



La-Net

AGE 124

FARM TECHNOLOGY



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Course title: Farm Technology

Course credit load: 2 Units

Series 1: Concepts and Need for Farm Technology and Mechanisation

- **Part 1.1: Introduction to Farm Technology**
 - Sub Part 1.1.1: Definition and scope of farm technology
 - Sub Part 1.1.2: Historical development of farm technology
 - Sub Part 1.1.3: Components and classification of farm technology
- **Part 1.2: Need and Justification for Farm Mechanisation**
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- **Part 1.3: Farm Power: Concepts and Sources**
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Introduction

Agriculture in the twenty-first century is increasingly technology-driven. From the hand hoe used by subsistence farmers to satellite-guided precision tractors, the tools and systems that farmers use to produce food have evolved continuously in response to the need to grow more food on limited land with fewer workers. Understanding the principles, history, and rationale of farm technology and mechanisation is the starting point for any agriculture student who intends to practise, teach, or manage in the modern agricultural sector.

The aim of this Series is to introduce you to the concepts, need, and justification for farm technology and mechanisation, the sources and classification of farm power, and the role of information and communications technology in supporting agricultural production and management decisions.

We shall commence this Series by defining farm technology and tracing its development. Next, we will examine the arguments for mechanisation and the constraints that limit its adoption in Nigeria. Following that, we will survey the sources of farm power from human effort to electricity and solar energy. Finally, we will wrap up with an introduction to ICT applications in agriculture and precision farming.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 1.1** define farm technology and describe its scope and components (Linked to Part 1.1),
- **SLO 1.2** trace the historical development of farm technology from manual tools to modern mechanisation (Linked to Part 1.1),
- **SLO 1.3** explain the need and justification for agricultural mechanisation (Linked to Part 1.2),
- **SLO 1.4** identify the constraints to mechanisation in Nigeria and describe their socio-economic implications (Linked to Part 1.2),
- **SLO 1.5** define farm power and classify its sources (Linked to Part 1.3),



- **SLO 1.6** describe human and animal power in agriculture and explain their role and limitations (Linked to Part 1.3),
- **SLO 1.7** describe mechanical and alternative farm power sources and explain their applications (Linked to Part 1.3),
- **SLO 1.8** identify the main ICT applications in agriculture (Linked to Part 1.4), and
- **SLO 1.9** explain the principles of precision agriculture and describe digital tools used for farm management and decision support (Linked to Part 1.4).

1.1 Introduction to Farm Technology

1.1.1 Definition and scope of farm technology

Farm technology refers to the application of scientific and engineering knowledge to the design, development, and operation of tools, machines, systems, and processes used in agricultural production. Its scope covers all the technical inputs and systems that enable land preparation, planting, crop protection, harvesting, post-harvest handling, animal production, and farm management to be performed more efficiently, safely, and at greater scale than would be possible with unaided human effort alone.

The scope of farm technology therefore extends from the simplest hand tools (hoes, cutlasses, and hand sprayers) through animal-drawn implements to motorised machinery, electronic sensing systems, drones, and computer-based decision support tools. Farm technology also encompasses the supporting knowledge and skills required to select, operate, maintain, and repair agricultural equipment. For agriculture students in Nigeria, understanding farm technology is essential for advising farmers on equipment selection, troubleshooting field problems, and contributing to the mechanisation of Nigerian agriculture.

Fill in the blank: Farm technology refers to the application of scientific and engineering knowledge to the design and operation of tools, machines, and systems used in _____ production.



SPECTRUM OF FARM TECHNOLOGY: FROM SIMPLE HAND TOOLS TO DIGITAL FARMING SYSTEMS

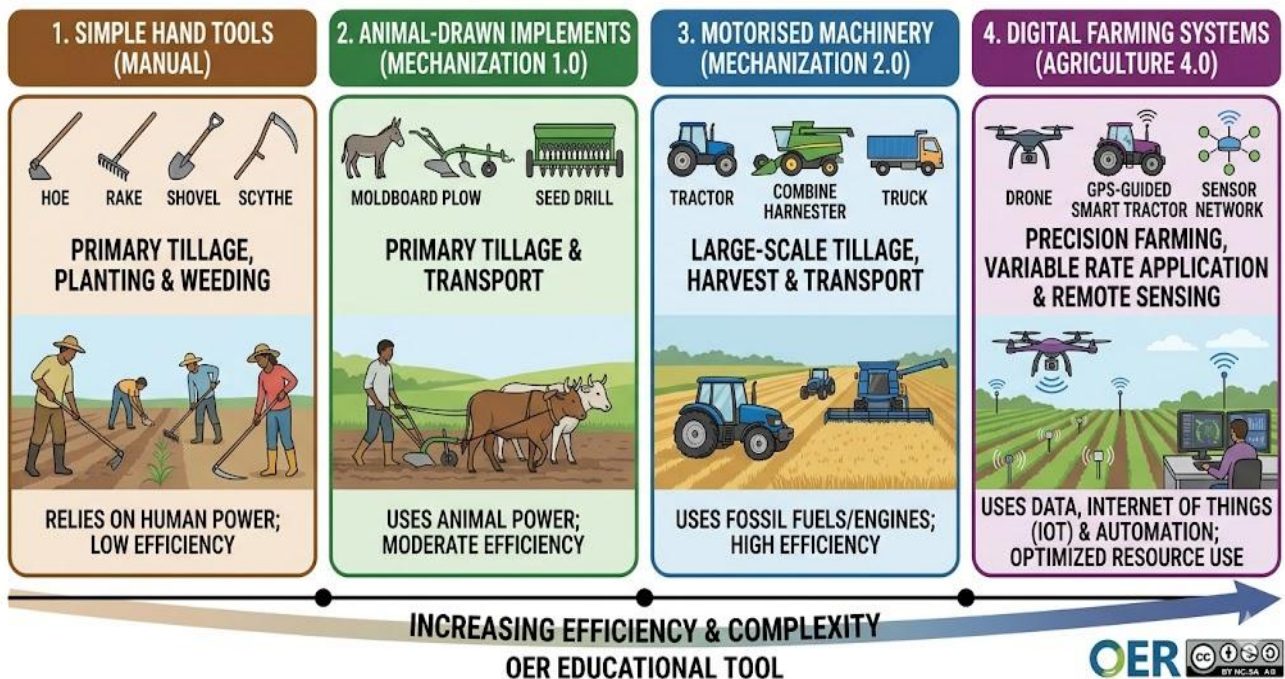


Figure 1.1: Diagram showing the scope of farm technology from hand tools through animal-drawn implements to motorised machinery and digital systems

1.1.2 Historical development of farm technology

The history of farm technology parallels the broader history of human civilisation. The earliest agricultural tools were simple digging sticks and stone hoes used to break the soil surface. The domestication of draft animals (oxen, horses, donkeys) around 3,000 BCE enabled the development of the animal-drawn plough, the first major advance in agricultural mechanisation. The iron age brought stronger, more durable implements. The eighteenth and nineteenth centuries saw the invention of the seed drill (Jethro Tull, 1701), mechanical threshers, and eventually steam-powered farm machinery.

The twentieth century was the era of the internal combustion engine tractor, which replaced animal power on large farms worldwide from the 1920s onwards. Green Revolution technologies of the 1960s and 1970s combined improved seed varieties with mechanised irrigation, mechanised tillage, and fertiliser application to dramatically increase global food production. From the 1980s, electronic sensors, GPS, and computers began to be integrated into farm



machinery, leading to the precision agriculture revolution. In Nigeria, the history of farm technology is characterised by a dominant smallholder sector still reliant on hand tools, alongside government-supported mechanisation programmes that have had mixed success.

