 60 cm x 60 cm x 60 cm.
   - **c.** Enrich soil with well-decomposed organic manure (compost or poultry droppings). Mix topsoil with phosphorus fertiliser (e.g. Triple Superphosphate, TSP) to promote root growth.
3. **Seedling selection**

   Select grafted or budded seedlings of choice that are disease-free and growing vigorously. They ensure early fruiting, disease resistance, and uniform fruit quality.
4. **Planting**

   Planting should be done at the beginning of the rainy season to ensure adequate water. The seedling should be removed from the nursery bag carefully and placed upright in the hole, and filled with the soil-manure mix. The soil around the base should be firmed and watered immediately.
5. **Maintenance and care**
   - **a.** *Watering*: There should be regular watering of trees during the first year, especially in dry periods. Drip irrigation can be used for water efficiency.
   - **b.** *Mulching*: Apply dry grass or leaves around the base to retain moisture and suppress weeds.
   - **c.** *Pruning*: Dead or diseased branches should be removed to encourage healthy growth and fruiting. Shape/trim young trees to allow light penetration.
   - **d.** *Fertiliser application:* Apply NPK (e.g. 15-15-15) or organic compost annually based on tree age and soil test results.

**e.** *Pest and disease control:* Use Integrated Pest Management (IPM) and monitor pests regularly. Neem extracts or biopesticides can be used. Natural predators like spiders and beetles should be conserved

6. **Technologies that can be integrated**
   - **a.** Soil testing kits for soil fertility analysis.
   - **b.** Mobile apps for weather alerts and pest identification (e.g. Esoko, AgroCenta).
   - **c.** Drip irrigation systems for efficient use of water.

You have learned the principles of fruit tree cultivation — now it is time to get your hands dirty! Let us turn knowledge into action by growing your own fruit tree from scratch, using the correct substrate, medium, and techniques.

### Project Work Activity – Grow Your Own Fruit Tree

This project is about growing your own selected fruit tree, and the purpose is to let you practise and apply what you have learned about fruit tree production through real planting and care.

#### Steps

1. Find two classmates to form a group
2. Agree on the type of fruit tree you would like to grow (eg mango, guava, citrus).
3. Collect substrate, pots/bags, seeds or seedlings, water, tools, and protective gear.
4. Mix the substrate and other media as needed for your chosen tree.
5. Place the seed or seedling in the medium at the correct depth, firm it gently, and water lightly.
6. Follow what you learned earlier about proper planting, watering, and pest prevention.
7. Water as needed, check for pests, and note any changes in growth over the following weeks and months.
8. Share your project's progress with the class, including photos.

## EXTENDED READING

Watch or examine these videos on the application of key principles of tree crop production

- How to prepare land for planting: https://www.youtube.com/watch?v=_JDxmRAYLnk

- Nursery practices and transplanting operations

https://www.youtube.com/watch?v=cYLAJo0S1NU

- Tree nursery establishment and management

https://www.youtube.com/watch?v=XZh7rv-3p94

- How to plant tree fruits for maximum growth and harvest

https://youtu.be/sNjJZyd1q4U

# REVIEW QUESTIONS

1. Outline the essential components of a sustainable tree crop production plan suitable for a smallholder farmer in a tropical region. Your outline should include land preparation, crop selection, propagation method, spacing, crop maintenance, and expected outcomes.
2. Analyse the environmental and economic consequences of poor tree crop production practices. Propose innovative solutions that can enhance sustainability and productivity in long-term tree crop farming systems.
3. Analyse how cultivating fruit trees can help reduce both economic vulnerability and environmental degradation in your community. Give two examples to support your analysis.

SECTION

6

# FISH FARMING

# ECONOMIC PRODUCTION OF FISH

## Introduction

Hello learner! Welcome to Section 6 of Year Three Learner Material. In this section, you will explore the economic importance of fish production, including its role in national development, and learn how to raise fish in a pond or tank using appropriate methods and technologies. The section also introduces you to support organisations that assist fish farmers and highlights technology transfer methods that promote modern fish farming practices. In addition, you will examine the role of rural credit in supporting small-scale farmers. By the end of this section, you should understand the economic value of fish farming, demonstrate knowledge of fish production practices, identify key support agencies, and appreciate the importance of access to credit and technology in improving fish farming in Ghana and beyond.

**KEY IDEAS**

- **Economic importance of fish rearing**: This refers to everything that an individual or group stand(s) to benefit from the rearing of fish.
- **Extension services**: This refers to a situation where experts in fish farming (or extension officers) visit farms regularly to provide advice, diagnose problems, and guide farmers on best practices in pond management, feeding and disease control.
- **Fish rearing/aquaculture**: This refers to the practice of raising fish in a controlled environment.
- **Participatory approach**: This is an approach that combines elements of top-down and bottom-up strategies.
- **Technology transfer in fish farming**: This is the process of disseminating new knowledge, innovations and improved farming techniques to fish farmers.
- **Value chain**: This refers to the processes or activities by which a company adds value to an article through production, marketing and the provision of after-sales services.

# ECONOMIC IMPORTANCE OF FISH PRODUCTION

## Economic Importance of Fish Production

Fish production plays a crucial economic role for the livelihoods of producers (fish farmers) and the broader value chain (processing, marketing, distribution and export). It supports income generation, employment, food security, gender equity and rural development, making it a cornerstone of many local and national economies. The

economic importance of fish production is significant at local, national and global levels. Some key areas where fish production contributes economically include:

## Economic Importance for Producers (Fish Farmers)

1. **Income generation**

   Fish farming (aquaculture) often serves as a primary or supplementary income source, especially in rural areas.

2. **Employment and livelihoods**

   Aquaculture is an important part of Ghana's fisheries sector. It provides an alternative source of fish and contributes to food security, employment and rural development. Aquaculture provides direct employment in catching and rearing fish for millions of people worldwide. The direct employment includes fishing, fish farming, processing, transportation and marketing. It is often a critical source of income for low-income families and small-scale farmers. The sector supports an estimated 10 % of the population and indirectly supports the livelihoods of 2.2 million people in Ghana. In many developing countries, entire families are involved, ensuring sustainable livelihoods at the family level.

3. **Food security and nutrition**

   Fish is a major and accessible source of animal protein and essential nutrients like omega-3 fatty acids for many Ghanaians, with an average per capita fish consumption around 20-25 kg per annum, which is higher than the world average. Subsistence fish farmers rely on part of their catch for household consumption and for improving dietary diversity. It is affordable and accessible and helps to combat malnutrition and hunger in many regions. Fish production also supports local and national efforts toward sustainable food systems. About 75 % of total fish production is consumed locally. As much as 60 % of animal protein in the Ghanaian diet is fish. The sector plays a vital role in ensuring food and nutrition security, especially in coastal and riverine communities.

4. **Tourism and recreation**

   Fishing supports recreational industries, such as sport fishing and eco-tourism. Healthy aquatic ecosystems enhance coastal tourism, generating additional revenue.

5. **Asset building**

   The investment in nets, cages and earth ponds creates capital assets for producers. These assets can improve long-term economic stability and resilience to shocks (like crop failures, especially for those who do both).

## Economic Importance for the Broader Value Chain

1. **Processing and value addition**

   Fish undergoes various processing stages such as drying, smoking, freezing and canning, thereby creating jobs and adding value to the fish. Processing boosts income through higher-priced products for both domestic and export markets.

2. **Market development and trade**

   Fish and fish products are among the most traded food commodities globally, contributing significantly to GDP. The export of fish brings in foreign exchange for many nations. Aquaculture is one of the fastest-growing food producing sectors in many developing nations. Fish production plays a crucial role in Ghana's economy, contributing significantly to GDP, providing livelihoods and ensuring food security. The "Aquaculture for Food and Jobs" programme in Ghana aims to produce an additional 20,000 tonnes of fish annually, create 60,000 jobs and contribute about $40 million to the GDP.

3. **Foreign exchange earnings**

   Some of the fish, especially smoked catfish, is exported to neighbouring countries on a small scale.

4. **Employment in allied sectors/Industrial growth and development**

   Aquaculture leads to indirect employment in sectors such as ice production and cold chain logistics; fish processing, packaging and marketing; retail and export logistics; fishing gear manufacturing; feed production.

## Broader Socioeconomic Impacts

1. **Poverty alleviation:** Community-based aquaculture initiatives help reduce vulnerability and dependency.
2. **Gender empowerment:** Women play key roles in fish processing and trading, especially in small-scale fish farming. It also supports gender equity through income opportunities and skills development.

### Activity 6.1 Exploring the Fish Food Chain

This activity is about exploring the fish food chain to identify the key players and investigating the economic activities, benefits, and challenges of the main players in the fish food chain.

#### Steps

1. Search online to list key players in the fish food chain (from production to sale)

2. Use textbooks or Internet resources, or interviews with local fish farmers, processors, and sellers to gather real-life information.
3. For each player:
   a. Describe what they do (economic activities)
   b. List their benefits (e.g. income, job creation, food supply)
   c. Note their challenges (e.g. high feed costs, poor storage, market access issues)
   d. Explain how they contribute to income generation and employment.
4. Put your results in a clear table or chart for easy understanding.

### Sample Table

| Player in fish food chain | Economic activities | Benefits | Challenges | Contribution to income generation | Contribution to employment |
|---|---|---|---|---|---|
| Fish farmers | | | | | |
| Processors | | | | | |
| Traders or wholesalers | | | | | |
| Retailers | | | | | |
| Transporters | | | | | |

5. Turn your table into a poster
6. Present your findings and answer questions from class members.

# PREREQUISITES FOR FISH FARMING

The prerequisites for aquaculture are the essential conditions and resources needed to successfully start and maintain a fish farm. Here are the key prerequisites:

1. **Suitable site**
   a. *Water availability:* A reliable and clean water source (e.g. rivers, boreholes, springs, or reservoirs) is needed.
   b. *Soil type*: For earthen or dugout ponds, preferably clayey, but also loamy soil that can retain water can be selected.
   c. *Topography*: The site should be gently sloping to facilitate drainage and pond construction.
   d. *Accessibility*: Good roads and proximity to markets for inputs and fish sales are essential.

2. **Capital and financial resources**

   Funds are needed for

   **a.** Pond or tank construction

   **b.** Fingerlings or juveniles (young fish)

   **c.** Fish feed

   **d.** Water supply and aeration equipment

   **e.** Labour, transport and maintenance

3. **Knowledge and skills**

   There is the need to understand fish biology and behaviour, feeding practices and nutrition, water quality control, disease prevention and management, and harvesting and marketing. Training or technical support is recommended from agricultural extension services or aquaculture experts.

4. **Quality fish feed**

   There should be balanced, high-quality feed, commercial or locally made. The feed must meet the nutritional needs of the species and age group of the fish being raised.

5. **Market access**

   Target markets for the fish should be identified before fish farming starts. Links should be established with buyers, restaurants, processors, or local consumers for a ready market before production.

## Activity 6.2 Requirements for Establishing a Fish Farm

This activity is about investigating the basic requirements for starting a fish farm in your local area.

1. Identify possible information sources (local farmers, agricultural extension officers, Internet, textbooks)
2. Investigate the following requirements:
   **a.** Water sources (rivers, wells, boreholes, rainwater harvesting).
   **b.** Land (size, location, soil types).
   **c.** Species suitability (types of fish that thrive locally)
   **d.** Climate conditions (temperature, rainfall patterns).
   **e.** Feed availability (local suppliers, cost, quality, and storage options)
3. Record findings in a simple table.
4. Discuss findings with your classmates.

# FISH REARING

Fish rearing (aquaculture) is the practice of raising fish in controlled environments such as tanks, ponds, or cages for commercial or subsistence purposes. Aquaculture contributes significantly to food security, income generation and sustainable fisheries.

## Methods of Raising Fish

Fish can be raised using different methods depending on the available space, resources, type of water body and farming goals. Below are the main methods of fish farming used globally:

1. **Pond culture**

   Fish are raised in man-made or natural ponds (earthen, concrete, tarpaulin). It is the most common method, especially in rural areas. Water can be obtained from rain, a borehole, a stream, or a river. Fish are fed and monitored regularly. It is suitable for rearing tilapia, catfish and carp.

2. **Cage culture**

   Fish are grown in floating net cages placed in rivers, lakes, or reservoirs. It uses natural water bodies. Cages are made of mesh supported by floating frames and the water quality relies on the surrounding source. It is suitable for rearing tilapia, catfish and trout.

3. **Tank culture**

   Fish are raised in concrete, plastic, or fibreglass tanks on land. It is easy to control water quality and feeding. Requires a constant water supply and proper drainage. It is often used in urban or intensive systems. It is suitable for rearing fingerlings, ornamental fish and tilapia.

4. **Raceway (Flow-through) culture**

   Fish are raised in long, narrow concrete channels with flowing water. It requires a continuous flow of clean water from a spring or river with high oxygen levels. It is suitable for rearing trout, salmon and catfish.

5. **Recirculating Aquaculture System** (RAS)

   A high-tech method where water is filtered, cleaned and reused in indoor tanks. It uses mechanical and biological filters. It is environmentally friendly and space-efficient. It is expensive to set up and operate and, suitable for rearing tilapia, barramundi and ornamental fish.

6. **Integrated fish farming**

   This method combines fish farming with agriculture or livestock (e.g. fish + rice, fish + poultry). The waste from one component (e.g. manure) is used to fertilise

the pond. It increases farm productivity and reduces waste management. It is suitable for rearing carp, tilapia and catfish.

# Water Quality Management

The temperature, turbidity, pH, dissolved oxygen and ammonia levels of the water should be monitored.

1. **Clean and unpolluted water**

   The water should be free from chemicals, heavy metals, and industrial waste. The turbidity (the cloudiness or haziness of water) caused by the presence of suspended particles should be checked. High turbidity in fish farming can negatively impact fish health and growth by reducing light penetration, harming gill function and affecting food availability. It can also impact the biofilter and degasser performance in recirculating systems, potentially leading to water quality issues and mortality.

2. **Proper pH and temperature**

   Most fish species prefer pH 6.5–8.5 and temperatures between 25-30°C.

3. **Oxygen levels**

   Sufficient dissolved oxygen is critical for fish survival and growth. Regular water exchange or aeration may be required

## Selection of fish species

Species chosen should be suitable for the climate and water conditions and with high market demand. Tilapia, catfish, carp and trout are suitable for freshwater, while milkfish, mullet, sea bass, shrimp and salmon can be reared in brackish/marine environments.

## Seed (fingerlings) selection

Use healthy, disease-free fingerlings from a certified hatchery. Stocking density should be based on species and pond size.

## Pond or tank infrastructure

This can be earthen ponds, concrete tanks, cages, raceways or recirculating aquaculture systems (RAS), depending on resources and goals. There should be proper drainage, inlet/outlet systems for water management and security to prevent theft or predator attacks.

### Health and disease management

Regular monitoring of fish health and water quality is necessary. Preventive measures like quarantine, vaccination and use of probiotics or approved medications are recommended.

### Licensing and regulations

Fishers should comply with local environmental and aquaculture laws, including permits for pond construction, water use and fish sales.

## Fish Feeding

The feed must meet the nutritional needs of the species and age group of the fish being raised. Fish feed on natural food sources such as algae and plankton, but in aquaculture, they are typically fed on bran, pellets, fish meal and rice polish. Feed should be given 2 – 3 times a day, depending on the age and species. Generally, young fish should be fed three times, while older fish should be fed two times.

**Figure 6.1:** A Picture of Raceways fish pond (Superior Raceway Systems Africa)

## Construction of Fish Ponds

There are three main types of fish ponds used in aquaculture, each designed based on terrain, water source and fish farming goals. These are earthen ponds, concrete ponds and tarpaulin (mobile) ponds. However, cage ponds are also common in Ghana, especially along the Volta Lake.

### Earthen ponds

They are constructed by excavating the soil or by building embankments with clayey soil to hold water. Water is supplied by rainfall, streams, rivers or underground sources. It is best for rural areas with suitable clayey soil and access to land and water. They have a large surface area, which often supports semi-intensive or extensive fish farming. The types of fish reared in such ponds are tilapia, catfish and carp. The main advantages of the earthen ponds are their low construction cost and suitability for extensive or semi-intensive fish farming. However, they are easily silted, with low water quality, and particularly low oxygen tension.

**Figure 6.2:** Pictures of Earthen Dugout Fish Ponds

## Steps in constructing earthen fish ponds

1. *Site selection*: Choose a flat or gently sloping land with clayey soil in an area with high rainfall or natural source of water.
2. *Design and marking:* Decide on pond dimensions (e.g. 20 m × 10 m). Mark boundaries using pegs and ropes.
3. *Excavation*: Dig out soil, preferably with excavators, to the desired depth (usually 1– 1.5 metres).
4. *Embankment construction*: Use excavated soil to build walls around the pond and compact the walls properly to avoid leaks.
5. *Inlet and outlet installation*: Install PVC pipes or channels to bring water in and drain it out. Ensure a proper slope for drainage.
6. *Adding lime and fertiliser*: Apply agricultural lime to reduce acidity and add organic manure to promote plankton growth (natural fish food).
7. *Filling the pond*: Fill with clean water and leave it for 5–7 days before stocking fish.

## Concrete ponds

They are made with concrete walls and floors and are often rectangular or circular (Plate 6.3). Concrete ponds usually measure 3 m × 2 m × 1.2 m (L x B x D). All the inner surfaces are tiled or plastered with waterproof cement or sealant to prevent leakage and bruising of the fish. They are built above or partly below ground for easy water and aeration control. They are common in urban and peri-urban areas and last for many years, and are used for rearing fingerlings, ornamental fish and catfish. Their main advantages include easy management and cleaning, good water supply and drainage control, and suitability for intensive fish farming.

The disadvantages are that:

1. the concrete ponds require expertise to build properly to avoid cracks and leaks.

2. they are more expensive to construct than other pond types like tarpaulin ponds.
3. if not properly maintained, algae and bacteria can overgrow, requiring regular cleaning and disinfection.

This is a video link to the demonstration on the construction of a concrete catfish pond. https://www.youtube.com/watch?v=4TKgR_ELjEs&t=129

**Figure 6.3: A.** A circular concrete tank under construction

**B.** A completed rectangular concrete tank

## Tarpaulin (Mobile) ponds

They are made from PVC or heavy-duty tarpaulin material stretched over a metal, plastic, or wooden frame. They are portable and easy to install and ideal for small spaces. They are used where soil or space is unsuitable for earthen ponds. They are less expensive to build and good for beginners, urban fish farmers, small-scale projects, or backyard fish farming. They are easy to clean and manage diseases.