Fill in the blank: The animal-drawn _____ was the first major advance in agricultural mechanisation, developed after the domestication of draft animals around 3,000 BCE.

tools to modern precision agriculture

1.1.3 Components and classification of farm technology

Farm technology can be classified into four main categories based on the nature and complexity of the technology involved. **Hand tools** (hoes, cutlasses, rakes, hand sprayers) are operated entirely by human muscular effort; they are low-cost, widely available, and suitable for small plots but are limited in productivity. **Animal-drawn implements** (ploughs, harrows, ridgers, seeders, carts) use draft animal power multiplied by simple mechanical design; they increase productivity significantly over hand tools at modest cost.

Motorised equipment (tractors, power tillers, combine harvesters, irrigation pumps) uses internal combustion engines or electric motors to power agricultural operations at high throughput and large scale. **Precision and digital technology** (GPS-guided tractors, drone sprayers, soil sensors, farm management software) integrates electronics, computing, and data analytics to optimise the application of inputs and the management of farm operations. Each category is appropriate for a different scale of operation, level of capital investment, and farming system context.

Fill in the blank: Farm technology is classified into four categories: hand tools, animal-drawn implements, _____ equipment, and precision and digital technology.

Category	Examples	Scale of Use	Capital Requirement
<u>Hand tools</u>	Hoe, cutlass, hand fork, watering can	Small-scale, subsistence farming	Very low — affordable for individual farmers



<u>Animal-drawn implements</u>	Plough, harrow, ridger, cart	Medium-scale farming in rural areas	Low to moderate — cost of animals and implements
<u>Motorised equipment</u>	Tractors, power tillers, harvesters, irrigation pumps	Large-scale and commercial farms	High — requires significant investment and maintenance
<u>Precision/digital technology</u>	Drones, GPS-guided tractors, soil sensors, farm management apps	Commercial and modern farms	Very high — advanced technology, training, and infrastructure

Table 1.1: Classification of farm technology by category, examples, scale, and capital requirement

Pilot questions 1.1

1. Define farm technology and state three activities it covers.
2. Name the first major advance in agricultural mechanisation and explain what made it significant.
3. List the four categories of farm technology and give two examples of each.
4. Explain why understanding farm technology is important for an agriculture student in Nigeria.
5. What development from the 1980s onwards led to the precision agriculture revolution?

1.2 Need and Justification for Farm Mechanisation

1.2.1 Arguments for agricultural mechanisation

Agricultural mechanisation is justified by the need to address several interrelated challenges in food production. **Labour shortage and timeliness** — mechanisation enables farm operations to be completed within the narrow time windows dictated by rainfall seasons and crop growth stages, even when rural labour is scarce or expensive. **Scale and productivity** — machines allow a single operator to cultivate far more land per day than is possible with hand tools, increasing the area that can be farmed and the quantity of food that can be produced.



Quality and precision — machines can apply inputs (seeds, fertilisers, pesticides) more uniformly and at more precise rates than hand application, reducing waste and improving crop establishment and yield. Reduced drudgery — mechanisation reduces the physically demanding nature of farm work, making agriculture more attractive to young people and women and improving the health and wellbeing of farm workers. Value addition — processing machines extend the range of marketable products that can be produced from farm output, adding economic value along the agricultural value chain. Taken together, these arguments support the view that mechanisation is not a luxury but a necessary component of any strategy to modernise Nigerian agriculture and achieve food security.

Fill in the blank: Agricultural mechanisation allows a single operator to cultivate far more land per day than with hand tools, increasing both the _____ farmed and the quantity of food produced.

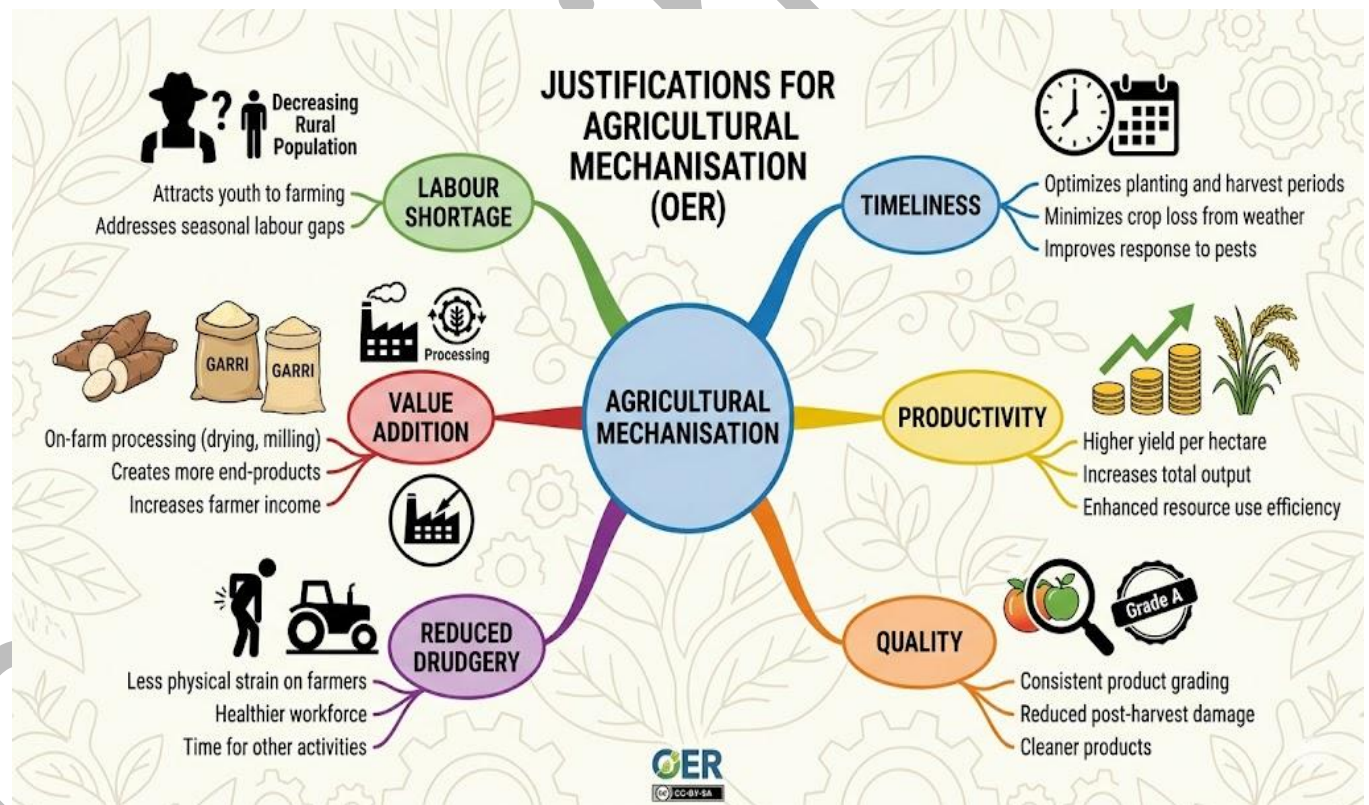


Figure 1.3: Diagram showing the multiple justifications for agricultural mechanisation arranged around a central need for food security



1.2.2 Constraints to mechanisation in Nigeria

Despite the clear benefits of mechanisation, its adoption in Nigeria faces serious constraints.

Small farm size — the majority of Nigerian farms are less than 2 hectares, too small to justify the capital cost of most motorised equipment; machines designed for large-scale commercial farming are economically inappropriate for smallholder plots. **High capital cost** — tractors, combine harvesters, and irrigation equipment represent capital investments that are beyond the reach of most smallholder farmers without credit or subsidy support.

Inadequate rural infrastructure — poor road networks in rural areas make it difficult to transport heavy machinery to the farm and to access fuel, spare parts, and repair services. Limited technical skill — many rural farmers lack the skills to operate, maintain, and repair modern machinery, resulting in rapid equipment breakdown and abandonment. Inappropriate technology design — much of the farm machinery available in Nigeria is designed for conditions in temperate developed countries and performs poorly in tropical soils and terrain. Government policy gaps — inconsistent mechanisation support programmes, poor maintenance of publicly owned farm equipment depots, and inadequate extension services for machine operation all constrain adoption.

Fill in the blank: The majority of Nigerian farms are less than _____ hectares, making them too small to economically justify the capital cost of most motorised farm equipment.

Constraint	Description
<u>Small farm size</u>	Fragmented land holdings make mechanisation uneconomical and difficult to implement.
<u>High cost</u>	Machinery purchase, fuel, and maintenance are expensive for smallholder farmers.
<u>Poor infrastructure</u>	Inadequate rural roads, electricity, and water supply hinder equipment use and servicing.
<u>Skill gaps</u>	Limited technical knowledge and training reduce effective operation and maintenance of machines.
<u>Inappropriate technology</u>	Imported machines often unsuitable for local soils, crops, and small-scale farming systems.



<u>Policy weaknesses</u>	Inconsistent government support, weak credit systems, and poor extension services slow adoption.
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Box 1.1: Key constraints to agricultural mechanisation in Nigeria and proposed solutions

1.2.3 Socio-economic and environmental implications

Mechanisation has both positive and negative socio-economic implications. On the positive side, it increases agricultural productivity, raises farm incomes, reduces food prices for consumers, creates jobs in machinery sales, maintenance, and operation, and makes farming more attractive to educated young people. It also enables the expansion of cultivated area and the cultivation of labour-scarce crops at commercial scale, supporting agribusiness development and agricultural value chain growth.

On the negative side, mechanisation can displace agricultural labour, particularly in economies where rural employment opportunities are limited, potentially worsening rural poverty if the benefits of increased productivity are captured by a small number of large farm operators. Environmentally, heavy machinery can cause soil compaction, reducing infiltration and increasing runoff; chemical spraying equipment, if misused, contributes to pesticide contamination of water and soil; and land clearance using bulldozers destroys vegetation and accelerates erosion. Sustainable mechanisation strategies therefore seek to capture productivity benefits while minimising negative environmental and social effects, for example by promoting appropriate-scale technology, farmer cooperatives for shared equipment ownership, and conservation tillage practices.

Fill in the blank: Heavy farm machinery can cause soil _____, which reduces water infiltration and increases surface runoff, leading to erosion and reduced soil productivity over time.

Pilot questions 1.2

1. State four arguments that justify the mechanisation of Nigerian agriculture.
2. Explain why small farm size is a constraint to mechanisation and suggest one solution.
3. Describe two ways in which farm mechanisation can create employment in rural areas.



4. Explain how heavy farm machinery can harm the environment.
5. What is meant by appropriate-scale technology in the context of farm mechanisation?

1.3 Farm Power: Concepts and Sources

1.3.1 Definition and classification of farm power

Farm power is the energy or force applied to perform agricultural work. It is measured in watts (W) or kilowatts (kW) (SI units) or in horsepower (hp) in traditional engineering units (1 hp = 0.746 kW). Farm power is distinct from farm energy: energy is the capacity to do work (measured in joules or kilowatt-hours), while power is the rate at which work is done (energy per unit time). The total farm power requirement for a farming system is determined by the type and number of operations to be performed, the timeliness required, and the area to be covered.

Farm power sources are classified into three broad categories: biological power (human and animal effort), mechanical power (internal combustion engines and electric motors driving tractors, pumps, and other machines), and alternative or renewable power (wind energy, solar energy, biogas, and water power). In Nigeria, the dominant source of farm power for smallholder agriculture remains human labour (estimated to supply over 70 per cent of total farm energy), supplemented by animal traction in the northern states and motorised machinery on commercial farms. Understanding the characteristics, advantages, and limitations of each power source is essential for selecting the most appropriate power system for a given farming context.

Fill in the blank: Farm power is measured in _____ (kW) in SI units or in horsepower (hp) in traditional engineering units, where 1 hp equals 0.746 kW.



CLASSIFICATION OF FARM POWER SOURCES (OER DIAGRAM)

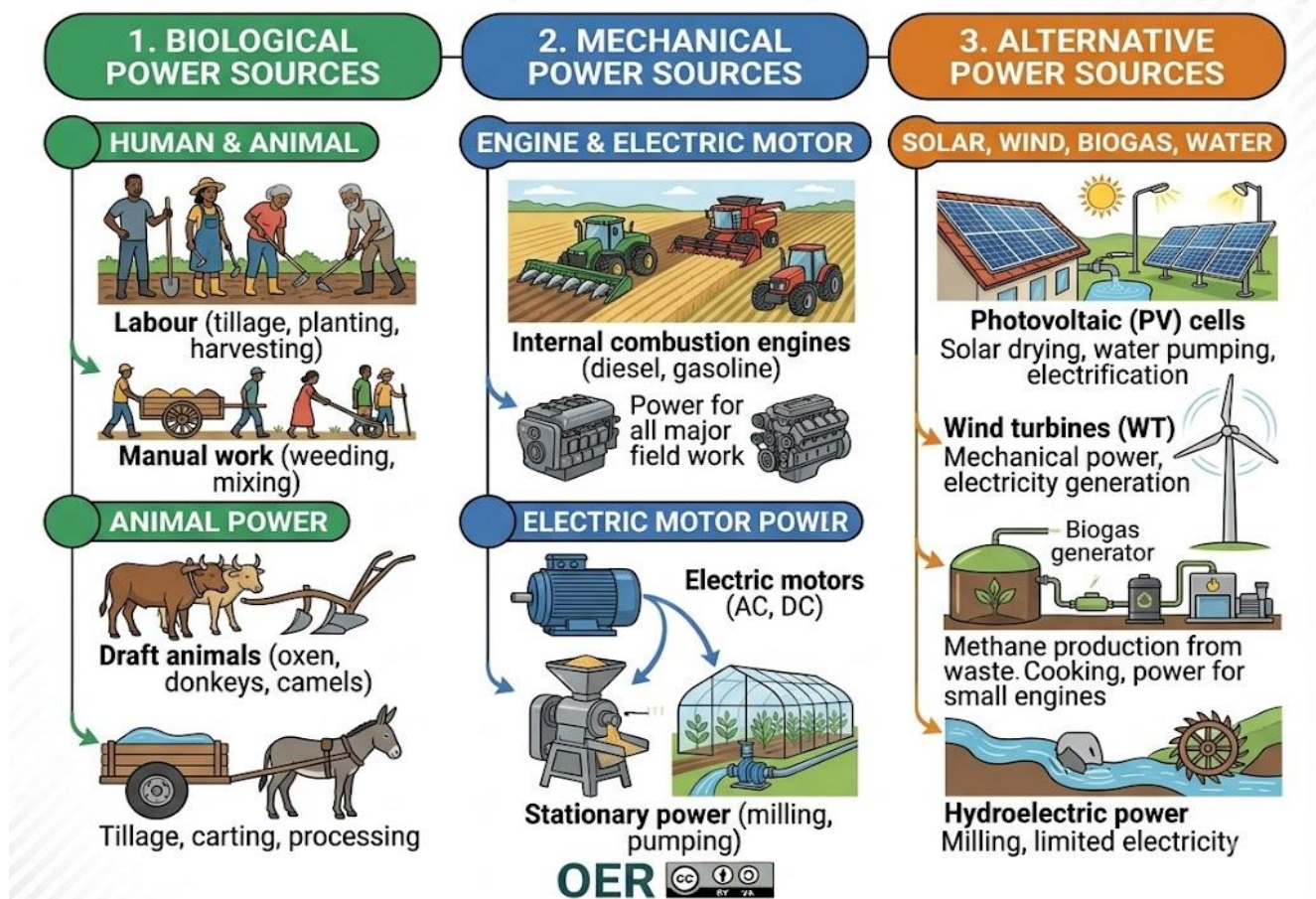


Figure 1.5: Diagram classifying farm power sources into biological, mechanical, and alternative categories with examples of each

1.3.2 Human and animal power in agriculture

Human power is the oldest and most universally available source of farm energy. The average adult can sustain a working power output of approximately 0.05 to 0.10 kW (50 to 100 watts) over a full working day. This is sufficient for hand-tool operations including hoeing, planting, weeding, and hand harvesting on small plots but is entirely inadequate for covering the large areas needed to feed growing urban populations. In Nigeria, heavy dependence on human power for farming is a major constraint on the expansion of agricultural production and a contributor to rural poverty.