Their Advantages are:

1. Low cost and easy to set up.
2. Portable and space-saving.
3. Ideal for beginners and urban fish farming.

**Figure 6.4:** Tarpaulin pond for backyard aquaculture.

## Cage pond

(Cage culture) Cage fish ponds are floating enclosures (cages) placed in natural water bodies like rivers, lakes, reservoirs, or large ponds (Figure 6.5). The cages are usually made from netting or mesh and supported by metal, plastic, or bamboo frames that float on the surface. They are suspended in open water, allowing water to flow freely through them. Fish are confined in cages but share the water body with wild species. The sizes of cages can vary depending on the number of fish and the type of water body. They are usually rectangular or circular and secured with floats and anchors. The common fish raised are tilapia, catfish, trout and carp.

### Advantages of cage ponds

1. Low construction cost compared to concrete ponds.
2. Utilises existing natural water.
3. Easier to monitor and harvest fish.
4. Ideal for intensive farming in areas with large water bodies.

### Disadvantages

1. Susceptible to water pollution and disease spread from the open water.
2. Theft and predation risk if not protected.
3. It requires water bodies with good oxygen flow and depth.

**Figure 6.5:** Cage fish pond on Volta Lake in Ghana

### Activity 6.3 Create Your Own Mini Fish Farm Layout

This activity is about creating a simple layout of a small-scale fish pond using drawings or 3D models.

1. Review content on fish pond/ tank components to understand their functions.
2. Select your preferred design format (hand drawing, poster, or 3D model)

3. Sketch or model the pond/tank showing:
   a. Water source (pipe, pump, or inlet channel)
   b. Filtration system (sand filter, net screen, or simple mechanical filter)
   c. Feeding area (Marked zone for adding feed)
   d. Fish shelter (rocks, PVC pipes, or shaded sections).
4. Label all the parts clearly to show their purpose.
5. Review the design to ensure all the necessary features are included.
6. Present the layout or model to the class, explaining each feature and its role.

# SUPPORT ORGANISATIONS FOR KEY STAKEHOLDERS IN FISH PRODUCTION

When you were in Year 2, you explored the support organisations that help arable crop farmers, traders, and processors — from providing training and credit facilities to offering market access and technical advice. Just as those groups boost crop production, similar organisations exist to support stakeholders in fish production. Let's dive in and discover how they make a difference in the fishing industry.

## Support Organisations in Fish Production

Some relevant support organisations offer services to key stakeholders in the fisheries value chain, including fish farmers, distributors and small-scale traders. These organisations operate locally, nationally, and internationally, and provide training, access to finance, extension support, market access, policy advocacy, and research.

## Government institutions that support the fisheries value chain

***Table 6.2***: Government Institutions involved in the Fisheries Value Chain

| Organisation | Services Provided | Stakeholders Supported |
|---|---|---|
| Ministry of Fisheries and Aquaculture | Formulation of policy, training, regulations, subsidies, research | Fish farmers, traders, and distributors |
| Agricultural Extension Services (Ministry of Local Government) | On-site technical support, disease control, best farming practices | Fish farmers |
| Fisheries Development Boards or Agencies (e.g. Ghana Fisheries Commission) | Licensing, training, technical assistance, aquaculture promotion | Fish farmers and processors |

## International Organisations and Non-Governmental Organisations

***Table 6.3***: International Organisations and Non-Governmental Organisations involved in the Fisheries Value Chain

| Organisation | Services | Stakeholders Supported |
|---|---|---|
| Food and Agriculture Organisation (FAO) – Fisheries and Aquaculture Department | Supports small-scale aquaculture, provides training and manuals, and works with the government on sustainable fisheries policies and value chain improvement. Projects like FISH4ACP aim to improve value chains. | All stakeholders: fish farmers, processors, traders |
| WorldFish | Partners with local institutions to promote sustainable aquaculture practices, gender inclusion, nutrition-sensitive fish farming, research and technology transfer | Small-scale fish farmers, women traders |
| United States Agency for International Development (USAID) and Feed the Future Programs | Through Feed the Future and Ghana Fisheries Recovery Activity (GFRA), USAID supports fisheries governance, livelihoods, and resilience for fishers. Helps in market development, input access, and infrastructure support | Farmers, traders, Small and medium-scale enterprises (SMEs), small-scale traders, women in fisheries |
| AquaFish Innovation Lab (USAID-funded) | Capacity building, sustainable practices, aquaculture innovation | Fish farmers, researchers |
| WWF (World Wide Fund for Nature) | Sustainable fisheries, eco-certification, ecosystem restoration | Fishers, traders, conservation partners |
| Oxfam, CARE and the Netherlands Development Organisation **(**SNV) | Livelihood support, women's empowerment, market access | Small-scale traders, processors |

## Cooperatives and Farmer-Based Organisations (FBOs)

***Table 6.4***: Cooperatives and Farmer-Based Organisations involved in the fish value chain

| Organisation | Services | Stakeholders Supported |
|---|---|---|
| National Fish Farmers' Associations (e.g. Nigerian Tilapia and Aquaculture Developers Association) | Bulk input purchase, training, advocacy, market linkage | Fish farmers |
| Ghana National Association of Fish Farmers (GNAFF) | Advocacy on behalf of fish farmers, organises training workshops and technical seminars, facilitates access to inputs like fingerlings and feed, promotes best practices in aquaculture | Smallholder fish farmers, medium-scale commercial aquaculture businesses, youth in aquaculture |

| | | |
|---|---|---|
| Fisherfolk or Traders' Cooperatives | Credit access, bulk selling, collective bargaining | Distributors, small traders |
| Volta Fish Farmers Association (VoFFA) | Coordinates bulk purchase of feed and fingerlings, provides peer-to-peer technical support, promotes cage farming best practices, liaises with development partners (eg FAO, SNV) for capacity building | Cage fish farmers on Lake Volta, small-scale aquaculture entrepreneurs, youth and women in fish farming |
| Women in Fisheries Networks (eg AWFISHNET – African Women Fish Processors and Traders Network) | Advocacy, empowerment, training | Women traders and processors |

## Financial and Microfinance Institutions

***Table 6.5***: Financial and microfinance institutions involved in the fish value chain

| Organisation | Services | Stakeholders |
|---|---|---|
| Agricultural Development Banks | Loans, insurance, financial training | Farmers, traders |
| Microfinance Institutions (MFIs) | Small loans, mobile banking, savings groups | Small-scale traders |
| Credit Unions & Savings and Loans Groups | Access to working capital | Distributors, processors |

## Private Sector & Input Suppliers

***Table 6.6***: Private Sector & Input Suppliers involved in the fish value chain

| Organisation | Services | Stakeholders Supported |
|---|---|---|
| Aquaculture feed and equipment companies (E.g Skretting, Aller Aqua, Agritech Ghana Ltd) | Training, input supply, technical assistance | Fish farmers |
| Fish processing and cold chain companies | Storage, value addition, logistics | Distributors, traders |
| Retail and export companies | Market access, quality assurance, logistics | Distributors, processors |

## Research and Academic Institutions

***Table 6.7***: Research and academic institutions involved in the fish value chain

| Organisation | Services | Stakeholders Supported |
|---|---|---|
| Universities with aquaculture or fisheries programmes (eg University of Cape Coast, CSIR-Water Research Institute | Training, extension, applied research | Fish farmers, learners, extension officers |

| | | |
|---|---|---|
| National Aquaculture Research Institute | Breeding research, disease control, extension support | Fish farmers |

### Activity 6.4 Mapping Aquaculture Support: Who Helps Fish Farmers?

1. Gather information using the Internet, textbooks, or local contacts and identify organisations, such as:
   a. *International*: FAO (Food and Agriculture Organisation), World Aquaculture Society (WAS).
   b. *National/Local:* Ghana Chamber of Aquaculture.
2. List the types of support each provides: technical advice, training, marketing info, advocacy, funding, research.
3. Categorise services under headings like:
   a. Technical & research support
   b. Training & capacity building
   c. Marketing & information
   d. Policy & advocacy
   e. Financial & infrastructure support
4. Discuss each organisation's role: how they help fish farmers, processors, and other stakeholders.
5. Prepare a table to share your findings with your classmates

# TECHNOLOGY TRANSFER METHODS FOR FISH FARMING

In Year 1, you explored technology transfer approaches, focusing on agricultural extension systems — how new ideas and practices move from experts to farmers. Now in Year 3, we will apply those same principles to fish farming. You will discover why technology transfer matters in aquaculture, the approaches used, and the methods that help fish farmers adopt better practices for higher yields and healthier stock.

## Introduction to Transfer of Technology (ToT) in Fish Farming

Transfer of Technology in fish farming refers to the process of disseminating new knowledge, innovations, and improved fish farming techniques from research institutions, universities, and experts to fish farmers to enhance productivity,

improve farm management practices, increase profitability, and promote sustainable aquaculture.

## Importance of Transfer of Technology in Fish Farming

1. Promotes adoption of modern and efficient practices.
2. Helps fish farmers improve production and income.
3. Encourages sustainable use of water and feed resources.
4. Facilitates disease management and biosecurity.
5. Enhances access to markets and value chains.

## Approaches to Transfer of Technology in Fish Farming

The effectiveness of technology transfer depends on the strategy or approach used to deliver the information and innovations to fish farmers. The main approaches used are:

### Top-down Approach

In this approach, technology originates from research institutions or universities. Researchers develop new practices or innovations such as improved fish feed, pond management techniques, or disease control measures. These technologies are then passed on to farmers through extension agents or government agencies. This approach is implemented in Ghana through government-led initiatives by the Fisheries Commission.

#### Strengths of the top-down approach

1. It ensures rapid dissemination of scientifically validated technologies
2. It promotes uniform message delivery across regions
3. It provides clear metrics for measuring adoption rates
4. It is efficient for introducing basic techniques to new farmers.

#### Limitations of the top-down approach

1. It often fails to consider local context and indigenous knowledge
2. It limits farmer input in technology development
3. It suffers high dropout rates when external support ends
4. Often does not align with farmers' needs and resources.

## Bottom-up Approach

This approach begins with farmers themselves identifying their challenges and setting priorities. They participate in the design, testing and evaluation of the new technology. Extension and research bodies provide support rather than dictating solutions. Emphasis is on farmer empowerment and ownership.

### Strengths of the bottom-up approach

1. Farmers are actively involved, boosting their confidence and ownership of new technologies.
2. Because technologies stem from farmers' actual needs and realities, they are more easily adopted.
3. Solutions are tailored to local conditions and cultural practices, making them more practical.
4. Farmers develop skills in problem-solving and innovation, which can be applied to other challenges.
5. Farmers' local knowledge can lead to creative, low-cost solutions that outsiders might not think of.

### Limitations of the bottom-up approach

1. Farmers might lack scientific understanding or advanced techniques, which can slow innovation.
2. Building consensus and involving everyone takes time compared to top-down approaches.
3. Farmers might not have access to the financial resources, materials, or equipment needed to test ideas.
4. Locally developed solutions might work in one place, but need to be adapted to be used more widely.
5. Without strong facilitation, ideas might remain fragmented or not move beyond the farm level.

## Participatory Approach

This approach combines elements of top-down and bottom-up strategies. It encourages joint decision-making and cooperation between researchers, extension officers and farmers. Farmers are actively involved in technology development and adaptation by contributing their local knowledge and practices, while researchers provide scientific expertise. For example, co-designing fish hatchery systems, where farmers' ideas on water supply and breeding practices are combined with researchers' technical knowledge, depicts this approach. A participatory approach is implemented through

NGO-led projects that emphasise farmer participation, co-development of technologies with fish farmers, peer-learning networks, and demonstrations by lead farmers.

### Strengths of the participatory approach

1. *Enhanced adoption of technology:* Involving fish farmers in the development and testing of technologies increases their understanding, trust, and willingness to adopt innovations.
2. *Context-specific solutions:* Technologies are adapted to local environmental, social, and economic conditions, making them more relevant and sustainable for farmers.
3. *Empowerment and capacity building:* Farmers gain practical knowledge and confidence through hands-on involvement, fostering self-reliance and skill development.
4. *Stronger collaboration*: Encourages cooperation among researchers, extension agents, and farmers, leading to continuous feedback and improvements in technology.
5. *Ownership and responsibility*: Farmers feel a sense of ownership over the technology, increasing commitment to proper implementation and maintenance

### Limitations of the participatory approach

1. *Time-consuming process:* Participatory methods often require longer periods for planning, consultation, and implementation, which can delay results.
2. *Resource-intensive:* Requires more human, financial, and logistical resources for organising meetings, training sessions, and follow-ups.
3. *Possible conflicts*: Differences in opinions among stakeholders may lead to conflicts, slowing down decision-making and adoption.
4. *Variability in participation*: Not all farmers may actively engage due to differences in interest, education level, or influence within the community.
5. *Limited scientific control*: Involvement of non-experts can lead to inconsistencies in data collection and application, potentially affecting research quality and outcomes.

## Integrated Approach

This approach involves multiple stakeholders working together – government agencies, NGOs, private companies, research institutions and farmers. It coordinates resources, knowledge and efforts to achieve common goals in fish farming. A Public-Private Partnership (PPP) project that brings together feed companies, government agencies and extension services to train farmers on cage fish farming is an example of this method. This approach operates with two different models:

### Adaptive transfer model

1. Combines technical expertise with farmer knowledge
2. Initial introduction of technologies, followed by participatory adaptation
3. Feedback mechanisms to inform ongoing research
4. Flexible implementation based on the farmer's capacity

### Innovation systems approach

1. Recognises multiple sources of innovation (not just research)
2. Networks of diverse stakeholders collaborating
3. Focuses on an enabling environment for innovation
4. Emphasises linkages between actors in the system
5. It facilitates resource sharing and comprehensive support to farmers.
6. It also brings in diverse expertise and funding opportunities.
7. But coordination among many stakeholders can be complex, and the risk of conflicting interests if roles and responsibilities are not clearly defined is real.

## Methods of Transfer of Technology in Fish Farming

Effective technology transfer ensures that fish farmers adopt improved practices to enhance productivity, sustainability, and profitability. The main methods used to transfer technology in fish farming include:

1. **On-farm demonstrations**

   Practical training held on model farms or progressive farmers' ponds, where farmers observe and practise key activities like pond preparation, water management, stocking, feeding, and harvesting. This hands-on method builds confidence, deepens understanding, and allows immediate expert feedback.

2. **Training workshops and seminars**

   Organised by government agencies, researchers, universities, or NGOs, these events cover topics such as hatchery management, feed processing, disease control, and water monitoring. They combine lectures, practical work, and discussions for effective, applicable learning.

3. **Field days and exposure visits**

   Farmers visit successful fish farms, research centres, or demonstration sites to observe real-world best practices. These visits motivate farmers and encourage them to adopt proven techniques on their farms.

4. **Extension services**

   Trained officers, NGOs, or private experts visit farms regularly to give advice, solve problems, and guide farmers on good pond management, feeding, and disease control, bridging the gap between research and on-farm practice.

5. **Use of mass media**

   Radio, television, posters, newsletters, and magazines share key messages on improved fish farming, reaching a wide audience, especially in remote areas with limited training opportunities. Educational broadcasts help reinforce learning.

6. **ICT and digital tools**

   Mobile apps, SMS, WhatsApp groups, and YouTube videos provide farmers with regular technical advice and updates, for example, on feeding or water management. These tools offer practical, cost-effective, and rapid knowledge sharing.

7. **Farmer Field Schools (FFS)**

   Groups of farmers meet regularly to learn by doing, monitoring their ponds, discussing challenges, and exploring solutions together. This participatory method builds peer learning and confidence in adopting new technologies.

8. **Model fish farms or technology villages**

   Specially developed centres showcasing integrated modern fish farming technologies, serving as hubs for skills development, research, and knowledge exchange.

## Challenges in Technology Transfer for Fish Farming

The process of sharing and adopting new technologies in fish farming is often hindered by several practical challenges, such as:

1. **Low literacy levels among Ghanaian farmers**: Many small-scale fish farmers have limited education, making it hard to understand technical manuals, interpret data, or follow written instructions, which hampers the adoption of new practices.
2. **Inadequate extension personnel and logistics**: There is a shortage of trained aquaculture extension officers, and many lack resources to reach remote farmers, resulting in poor outreach and weak follow-up.
3. **Resistance to change from traditional methods**: Farmers often stick to long-practised methods out of fear or uncertainty, making them reluctant to adopt innovations such as formulated feeds.
4. **Limited access to financial and technological resources**: Smallholders often lack funds to invest in improved technologies and may also struggle to obtain necessary equipment or quality fingerlings.

5. **Poor infrastructure and communication channels**: Bad roads, weak phone and internet connectivity, and limited electricity and water supply in rural areas restrict access to extension services and modern technologies.

## Strategies to Improve Transfer of Technology

Successful technology transfer in fish farming depends on overcoming key challenges and adopting targeted strategies. Here are some strategies that can make a big impact:

1. **Strengthen public–private partnerships in aquaculture**: Bringing together government, NGOs, the private sector, and research bodies helps pool resources, share expertise, and ensure regulation. Joint training and market linkages speed up technology adoption and make it more sustainable.
2. **Increased investment in training and recruiting extension officers**: Recruiting and continuously training more extension officers ensures farmers receive up-to-date, practical advice. This reduces farmer-to-officer ratios, improves outreach, and supports timely guidance, especially in remote areas.
3. **Develop localised and farmer-friendly learning materials:** Using simple, illustrated materials in local languages with real-life examples makes technical information clearer and more relevant, encouraging adoption among farmers with low literacy levels.
4. **Incorporate ICT solutions tailored to farmers' context**: Mobile apps, SMS, WhatsApp, and YouTube content in local languages, featuring relatable examples, can deliver practical, timely advice and overcome distance barriers where extension services are limited.
5. **Encourage farmer cooperatives and groups**: Cooperatives and groups support peer learning, resource sharing, and collective bargaining, while making it easier for extension officers to reach and train multiple farmers, boosting technology adoption.

## Stakeholder Roles in Aquaculture Technology Transfer

***Table 6.8***: Summary of stakeholder roles in aquaculture technology transfer

| Stakeholder | Roles in Technology Transfer |
|---|---|
| Government Institutions | Set policies, license farms, provide extension services and develop national plans |
| Research Institutions | Innovate, breed improved strains, develop feed and disease management protocols |
| Educational Institutions | Train professionals, conduct applied research and extend knowledge directly to farmers |
| Input Suppliers | Provide fingerlings, feeds, equipment and vet services |
| Fish Farmers | Adopt technology, adapt technology to suit local needs, provide feedback and train peers |

| | |
|---|---|
| Financial Institutions | Offer credit, microfinance and insurance to enable adoption |
| International Organisations | Fund infrastructure, introduce new technologies and offer technical assistance |
| NGOs | Train farmers, pilot technologies and strengthen farmer networks |

## Activity 6.5 Design a local fish farming brochure/advert

This activity is about creating a simple fish farming technology brochure or radio advert in a local language. The purpose of this activity is to help learners communicate fish farming effectively in a language and style that their local community can easily understand, thereby promoting the adoption of best practices and encouraging wider participation in aquaculture.