Animal power (draft animals including oxen, donkeys, horses, and camels) is the intermediate step between human labour and motorised machinery, providing two to ten times the power output of a human worker. Draft animals can pull implements (ploughs, harrows, ridgers, seed drills, carts) that would be impossible to operate by human effort alone. In Nigeria, animal traction is most widely used in the Guinea and Sudan savanna zones of the north and middle belt. The productivity of animal power is limited by the working hours of the animal, the need for feed, veterinary care, training, and the availability of suitable terrain; steep or waterlogged land cannot be cultivated by draft animals.

Fill in the blank: The average adult farmer can sustain a working power output of approximately 0.05 to _____ kW over a full working day, which is only sufficient for hand-tool operations on small plots.

1.3.3 Mechanical and alternative power sources

Internal combustion engines (burning petrol, diesel, or liquefied petroleum gas) are the dominant source of mechanical power in modern agriculture worldwide. Diesel engines power tractors, irrigation pumps, threshers, and stationary processing machines; they are durable, fuel-efficient at high loads, and capable of producing the high power outputs (15 to over 300 kW) required for large-scale farm operations. Petrol engines power smaller equipment such as chain saws, water pumps, knapsack sprayer motors, and small tillers used in vegetable production.

Alternative and renewable power sources are increasingly relevant as fossil fuel costs rise and environmental concerns grow. Solar photovoltaic (PV) systems power electric pumps for small-scale irrigation, battery charging for farm management devices, lighting for livestock buildings, and electric fencing. Biogas (produced from the anaerobic digestion of animal manure and crop residues) powers cooking stoves, generators, and stationary farm machines. Wind energy drives water-pumping windmills in arid and semi-arid areas. Small hydropower plants supply electricity in riverine areas. In the Nigerian context, solar irrigation pumps are the most rapidly expanding alternative power technology, offering reliable pumping for dry-season vegetable production without dependence on diesel supply.



Fill in the blank: _____ engines are the dominant source of mechanical power in modern agriculture, powering tractors, irrigation pumps, and stationary processing machines.

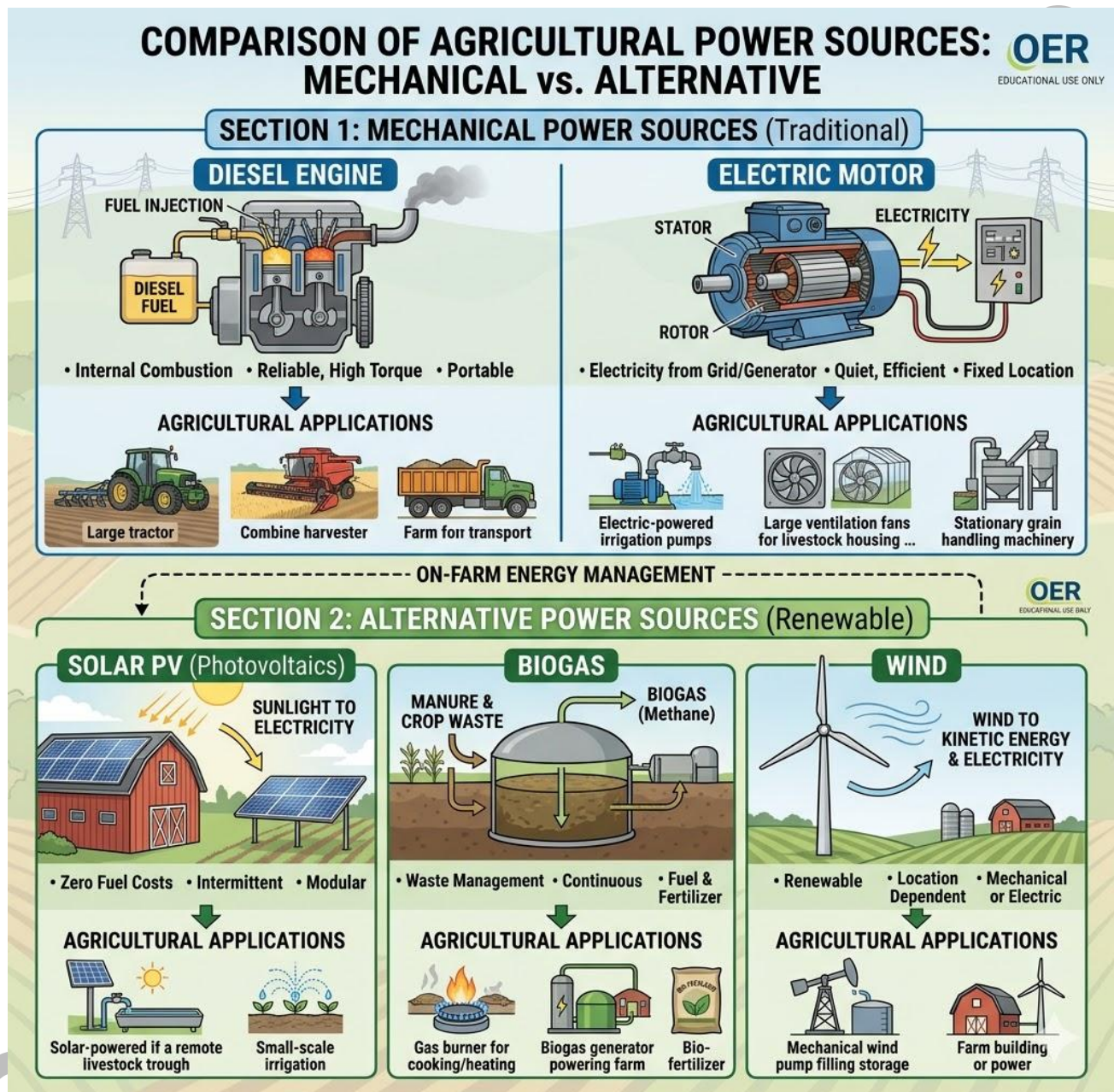


Figure 1.6: Diagram comparing mechanical (diesel engine, electric motor) and alternative (solar PV, biogas, wind) power sources for agricultural applications

Pilot questions 1.3

1. Define farm power and distinguish it from farm energy.



2. State the three broad categories of farm power sources with one example of each.
3. Explain why human power alone is inadequate for feeding a growing urban population.
4. Describe two advantages and two limitations of animal power in Nigerian agriculture.
5. Explain why solar irrigation pumps are the most rapidly expanding alternative power technology in Nigeria.

1.4 ICT in Agriculture

1.4.1 Overview of ICT applications in agriculture

Information and Communications Technology (ICT) in agriculture encompasses all digital tools and systems used to collect, store, process, transmit, and apply information to improve agricultural production, management, and marketing. ICT applications in agriculture span a wide range: mobile phones and SMS services provide farmers with weather forecasts, market prices, and extension advice; internet platforms connect producers directly to buyers; GPS and GIS enable precise mapping of farm resources and spatial planning; satellite and drone remote sensing monitors crop health across large areas; and sensor networks track soil moisture, temperature, and animal behaviour in real time.

In Nigeria, the most transformative ICT application for smallholder farmers has been the mobile phone, which enables real-time market price information that has reduced information asymmetries between farmers and traders and improved farm-gate prices. Platforms such as Farmcrowdy, Hello Tractor, and digital extension services provided by the Agricultural Development Programmes (ADPs) have extended market access and technical advisory services to rural producers. ICT also supports the regulatory and data functions of government agencies (Federal Department of Agriculture, land registration, pest and disease surveillance databases) that underpin agricultural policy and planning.