1. Pair up with a classmate.
2. Decide on a specific fish farming technology to promote (eg improved formulated feed, pond management, or water quality control).
3. Gather simple, accurate information about the technology and its benefits for fish farmers.
4. Agree on a local language that most farmers in your community understand. Choose whether your group will make a brochure or a radio advert.
5. Draft the content
   a. *For a brochure*: Create short sentences, catchy headings, and include simple diagrams or photos.
   b. *For a radio advert*: Write a short script (30–60 seconds) with a clear introduction, main message, and closing call-to-action.
6. Make sure all terms are explained in everyday language that farmers can easily understand.
7. Design & record
   a. *For brochures*: Arrange the text and images neatly, keeping it colourful and easy to read.
   b. *For radio*: Practise reading the script aloud with clear pronunciation, then record if possible.
8. Check your work for accuracy, clarity, and appeal.
9. Share your brochure or play your radio advert for feedback from classmates.

# RURAL CREDIT FOR FARMING

## Basic Concepts of Rural Credit

Rural credit refers to loans and financial support extended to farmers and rural households for agricultural and related activities. The objective of the credit is to enhance agricultural productivity, improve livelihoods and reduce rural poverty. It is also a financial service provided to agricultural producers and rural enterprises to support production, marketing and other agricultural activities.

## Types of Rural Credit Based on The Source and Regulation

Here, three types of credit exist:

### Formal credit

These are structured loans given to farmers and rural entrepreneurs by regulated financial institutions. The major financial institutions and the credit facilities offered are:

1. *Commercial banks*: Offer large loans with strict requirements and collateral, often difficult for smallholder farmers to access.
2. *Rural banks*: Operate in rural areas to serve local communities with more flexible terms for agricultural and small business needs.
3. *Agricultural development banks*: Specialise in financing agricultural projects and rural development, often with government support and sector-specific loan products.

### Semi-formal credit

These institutions are registered and operate under financial regulations, but are more flexible than formal banks. Examples are:

1. *Cooperatives*: Member-owned groups that pool resources to offer loans at reasonable interest rates to members.
2. *Credit unions*: Community-based financial organisations that provide savings and credit services to members, often with low interest rates and minimal collateral.
3. *Microfinance institutions*: Provide small loans (microcredit) to low-income rural individuals, particularly women, to support small-scale enterprises and farming.

## Informal credit

These are unregulated, community-based credit sources that offer quick loans but usually lack legal protection or standard terms. Some informal credit providers are:

1. *Money lenders*: Provide quick loans, often at high interest rates and without formal procedures.
2. *Relatives and friends*: Offer interest-free or low-interest loans based on trust and personal relationships.
3. *Rotating savings groups (Susu)*: Community-based savings groups where members contribute regularly and take turns receiving lump-sum payments.
4. *Traders*: Advance credit to farmers for inputs or in exchange for future harvests, often tying farmers to specific buyers.

## Advantages and Disadvantages of the Sources of Rural Credit

***Table 6.9***: Advantages and Disadvantages of the Sources of Rural Credit

| Source of Rural Credit | Advantages | Disadvantages |
|---|---|---|
| Formal Sources (e.g., Commercial banks, Agricultural Development banks, Rural banks, Cooperative banks) | **a.** Provide large amounts of credit, suitable for long-term projects<br>**b.** Offer lower interest rates, regulated by central authorities<br>**c.** Ensure legal protection for both lender and borrower<br>**d.** Offer technical advice and support services<br>**e.** Encourage financial discipline and documentation | **a.** Require collateral/ security, which many rural farmers may lack<br>**b.** Lengthy procedures and documentation<br>**c.** Often located far from rural areas, causing access issues<br>**d.** May not cater for urgent or short-term credit needs-<br>**e.** High rate of loan rejection for small or unregistered farmers |
| Semi-formal Sources (e.g. Microfinance institutions, NGOs, Credit unions, self-help groups, Village Savings and Loans Associations – VSLAs) | **a.** Easier access than formal institutions<br>**b.** Provide credit to smallholder and marginalised farmers<br>**c.** Group lending helps reduce default risks<br>**d.** Often involve financial literacy training<br>**e.** May accept non-traditional collateral like group guarantees | **a.** Interest rates may be higher than formal sources<br>**b.** Loan sizes are often small, limiting investment<br>**c.** Limited reach and geographical coverage<br>**d.** Sustainability of some institutions is a concern<br>**e.** Group pressure or dynamics may cause social friction |

| | | |
|---|---|---|
| Informal Sources (e.g. moneylenders, traders, friends, relatives, rotating savings groups – susu) | **a.** Quick and easy access with minimal documentation<br>**b.** No collateral is usually required<br>**c.** Highly flexible repayment arrangements-<br>**d.** Readily available during emergencies<br>**e.** Culturally familiar and trusted by rural dwellers | **a.** Often charge very high interest rates<br>**b.** Risk of exploitation or coercion by lenders-<br>**c.** No legal protection for borrowers<br>**d.** May lead to debt traps<br>**e.** Typically, limited loan amounts and short-term duration |

## Types of Rural Credit Based on Repayment Duration

Agricultural credit can be classified based on the duration of the loan and its purpose. These classifications help financial institutions and policymakers design tailored credit products for farmers' diverse needs. These include:

1. *Short-term credit*: This type of credit has a repayment period of up to 12 months. It is usually taken to meet immediate farm production needs for a single growing season. It is used to purchase seeds, fertilisers, pesticides, payment for hired labour and day to-day operating expenses.
2. *Medium-term credit*: This has a repayment duration of one to five years. It is mostly contracted to acquire assets that improve farm productivity and income over multiple seasons. It is used to purchase farm machinery (eg tractors, irrigation pumps), livestock breeds and the development of permanent structures like farm sheds. Repayment is structured in instalments based on asset usage and income generated.
3. *Long-term credit*: This type of rural credit has a repayment duration of over five years. It is usually contracted to finance large investments in land and infrastructure for long-term farm development. Its main uses include:
   - **a.** Land purchase and consolidation
   - **b.** Establishing irrigation systems or water harvesting structures
   - **c.** Plantation establishment (e.g. oil palm, cocoa, orchards).

# Operations of Rural Credit Systems

## Formal credit operations

Formal rural credit is provided by licensed financial institutions such as commercial banks, agricultural banks, and Rural and Community Banks (RCBs). The process follows structured procedures to ensure responsible lending.

## Application process

1. *Loan application submission*: Farmers or agribusinesses submit detailed applications, often with a farm business plan, outlining production goals, cash flow projections, and loan usage.
2. *Verification of borrower information*: The bank verifies personal identification, farm ownership or tenancy agreements, and financial records to assess eligibility.
3. *Collateral assessment*: Lenders evaluate available collateral such as land titles, machinery, or use group guarantees (especially in cooperative lending).
4. *Loan approval and disbursement*: After assessment, loans are approved and funds are disbursed either in cash or in-kind (e.g. inputs). Approval times vary depending on institutional policies.

## Repayment mechanisms

1. *Fixed instalment schedules*: Borrowers repay loans in equal monthly or quarterly instalments that include both principal and interest.
2. *Seasonal repayment*: For agricultural loans, repayment may be structured around harvest periods, allowing flexibility when cash inflow is seasonal.

## Interest calculation methods

1. *Flat rate*: Interest is charged on the total loan amount, regardless of repayments made.
2. *Reducing balance*: Interest is charged on the outstanding balance, reducing over time as the loan is repaid.

# Microfinance Operations

Microfinance institutions (MFIs) are specialised financial entities that provide small loans, savings, and other financial services to low-income individuals, especially smallholder farmers and rural micro-entrepreneurs. Unlike traditional banks, MFIs often do not require conventional collateral. Instead, they rely on group guarantees, character assessments, or the use of social networks to ensure repayment. Their operations are designed to improve financial inclusion, support income-generating activities, and reduce poverty in underserved rural areas. MFIs also offer training in financial literacy and business management to enhance loan effectiveness and sustainability.

Borrowers access loans by forming groups.

## Groups for accessing microfinance loans

1. *Solidarity groups*: Farmers form small groups of 5–10 members who apply for loans collectively.
2. *Joint liability groups*: Each group member is responsible for ensuring the others repay, creating strong peer pressure and mutual accountability.
3. *Peer monitoring groups*: Members monitor each other's loan use and repayment behaviour, reducing default risk.

## Innovative features of microfinance operations

1. *Progressive lending*: Loan sizes increase with successful repayment history, encouraging good credit behaviour.
2. *Frequent repayment schedules*: Loans are repaid weekly or monthly, making it easier for borrowers with irregular income streams.
3. *Mandatory savings*: Borrowers are often required to save a small amount before or during the loan period, building financial discipline.
4. *Non-traditional collateral*: Instead of land titles, MFIs may accept group guarantees, household items, or community reputation as collateral.

# Government Credit Programmes

Governments intervene in rural credit to improve access, affordability and food security by supporting farmers directly or through partnerships. Some government interventions are:

1. **Input credit schemes**
   a. *Subsidised inputs on credit*: Farmers receive fertilisers, improved seeds and chemicals on credit and repay after harvesting.
   b. *Block farming programmes*: The government supports groups of farmers cultivating a common crop on adjacent lands, supplying inputs and supervising production.
   c. *Planting for Food and Jobs (PFJ)*: Includes a credit component where farmers receive inputs with deferred payment, encouraging increased food production.
2. **Implementation mechanisms of government credit programmes**
   a. *Direct provision*: Some programmes are implemented directly by government agencies like the MOFA (Ministry of Food and Agriculture) to farmers,
   b. *Public-Private Partnerships (PPPs)*: The Government partners with agribusinesses or financial institutions to reach more farmers with credit and inputs.

c. *Interest rate subsidies:* The Government absorbs part of the interest to reduce borrowing costs for farmers through selected banks and MFIs

# Importance of Rural Credit in Agriculture

## Economic importance

1. *Increased agricultural productivity:* It enables farmers to adopt improved technologies (seeds, fertilisers), facilitates mechanisation and irrigation investments. It also promotes the transition from subsistence to commercial farming
2. *Income enhancement*: It helps to break poverty cycles through productive investments, creates employment opportunities in rural areas and stabilises seasonal income fluctuations.
3. *Market participation*: It promotes bulk selling rather than distress sales, strengthens farmers' bargaining power and supports value addition activities.

## Social importance

1. *Food security enhancement*: It helps stabilise food production, reduces vulnerability to production shocks and improves household nutrition through diversified production.
2. *Rural development*: Rural credit to farmers helps to reduce rural-urban migration, support infrastructure developments and reinforce community institutions.
3. *Empowerment of vulnerable groups*: Rural credit enables vulnerable groups like women and the youth who are interested in farming to have access to credit, promoting integration of marginalised communities.

# Challenges and Innovations in Rural Credit

## Persistent challenges

1. *High transaction costs:* rural credit faces limited rural banking infrastructure due to the dispersion of clients, which results in small loan sizes with high administrative costs.
2. *Risk management issues*: Rural credit usually faces high risk as agriculture is weather-dependent in Ghana, prices are unstable, and there is limited insurance of produce.
3. *Information irregularity*: Rural credit is prone to challenges such as a lack of credit history for smallholder farmers, difficulty in assessing borrower creditworthiness and limited collateral options for smallholder farmers.

# Innovative Approaches to Addressing Challenges Faced by Rural Credit

## Digital financial services

1. *Mobile money platforms*: Mobile money services allow farmers to receive loan disbursements and repay instalments directly through their mobile phones. This reduces transaction costs and eliminates the need for travel to bank branches.
2. *Agent banking models*: Local shops and kiosks act as agents for banks, enabling farmers in remote areas to access loan services, deposit and withdraw funds, and make repayments easily, expanding rural credit coverage.
3. *Digital credit scoring*: Instead of relying on traditional credit history, financial institutions use data from mobile phone usage, utility payments, and farming records to assess borrowers' creditworthiness. This helps extend credit to farmers without formal collateral or credit history.

## Value chain financing

1. *Contract farming with embedded financing:* Agribusinesses provide upfront financing or inputs to farmers under production contracts. In return, farmers agree to supply their harvest to the agribusiness, securing repayment and improving access to credit.
2. *Warehouse receipt systems*: Farmers store harvested produce in certified warehouses and receive a receipt. These receipts serve as collateral for loans from banks or microfinance institutions, helping farmers access credit during post-harvest periods.
3. *Out-grower schemes with input credit*: Large processors or exporters support smallholder farmers by providing seeds, fertilisers, and other inputs on credit. Farmers repay these inputs from the proceeds of selling their produce, often through a deduction at sale.

## Risk mitigation tools

1. *Weather index insurance*: Farmers and lenders are protected from climate related risks by insurance linked to weather indices (like rainfall or drought levels). This ensures loan repayment even during adverse weather conditions.
2. *Price guarantees (Forward contracts)*: Agreements to sell produce at predetermined prices reduce market risks and provide more stable incomes. This encourages lenders to extend credit, knowing farmers have secured buyers.
3. *Portfolio guarantees*: Development organisations or governments provide partial guarantees to financial institutions' loan portfolios targeting

smallholder farmers. This reduces the lending risk and motivates banks to lend more to rural communities.

## Activity 6.6 Rural Credit for Farmers

This activity is about understanding the role of rural credit and how to obtain it. It considers the advantages and disadvantages of the sources of rural credit for smallholder farmers. The purpose of the activity is to find out what rural credit is, where farmers can get it, and which sources suit smallholders best.

1. Partner with a classmate.
2. Agree on the definition of rural credit.
3. List common local sources of rural credit (formal and informal).
4. Use textbooks, learner material or the Internet to discover how each source normally works. Write down relevant notes.
5. Compare the advantages and disadvantages of each source in a table.
6. Decide which sources suit different farming situations.
7. Prepare a short poster summary of your findings.
8. Present findings to your classmates.

# REVIEW QUESTIONS

1. Analyse how fish production contributes to the livelihood of producers and explain the ways it supports the broader value chain. Support your answer with specific examples.
2. How can a fish farming system be adapted to ensure sustainability and productivity in a rural area facing seasonal water shortages and limited access to fish feed?
3. Evaluate how at least three support organisations differ in the types of services they provide to fish farmers, distributors, and small-scale traders. Based on your evaluation, recommend the most appropriate organisation for each stakeholder group and justify your choices with specific examples.

***(Note that questions 4 to 13 are multiple-choice questions)***

4. In the Farmer Field School (FFS) method, what role do farmers usually play? (Level 2)
   - **A.** They only observe demonstrations
   - **B.** They act as passive learners in the process
   - **C.** They learn by doing through group experiments
   - **D.** They fund all the training activities by themselves
5. Which of the following approaches helps adapt fish farming technology to local conditions?
   - **A.** Using farmer field research methods
   - **B.** Using conferences at the national level
   - **C.** Sending equipment without training
   - **D.** Giving fish feed samples only to farmers
6. What is the main aim of participatory extension approaches?
   - **A.** To advertise products
   - **B.** To tell farmers what to do
   - **C.** To involve farmers in decision-making
   - **D.** To help farmers learn new technology
7. The technology transfer method that is most suitable for reaching many farmers at once is...
   - **A.** personal visit.
   - **B.** group meeting
   - **C.** radio broadcast

**D.** farm conferences.

**8.** Why are fish farming cooperatives useful in technology transfer?

**A.** They provide security for farms

**B.** They help members avoid taxes

**C.** They share information and resources

**D.** They enforce rules and regulations on the farm

**9.** Which method is most effective in helping farmers solve local fish farming problems?

**A.** Viewing online content

**B.** Sending monthly reports

**C.** Top-down decision making

**D.** Participatory Rural Appraisal

**10.** What role does ICT play in fish farming technology transfer?

**A.** Delays communication

**B.** Replaces field visits

**C.** Prevents farmer-to-farmer contact

**D.** Enhances access to timely information

**11.** Why are farmer exchange visits considered useful?

**A.** Farmers get free transport

**B.** Farmers share experiences

**C.** Farmers get more knowledge

**D.** They collect government subsidies

**12.** A technology transfer activity that allows farmers to observe and ask questions is called

**A.** A radio programme

**B.** A farm conference

**C.** A demonstration session

**D.** A television advertisement.

**13.** What is the importance of using local languages in technology transfer for fish farming?

**A.** It reduces the cost of transfer

**B.** It adds entertainment to the process

**C.** It makes it more scientific and practical

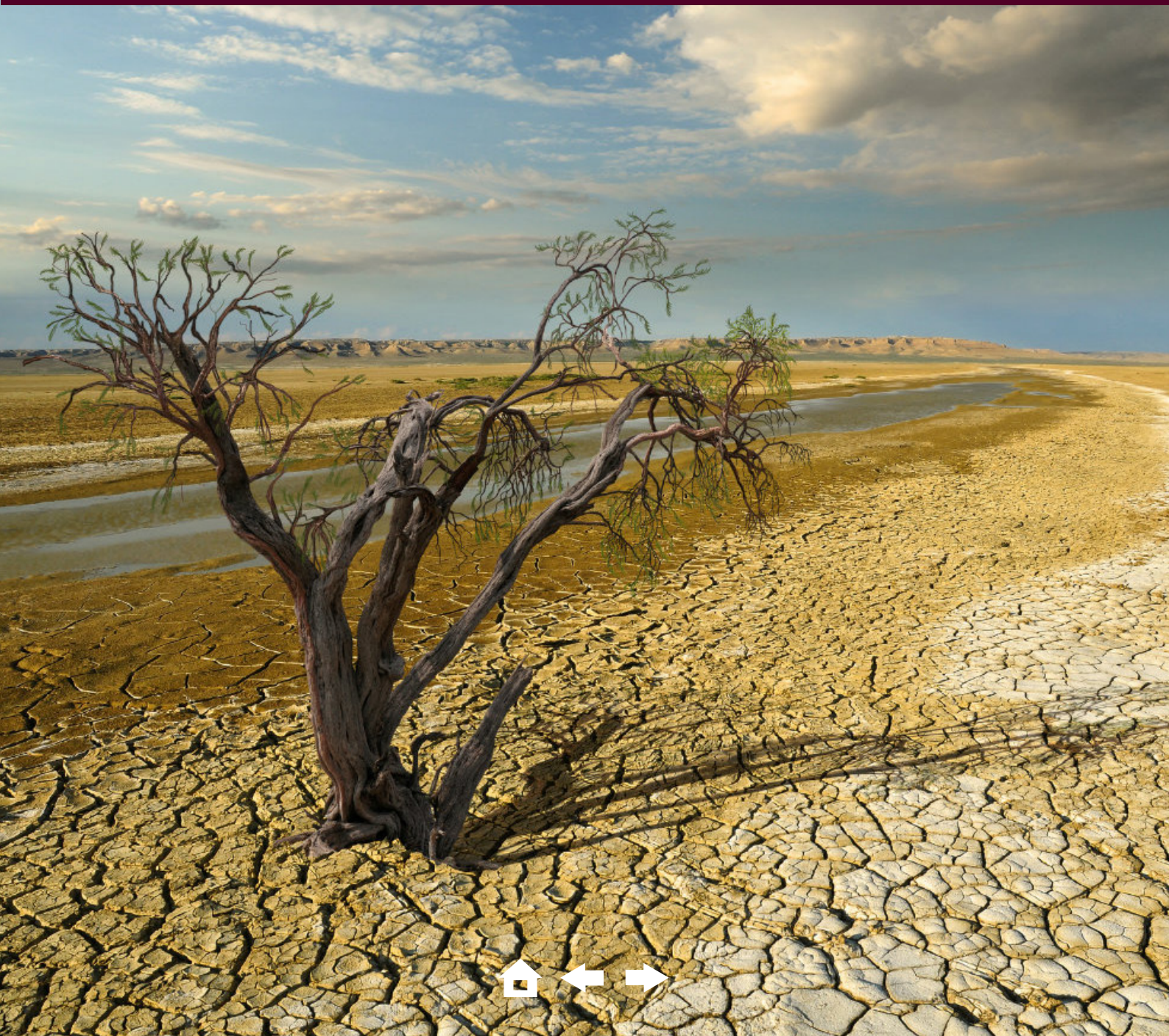
**D.** It makes the message more understandable

**14.** Compare and contrast the suitability of formal versus informal credit sources for smallholder farmers in Ghana.

SECTION

7

# NATIONAL AND GLOBAL POLICIES ON CLIMATE CHANGE



# CLIMATE VARIABILITY AND CLIMATE CHANGE

## Introduction

In Year 1, you learned about climate change mitigation measures and how they relate to society and agriculture. You also explored how these measures support sustainable rural farming. In Year 2, the focus was on global warming and how it threatens the environment and rural livelihoods. You also looked at major changes in the atmosphere and their effects on nature and farming communities. This section builds on that knowledge by looking at current environmental and ethical issues in agriculture. You'll learn about climate policies like the Kyoto Protocol, the Paris Agreement, and Ghana's National Climate Change Policy. You will also be introduced to the REDD+ strategy, which helps protect forests and fight climate change. Lastly, you shall look at animal welfare—what it means, why it matters, and how culture, laws, and personal choices affect how animals are treated in farming.