Fill in the blank: The most transformative ICT application for Nigerian smallholder farmers has been the _____ phone, which provides real-time market price information and reduces information asymmetries.



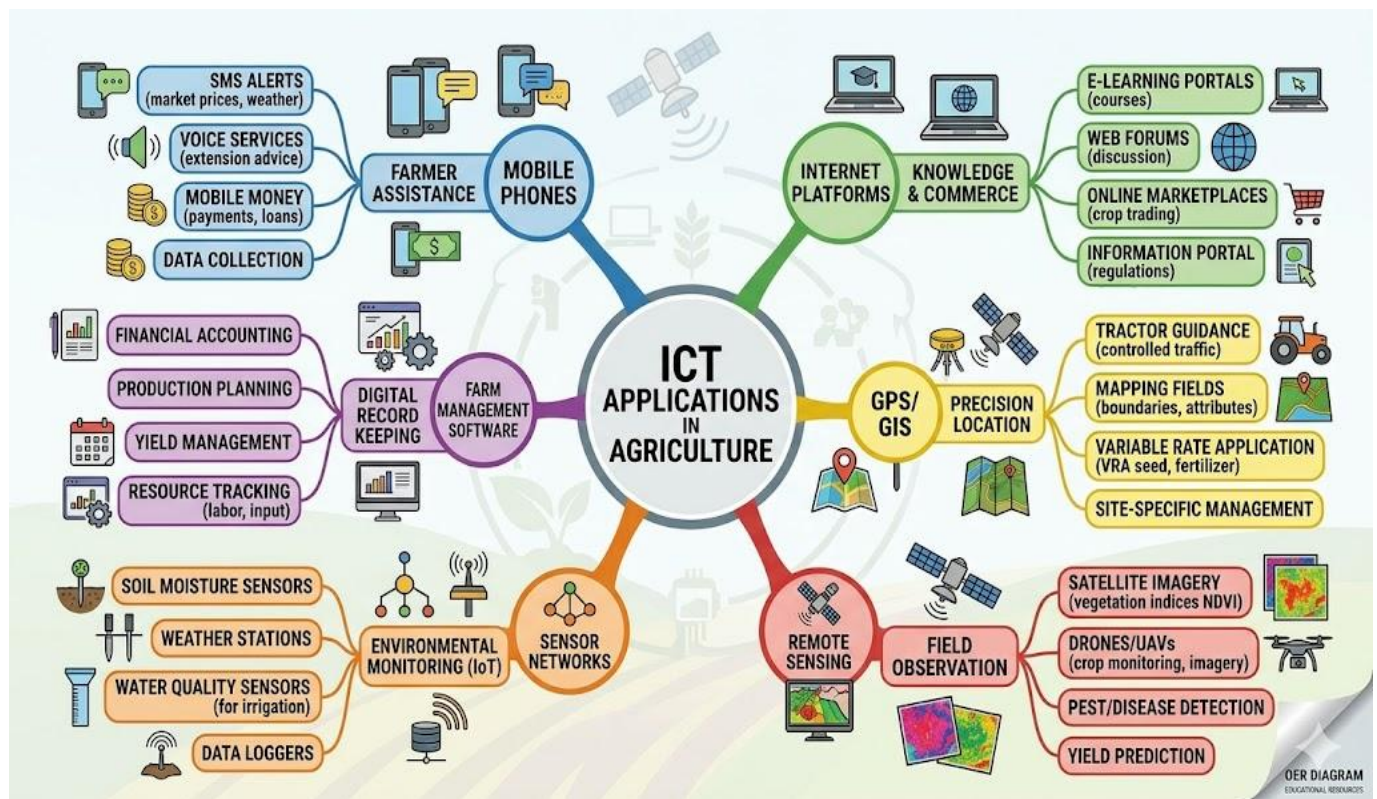


Figure 1.7: Diagram showing the range of ICT applications in agriculture from mobile phones and weather services to GPS, drones, and sensor networks

1.4.2 Precision agriculture and digital tools

Precision agriculture (PA) is a farm management concept that uses information technology to ensure that crops and soil receive exactly what they need for optimum health and productivity. Rather than applying inputs (seed, fertiliser, water, pesticide) uniformly across the whole farm, precision agriculture uses spatial data to identify zones of variability within the field and applies variable-rate inputs matched to the specific needs of each zone. The result is more efficient use of inputs, reduced environmental impact, and improved crop yield and quality.

Digital tools used in precision agriculture include: GPS receivers (for accurate positioning of farm equipment and mapping of field variability), yield monitors (sensors on combine harvesters that record grain yield as the machine moves across the field), variable-rate applicators (fertiliser spreaders and sprayers that adjust application rate based on prescription maps), unmanned aerial vehicles (UAVs or drones) fitted with multispectral cameras (for mapping crop health using



vegetation indices such as NDVI), and soil electrical conductivity sensors (for mapping soil texture and organic matter variability). In Nigeria, precision agriculture adoption is still in its early stages, but GPS-guided tractors and drone spraying services are beginning to be used on larger commercial farms.

Fill in the blank: Precision agriculture applies _____ inputs matched to zone-specific field data rather than uniform application, reducing waste and improving efficiency across the farm.

1.4.3 ICT for farm management and decision support

Farm management software and decision support systems (DSS) use data collected from the farm and from external sources (weather forecasts, market prices, agronomic databases) to help farm managers plan operations, allocate resources, and evaluate performance. Simple farm management software records planting dates, input applications, labour costs, and yields, enabling calculation of profitability and identification of areas for improvement. More advanced DSS models integrate real-time weather data with crop growth models to predict optimal planting windows, irrigation scheduling, and pest outbreak risk.

At the national and institutional level, ICT supports agricultural planning through geographic information systems (GIS) that map land use, soil types, rainfall patterns, and infrastructure. Remote sensing satellites monitor vegetation cover, identify irrigated areas, and track crop production at regional scale for food security early warning. FAO's GIEWS and Nigeria's FMARD information systems use these data to alert decision-makers to emerging food supply deficits. For the student of farm technology, developing basic competency in agricultural data collection, farm record-keeping software, and interpretation of GIS-based agricultural maps is an increasingly important professional skill.

Fill in the blank: Decision support systems in agriculture integrate weather forecasts with _____ growth models to predict optimal planting windows, irrigation scheduling, and pest outbreak risk.