**KEY IDEAS**

- **Carbon**: The element found in greenhouse gases such as carbon dioxide that contributes to global warming.
- **Deforestation**: The cutting down of forests, which releases carbon and reduces the Earth's ability to absorb $CO_2$.
- **Ecosystem**: A natural environment where plants, animals, and people interact and depend on each other.
- **Greenhouse gases**: Gases such as carbon dioxide and methane that trap heat in the atmosphere and cause climate change.
- **Policy**: A set of rules or plans made by governments to tackle issues like climate change.
- **Vulnerability**: The level of risk people or environments face from the impacts of climate change.

# GLOBAL & NATIONAL POLICIES ON CLIMATE CHANGE

In previous years, you learned what causes climate change, its dangers, and ways to reduce its effects, especially on farming and communities. Now, you will explore global and national policies that guide these actions, helping protect our environment and secure sustainable livelihoods for all.

# Introduction to Climate Change Policies

Climate change policies are the formal decisions, plans, and actions taken by governments at all levels to address the causes and impacts of climate change, for more resilient societies and ecosystems. Notable among the policies are the international Paris Agreement and Ghana's National Climate Change Policy. This week is devoted to examining how these policies are designed to address climate change, their implementation strategies and their impacts at both global and national levels.

## Key Climate Change Policy Dimensions

1. *Mitigation*: Involves policies that focus on reducing greenhouse gas emissions to limit climate change severity (e.g. shifting to renewable energy, promoting low-carbon transport).
2. *Adaptation*: Concerns actions to adjust systems and communities to the unavoidable impacts of climate change (e.g. climate-resilient infrastructure, early warning systems). Resilience-building: Broader strategies to enhance the capacity of communities and ecosystems to withstand, recover from, and transform in response to climate stresses.

## Policy Instruments

1. *Legal frameworks*: Laws, regulations, and standards that set climate targets and enforce compliance (e.g. national climate acts, emission caps).
2. *Economic incentives*: Tools like carbon taxes, subsidies for green technologies, and market-based instruments to encourage climate-positive investments.
3. *Regulatory standards*: Mandates for energy efficiency, land use, and emissions control to guide sectors and industries.
4. *Education programmes*: Awareness campaigns and training programmes to build understanding and support for climate action across society.

## Multi-Level Governance

1. *International*: Agreements like the Paris Agreement set global targets and coordinate national efforts.
2. *Regional*: Cooperation among neighbouring countries or regions to address shared climate challenges (e.g. African regional climate strategies).
3. *National*: National climate policies and strategies that translate global commitments into country-specific action plans.
4. *Local*: Local government and community-level initiatives tailored to local contexts and vulnerabilities.

## Evolution of Climate Change Policies

The global response to climate change has evolved from early scientific recognition in the 1980s to formal policy frameworks and national action plans today. Over time, climate change has become a central part of the global development and sustainability agenda.

1. **First wave: Scientific Assessment and Awareness (1980s – Early 1990s)**
   - **a.** The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 to assemble scientific evidence and raise global awareness.
   - **b.** Key scientific reports in this period laid the foundation for climate action, highlighting greenhouse gas emissions as a driver of global warming.
2. **Second wave: International Framework Development (1990s – 2000s)**
   - **a.** The United Nations Framework Convention on Climate Change (UNFCCC) was adopted in 1992, providing a legal basis for global cooperation.
   - **b.** The Kyoto Protocol (1997) introduced binding emission targets for industrialised countries, marking the first serious step toward emissions reduction.
3. **Third wave: Implementation and Nationally Determined Contributions (2010s – Present)**
   - **a.** The Paris Agreement (2015) shifted the focus to nationally determined contributions, where each country defines its own climate goals.
   - **b.** Countries began integrating climate action into national policies, focusing on mitigation (reducing emissions) and adaptation (managing impacts).
4. **Current trends: Integrated Approaches Linking Climate, Development and Sustainability**
   - **a.** Climate policies are now integral to achieving the Sustainable Development Goals (SDGs).
   - **b.** There is a push for nature-based solutions, green financing, and climate-resilient infrastructure.
   - **c.** Emerging focus on loss and damage and climate justice to protect vulnerable communities.
5. **United Nations Framework Convention on Climate Change (UNFCCC)**
   - **a. Establishment**

   The UNFCCC was adopted in 1992 during the Rio Earth Summit in Brazil and officially entered into force in 1994. It is the foundational treaty for global cooperation on climate change, and nearly all countries (198 parties) signed it.

### b. Objective

The UNFCCC aims to stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic (human-caused) interference with the climate system. This objective is intentionally broad to accommodate future scientific insights and policy frameworks.

### c. Key principles of the UNFCCC include

**i.** *Common but differentiated responsibilities*: Recognises that while climate change is a global challenge, developed countries (with historically higher emissions) have a greater responsibility to provide support to developing countries.

**ii.** *Intergenerational equity:* Stresses the rights and well-being of future generations when addressing climate change.

**iii.** *Precautionary principle*: Encourages preventing or minimising climate change impacts even in the absence of complete scientific certainty.

### d. Conference of the Parties (COP)

The COP is the supreme decision-making body of the UNFCCC. It convenes annually to review implementation progress, set new targets and negotiate international agreements (like the Kyoto Protocol in 1997 and the Paris Agreement in 2015). COP meetings also provide a platform for countries to share knowledge and build partnerships.

### e. Financing mechanisms

The UNFCCC established several financial support mechanisms to help developing countries mitigate and adapt to climate change:

**i.** *Global Environment Facility (GEF)*: Provides grants and concessional funding for climate projects in developing countries.

**ii.** *Special Climate Change Fund (SCCF):* Focuses on adaptation, technology transfer, and capacity building for vulnerable countries.

**iii.** Additional funding bodies (like the Green Climate Fund established later) also work to support the objectives of the UNFCCC.

## 6. Kyoto Protocol

The Kyoto Protocol was adopted in December 1997 in Kyoto, Japan, and entered into force in 2005. It set the legally binding greenhouse gas emission reduction targets for developed (Annex I) countries, averaging a 5.2 % cut below 1990 levels during its first commitment period (2008–2012). A second period (2013–2020) was agreed under the Doha Amendment but not fully ratified. To help achieve targets, the Protocol introduced flexibility mechanisms including the Clean Development Mechanism (CDM), Joint Implementation (JI) and emissions trading. Ghana, as a developing (non-Annex I) country, had no binding targets but benefits from CDM projects supporting sustainable development.

7. **Paris Agreement**

   Adopted in December 2015 at COP21 in Paris and entered into force in November 2016, the Paris Agreement aims at keeping the global temperature rise well below 2°C, striving for 1.5°C. Unlike the Kyoto Protocol, it requires all countries to submit Nationally Determined Contributions (NDCs), updated every five years to increase ambition. It commits developed nations to mobilise $100 billion annually for climate action in developing countries and establishes a common transparency framework. Although agriculture is not explicitly detailed, the Agreement recognises its links to food security, adaptation, and mitigation, with the Koronivia Joint Work on Agriculture later addressing agricultural climate actions.

## Ghana's National Climate Change Policies

Ghana has developed a comprehensive set of policies and plans to guide its response to climate change. These policies are:

### National Climate Change Policy (NCCP)

The NCCP was adopted in 2013 as Ghana's primary policy document for addressing climate change. It sets the strategic direction for climate-related actions and guides national, regional, and local-level efforts. The policy envisions Ghana as a climate-resilient and climate-compatible economy, capable of achieving sustainable development while addressing climate change challenges. The NCCP is built on five key pillars:

1. ***Governance and coordination:*** Establishing robust institutional structures and ensuring effective stakeholder collaboration for climate action.
2. ***Science, technology and innovation:*** Harnessing research, technology transfer and innovation to support climate resilience and reduce emissions.
3. ***Finance:*** Mobilising both domestic and international climate finance to implement climate actions and build resilience.
4. ***International cooperation:*** Promoting Ghana's engagement in global climate processes and fostering partnerships for effective implementation.
5. ***Adaptation and mitigation***: Integrating climate actions into priority sectors (such as agriculture, forestry, energy, and water resources) to reduce emissions and manage climate risks.

### Ghana's Nationally Determined Contributions (NDCs) on Agriculture

Recognising the importance of agriculture for livelihoods on the one hand, and climate-harming emissions from agricultural activities, Ghana prioritises climate-smart agricultural practices, including:

1. **Modified community-based conservation agriculture:** Promoting sustainable soil and water management while improving yields.
2. **Livestock emission reduction through feed improvement:** Enhancing feed quality to reduce enteric fermentation and methane emissions.
3. **Rice straw composting and biogas production:** Turning rice residues into valuable resources, reducing emissions from burning or decomposition.
4. **Climate-smart agriculture in 43 administrative districts:** Scaling up sustainable practices to enhance resilience and reduce vulnerability across a significant portion of the country.
5. **Savannah restoration and sustainable forest management**: Restoring degraded lands and conserving forest ecosystems to increase carbon sinks and improve local livelihoods.

## National Adaptation Plan

Ghana's National Adaptation Plan (NAP) provides a structured, multi-sectoral, and participatory framework to address medium- and long-term climate adaptation needs by integrating them into national development planning. Prioritising the agriculture sector, the NAP promotes drought-resistant crops, improved irrigation, livelihood diversification, early warning systems, and sustainable land management to build resilience and reduce vulnerability to climate change.

## Activity 7.1 Exploring Climate Change Policies

This activity is about exploring different global and national climate change policies.

### Steps

1. Search online or use your learner material to find
   - At least 3 global climate change policies
   - At least 3 national climate change policies for Ghana
2. Write a report using the template below

### REPORT TEMPLATE

**A.** Introduction

(Why do we need policies to fight climate change? How can these policies help people and the environment?) Write 2–3 sentences

**B.** Global climate change policies (Policy name, year started, purpose)

| Policy Name | Year Started | Purpose |
|---|---|---|
| i | | |
| ii | | |
| iii | | |

**C.** National climate change policies for Ghana

(Policy name, year started, purpose)

| Policy Name | Year Started | Purpose |
|---|---|---|
| i | | |
| ii | | |
| iii | | |

**D.** Implementation Check

*(Is the policy working well? Good results? Challenges?)*

**E.** Suggestions

*(How can the policy work better? New ideas?*

**F.** Conclusion

*(Why is it important to have strong climate change policies?)*

3. Turn your report into a poster presentation or short PowerPoint presentation capturing introduction, body (Hint: Use the content captured in the report template from B to E) and conclusion to share with the class.
4. Share your work with your classmates. Listen to others and note similarities and differences in findings.

# THE REDD+ STRATEGY ON CLIMATE CHANGE

## Definition and Evolution of REDD+

REDD+ stands for Reducing Emissions from Deforestation and Forest Degradation, plus conservation, sustainable management of forests, and enhancement of forest carbon stocks. The historical development of REDD+ includes:

1. **RED (2005):** Initially focused only on reducing emissions from deforestation.
2. **REDD (2007):** Expanded to include forest degradation.
3. **REDD+ (2009):** Further broadened to encompass conservation, sustainable forest management, and the enhancement of forest carbon stocks.

The core concept of REDD+ revolves around performance-based payments for measurable forest carbon outcomes. Globally, REDD+ is under the umbrella of the United Nations Framework Convention on Climate Change (UNFCCC).

## The Three Phases of REDD+ Implementation

REDD+ is implemented in phases. The phases develop progressively to ensure countries are fully prepared, piloted, and equipped for performance-based carbon payments.

### Phase 1(Readiness)

This involves developing national policies, building institutional capacity, creating governance structures, and preparing a REDD+ strategy with stakeholder consultations, safeguards, baselines, and forest monitoring systems to lay a strong foundation for REDD+ implementation.

### Phase 2 (Implementation)

This focuses on pilot projects and demonstration activities, developing incentive mechanisms and benefit-sharing, strengthening governance, clarifying tenure, and addressing capacity gaps to put REDD+ plans into practice while delivering co-benefits.

### Phase 3 (Results-Based Payments)

The objective of this phase is to provide sustainable, performance-based funding to maintain long-term emission reductions and forest management efforts. This phase involves full-scale implementation of REDD+ activities across the country or selected landscapes, including measurement, reporting and verification (MRV) systems to quantify emission reductions and removals accurately. Results-based finance (RBF) – payments are made based on verified emission reductions (e.g. through carbon markets or international donors). Ensuring social and environmental safeguards are met during implementation.

## Ghana's Current Status: Transitioning from Phase 2 to Phase 3

1. Ghana has completed the readiness phase, including the formulation of its REDD+ Strategy and development of robust forest monitoring and safeguard systems.
2. Ghana has implemented several demonstration and pilot activities, notably through the Ghana Cocoa Forest REDD+ Programme (GCFRP) in the high forest zone, which addresses deforestation in cocoa landscapes.
3. Currently, Ghana is transitioning into Phase 3 in selected landscapes. This involves moving towards results-based payments for verified emission

reductions, such as through its partnership with the World Bank's Forest Carbon Partnership Facility (FCPF) Carbon Fund.

4. Ghana has already received payments for verified emission reductions under the FCPF Carbon Fund, indicating early steps into Phase 3.

## Ghana's Forest Context and Drivers of Deforestation

Ghana's biodiverse forests are crucial for livelihoods and the economy but are under severe threat from deforestation and degradation, which affect the ecosystems, carbon stocks, and dependent communities. These pressures mainly stem from direct human activities. This includes:

1. **Agricultural Expansion**

   Agriculture is the largest driver, responsible for 50-60 % of forest loss. It occurs through:

   a. ***Cocoa farming***: Cocoa cultivation is a major economic activity in Ghana's forest zones. The shift to full-sun cocoa varieties (as opposed to shade-grown cocoa) significantly increases forest clearing to create open farms for higher yields. Full-sun cocoa farms deplete soil fertility quickly and require continuous expansion into forest areas.

   b. ***Food crop cultivation:*** Traditional slash-and-burn methods are still widely practised. In this system, farmers clear forest land by cutting and burning vegetation to create temporary farmland. Soil fertility declines rapidly, forcing farmers to move to new forest areas and this results in continuous forest loss.

   c. ***Oil palm plantations***: Expansion of oil palm as a cash crop also drives deforestation, especially in forested areas with good rainfall. This often involves large-scale clearing of forest land for monoculture plantations.

2. **Logging**

   Both legal and illegal logging contribute significantly to forest degradation (about 15-20 %). Legal timber extraction is regulated but often poorly monitored, while illegal logging is widespread, driven by domestic demand and export. Selective logging degrades forests by opening canopies and fragmenting habitats, even if it does not fully clear forest cover.

3. **Fuelwood and charcoal production**

   In Ghana, fuelwood and charcoal remain the primary energy sources for about 76 % of households (especially in rural and peri-urban areas). Trees are cut to meet this demand, leading to gradual forest degradation, especially around communities.

4. **Mining activities**

   Both legal large-scale mining and illegal small-scale (galamsey) operations destroy large stretches of forest cover. Illegal mining is particularly devastating

due to the use of excavators and other heavy equipment to clear forests, which disturbs river courses and degrades soils.

5. **Infrastructure development**

   Road construction, settlements and energy projects (e.g. hydropower, transmission lines) result in permanent forest loss. Roads, for example, provide access to previously remote forests, enabling further encroachment for agriculture, logging, or mining. Urban expansion and settlements continue to eat into forest margins.

## Underlying Causes of Deforestation and Forest Degradation

The direct drivers of deforestation and forest degradation are fuelled by deeper, systemic issues that make forest loss persistent and difficult to reverse. Some of the underlying causes are:

1. **Economic factors**

   Economic factors that drive deforestation and degradation include:

   a. ***Poverty***: Many rural communities rely heavily on forest resources for survival, such as fuelwood, hunting and farming.

   b. ***Market demand:*** High demand for commodities like cocoa, timber and charcoal encourages forest clearing.

   c. ***Limited alternative livelihoods***: Without viable income options, communities continue these unsustainable activities.