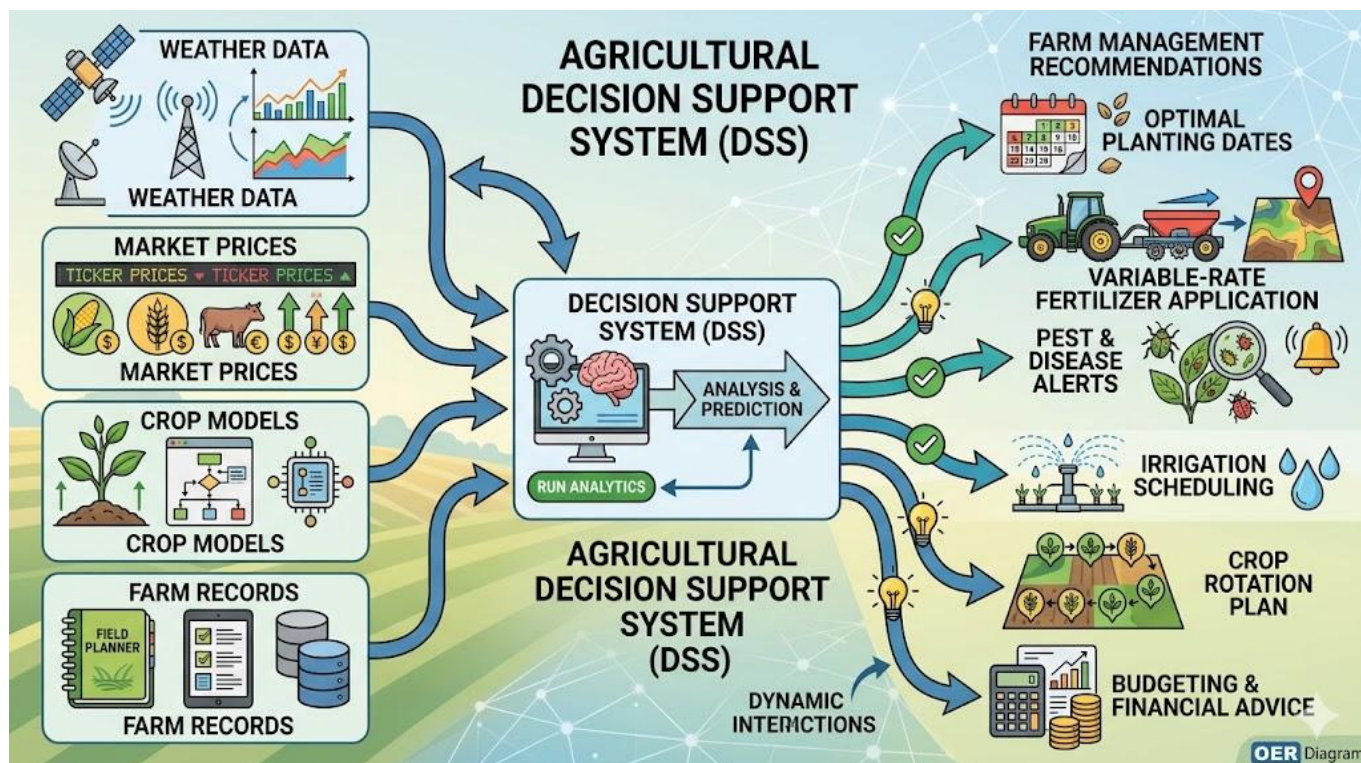


Figure 1.9: Diagram showing how ICT decision support systems integrate weather data, market information, and crop models to support farm management decisions

Pilot questions 1.4

1. Define ICT in agriculture and give three examples of ICT applications used by Nigerian farmers.
2. Explain what precision agriculture means and state two benefits it offers over conventional uniform-rate farming.
3. Name four digital tools used in precision agriculture and state the function of each.
4. Explain how farm management software helps a farmer improve profitability.
5. Describe one ICT application used for food security monitoring at the national level.

Series Summary

This Series has introduced the foundational concepts of farm technology and mechanisation, the sources and classification of farm power, and the role of ICT in agriculture. We began by defining farm technology and tracing its historical development from ancient hand tools through



animal-drawn implements and steam power to the modern precision agriculture era, and classified farm technology into four categories: hand tools, animal-drawn implements, motorised equipment, and precision and digital technology. We then examined the need and justification for agricultural mechanisation, covering the productivity, timeliness, quality, and drudgery-reduction arguments, as well as the constraints — small farm size, high capital cost, poor infrastructure, limited skill, and policy gaps — that limit adoption in Nigeria, and the socio-economic and environmental implications of mechanisation.

Following that, we surveyed the sources of farm power, distinguishing biological (human and animal), mechanical (internal combustion engine, electric motor), and alternative (solar, biogas, wind) power sources, and described their characteristics, applications, and limitations. Finally, we introduced ICT in agriculture, covering the range of applications from mobile phones and GPS to precision agriculture tools including yield monitors, variable-rate applicators, and drone remote sensing, and explained how farm management software and decision support systems help farmers and planners make better-informed decisions. By completing this Series, you should now be able to achieve all nine Series Learning Outcomes (SLO 1.1 to SLO 1.9).

Glossary of Terms

- **Animal traction:** the use of draft animals (oxen, donkeys, horses, camels) to pull farm implements; an intermediate power source between hand tools and motorised machinery widely used in the Nigerian savanna zones.
- **Biogas:** a combustible gas (mainly methane) produced by the anaerobic digestion of organic materials including animal manure and crop residues; used to power farm cooking stoves, generators, and stationary machines.
- **Decision support system (DSS):** a computer-based tool that integrates data from multiple sources (weather, crop models, market information) to generate management recommendations to assist agricultural decision-makers.
- **Draft animal:** an animal used to provide tractive power for pulling farm implements; includes oxen, donkeys, horses, camels, and buffaloes.



- **Farm mechanisation:** the adoption of machines and motorised equipment to perform agricultural operations that were previously done by human or animal power.
- **Farm power:** the energy or force applied per unit time to perform agricultural work; measured in kilowatts (kW) or horsepower (hp).
- **Farm technology:** the application of scientific and engineering knowledge to the design, development, and operation of tools, machines, systems, and processes used in agricultural production.
- **GIS (Geographic Information System):** software that captures, stores, analyses, and displays geographically referenced data; used in agriculture for land use mapping, soil mapping, and spatial planning of farm operations.
- **GPS (Global Positioning System):** a satellite-based navigation system that provides accurate position data; used in precision agriculture for field mapping, yield monitoring, and guidance of farm machinery.
- **Horsepower (hp):** a traditional unit of power commonly used in agricultural engineering; 1 hp = 0.746 kW.
- **ICT (Information and Communications Technology):** the diverse set of digital tools and systems used to collect, store, process, and transmit information; in agriculture, includes mobile phones, internet, GPS, remote sensing, and farm management software.
- **Internal combustion engine:** an engine that produces mechanical power by burning fuel (petrol, diesel, or gas) inside cylinders; the dominant source of mechanical power for tractors and other motorised farm equipment.
- **NDVI (Normalised Difference Vegetation Index):** a remote sensing index calculated from satellite or drone multispectral imagery that indicates the density and health of vegetation; widely used in precision agriculture for crop monitoring.
- **Precision agriculture (PA):** a farm management approach that uses spatial data and information technology to optimise the application of inputs (seed, fertiliser, water, pesticide) to match the specific needs of different zones within a field.



- **Remote sensing:** the acquisition of information about the Earth's surface using satellite or airborne sensors without physical contact; used in agriculture to monitor crop health, map vegetation, and estimate yields over large areas.
- **Solar PV (photovoltaic):** a technology that converts sunlight directly into electricity using semiconductor panels; used in Nigerian agriculture for powering irrigation pumps, lighting, and farm management devices.
- **UAV (Unmanned Aerial Vehicle) / Drone:** a remotely piloted aircraft used in precision agriculture for aerial mapping, crop health monitoring, and in some cases variable-rate spraying of pesticides or fertilisers.
- **Variable-rate application:** the technology-enabled practice of applying farm inputs (fertiliser, seed, pesticide, water) at rates that vary across the field based on digital prescription maps derived from spatial data.
- **Yield monitor:** a sensor system on a combine harvester that records grain yield continuously as the machine moves through the field, producing a spatial map of yield variability for subsequent analysis.