2. **Policy and governance issues**

   Policy and governance issues that directly drive deforestation and degradation are:

   a. ***Weak enforcement:*** Forestry laws exist, but they're not fully enforced, especially in remote areas.

   b. ***Unclear land tenure:*** Confusion about forest and land ownership discourages sustainable management.

   c. ***Policy inconsistencies:*** Agricultural policies can conflict with forest conservation efforts.

3. **Demographic pressures**

   Demographic factors that promote deforestation and degradation are:

   a. ***Population growth:*** Increasing demand for land and resources as the population expands.

   b. ***Migration***: Movement to forest frontiers for farming and jobs adds pressure on forest areas.

4. **Technological factors**

   Limited access to intensification technologies also leads to deforestation and degradation. For example, farmers often lack tools and know-how for greater yields on existing farmland, leading to forest clearing to expand their farms.

5. **Cultural practices**

   Some cultural practices also promote deforestation and degradation in Ghana. These include:

   a. ***Traditional farming methods:*** Slash-and-burn, shifting cultivation and open burning are common traditional practices that contribute significantly to deforestation and degradation in Ghana

   b. ***Land management approaches***: Long-standing norms often prioritise short-term gains over long-term sustainability.

### Activity 7.2 Exploring REDD+ and its phases

This activity is about exploring the REDD+ strategy and its phases.

1. Explore the learner material or search online using trusted sources to understand what the REDD+ strategy means and how its different phases work.
2. Write down relevant notes on:
   a. Definition of REDD+ Strategy
   b. The three phases of REDD+ Implementation
3. Discuss the REDD+ strategy and the phases in the strategy with your classmates

# INTRODUCTION TO ANIMAL WELFARE

## Meaning and Importance of Animal Welfare

Animal welfare refers to the physical and mental state of animals concerning the conditions in which they live and die. It encompasses how an animal copes with its environment, including its health, comfort, nutritional status, safety, ability to express natural behaviours and freedom from distress, pain and suffering. In animal production, welfare includes providing proper nutrition, shelter, disease prevention, humane handling and freedom from stress.

## Importance of Animal Welfare in Animal Production

1. **Ethical considerations**: That animals are capable of experiencing pain, suffering and exhibiting positive states.
2. **Productivity and economics**

   Better welfare results in:

   **a.** higher growth rates and production levels

   **b.** improved reproduction rates

   **c.** lower disease incidence and mortality

   **d.** reduced veterinary costs

   **e.** Better quality animal products
3. **Food safety and public health**

   Poor welfare increases stress, which can:

   **a.** Compromise immune function

   **b.** Increase disease susceptibility

   **c.** Elevate the risk of zoonotic disease transmission

   **d.** Lead to higher antimicrobial drug use, contributing to resistance
4. **International trade**

   Meeting welfare standards is increasingly important for:

   **a.** Access to export markets

   **b.** Compliance with trade requirements

   **c.** Meeting consumer expectations in global markets

## The Ghanaian Context of Animal Welfare

The traditional animal production systems in Ghana:

1. often provide some aspects of good welfare (free-range, natural behaviours)
2. is creating new welfare challenges due to the intensification of production
3. is witnessing increasing demand for animal welfare assurances from the growing middle class
4. are sometimes at odds with modern welfare concepts
5. is balancing improved productivity with welfare considerations

## The Five Freedoms of Animal Welfare

The Five Freedoms framework, developed by the UK Farm Animal Welfare Council, provides a comprehensive approach to assessing animal welfare. In Ghana, these principles are increasingly recognised as benchmarks for animal production practices. ***Table 7.2*** shows the five freedoms of animal welfare, the Ghanaian context and its application.

***Table 7.2***: The Five Freedoms of Animal Welfare

| SN | Freedom of Animal Welfare | Weaknesses in the Ghanaian Context | Responses/Application |
|---|---|---|---|
| 1. | Freedom from hunger and thirst (Ready access to fresh water and a diet to maintain health and vigour) | • Seasonal feed and water shortages during dry seasons<br>• Limited knowledge of feed quality and nutrition among smallholders<br>• Water accessibility challenges in rural production systems<br>• Free-range systems often require animals to forage extensively | • Development of drought resistant fodder crops<br>• Training in balanced ration formulation using local ingredients<br>• Water harvesting and storage systems for livestock |
| 2. | Freedom from discomfort (Appropriate environment including shelter and comfortable resting areas) | • Extreme temperatures (particularly in the northern regions)<br>• Limited housing infrastructure in smallholder systems<br>• Inappropriate flooring and bedding materials<br>• Overcrowding in some intensive systems | • Low-cost, locally- appropriate housing designs<br>• Shade provision in pastoral systems<br>• Ventilation improvements in intensive units<br>• Appropriate stocking density guidelines |
| 3. | Freedom from pain, injury, and disease (Prevention, rapid diagnosis and treatment) | • Limited veterinary services in rural areas<br>• High prevalence of preventable diseases<br>• Traditional practices like branding and castration without anaesthesia<br>• Insufficient biosecurity measures | • Community-based animal health workers<br>• Vaccination programmes for endemic diseases<br>• Training in humane handling and management<br>• Improved access to veterinary pharmaceuticals |
| 4. | Freedom to express normal behaviour (Sufficient space, proper facilities, and company of the animal's kind) | • Traditional systems often allow natural behaviours<br>• Increasing confinement in peri-urban production<br>• Tethering practices limit movement<br>• Social isolation in some production systems | • Promoting appropriate group housing<br>• Enrichment in confined systems<br>• Balancing free-range benefits with protection needs<br>• Education on the behavioural needs of different species |

| | | | |
|---|---|---|---|
| 5. | Freedom from fear and distress (Ensuring conditions and treatment that avoid mental suffering) | • Rough handling during transportation<br>• Stressful marketing and slaughter practices<br>• Mixed-species housing, causing fear<br>• Limited understanding of animal psychology | • Training in low-stress handling techniques<br>• Improved transport conditions<br>• Humane slaughter methods<br>• Separation of species where appropriate |

# National and International Laws and Regulations Governing Animal Welfare

Both national and international laws and regulations play a vital role in setting standards for the humane treatment of animals. In Ghana, animal welfare is addressed through:

## Ghana's National Legal Framework

### Current legislation

1. ***Animals (Control of Importation) Ordinance (Cap 247):*** Controls animal imports but has limited welfare provisions
2. ***Criminal Offences Act, 1960 (Act 29):*** Section 47 prohibits the cruel treatment of animals
3. ***Veterinary Surgeons Law, 1992 (PNDC Law 305):*** Regulates veterinary practice, including animal treatment
4. ***Diseases of Animals Act, 1961 (Act 83):*** Focuses on disease control but includes some welfare aspects
5. ***Local Government Act, 2016 (Act 936):*** Empowers district assemblies to make bylaws on animal keeping

### Policy frameworks

1. ***Livestock Development Policy and Strategy (2016):*** Incorporates animal welfare as a component of sustainable livestock development
2. ***Ghana Veterinary Services Strategic Plan***: Includes welfare considerations in veterinary service delivery
3. ***Food and Agriculture Sector Development Policy (FASDEP II)***: References animal welfare in livestock production

## Gaps and challenges in Ghanaian animal welfare laws

1. Lack of comprehensive animal welfare legislation
2. Outdated legal provisions not reflecting current scientific understanding of animal welfare
3. Limited enforcement mechanisms and resources
4. Inadequate penalties for welfare violations
5. Fragmented responsibility across multiple agencies

# International Regulations

1. **The World Organisation for Animal Health (WOAH)**

   WOAH sets internationally recognised standards and guidelines for animal health and welfare. Its standards cover various aspects of animal care, including housing, feeding, transport, and slaughter. Member countries are encouraged to adopt these guidelines to ensure humane treatment of animals and facilitate safe international trade in animals and animal products.

2. **The European Union (EU)**

   The EU has some of the most stringent animal welfare laws in the world. These regulations cover the entire lifecycle of animals - from rearing and housing conditions to transportation and slaughter practices. The EU mandates minimum space requirements, bans certain harmful practices (e.g. battery cages for laying hens), and enforces regular inspections to ensure compliance.

3. **The Universal Declaration on Animal Welfare (UDAW)**

   UDAW is a proposed global agreement supported by various governments and organisations, aimed at recognising animals as sensitive beings and promoting their welfare worldwide. Although not legally binding, it seeks to encourage countries to adopt and improve animal welfare laws and policies in line with internationally accepted principles.

4. **Other international frameworks on animal welfare**

   a. *UN Sustainable Development Goals (SDGs):* Animal welfare is directly or indirectly woven into SDGs like Zero Hunger (2), Good Health (3), Responsible Consumption (12), and Life on Land (15), with the plea to promote sustainable and ethical livestock practices.

   b. *FAO Good Agricultural Practices (GAP):* These guidelines integrate animal welfare into sustainable farming systems, emphasising health, nutrition, and humane treatment.

   c. *ISO Technical Specification on Animal Welfare Management*: A voluntary global standard that helps organisations implement structured animal welfare practices across the supply chain.

**d.** *World Trade Organisation (WTO):* While not regulating welfare directly, WTO acknowledges animal welfare in trade policies, especially regarding sanitary and phytosanitary (SPS) measures.

## Regional Agreements on Animal Welfare

1. **African Union Animal Health Strategy:** Integrates animal welfare into broader animal health and disease control efforts, promoting humane treatment as part of sustainable livestock development across Africa.
2. **ECOWAS Agricultural Policy (ECOWAP):** Highlights the importance of animal welfare in regional livestock trade and production systems, aiming to harmonise welfare standards among West African states.
3. **African Platform for Animal Welfare (APAW):** Serves as a regional coordination mechanism to advocate, harmonise, and implement animal welfare policies and practices across African countries.

## The Role of Government Agencies in Enforcing Animal Welfare Laws

1. **Veterinary Services Directorate (Ministry of Food and Agriculture)**

   Lead agency for animal health and welfare in Ghana. Its specific functions are:

   **a.** Enforcement of existing welfare regulations

   **b.** Inspection of animal production facilities

   **c.** Regulation of animal transport and markets

   **d.** Disease surveillance and control.

   **e.** Training and certification of slaughterhouse workers

2. **Environmental Protection Agency (EPA)**

   The agency plays the following roles in Animal Welfare in Ghana:

   **a.** *Environmental impact assessment of livestock facilities:* The EPA assesses the environmental impact of livestock farms, ensuring that animal housing and farming operations meet welfare standards.

   **b.** *Pollution control in animal production*: It monitors emissions such as ammonia and greenhouse gases from animal farms to ensure they do not reach levels that can affect both animal and human health.

   **c.** *Waste management standards affecting animal housing*: The agency enforces proper manure management practices to maintain hygienic conditions in animal housing.

### 3. Ghana Standards Authority (GSA)

GSA's roles in ensuring animal welfare are:

**a.** *Development of standards for animal products:* GSA formulates national standards to ensure the safety, quality, and humane handling of animal-derived products such as meat, milk and eggs, aligning with international best practices.

**b.** *Welfare certification schemes:* It implements certification programmes that incorporate animal welfare criteria, ensuring that production systems meet ethical and hygienic requirements.

**c.** *Inspection of production facilities for compliance*: GSA inspects farms, abattoirs and processing units to verify adherence to established standards, including those related to animal health, housing, and treatment.

### 4. Local Government Authorities

They are responsible for:

**a.** *Enforcement of by-laws on animal keeping*: Local governments implement and enforce municipal by-laws regulating the proper care, housing, and number of animals kept within communities to promote welfare and public health.

**b.** *Licensing of animal businesses*: They issue licenses to animal-related businesses such as farms, veterinary clinics and pet shops, ensuring compliance with welfare and operational standards.

**c.** *Management of public slaughter facilities*: Local authorities oversee the operation and hygiene of public abattoirs, ensuring animals are handled and slaughtered humanely, and facilities meet safety standards.

**d.** *Control of stray animals*: They are responsible for managing stray animal populations through capture, sheltering, and public awareness campaigns to prevent cruelty and disease transmission.

### 5. Universities and Research Institutions

Universities and research institutions in Ghana play a key role in promoting animal welfare through:

**a.** *Research on animal welfare issues*: Conduct studies on animal behaviour, health, housing and stress to inform evidence-based welfare improvements.

**b.** *Training of animal science and veterinary students*: Integrate animal welfare principles into curricula to equip future professionals with knowledge and ethics.

**c.** *Development of context-appropriate welfare assessment tools*: Design tools tailored to local farming systems for evaluating animal well-being under Ghanaian conditions.

**d.** *Extension services to farmers*: Provide outreach and training to farmers on humane animal handling, housing, and health management practices.

## Challenges in Enforcing Animal Welfare Issues

1. **Limited legal authority for prosecution:** Weak or outdated laws and limited enforcement powers hinder effective legal action against animal cruelty.
2. **Resource constraints for regular inspections**: Insufficient funding, personnel, and logistics limit the ability to conduct routine monitoring and enforcement.
3. **Competing priorities within enforcement agencies:** Agencies often prioritise public health and safety over animal welfare due to limited capacity and broad mandates.
4. **Cultural and economic barriers to compliance:** Traditional practices and financial limitations may conflict with modern animal welfare standards.
5. **Lack of awareness among producers and consumers**: Many stakeholders are unaware of welfare principles, reducing motivation for humane practices and consumer demand for ethically produced products.

## Vegetarianism

Vegetarianism is the practice of not eating meat and, in some cases, other animal products. It is often motivated by:

1. **Animal welfare concerns:** Many vegetarians believe that avoiding animal products helps reduce cruelty and exploitation in industrial farming systems.
2. **Environmental reasons:** Livestock farming contributes to deforestation, greenhouse gas emissions and water pollution.
3. **Health benefits:** Some people adopt vegetarian diets to reduce the risk of chronic diseases such as obesity, heart disease and diabetes.
4. **Cultural or religious beliefs:** In some traditions, non-violence and respect for all life forms encourage plant-based diets.

## Vegetarianism in the Ghanaian Context and Cultural Attitudes

In Ghana, vegetarianism is influenced by cultural, social, and religious beliefs. While not widely practised as a formal lifestyle choice, many elements of traditional Ghanaian life naturally align with plant-based eating:

1. **Traditional diets are often plant-based**

   Historically, many Ghanaian meals have centred around plant-based staples such as *cassava*, yam, plantain, rice, beans, and leafy vegetables. Animal protein, when used, is often served as a supplement rather than the main focus of the meal. This naturally encourages a semi-vegetarian dietary pattern, especially in rural areas.

2. **Cultural significance of animal products**

   Despite the plant-heavy diet, meat and fish hold symbolic and social value**.** In traditional ceremonies – such as funerals, naming ceremonies, festivals, and weddings – animal products (e.g., goat, chicken, fish) are often considered essential for hospitality and status. This has contributed to the perception that a meal is incomplete or less prestigious without meat.

3. **Religious influences**

   Some religious groups in Ghana promote vegetarianism as part of their beliefs and practices. For example, Seventh-Day Adventists, who have a notable presence in Ghana, advocate for vegetarianism on both health and spiritual grounds. This has helped raise awareness of the benefits of plant-based diets in certain communities.

## Importance of Vegetarianism in Animal Welfare

1. **Reduction in animal slaughter**

   Every year, millions of animals are slaughtered for human consumption. Many of these animals are raised in inhumane conditions. Vegetarianism reduces the need to kill animals, helping to protect their right to life.

2. **Reduction in cruel farming practices**

   In industrial livestock systems, animals are often confined in small, overcrowded spaces, painful procedures without anaesthesia (e.g., debeaking, tail docking) and stressful transportation and slaughter methods. A vegetarian diet reduces these practices.

3. **Promotion of humane treatment**

   Vegetarianism supports the idea that animals are beings that feel pain, stress, and exhibit fear, and should not be subjected to unnecessary suffering. It encourages respect for animal life and promotes the development of more ethical food systems.

4. **Encouragement of sustainable and ethical alternatives**

   The rise in vegetarianism encourages innovation in plant-based meat alternatives and ethical farming practices.

   This shift leads to a reduction in factory farming, where most welfare abuses occur.

## Activity 7.3 Animal Welfare in a Changing Climate

Get ready to dive into how we care for animals in a changing climate—let's explore, create, and share your best ideas!

1. Explore the learner material or search online using trusted sources to understand animal welfare and climate change
2. Take notes on key points like what animal welfare means and how climate change affects animals
3. Pair up with a classmate and discuss these questions:
   - **a.** What is animal welfare?
   - **b.** Why is it important, especially now with climate change?
   - **c.** How can people protect animals when the climate is changing?
4. Write down the main points from your group's discussion.
5. Design a simple poster or slide that shows:
   - **a.** The meaning of animal welfare
   - **b.** Why it's important in the light of climate change
   - **c.** At least one idea to protect animals in changing weather
6. Share your poster or slide with the class
7. Listen to other classmates and compare ideas.

# REVIEW QUESTIONS

1. Agriculture in Ghana depends heavily on weather and climate. Changes in rainfall, rising temperatures, and extreme weather events affect crops, livestock, and rural livelihoods. Global and national climate change policies aim to reduce these threats and support sustainable farming. Analyse how global and national climate change policies are influencing agriculture in Ghana.
2. Ghana's REDD+ programme is guided by a clear structure to ensure smooth planning, funding, and monitoring. Different institutions work together to make REDD+ successful at both national and local levels. Describe the governance structure for REDD+ in Ghana and the roles of key institutions.
3. Both government bodies and non-governmental organisations play important roles in protecting animals. Understanding how they work helps us appreciate how animal welfare is enforced in Ghana. Compare the roles of the Veterinary Services Directorate and non-governmental organisations in enforcing animal welfare standards.

# ANSWERS TO REVIEW QUESTIONS

## Section 1

1. Refer to the content on *procedure of budding and grafting in the learner material*.

2. Budding and grafting, and the mini-sett technique are both vegetative propagation methods, but they differ significantly in their procedures, crop focus, and overall impact.

   **a.** Procedure

   - Budding and grafting involve joining a scion (bud or stem) from a desired fruit tree variety to a compatible rootstock, ensuring the cambium layers align for fusion. The process includes preparation of both plant parts, insertion or joining, securing with binding materials, and aftercare.
   - The mini-sett technique, on the other hand, involves cutting yam tubers into small setts (50–100g), treating them to prevent rot, and planting them directly in the field. It does not involve joining plant parts.

   **b.** Crop type

   - Budding and grafting are used for perennial fruit crops such as mango, citrus, and avocado.
   - The mini-sett technique is used exclusively for yam, a tuber crop.

   **c.** Effectiveness in improving yield and quality

   - Budding and grafting improve tree crop productivity by combining traits such as disease resistance, early maturity, and high fruit quality, while also allowing the propagation of specific cultivars.
   - The mini-sett technique increases seed availability, reduces wastage of yam tubers, and improves germination rates, leading to higher yields and better planting efficiency in yam production.