Concept Check Questions [Series 1]

Objective Questions

1. Farm technology refers to the application of scientific and engineering knowledge to tools, machines, and systems used in _____ production. (Linked to SLO 1.1)
2. The animal-drawn plough was the first major advance in farm mechanisation, developed after the domestication of draft animals around _____ BCE. (Linked to SLO 1.2)
3. The majority of Nigerian farms are less than _____ hectares, making them too small to justify most motorised equipment. (Linked to SLO 1.4)
4. Farm power is measured in kilowatts (kW) or in _____ (hp) in traditional engineering units. (Linked to SLO 1.5)
5. Precision agriculture applies _____ inputs based on spatial data rather than uniform rates across the whole field. (Linked to SLO 1.9)



Short-Answer Questions

6. Explain the four categories of farm technology and give one example of each. (Linked to SLO 1.1)
7. State four arguments that justify agricultural mechanisation in Nigeria. (Linked to SLO 1.3)
8. Explain why human power alone is insufficient to feed Nigeria's growing population. (Linked to SLO 1.6)
9. Explain what precision agriculture is and state two digital tools used in it. (Linked to SLO 1.9)
10. Describe how mobile phones have improved the economic position of Nigerian smallholder farmers. (Linked to SLO 1.8)

Long-Answer Questions

11. Analyse the need and justification for agricultural mechanisation in Nigeria, covering the productivity, timeliness, and quality arguments in favour, the constraints that limit adoption, and the socio-economic and environmental implications that must be managed. (Linked to SLOs 1.3, 1.4)
12. Discuss the sources of farm power available to Nigerian farmers, classifying them into biological, mechanical, and alternative categories, describing the characteristics and limitations of human and animal power, and explaining the applications of diesel engines and solar photovoltaic systems. (Linked to SLOs 1.5, 1.6, 1.7)
13. Evaluate the role of ICT in modern agriculture, explaining the range of ICT applications from mobile phones to precision agriculture, describing how farm management software and decision support systems improve farm decisions, and assessing the current and potential impact of ICT on Nigerian agriculture. (Linked to SLOs 1.8, 1.9)

Answers to Concept Check Questions [Series 1]

Objective Questions

1. Agricultural.
2. 3,000.
3. 2.
4. Horsepower.



5. Variable-rate.

Short-Answer Questions

6. Hand tools (example: hoe) — operated by human effort alone, low cost, suitable for small plots. Animal-drawn implements (example: ox plough) — use draft animal power, intermediate productivity. Motorised equipment (example: tractor) — use internal combustion engines, high throughput and scale. Precision/digital technology (example: GPS-guided tractor) — integrate electronics and data to optimise input application and farm management.
7. Any four: addresses labour scarcity and allows timely completion of operations; increases the area cultivated per worker, raising food supply; improves uniformity and precision of input application; reduces physical drudgery and makes farming more attractive; enables value addition through processing machinery.
8. A human worker can sustain only 0.05 to 0.10 kW of power over a working day; this is sufficient only for small plot operations; Nigeria's population exceeds 220 million and is growing rapidly; the area that must be cultivated to feed this population requires power outputs far beyond what human labour can supply; without machinery, the area that can be farmed per worker is so limited that food production cannot keep pace with population growth.
9. Precision agriculture is a farm management approach that uses spatial data and information technology to optimise input application to match the specific needs of different zones within a field rather than applying uniform rates everywhere. Two digital tools: GPS receiver (accurate field positioning and mapping of yield variability); yield monitor (sensor that records grain yield spatially as the combine harvester moves through the field).
10. Mobile phones provide farmers with real-time price information from multiple markets, enabling them to compare prices before selling and choose the market offering the best price; this reduces the information asymmetry that previously allowed traders to buy cheaply from uninformed farmers; documented studies in Nigeria and West Africa have shown significant increases in farm-gate prices and farm incomes following mobile phone adoption in rural farming communities.

Long-Answer Questions

11. Basic response: Arguments for mechanisation: labour scarcity and timeliness, increased cultivated area and food supply, improved input precision and quality, reduced drudgery, value addition. Constraints: small farm size (<2 ha), high capital cost, poor rural infrastructure, limited



technical skills, inappropriate technology design, inconsistent government policy. Socio-economic implications: positive (productivity, income, jobs, food prices); negative (labour displacement, rural-urban migration). Environmental implications: soil compaction from heavy machinery, pesticide pollution from sprayers, erosion from land clearance.

12. Value-added response: The most effective approach to mechanisation in Nigeria is not transplanting large-scale equipment from developed countries but developing or adapting appropriate-scale machinery suited to smallholder conditions: two-wheel power tillers rather than 100 hp four-wheel tractors; motorised knapsack sprayers rather than boom sprayers; small-scale processing machines accessible through farmer cooperatives. Shared equipment ownership models (like Hello Tractor's equipment-sharing platform) and agricultural mechanisation service centres reduce the effective capital barrier without requiring each farmer to own machinery individually.
13. Basic response: Biological power: human (0.05 to 0.10 kW, universal but inadequate for large scale); animal (2 to 10 times human output, suitable for draft implement operations). Mechanical: diesel engine (dominant, powers tractors and pumps, durable and high-powered); electric motor (efficient, low maintenance, requires reliable power supply). Alternative: solar PV (growing rapidly for irrigation pumps, no fuel cost, grid-independent); biogas (powers stationary machines from farm organic waste); wind (water pumping in arid areas).
14. Value-added response: The energy transition in Nigerian agriculture is moving from human and animal power toward diesel engines with a growing contribution from solar PV. The key constraint on the transition to solar-powered irrigation is the capital cost of the solar panel and pump system, which is falling rapidly as panel prices decline globally. The economic case for solar irrigation in dry-season vegetable production is now compelling in many Nigerian contexts, where the high value of vegetables and the high cost of diesel make solar the least-cost power option over the system's lifetime. Teaching students to compare lifecycle costs rather than just capital costs is essential for effective technology advisory work.
15. Basic response: ICT applications range from mobile phones (market prices, weather, extension), internet platforms (market access, input supply), GPS/GIS (field mapping, precision application), remote sensing (crop health monitoring), to farm management software (records, profitability). DSS integrate weather and crop models to advise on planting, irrigation, and pest management. National-level applications include GIS-based land use mapping and FAO GIEWS for food security monitoring.
16. Value-added response: The transformative potential of ICT in Nigerian agriculture has so far been only partially realised because most adoption is concentrated at the mobile phone/SMS



level, with precision agriculture and DSS adoption confined to a small number of large commercial farms and research institutions. The next phase of ICT impact will depend on: expanding mobile broadband coverage in rural areas; developing and promoting locally relevant apps in Hausa, Yoruba, and Igbo; integrating ICT tools into agricultural extension programmes; and training a new generation of agriculture graduates who can bridge the gap between information technology and practical farming knowledge. This course contributes directly to that last objective.

Answers to Pilot Questions [Series 1]

Part 1.1: Introduction to Farm Technology

1. Farm technology is the application of scientific and engineering knowledge to tools, machines, and systems in agricultural production; three activities: land preparation (tillage, planting), crop protection (spraying), harvesting and post-harvest processing.
2. The animal-drawn plough was the first major advance; it was significant because it multiplied the productive capacity of a single farmer by harnessing the tractive power of a draft animal, enabling deeper, faster tillage of larger areas than was possible with a hand hoe, and allowing cultivation of heavier soils unsuitable for manual digging.
3. Hand tools (hoe, cutlass); animal-drawn (ox plough, ridger); motorised (tractor, irrigation pump); precision/digital (GPS-guided tractor, drone sprayer).
4. Understanding farm technology allows an agriculture student to advise farmers on appropriate equipment selection for their farming system and scale, diagnose and troubleshoot field performance problems, contribute to mechanisation planning and policy, and participate competently in the operation and supervision of agricultural engineering activities as required by the course learning outcomes.
5. The integration of GPS, electronic sensors, and computers into farm machinery from the 1980s onwards, enabling precise field positioning, real-time data collection, and variable-rate application of inputs, collectively led to the precision agriculture revolution.

Part 1.2: Need and Justification for Farm Mechanisation



1. Any four: addresses rural labour scarcity and enables timely operations; increases area cultivated per worker, raising total food supply; improves precision and uniformity of input application; reduces physical drudgery, making farming more attractive; enables value addition through processing equipment.
2. Most Nigerian farms are under 2 hectares, too small for the capital cost of most motorised equipment to be recovered from the income it generates; one solution is the cooperative or hire service model where multiple smallholders pool resources or hire equipment from a mechanisation service centre, reducing the capital cost per farm unit.
3. Any two: machinery sales, servicing, and repair create skilled technical jobs; machine operators and drivers are needed on commercial farms; fuel distribution and spare parts retail create rural trading employment; equipment hire service entrepreneurs create businesses based on hiring tractors and other machines to smallholders.
4. Heavy machinery compacts the topsoil, reducing pore space, water infiltration, and root penetration; compacted soils are more prone to surface runoff and erosion; bulldozer land clearance strips surface vegetation, exposing bare soil to raindrop splash and sheet erosion; repeated tillage with heavy discs can create a tillage pan below ploughing depth.
5. Appropriate-scale technology refers to farm equipment that is matched in size, power, complexity, and cost to the actual scale of operation of the target users; for Nigerian smallholder farmers this means machines smaller and simpler than those designed for large-scale commercial farming in developed countries, such as two-wheel power tillers, motorised hand sprayers, and small-scale processing machines, which are affordable, maintainable, and economically viable at farm sizes of 1 to 5 hectares.