## Section 2

1.

   **a.** Critical analysis of potential impacts

   **Ecological impacts**

   Integrating bee-keeping with cashew production can greatly improve pollination through increased pollinator density and diversity, resulting

in significantly higher fruit set and reinforcing beneficial plant-pollinator relationships. While managed honeybees (Apis mellifera) offer substantial pollination benefits, relying solely on them may risk ecological imbalance; therefore, supporting both managed and native pollinators is essential for system resilience. Establishing bee-keeping also calls for habitat enhancement measures—such as maintaining flowering understory plants and hedgerows—which not only support diverse pollinator species but also boost other ecosystem services like natural pest control, improved soil health, and enhanced nutrient cycling. Research from similar environments suggests that such habitat improvements can reduce pest pressure by supporting populations of natural enemies.

**Economic impacts**

The integration offers substantial benefits through multiple mechanisms. Integrating bee-keeping with cashew production in Ghana is expected to boost yields through enhanced pollination, leading to increased fruit set, reduced fruit drop, and improved quality, with studies from similar environments suggesting potential yield gains of 15–25%. While initial investment and annual management costs are considerable, the financial returns from improved crop output and honey production—supplemented by secondary products like beeswax and propolis—provide opportunities for economic diversification and resilience. Success relies on tailored business models such as individual ownership, cooperatives, or specialised pollination services. Socially, the approach requires extensive farmer training, effective extension services, and careful labour management, especially during peak cashew periods. Cooperative management can strengthen community ties, but successful adoption depends on robust local organisation and sensitivity to traditional cultural attitudes towards bees.

**b.**

- Climate change presents significant threats to the proposed bee-keeping integration through multiple pathways.
- Rising temperatures affect both cashew flowering physiology and bee behaviour. Research indicates that temperatures exceeding 38°C reduce honeybee foraging activity by 50-80%, while also accelerating nectar desiccation in mango flowers, reducing their attractiveness to pollinators.
- Changing precipitation patterns may disrupt the synchrony between peak mango flowering and optimal colony strength, particularly if unseasonal rains during flowering prevent effective foraging flights.
- Increased climate variability also threatens the stability of both systems. More frequent extreme weather events, including prolonged droughts and intense storms, directly impact honey bee forage availability throughout the year. Changes in temperature and humidity profiles may alter the prevalence and distribution of bee diseases and pests, with potential

emergence of new threats as ecological relationships shift. Mango flowering may become less predictable, making it difficult to time colony build-up appropriately.

- Effective adaptation requires implementing strategies at multiple levels. At the bee management level, adaptations should include selecting and breeding for heat tolerant honeybee strains, incorporating genes from adapted local populations. Hives must be modified by enhancing ventilation, providing shade, and ensuring water availability within 100 m of all hives.
- For orchard management, establishing diverse flowering hedgerows using drought-adapted species creates a critical alternative area of forage during stress periods. The plant species should be selected with emphasis on plants with different climate responses to ensure resource availability under various scenarios. Irrigation infrastructure should be provided or upgraded to include water-efficient delivery systems that can support both mango trees and bee forage plants during drought periods.
- System diversity enhances resilience to climate variability. Beyond honeybees, the programme should support multiple pollinator species through habitat enhancement targeting various nesting requirements and foraging preferences. Mango variety diversification, incorporating cultivars with different flowering periods and climate tolerances, reduces the risk of complete pollination failure in abnormal weather years.
- Knowledge systems must also adapt to changing conditions. Establishing phenological monitoring programmes where farmers track and share flowering times, bee activity patterns, and weather events would build a district-level early warning system for potential mismatches. This could be enhanced through digital platforms, allowing real-time information sharing and coordinated responses across the landscape.
- The most resilient approach should include adaptive management principles, where interventions are treated as learning opportunities. Regular assessment of outcomes against changing climate parameters would inform continuous adjustment in the system. Building this adaptive capacity requires not just technical solutions but strengthening social networks for knowledge sharing and collaborative problem-solving as new challenges emerge in this complex social-ecological system.

## Section 3

**1.**

**a.** Tool/App: Google Earth or AgriGIS

***How it helps***

- Google Earth allows people to view and measure their farm size using satellite images.

AgriGIS helps them draw boundaries, plan layouts, and map soil types or irrigation lines.

This reduces the need to measure land manually with tape or sticks, saving time and energy.

**b.** Tool/App: Plantix (Mobile App)

***How it helps***

- Plantix allows farmers to take a photo of a sick plant and get instant diagnosis of pests or diseases.
- It also gives advice on treatment, such as the correct pesticide or natural control method.
- This reduces guesswork, helps prevent crop loss, and avoids wasting money on the wrong chemicals.

**c.** Tool/App: Facebook Marketplace/WhatsApp Business App

***How it helps***

- These platforms help people to advertise and connect with buyers easily without travelling far.
- They can upload photos, list prices, and receive calls or messages from customers.
- This saves transport costs and time and gives them wider market access.

**2.**

**a.** How weather apps and sensors help farmers

- Weather apps show daily forecasts (rain, sun, wind) on phones.
- Sensors check soil moisture, rainfall, and temperature on the farm.
- These tools give accurate, up-to-date weather information to help farmers plan their work.

**b.** Farming decisions improved by good weather information

- **Planting**: Know the right time to plant before rain starts.
- **Watering**: Avoid watering when rain is coming—save time and water.
- **Harvesting**: Pick crops before rain spoils them.
- **Pest control:** Know when weather conditions may cause pest attacks.

**c.** How the tools reduce labour and stress

- No need to walk far or guess—Apps and sensors do the thinking.

- Farmers worry less about crop loss from bad weather.
- Saves energy, time, and money.

**d.** Challenges in rural areas

- Some farmers don't have smartphones or Internet.
- Some don't know how to use the Apps or tools.
- Weather sensors can be expensive to buy.
- Some farmers may not trust new technology at first.

## Section 4

**1.** Refer to the content on *soil formation processes*.

**2.** Steps involved in conducting a field investigation of a soil profile and how each soil horizon is identified.

- **Site selection and pit preparation:** A pit measuring about 2 m x 1 m x 1 m is dug with one clean vertical wall to expose the soil layers clearly.
- **Observation of soil horizons:** Observe differences in colour, texture, composition, and moisture content to distinguish layers. For example,

  *O horizon:* Dark, organic-rich top layer made of decomposed matter.

  *A horizon (Topsoil):* Dark brown with high humus, fertile and loose in texture.

  *B horizon (Subsoil):* More compact, often reddish or yellow due to accumulation of iron and clay.

  *C horizon*: Made of partially weathered parent material, coarse and stony.

  *D horizon:* Unweathered bedrock, hard and solid.
- **Recording findings:** A labelled diagram of the soil profile is drawn, and group observations are written into a report, including inferences about soil fertility and structure.

**3.** The formation of soil profiles in different environments is influenced by the combined action of five major factors: parent material, climate, organisms, topography, and time. These factors interact in complex ways to shape the depth, structure, and fertility of soil.

- Parent material provides the basic mineral content of the soil. For example, soils formed from volcanic rocks tend to be rich and fertile, while those from quartz-rich rocks may be sandy and nutrient-poor.
- Climate plays a key role in the rate of weathering and leaching. Warm, wet climates support faster chemical weathering and deeper soil development, while cold or dry climates slow these processes.

- Organisms, including plants, animals, and microorganisms, contribute to soil development by decomposing organic matter, mixing soil layers, and releasing acids that break down rock.
- Topography affects drainage and erosion. Soils on flat land develop more fully, while those on steep slopes are thinner due to runoff and erosion.
- Time allows these factors to act continuously. Older soils usually have more distinct horizons and are better developed than younger ones.

Together, these factors determine how soils differ across landscapes. For example, a tropical lowland area may have deep, red soils rich in iron due to long-term leaching and high rainfall, while a steep, rocky hillside may have shallow, undeveloped soils with visible bedrock.

**4.** Refer to the content on *physical properties of soil (texture and structure)*

**5.** Refer to the content on *physical properties of soil (texture and structure)*

**6.** Soil structure and texture are two critical physical properties that significantly influence a farmer's decision-making regarding land preparation, irrigation, and crop selection. These properties determine how soil holds water, supports root growth, and responds to tillage.

- **Land preparation**

  Soil texture and structure play a critical role in a farmer's decision-making during land preparation. Sandy soils, being light and coarse, are easy to till but often lack cohesion and nutrient retention, while clayey soils, though nutrient-rich, are dense and difficult to work, especially under extreme moisture conditions. Loamy soils offer the ideal balance for tillage due to their moderate texture. In parallel, soil structure influences aeration and compaction—granular and crumb structures enhance root penetration and ease of tillage, whereas massive or platy structures restrict these processes due to poor porosity and compaction. Therefore, understanding both properties helps farmers choose the most suitable soil management practices for optimal crop growth and productivity.

- **Irrigation planning**

  Soil texture and structure significantly influence irrigation planning and water management in agriculture. Sandy soils, with large particles and wide pores, drain quickly and require frequent but light irrigation to prevent water loss and drought stress. In contrast, clayey soils have fine particles that retain moisture longer, demanding less frequent yet carefully controlled watering to avoid waterlogging. Additionally, soil structure, such as blocky or prismatic, impacts water movement—promoting vertical infiltration while restricting lateral spread. By evaluating both texture and structure, farmers can design irrigation schedules that optimise water use efficiency and support healthy plant growth across different soil types.

- **Crop selection**

  Soil texture and structure play a crucial role in guiding farmers' crop selection. Root crops like groundnuts and carrots thrive in sandy or loamy soils, which offer loose texture and adequate aeration for root development. Conversely, clayey soils, known for high water retention, are better suited for water-loving crops such as rice or sugarcane, especially in regions with frequent flooding. Crops like vegetables and maize perform well in loamy soils with granular or crumb structures that ensure both drainage and moisture retention. For instance, a farmer in the savanna zone may favour groundnuts with drip irrigation on sandy soil, while another in a riverine clay-rich area might grow rice using raised beds to control excess moisture. In horticulture, loamy soils with crumb structures are preferred for supporting deep root growth and nutrient efficiency.

## Conclusion

A clear understanding of soil texture and structure empowers farmers to make informed decisions that directly impact agricultural success. By selecting crops that match the physical characteristics of the soil, optimising land preparation and tillage practices, and designing efficient irrigation systems, farmers can improve crop yields while conserving resources. Ultimately, this knowledge fosters more sustainable and resilient farming systems tailored to diverse environmental conditions.

**7.** B

**8.** A

**9.** D

**10.** D

**11.** D

**12.** A

**13.** C

**14.** D

**15.** D

**16.** A

**17.** Soil organic matter improves nutrient availability in sandy soil by:

- **Enhancing nutrient retention:** It holds onto essential nutrients (like nitrogen, phosphorus, and potassium) that would otherwise leach away in sandy soils.
- **Boosting microbial activity:** Organic matter feeds soil microbes that help break down organic materials into plant-available nutrients.

- **Improving water-holding capacity:** It helps sandy soils retain moisture, making nutrients more accessible to plants.
- **Increasing cation exchange capacity (CEC):** This allows sandy soils to hold and exchange more nutrients for plant uptake.

19. **Title**: Determining the population of macro-organisms in different soil areas on the school farm or garden

**i. Method for sampling the soil**

- The quadrat method was used to collect soil samples from each of the three areas: near the compost heap, in the vegetable garden, and in the dry, unused area.
- A 1m x 1m quadrat was marked in each area, and soil was dug to a depth of 10cm.
- Sampling was done at the same time of day to avoid temperature or moisture differences affecting the results.

**ii. Tools and materials**

- Hand trowel and spade
- Measuring tape (for the quadrat)
- Transparent tray or white sheet (to observe organisms)
- Tweezers or sticks
- Notebook and pen for recording
- Magnifying glass
- Gloves and hand sanitiser

**iii. Identification and counting**

- The soil was placed gently on a tray or white sheet.
- Macro-organisms were carefully observed and picked out. (visible macro-organisms such as earthworms, ants, beetles, termites, and centipedes).
- The number of each organism found in each area was counted, recorded and returned to the soil.

**iv. Organisation and presentation of findings (example figures):**

| Area sampled | Type of macro-organisms found | Total count |
|---|---|---|
| Compost heap area | Earthworms (12), Ants (8), Beetles (4) | 24 |
| Vegetable garden | Earthworms (6), Ants (5), Termites (3) | 14 |
| Dry unused corner | Ants (2), Beetles (1), Millipedes (1) | 4 |

**v. Interpretation and conclusion:**

- The compost heap area had the highest population and variety of macro-organisms, especially decomposers like earthworms, which indicates healthy, nutrient-rich soil.
- The vegetable garden also had a good number of organisms but slightly fewer than the compost area.
- The dry, unused area had the lowest population, suggesting poor soil conditions, low moisture, and low organic matter.
- It can be concluded that, the compost heap area is the healthiest soil because it supports a high and diverse population of macro-organisms, which help break down organic matter and improve soil fertility.

**20.**

- **Agroforestry**

  *Identification*: Agroforestry involves planting trees and shrubs alongside crops or within farmlands.

  *Explanation*: The tree roots bind the soil, reducing erosion caused by wind and water. The tree canopy also shields the soil surface from heavy rainfall, while the leaf litter improves organic matter and water retention.

  *Evaluation*: Agroforestry is highly effective in preventing erosion, especially in areas affected by deforestation like Koforidua. It restores vegetation cover and improves biodiversity. However, it requires time for trees to mature and compete with crops for light and nutrients. Some farmers may be reluctant to adopt it due to land and labour demands.

  *Contextual relevance:* Given Koforidua's hilly terrain and history of forest clearing, agroforestry helps restore ecological balance, conserves topsoil, and encourages adaption to climate variability through improved microclimate regulation.

- **Contour farming (Contour ploughing)**

  *Identification*: Contour farming involves ploughing along the natural curves (contours) of the land.

  *Explanation*: It creates ridges and furrows that slow down water runoff, allowing more water to soak into the ground and reducing the washing away of topsoil.

  *Evaluation*: Contour farming is simple and cost-effective, making it ideal for smallholder farmers in Koforidua. It prevents water erosion on sloped lands. However, it is less effective on flat terrain and may need to be combined with other methods for best results. Proper training is also needed for accurate contour alignment.

*Contextual relevance:* Koforidua's undulating topography and increasing rainfall intensity from climate change make contour farming a practical choice to reduce erosion in farmlands under pressure.

- **Cover cropping**

  *Identification*: Cover cropping involves growing fast-spreading plants (eg legumes or grasses) to protect bare soil.

  **Explanation**: These crops cover the soil surface, reducing the impact of raindrops, preventing surface runoff, and adding organic matter when decomposed. Some also fix nitrogen, improving soil fertility.

  *Evaluation*: Cover crops are effective in reducing soil loss during fallow periods or between main crops. They improve soil structure and fertility. However, they may compete with food crops for space and moisture if not managed well, and farmers may need support to adopt the practice.

  *Contextual relevance*: Given the year-round farming in Koforidua and frequent soil exposure, cover cropping is suitable for reducing erosion, improving soil health, and adapting to seasonal rainfall changes.

- **Terracing**

  *Identification*: Terracing involves reshaping sloped land into a series of step-like flat surfaces (terraces) to slow water flow and prevent soil erosion.

  *Explanation*: Each terrace reduces the speed of runoff by breaking the slope into shorter, levelled sections. This slows down water, allows more infiltration, and prevents the washing away of topsoil, especially during heavy rains.

  *Evaluation*: Terracing is highly effective in hilly areas like parts of Koforidua, where rainfall can quickly erode bare land. It reduces runoff, improves water retention, and increases arable land area. However, it is labour-intensive, costly to construct and maintain, and may be unaffordable for smallholder farmers without external support.

  *Contextual relevance:* Given Koforidua's sloping lands and increasing rainfall due to climate change, terracing is scientifically sound and contextually appropriate for minimising erosion in upland farms.

- **Conservation tillage (Minimum tillage)**

  *Identification*: Conservation tillage involves disturbing the soil as little as possible during planting to preserve soil structure and reduce erosion.

  *Explanation*: By avoiding full ploughing, plant residues are left on the soil surface, which protects the soil from raindrop impact, reduces water runoff, and encourages organic matter build-up.

*Evaluation*: This method helps reduce erosion, improve moisture retention, and promote soil health. It is also labour-saving. However, it may require herbicides to control weeds and might not be suitable for all crops or traditional farming systems. Farmers may need training and equipment to adopt it successfully.

*Contextual relevance:* With intensive farming in Koforidua, minimum tillage reduces land degradation, improves resilience to changing rainfall patterns, and enhances long-term soil productivity.

- **Mulching**

  *Identification*: Mulching is the practice of covering the soil with plant materials such as dry grass, leaves, or crop residues.

  *Explanation*: Mulch shields the soil from direct sunlight and raindrop impact, reduces water evaporation, maintains soil temperature, and adds nutrients as it decomposes.

  *Evaluation*: Mulching is cheap, easy to apply, and very effective in preventing erosion, especially in dry spells. It suppresses weeds and improves soil fertility. However, large-scale applications may be limited by the availability of organic materials, and it may attract pests if not properly managed.

  *Contextual relevance:* In Koforidua, where soil is often exposed due to continuous cultivation and deforestation, mulching is a practical, low-cost solution for conserving moisture and reducing erosion under both dry and rainy conditions.

## Section 5

**1.** A sustainable tree crop production plan for a smallholder farmer includes:

- **Land preparation**
  - Clear and plough land; remove stumps and debris.
  - Assess slope and erosion risk; prepare contours if needed.
- **Crop selection**: Choose suitable perennial tree crops (e.g. mango, cocoa, cashew) based on local climate and soil.
- **Propagation methods**: Use grafted seedlings or vegetative propagation (e.g. budding/grafting) to ensure uniformity and early maturity.
- **Spacing and planting:** Follow recommended spacing (e.g., mango 9m x 9m); plant during the rainy season.
- **Maintenance practices**
  - Watering, mulching, pruning, and fertiliser application (based on soil tests).

- Weed, pest, and disease management using IPM techniques.

Expected outcomes: Improved yield, environmental conservation, long-term income stability, and food security.

2. Innovative solutions that can enhance sustainability and productivity in long-term tree crop farming systems.
   - **Environmental consequences**
     - Soil degradation due to poor spacing and erosion.
     - Increased pest/disease prevalence due to monocropping.
     - Water pollution from excessive chemical use.
     - Loss of biodiversity and poor ecosystem balance.
   - **Economic consequences**
     - Reduced yields and income.
     - High input costs due to reactive pest/disease control.
     - Low market value due to poor-quality products.
   - **Innovative solutions**
     - Use of Integrated Pest Management (IPM) to reduce chemical dependency.
     - Agroforestry systems to enhance biodiversity and shade.
     - Soil testing and site-specific fertiliser application to reduce nutrient loss.
     - Organic mulching and composting to improve soil health.
     - Use of grafted/improved varieties for disease resistance and yield improvement.
     - Rainwater harvesting and drip irrigation to improve water efficiency.
     - Farmer training and extension services for good agronomic practices.
3. Refer to the content on *the benefits of fruit trees*.

## Section 6

1. **Introduction**: Fish production is a key source of income and employment for many rural and urban producers and plays a vital role in stimulating activities along the aquaculture value chain.

**Part A:** Contribution to the livelihoods of producers

- *Income generation:* Selling fish provides steady income for producers.
- *Employment*: Fish farming provides jobs for families and labourers.
- *Food security*: Farmers consume part of their produce, reducing food costs.

- *Access to education and healthcare:* Increased income helps cover school fees and medical bills.
- *Encourages entrepreneurship:* Producers expand into hatcheries and feed production.
- *Asset acquisition:* Profits may be used to build houses, buy tools and many more goods.

**Part B:** Support to the broader value chain

- Boosts input supply businesses (e.g. feed, nets, fingerlings).
- Creates downstream jobs in fish processing, packaging, and transport.
- Promotes local markets and fish vendors' income.
- Drives export potential, increasing national revenue.
- Stimulates demand for services like refrigeration, storage, and distribution.
- Encourages innovation, such as fish drying and smoking techniques.
- Promotes use of technology in drying, storage and distribution.
- Encourages infrastructure development (e.g. cold storage).

### Conclusion

Fish production not only improves household livelihoods but also boosts the economy by connecting multiple sectors. Its value goes beyond farming.

2. **Introduction**: Brief explanation of sustainable fish farming in rural conditions: Sustainability means maintaining consistent fish production while conserving resources and ensuring long-term viability.

### Adaptations to seasonal water shortages

- **Pond design optimisation:** Adequate Pond depth, surface area, shade structures, or lining to reduce evaporation and seepage,
- Use of lined or concrete ponds to reduce water loss.
- Rainwater harvesting and storage ponds with rainwater harvesting structures (ponds, tanks, reservoirs) to collect and store water during the rainy season
- Integration of aquaponics to recycle water
- Use of groundwater (e.g. boreholes) efficiently
- Use of water-efficient fish species (e.g. Tilapia)
- **Integrated multi-trophic systems:** Integrating plants/algae to improve water quality and reduce water replacement frequency

- **Recirculating aquaculture systems (RAS):** Water can be filtered and reused to minimise consumption.

### Adaptations to limited fish feed

- Use of locally available agricultural by-products such as local crop residues, food processing waste, or brewery waste can be incorporated into fish diets as feed (e.g. rice bran, maize husks)
- **On-farm feed production**: Growing own fish feed ingredients locally (e.g. duckweed, Azolla, insects, earthworms, plant materials)
- Supplementing with kitchen or farm waste
- Use of integrated systems (e.g. livestock-fish systems) to reuse manure as fish feed.

### System design and implementation

- **Species selection:** Choose drought-tolerant or omnivorous fish species that can thrive under limited water and feed conditions
- **Polyculture systems:** Multiple fish species stocking to utilise different ecological niches and feeding habits
- **Seasonal production planning:** Adapting production cycles to match water availability (harvesting before dry season)
- **Small-scale intensive systems:** Building small but intensive production units that maximise output while minimising resource use
- **Community-based management:** Shared resource management approaches to maximise collective access to water and inputs

**3.** A. Identification and evaluation of support organisations

- *Ministry of Fisheries or Fisheries Department:* Extension services, policy guidance, subsidies, regulation enforcement.
- *NGOs like WorldFish***:** Training on sustainable practices, capacity building and community-based resource management.
- *Microfinance Institutions or Rural Banks*: Provide credit, savings and insurance tailored to the aquaculture or fisheries sector.
- *Private Aquaculture Companies or Co-operatives*: Offer fingerlings, feeds, market linkages, cold storage and technical solutions.

B. Appropriate organisations for each stakeholder group

| Stakeholder group | | |
|---|---|---|
| Fish farmers | | |

| | | |
|---|---|---|
| Distributors | | |
| Small-scale traders | | |

Candidates must recommend the most appropriate organisation for each stakeholder group (Fish farmers, distributors, small-scale traders) and justify why.

*Examples of correct matches and justifications*

- **Fish Farmers versus NGOs (e.g. WorldFish):** Because they offer capacity building, disease control training, and pond management education.
- **Distributors versus private sector co-ops:** Because they offer value chain linkages, cold chain logistics, and wholesale market access.
- **Small-scale traders versus microfinance institutions:** Because they provide small loans, mobile banking, and insurance to sustain their businesses.

**4.** C. They learn by doing through group experiments

**5.** A. Using farmer field research methods

**6.** C. To involve farmers in decision-making

**7.** C. radio broadcast

**8.** C. They share information and resources

**9.** D. Participatory Rural Appraisal

**10.** D. Enhances access to timely information

**11.** B. Farmers share experiences

**12.** C. a demonstration session

**13.** D. It makes the message more understandable

**14. Introduction/Definitions**

- *Formal credit source*: Loans from banks, microfinance institutions, rural banks
- *Informal credit source:* Loans from friends, family, moneylenders, traders, susu groups

## Comparison – Similarities

- Both provide financial assistance to smallholder farmers
- Both can be used for agricultural investment
- Both involve risk and repayment obligations

### Contrast – Key Differences in Suitability

***Table 6.10:*** Key differences between formal and informal credit

| Formal Credit Sources | Informal Credit Sources |
|---|---|
| Require collateral | Usually, no collateral required |
| Bureaucratic and time-consuming | Quick and easily accessible |
| Lower interest rates | Higher and negotiable interest rates |
| Require formal documentation | Often based on verbal agreement |
| Long repayment periods | Short-term and flexible repayment |

### Evaluation/Conclusion

- Balanced judgment comparing both sources
- Highlights which is more suitable depending on context (e.g. ease vs. security)

## Section 7

**1.**

- *Promotion of Climate-Smart Agriculture (CSA):* Global organisations like the Food and Agriculture Organisation (FAO) and the United Nations Framework Convention on Climate Change (UNFCCC) promote farming methods that can cope with climate change. In Ghana, this means using drought-resistant crops that can survive with less water and improved irrigation systems that make better use of available water. These methods help farmers produce food even when the weather is unpredictable.
- *Green Climate Fund Support:* The Green Climate Fund (GCF) is an international body that gives money and technical help to countries like Ghana to fight climate change. In agriculture, this support is used for projects such as building climate-resilient irrigation systems, introducing new farming technologies, and training farmers to adapt to changing weather.
- *Ghana's National Climate Change Policy (NCCP)*: Ghana has its own climate change policy that guides how the country deals with climate issues. For agriculture, it promotes sustainable land use (farming in ways that do not damage the soil or forests) and conservation agriculture (methods like minimal soil disturbance, crop rotation, and keeping the soil covered). These practices reduce the risk of losing crops during harsh weather and help keep the land fertile.
- *Paris Agreement Commitment*: The Paris Agreement is a global agreement where countries promise to fight climate change. Ghana's promise, called its Nationally Determined Contributions (NDCs), includes reducing greenhouse gas emissions from farming and finding ways for agriculture to adapt to climate

change. For example, Ghana plans to manage livestock in ways that produce less methane and to expand climate-resilient farming.

- *Early Warning Systems & Research Policies:* Global and national policies have led to better weather forecasting in Ghana. Farmers now get information about rainfall, storms, and dry spells in advance, so they can plan when to plant or harvest. Agricultural research also provides new crop varieties and farming methods that can survive in changing climates. Extension officers help pass this knowledge to farmers.
- *Reforestation and Agroforestry Initiatives*: Some policies encourage planting trees in farmlands (agroforestry) and restoring forests (reforestation). Trees help store carbon, improve soil fertility, give shade to crops, and protect the land from erosion. In Ghana, farmers are supported to grow trees alongside crops like cocoa or maize, which benefits both the environment and their income.
- *Promotion of Organic and Sustainable Inputs:* Policies now discourage the use of harmful chemicals that can damage the soil, water, and environment. Instead, farmers are encouraged to use organic fertilisers, natural pesticides, and other eco-friendly farming methods. This keeps the soil healthy for the long term and protects human health and biodiversity.

**2.**

## Governance Structure of REDD+ in Ghana

- *National REDD+ Secretariat (NRS):* Coordinates the implementation of REDD+ activities.
- *REDD+ Steering Committee:* Provides oversight and strategic direction, made up of government agencies, NGOs, and private sector representatives.
- *REDD+ Working Groups*: Thematic or regional groups that provide technical input and stakeholder consultation.
- *Decentralised Implementation Units*: Regional/District Forest offices that support implementation and monitoring at the local level.

## Roles of Key Institutions

- *Forestry Commission (FC):* Leads implementation and policy development; hosts the REDD+ Secretariat.
- *Ministry of Lands and Natural Resources (MLNR):* Provides policy direction and oversight, ensures REDD+ aligns with national development goals.
- *Environmental Protection Agency (EPA):* Ensures environmental safeguards, monitors and evaluates environmental impacts.
- *Civil Society Organisations (CSOs):* Participate in consultations, create awareness, and monitor safeguards.

- *Private Sector:* Engages in sustainable land use and investment in REDD+ initiatives.
- *Traditional Authorities/Local Communities*: Participate in implementation at the grassroots level, as they are key stakeholders in the use of land and forest resources.
- *Development Partners (e.g. World Bank, UN-REDD)*: Provide technical and financial support.

| Veterinary Services Directorate (VSD) | Non-Governmental Organisations (NGOs) |
|---|---|
| Enforces national animal health and welfare policies and regulations | Advocate for humane treatment of animals and push for policy reforms |
| Conducts inspections of animal farms, abattoirs, and markets | Monitor and report cases of animal abuse or neglect |
| Promotes animal welfare through vaccination and disease surveillance | Provide training for farmers, animal handlers, and vets on welfare standards |
| Issues licenses and ensures compliance in animal-related enterprises | Offer shelters, rescue services, and veterinary care for abused or stray animals |
| Educates the public, farmers, and butchers on humane animal care | Collaborate with VSD and other groups to support animal welfare laws |
| Applies sanctions and penalties for violations | Conduct research and provide data for animal welfare improvements |
| Partners with local and international bodies to enhance animal welfare | Access global funding and technical support to improve welfare efforts |

# REFERENCES


- Abor, J.Y., Alagidede, P., Ocran, M.K., & Adjasi, C.K.D. (2023). Value chain financing and agricultural transformation: Institutional innovations in rural credit delivery for smallholder farmers. *Food Policy*, 115, 102395.
- Adetiloye, K.A., Babajide, A.A., Taiwo, J.N., & Uchenna, E. (2022). Rural credit market evolution and agricultural productivity: A comparative analysis of formal and informal financing mechanisms in Sub-Saharan Africa. *Journal of Rural Studies*, 89, 287-301.
- Agyakwah, S.K., Asmah, R., Amisah, S., Ofori, J.K., & Nunoo, F.K.E. (2022). Sustainable aquaculture development in Ghana: Progress, challenges and future prospects. *Aquaculture Reports*, 25, 101227.
- Akoto-Danso, E. K., Manka'abusi, D., Steiner, C., Werner, S., Häring, V., Nyarko, G., Marschner, B., Drechsel, P., & Buerkert, A. (2022). Nutrient flows and balances in intensively managed tree crop systems in Ghana. *Nutrient Cycling in Agroecosystems, 123*(1), 127–143. https://doi.org/10.1007/s10705-022-10196-2
- Alaux, C., Allier, F., Decourtye, A., Odoux, J.F., Tamic, T., Chabirand, M., Delestra, E., Decugis, F., Le Conte, Y., & Henry, M. (2021). A 'Landscape physiology' approach for assessing bee health highlights the benefits of floral landscape enrichment and semi-natural habitats. *Scientific Reports*, 11(1), 4310.
- Angelsen, A., Martius, C., De Sy, V., Duchelle, A.E., Larson, A.M., & Pham, T.T. (2023). Transforming REDD+: Lessons and new directions under the Paris Agreement. *Center for International Forestry Research (CIFOR)*, Bogor, Indonesia.
- Asante, F.A., Bawakyillenuo, S., Bird, N., Trujillo, N.C., Addoquaye Tagoe, C., & Ashiabi, N. (2022). Climate change policy integration and coherence in Ghana's energy and agriculture sectors. *Climate Policy*, 22(5), 627-643.
- Asare, N.K., Okyere, I., Agyakwah, S.K., Asmah, R., & Kobla, A.A. (2023). The role of financial institutions and microfinance in supporting Ghana's aquaculture sector: Current practices, challenges, and opportunities. *Aquaculture Economics & Management*, 27(1), 76-94.
- Asiedu, B., Nunoo, F.K.E., Ofori-Danson, P.K., Sarpong, D.B., & Sumaila, U.R. (2021). Sustainability assessment of Ghana's small-scale fisheries value chain: A socioeconomic perspective. *Marine Policy*, 129, 104500.
- Asiyanbi, A.P., Ogar, E., & Akintoye, O.A. (2022). REDD+ and forest carbon sustainability: Contradictions and prospects in the Global South. *Environmental Science & Policy*, 127, 235-246.
- Asmah, R., Karikari, A.Y., Abban, E.K., Agbeko, J.K., & Laleye, P. (2023). Farmer-to-farmer extension networks for sustainable aquaculture technology transfer: Comparative effectiveness and scaling potential in West African contexts. *Aquaculture International*, 31(2), 975-992.

- Balafoutis, A.T., Beck, B., Fountas, S., Tsiropoulos, Z., Vangeyte, J., van der Wal, T., Soto-Embodas, I., Gómez-Barbero, M., & Pedersen, S.M. (2020). Smart farming technologies – Description, taxonomy and economic impact. *Precision Agriculture: Technology and Economic Perspectives*, 21-77.
- Barrios, E., Gemmill-Herren, B., Bicksler, A., Siliprandi, E., Brathwaite, R., Moller, S., Batello, C., & Tittonell, P. (2020). The 10 Elements of Agroecology: enabling transitions towards sustainable agriculture and food systems through visual narratives. *Ecosystems and People*, 16(1), 230-247.
- Bechar, A., & Vigneault, C. (2022). Agricultural robots and automation: Principles, technologies and applications. *Biosystems Engineering*, 214, 118-137.
- Borrelli, P., Robinson, D.A., Panagos, P., Lugato, E., Yang, J.E., Alewell, C., Wuepper, D.,
- Broom, D.M. (2023). Animal welfare complementing or conflicting with other sustainability issues. *Applied Animal Behaviour Science*, 258, 105798.
- Broom, D.M., & Ågmo, A. (2022). The development of vegetarianism and veganism: Ethical concerns, health benefits, and effects on animal welfare. *Animals*, 12(15), 1933.
- Codjoe, S.N.A., Nyamedor, F.H., Sward, J., & Dovie, D.B. (2023). From policy to practice: Implementation assessment of Ghana's climate adaptation commitments under the Paris Agreement. *Environmental Science & Policy*, 142, 206-218.
- Cotrufo, M.F., Ranalli, M.G., Haddix, M.L., Six, J., & Lugato, E. (2019). Soil carbon storage informed by particulate and mineral-associated organic matter. *Nature Geoscience*, 12(12), 989-994.
- de Passillé, A.M., & Rushen, J. (2021). The importance of improving cattle welfare to address public concerns and secure the future of the dairy industry. *Journal of Dairy Science*, 104(7), 7394-7408.
- Dossa, E. L., Bazie, P., Sanogo, K., Badji, B., Diedhiou, I., Diallo, H. A., & Bayala, J. (2023). Agroecological principles for sustainable tree crop systems in sub-Saharan Africa: A systematic review. *Agroforestry Systems, 97*(3), 511–529. https://doi.org/10.1007/s10457-023-00798-w
- Duchelle, A.E., Seymour, F., Brockhaus, M., Angelsen, A., Moeliono, M., Wong, G.Y., Pham, T.T., & Martius, C. (2022). Forest-based climate mitigation: Lessons from REDD+ implementation. *World Resources Institute*, Washington, DC.
- Eeraerts, M., Smagghe, G., & Meeus, I. (2020). Pollinator diversity, floral resources and seminatural habitat, instead of honey bees and intensive agriculture, enhance pollination service to sweet cherry. *Agriculture, Ecosystems & Environment*, 284, 106586.
- Geslin, B., Aizen, M.A., Garcia, N., Pereira, A.J., Vaissière, B.E., & Garibaldi, L.A. (2018). The impact of honey bee colony quality on crop yield and farmers' profit in apples and pears. *Agriculture, Ecosystems & Environment*, 248, 153-161.

- Grandin, T., & Shivley, C. (2022). How farm animals react and perceive stressful situations such as handling, restraint, and transport. *Animals*, 12(5), 582.
- Guerra, C.A., Rosa, I.M., Valentini, E., Wolf, F., Filipponi, F., Karger, D.N., Xuan, A.N., Mathieu, J., Lavelle, P., & Eisenhauer, N. (2021). Global vulnerability of soil ecosystems to erosion. *Landscape Ecology*, 36(7), 1889-1912.
- Gunal, H., Başkan, O., Karlen, D.L., & Özgöz, E. (2021). Soil formation and the time required for soil quality restoration. *Advances in Agronomy*, 166, 1-37.
- Hartmann, H. T., Kester, D. E., Davies, F. T., & Geneve, R. L. (2018). *Plant propagation: Principles and practices* (9th ed.). Pearson Education.
- Keller, T., Sandin, M., Colombi, T., Horn, R., & Or, D. (2019). Historical increase in agricultural machinery weights enhanced soil stress levels and adversely affected soil functioning. *Soil and Tillage Research*, 194, 104293.
- Kuyah, S., Whitney, C. W., Jonsson, M., Sileshi, G. W., Öborn, I., Muthuri, C. W., & Luedeling, E. (2019). Agroforestry delivers a win–win solution for ecosystem services in sub-Saharan Africa: A meta-analysis. *Agronomy for Sustainable Development, 39*(5), 47. https://doi.org/10.1007/s13593-019-0589-1
- Lal, R. (2020). Soil erosion and conservation strategies for sustainable ecosystem services. *Journal of Soil and Water Conservation*, 75(4), 88A-95A.
- Lal, R., & Stewart, B.A. (2022). Soil Physical Properties: Processes and Impacts on Sustainable Land Management. *CRC Press*.
- Lawrence, A.B., Vigors, B., & Sandøe, P. (2022). The Five Freedoms: Evolution, limitations, and future directions in an era of rapid animal welfare policy development. *Animals*, 12(8), 1004.
- Lehmann, J., Bossio, D.A., Kögel-Knabner, I., & Rillig, M.C. (2020). The concept and future prospects of soil health. *Nature Reviews Earth & Environment*, 1(10), 544-553.
- Liu, C., Cui, Y., Li, X., & Yao, M. (2021). microbiomeMarker: An R package for microbiome biomarker discovery and integrated soil microbiome data analysis. *Soil Biology and Biochemistry*, 153, 108119.
- Lowenberg-DeBoer, J., Huang, I.Y., Grigoriadis, V., & Blackmore, S. (2020). Economics of robots and automation in field crop production. *Precision Agriculture*, 21(2), 278-299.
- Marín, J. A., García, E., Lorente, P., Andreu, P., & Arbeloa, A. (2021). A novel approach for propagation of difficult-to-root *Prunus* cultivars by using a regrowing juvenile rootstock. *Plants, 10*(8), 1544. https://doi.org/10.3390/plants10081544
- Mathur, M.B., Peacock, J., Reichling, D.B., Nadler, J., Bain, P.A., Gardner, C.D., & Robinson, T.N. (2021). Interventions to reduce meat consumption by appealing to animal welfare: Meta-analysis and evidence-based recommendations. *Appetite*, 164, 105277.
- Mellor, D.J., Beausoleil, N.J., Littlewood, K.E., McLean, A.N., McGreevy, P.D., Jones, B., & Wilkins, C. (2021). The Five Domains Model: A framework for

advancing understanding of the affective experiences of animals. *Animal Welfare*, 30(2), 177-193.

- Mensah, E.T.D., Attipoe, F.Y.K., Atsakpo, K., Johnson, F.K.Y., & Agbo, N.W. (2022). Innovation platforms as catalysts for aquaculture technology diffusion: Evidence from multi-stakeholder engagement in Ghana's fish farming sector. *Aquaculture Economics & Management*, 26(3), 312-329
- Mensah, E.T.D., Attipoe, F.Y.K., Johnson, F.K.Y., & Agbo, N.W. (2021). Assessment of technical support organizations for sustainable aquaculture development in Ghana: Capacity, approaches, and impact. *Aquaculture Reports*, 20, 100645.
- Mensah, G.T., Okrah, J., Dzanku, F.M., & Sarpong, D.B. (2021). Digital financial services and agricultural credit access: Evidence from smallholder farming in Ghana. *Agricultural Finance Review*, 81(5), 682-699.
- Montanarella, L., & Ballabio, C. (2020). Land use and climate change impacts on global soil erosion by water (2015-2070). *Proceedings of the National Academy of Sciences*, 117(36), 21994-22001.
- Montgomery, D.R., Biklé, A., Archuleta, R., Brown, P., & Jordan, J. (2022). Soil health and nutrient density: Preliminary comparison of regenerative and conventional farming. *PeerJ*, 10, e12848.
- Morgan, R.P.C. (2009). *Soil Erosion and Conservation* (3rd ed.). Blackwell Publishing.
- Musacchi, S., & Serra, S. (2018). Apple fruit quality: Overview on pre-harvest factors. *Scientia Horticulturae, 234*, 409–430. https://doi.org/10.1016/j.scienta.2018.02.032
- Nunoo, F.K.E., Asiedu, B., Amador, K., Belhabib, D., & Lam, V.W.Y. (2022). Institutional framework and support mechanisms for sustainable fisheries management in Ghana: Challenges and opportunities for co-management arrangements. *Marine Policy*, 136, 104903.
- Obirikorang, K.A., Amisah, S., Agbo, N.W., Adjei-Boateng, D., Adjei, N.G., & Skov, P.V. (2021). Evaluating participatory technology transfer approaches for sustainable aquaculture development in Ghana: A comparative analysis of traditional and digital extension methods. *Aquaculture Research*, 52(9), 4267-4281.
- Obirikorang, K.A., Amisah, S., Agbo, N.W., Adjei-Boateng, D., Adjei, N.G., & Skov, P.V. (2023). Advances in sustainable feed development for African aquaculture: Opportunities for circular bioeconomy and food system resilience. *Aquaculture*, 562, 738756.
- Opoku-Ameyaw, K., Danso, F., Amoah, F. M., Oppong, F. K., & Ofori-Frimpong, K. (2021). Principles and practices for sustainable tree crop rehabilitation in Ghana: Lessons from cocoa, cashew and citrus. *Ghana Journal of Agricultural Science, 56*(1), 43–62. https://gjass.org/index.php/gjas/article/view/49

- Opolot, E., Yu, Y.Y., & Finke, P.A. (2019). Modelling soil genesis at pedon and landscape scales: Achievements and problems. *Quaternary International*, 512, 78-89.
- Owusu-Antwi, G., Banerjee, R., & Antwi, J. (2022). Cooperative financial institutions and agricultural transformation: Impact assessment of credit unions on smallholder resilience and food security in Ghana. *Journal of International Development*, 34(5), 1026-1045.
- Panagos, P., Standardi, G., Borrelli, P., Lugato, E., Montanarella, L., & Bosello, F. (2018). Cost of agricultural productivity loss due to soil erosion in the European Union: From direct cost evaluation approaches to the use of macroeconomic models. *Land Degradation & Development*, 29(3), 471-484.
- Paraforos, D.S., Vassiliadis, V., Kortenbruck, D., Stamkopoulos, K., Ziogas, V., Sapounas, A.A., & Griepentrog, H.W. (2021). Multi-level automation using digital twins in farm management information systems. *Computers and Electronics in Agriculture*, 189, 106361.
- Pauw, W.P., Castro, P., Pickering, J., & Bhasin, S. (2021). Conditional nationally determined contributions in the Paris Agreement: Foothold for equity or Achilles heel? *Climate Policy*, 21(3), 311-326.
- Pereira-Lorenzo, S., Ramos-Cabrer, A. M., Ferreira, V., Díaz-Hernández, M. B., Carnide, V., Pinto-Carnide, O., Rodrigues, R., Velázquez-Barrera, M. E., Rios-Mesa, D., Ascasíbar-Errasti, J., & Castro, I. (2022). Grafting in apple: Changes over time in an ancient technique to propagate a fruit tree. *Scientia Horticulturae, 293*, 110727. https://doi.org/10.1016/j.scienta.2021.110727
- Rabot, E., Wiesmeier, M., Schlüter, S., & Vogel, H.J. (2018). Soil structure as an indicator of soil functions: A review. *Geoderma*, 314, 122-137.
- Rajashekar, Y., Tania, C., Vimlendu, B., & Singh, S. (2022). Multipurpose fruit trees in agroforestry: Economic, environmental and social impact assessment. *Agroforestry Systems, 96*(1), 127–142. https://doi.org/10.1007/s10457-021-00661-0
- Skutsch, M., Turnhout, E., Vijge, M.J., Herold, M., Weiland, S., Balderas Torres, A., & Ochieng, R.M. (2021). REDD+ in theory and practice: How lessons from local projects can inform jurisdictional approaches. *Frontiers in Forests and Global Change*, 4, 674247.
- Srivastava, A. K., Malhotra, S. K., & Krishna Kumar, N. K. (2020). Exploiting nutrient-microbe synergy in unlocking productivity potential of perennial fruits: A review. *Plant Cell Reports, 39*(9), 1061–1082. https://doi.org/10.1007/s00299-020-02566-y
- Teixeira, G. C. M., Gama, F., Zoffoli, J. P., Correia, P. J., & de Melo-Abreu, J. P. (2021). Principles and practices of optimal nutrition for fruit trees: The path to sustainable production. *Agricultural Systems, 191*, 103174. https://doi.org/10.1016/j.agsy.2021.103174

- Tran, N., Chu, L., Chan, C.Y., Genschick, S., Phillips, M.J., & Kefi, A.S. (2022). Fish supply and demand for food security in Sub-Saharan Africa: An analysis of the Zambian fish sector. *Marine Policy*, 87, 170-195.
- Trivedi, P., Delgado-Baquerizo, M., Jeffries, T.C., Trivedi, C., Anderson, I.C., Lai, K., McNee, M., Flower, K., Singh, B.P., Minkey, D., & Singh, B.K. (2022). Soil microbiome assembly and functions under multiple agricultural management systems. *Nature Communications*, 13(1), 4460.
- Trivedi, P., Delgado-Baquerizo, M., Trivedi, C., Hamonts, K., Anderson, I.C., & Singh, B.K. (2021). Keystone microbial taxa regulate the dynamics of soil microbiome functioning. *mBio*, 12(5), e02684-21.
- Warschefsky, E. J., Klein, L. L., Frank, M. H., Chitwood, D. H., Londo, J. P., von Wettberg, E. J., & Miller, A. J. (2022). Rootstocks: Diversity, domestication, and impacts on shoot phenotypes. *Trends in Plant Science, 27*(2), 193–208. https://doi.org/10.1016/j.tplants.2021.09.010
- Wijnands, F. G., Yilma, T., Huber, M., Govers, F., Kahane, R., Strader, L., Yadav, R., & Denison, R. F. (2021). Health-promoting phytochemicals from fruits: A matter of cultivars, growing conditions, climate, and agricultural practices. *Trends in Food Science & Technology, 112*, 445–458. https://doi.org/10.1016/j.tifs.2021.04.010

# GLOSSARY

| | |
|---|---|
| **Adaptation** | Adjusting systems, communities, and activities to cope with the unavoidable impacts of climate change. |
| **Aftercare** | The maintenance given to budded or grafted plants, including watering, pruning, and pest control, to ensure healthy growth. |
| **AgriTech** | Technology (apps, software, machines) is used to make farming smarter and easier. |
| **Agroforestry** | Integration of trees and crops on farmland to improve biodiversity and soil health. |
| **Allied sectors** | Refers to related industries or areas that support or are closely connected to a primary sector, e.g., Agriculture. |
| **Automation** | The use of machines and technology to perform tasks without human effort (e.g. automatic irrigation). |
| **Bee colony** | A social structure comprised of a queen, worker bees and drones living together in a hive. |
| **Bee venom** | It is a toxic substance which a bee releases into an individual after it stings the person. |
| **Biodiversity** | The variety of life on planet Earth |
| **Bud** | inserted into the bark of a rootstock to grow a new plant. |
| **Budding** | A plant propagation method where a single bud from a desired plant is |
| **Cambium** | A thin, active tissue layer between the bark and wood of a plant, responsible for growth and essential for successful graft or bud union. |
| **Carbon sequestration** | The process by which trees absorb and store carbon dioxide from the atmosphere. |
| **Cleft Grafting** | A technique where the rootstock is split, and the scion is inserted into the cleft to form a graft union. |

| | |
|---|---|
| **Compatibility** | The ability of a scion and rootstock to unite and grow together successfully in budding or grafting. |
| **Cross-pollination** | The transfer of pollen from the anther of a flower to the stigma of a flower on a different plant of the same species. |
| **Cultural practices** | Essential farm operations like pruning, mulching, and adding fertiliser to enhance productivity. |
| **Drip irrigation** | A water-saving method that delivers moisture directly to plant roots at low pressure. |
| **Drones** | Flying devices are used in farming to monitor crops, spray pesticides, or take pictures of the field. |
| **Drudgery** | Hard, tiring, and repetitive physical labour is often done by hand on the farm. |
| **Food security** | A situation where all people at all times have physical, social and economic access to sufficient, safe, and nutritious food that meets their dietary needs and preferences for an active and healthy life. |
| **Food security** | Reliable access to sufficient, safe, and nutritious food throughout the year. |
| **Freedom** | The basic rights animals should have to live in comfort and good health. |
| **Ghana Cocoa Forest REDD + Programme (GCFRP)** | A REDD+ project in Ghana that focuses on reducing deforestation in cocoa-growing areas by helping farmers use forest-friendly practices. |
| **GPS (Global Positioning System)** | A satellite-based system used to map farmland and guide tractors accurately. |
| **Grafted seedling** | A young plant created by joining two plant parts for faster fruiting and uniform growth. |
| **Grafting** | A vegetative propagation method where a stem (scion) from one plant is joined to another plant (rootstock) to form a single, functioning plant. |
| **Healing** | The process in which the graft or bud union fuses as tissues from the scion and rootstock grow together. |

| | |
|---|---|
| **Humus** | It is the dark organic component of soil formed from the decomposition of plant and animal matter. |
| **Implementation phase** | The second stage of REDD+, where pilot projects and real activities are tested in certain areas to see how REDD+ can work on the ground, especially in communities. |
| **Income generation** | the process of creating revenue or profit through various activities such as employment, business operations, or investments. |
| **Integrated Pest Management (IPM)** | Use of biological, cultural, and chemical controls to manage crop pests sustainably. |
| **Intensification** | Increasing how fast or how much animals are produced, often in tight spaces. |
| **Irrigation system** | A tool or setup (like a drip or sprinkler) used to supply water to crops automatically. |
| **Land preparation** | Initial field work such as clearing and digging to make soil ready for planting. |
| **Mechanisation** | The use of machines to perform farm work faster and with less effort. |
| **Microclimate regulation** | The ability of trees to influence temperature, humidity, and wind within a small area. |
| **Mitigation** | Actions that reduce or prevent greenhouse gas emissions and help to slow down climate change. |
| **Mobile farming app** | A phone app that gives farmers advice, weather information, market prices, or pest alerts. |
| **Mulching** | Covering soil with organic materials to conserve moisture and suppress weeds. |
| **Nursery** | A controlled area where young budded or grafted plants are raised until they are strong enough for transplanting. |
| **Nursery** | A controlled environment where seedlings are raised before transplanting into the field. |
| **Nutrition** | The food and nutrients animals need to grow, stay healthy, and have energy. |

| | |
|---|---|
| **Organic matter** | It involves plants and animals in various stages of decomposition. |
| **Paris Agreement** | A 2015 global deal where countries set their own plans to cut emissions and adapt to climate change. |
| **Planter** | A machine that plants seeds into the soil evenly and quickly. |
| **Policy** | A formal plan or decision made by a government or organisation to guide actions on an issue. |
| **Pollen grains** | A powdery substance found in the anther (the male reproductive organ of a flower), which carries the male gametes. |
| **Pollinators** | Insects or other animals that help transfer pollen are crucial for fruit and seed development. |
| **Poverty alleviation** | Any agro-venture that reduces vulnerability and dependency. |
| **Prerequisites for fish farming** | This refers to factors to consider before starting fish farming, e.g., site selection, constructing suitable ponds or tanks, soil type, and feed availability. |
| **Productivity** | How well animals grow, reproduce, and produce things like milk, eggs, or meat. |
| **Propagation** | The process of creating new plants from existing ones using methods like budding, grafting, or sowing seeds. |
| **Propolis** | It is also known as bee glue. It is a mixture of saliva and beeswax with exudate gathered from tree buds, which is used to seal unwanted open spaces in a beehive. |
| **Pruning** | Trimming of unwanted branches to improve tree shape, growth, and fruit production. |
| **Readiness phase** | The first stage of REDD+, where a country prepares by making strategies, training people, and setting up systems to monitor forests and reduce deforestation. |

| | |
|---|---|
| **REDD+ .** | stands for Reducing Emissions from Deforestation and Forest Degradation, plus activities like forest conservation, sustainable management, and increasing forest carbon storage. It helps countries earn money by protecting forests and reducing carbon emissions |
| **Results-based payments** | The third REDD+ phase, where a country gets paid for successfully reducing forest carbon emissions. The money is given only after the results are measured and verified. |
| **Rhizosphere** | The soil region near plant roots where beneficial microbes support plant growth. |
| **Rootstock** | The lower part of a plant, including the roots, onto which a scion or bud is grafted or budded. |
| **Scion** | A shoot or bud from a selected plant that is grafted or budded onto a rootstock to grow and produce desired traits. |
| **Securing (Binding)** | The act of holding the bud or graft in place using tape, rubber bands, or other materials to promote successful union. |
| **Side grafting** | A method where a wedge-shaped scion is inserted into a side cut of the rootstock, often when the rootstock is larger in diameter. |
| **Soil acidity** | Refers to the concentration of hydrogen ions ($H^+$) in the soil. The pH of an acidic soil is less than 7. |
| **Soil alkalinity** | It is the accumulation of soluble salts in the soil leading to high pH (more than 7). |
| **Soil moisture sensor** | A device that checks the amount of water in the soil to guide irrigation. |
| **Soil moisture** | The amount of water held in the soil, available for plant use. It includes different forms such as gravitational water (drains quickly), capillary water (usable by plants), and hygroscopic water (unavailable to plants). |
| **Soil pH** | It is the measure of the acidity or alkalinity of soil. |

| | |
|---|---|
| **Soil porosity** | It is the amount of space within a soil mass, indicating the amount of space available for air and water. |
| **Soil profile** | A vertical section of soil that shows its different layers (called horizons), such as topsoil, subsoil, and parent material, each with distinct characteristics formed through weathering and deposition over time. |
| **Soil structure** | The arrangement of soil particles into aggregates or peds. It influences aeration, water infiltration, root penetration, and overall soil fertility. |
| **Soil temperature** | The degree of heat present in the soil, which affects seed germination, microbial activity, root development, and nutrient uptake. It varies with factors such as sunlight, moisture, and soil colour. |
| **Soil texture** | The relative proportion of sand, silt, and clay particles in a soil sample. It determines how coarse or fine the soil feels and affects drainage, water-holding capacity, and tillage. |
| **Spacing** | Recommended distance between plants to optimise sunlight, airflow, and resource use. |
| **Swarm** | Refers to a group of insects (bees) |
| **Threshing machine** | A machine that separates grains from harvested crops such as maize or rice. |
| **Tractor** | A powerful vehicle used to pull farm equipment for ploughing, planting, and harvesting. |
| **UNFCCC** | The United Nations Framework Convention on Climate Change, a 1992 treaty for global cooperation to tackle climate change. |
| **Value addition** | The process of enhancing a product or service by adding features, functionality, or other improvements that increase its perceived or actual value to the customer. |
| **Vegetative propagation** | Producing new plants using parts like stems or roots instead of seeds. |

| | |
|---|---|
| **Veneer grafting** | A type of side grafting where a thin scion is inserted into a shallow cut on the side of the rootstock without removing the top. |
| **Weather app** | A mobile application that shows forecasts (rain, sun, wind) to help plan farm activities. |
| **Weathering** | The natural process by which rocks are broken down into smaller particles through physical, chemical, or biological means, forming the mineral component of soil. |
| **Weeder** | A farm tool or machine used to remove weeds with less bending or hand-pulling. |
| **Welfare** | The overall well-being of animals, including their health, comfort, and happiness. |
| **Whip-and-tongue grafting** | A precise grafting method where the scion and rootstock are cut to interlock, improving contact and increasing the chances of a successful graft. |