Part 1.3: Farm Power: Concepts and Sources

1. Farm power is the rate at which energy is applied to do farm work (energy per unit time), measured in kilowatts or horsepower; farm energy is the total capacity to do work (measured in joules or kilowatt-hours); power describes how quickly work can be done while energy describes the total amount of work that can be done.
2. Biological (human, animal); mechanical (diesel engine, electric motor); alternative (solar PV, biogas, wind).
3. A human worker produces only 0.05 to 0.10 kW sustained power; Nigeria's population exceeds 220 million and is growing at approximately 3 per cent per year; the cultivated area and food



production required to feed this population grow correspondingly; a single human worker using hand tools can farm at most 0.5 to 1.0 hectares per season, which would feed only their own household; scaling this to feed urban populations requires a power input per farm worker orders of magnitude higher than human muscle can provide.

4. Advantages: available locally without fuel cost (feed and veterinary care are the running costs); suitable for small and medium plots; accessible to farmers without access to credit for machinery purchase. Limitations: limited to approximately 2 to 10 times human power output; cannot operate on steep, waterlogged, or stony terrain; require daily feeding, veterinary care, and training; working hours are limited and animals cannot be used for the full working day without rest.
5. Solar pumps use free, abundant sunlight as their energy source, eliminating recurring diesel fuel costs that are the major operating expense of conventional pumps; Nigeria has high solar irradiance (4 to 7 kWh/m²/day) making solar systems highly productive; solar panels have long lifetimes (20 to 25 years) with minimal maintenance; dry-season vegetable farming, which produces the highest-value crops in Nigerian agriculture, requires reliable irrigation precisely when solar radiation is most abundant; all these factors make the lifecycle economics of solar pumping increasingly favourable compared with diesel.

Part 1.4: ICT in Agriculture

1. ICT in agriculture is the use of digital tools to collect, process, and apply information to improve agricultural production, management, and marketing; three examples: mobile phones for market price information; GPS-guided tractors for field operations; drone imagery for crop health monitoring.
2. Precision agriculture uses spatial data and information technology to apply inputs at variable rates matched to zone-specific field needs rather than at uniform rates; two benefits: more efficient use of inputs (fertiliser, water, pesticides) reducing waste and cost; reduced environmental impact from over-application of agrochemicals in low-need areas.
3. Any four: GPS receiver (accurate field positioning and mapping of spatial variability); yield monitor (records grain yield spatially during harvesting); variable-rate applicator (adjusts fertiliser or pesticide rate according to a prescription map); drone with multispectral camera (maps crop health using NDVI indices); soil EC sensor (maps soil texture and organic matter variability).



4. Farm management software records all farm operations (planting dates, input applications, labour costs) and outputs (yields, prices received), enabling calculation of gross margin and net profit per crop and identification of the operations or input costs where efficiency can be improved; trend analysis across successive seasons reveals whether the farm is improving or deteriorating over time, enabling evidence-based management decisions rather than guesswork.
5. FAO's Global Information and Early Warning System (GIEWS) uses satellite remote sensing data, rainfall monitoring, and crop production statistics to monitor food supply conditions in all countries and alert governments and international agencies to emerging food supply deficits before they become crises; Nigeria's FMARD also maintains crop production monitoring databases that inform national food policy.

References and Attributions [Series 1]

Textual References (Books and External Sources)

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- FAO (Food and Agriculture Organization of the United Nations). (2013). Agricultural mechanization: A key input for sub-Saharan African smallholders. FAO Integrated Crop Management Vol. 20. FAO.
- Srivastava, A. K., Goering, C. E., Rohrbach, R. P., & Buckmaster, D. R. (2006). Engineering principles of agricultural machines (2nd ed.). ASABE.
- Fountas, S., Wulfsohn, D., Blackmore, B. S., Jacobsen, H. L., & Pedersen, S. M. (2006). A model of decision-making and information flows for information-intensive agriculture. *Agricultural Systems*, 87(2), 192-210.
- World Bank. (2019). Digital technology in agriculture: Taking stock of the evidence. World Bank.
- FAO (Food and Agriculture Organization of the United Nations). (2025). Guidelines for sustainable agriculture. FAO.

Figures, Plates, Tables, and Boxes



- Figure 1.1: Scope of farm technology spectrum Attribution: AI generated using prompt "Generate a diagram showing the spectrum of farm technology from simple hand tools through animal-drawn implements, motorised machinery, and digital farming systems." Suggested OER search string: "farm technology spectrum hand tools motorised machinery digital systems OER diagram".
- Figure 1.2: Farm technology historical development timeline Attribution: AI generated using prompt "Generate a horizontal timeline showing key milestones in farm technology development from ancient tools through the plough, steam engine, tractor, and precision agriculture." Suggested OER search string: "farm technology historical development timeline milestones OER diagram".
- Table 1.1: Farm technology classification table Attribution: AI generated using prompt "Generate a table classifying farm technology into hand tools, animal-drawn implements, motorised equipment, and precision/digital technology with examples, scale, and capital requirements." Suggested OER search string: "farm technology classification categories examples scale capital table OER".
- Figure 1.3: Justifications for agricultural mechanisation Attribution: AI generated using prompt "Generate a mind map showing the multiple justifications for agricultural mechanisation: labour shortage, timeliness, productivity, quality, reduced drudgery, and value addition." Suggested OER search string: "justifications agricultural mechanisation mind map food security OER diagram".
- Box 1.1: Constraints to mechanisation in Nigeria Attribution: AI generated using prompt "Generate a text box listing the key constraints to agricultural mechanisation in Nigeria including small farm size, high cost, poor infrastructure, skill gaps, and policy weaknesses." Suggested OER search string: "constraints agricultural mechanisation Nigeria solutions box OER".
- Figure 1.4: Mechanisation implications diagram Attribution: AI generated using prompt "Generate a two-column diagram showing positive and negative implications of agricultural mechanisation including productivity, income, soil compaction, and pollution." Suggested OER search string: "agricultural mechanisation positive negative implications socio-economic environmental OER diagram".
- Figure 1.5: Farm power sources classification Attribution: AI generated using prompt "Generate a three-column diagram classifying farm power sources into biological, mechanical, and alternative with examples." Suggested OER search string: "farm power sources classification biological mechanical alternative OER diagram".



- Plate 1.1: Ox-drawn plough in northern Nigeria Attribution: AI generated using prompt "Generate an image of two oxen pulling a mouldboard plough guided by a farmer in a northern Nigerian Guinea savanna farming system." Suggested OER search string: "ox-drawn plough Nigeria Guinea savanna animal traction OER image".
- Figure 1.6: Mechanical vs alternative power sources Attribution: AI generated using prompt "Generate a two-section diagram comparing mechanical power sources and alternative sources including solar PV, biogas, and wind with agricultural applications." Suggested OER search string: "mechanical alternative farm power sources comparison applications OER diagram".
- Figure 1.7: ICT applications in agriculture mind map Attribution: AI generated using prompt "Generate a mind map showing the range of ICT applications in agriculture including mobile phones, internet platforms, GPS/GIS, remote sensing, and sensor networks." Suggested OER search string: "ICT applications agriculture mobile GPS drone sensor farm management OER diagram".
- Figure 1.8: Precision agriculture cycle Attribution: AI generated using prompt "Generate a circular flowchart showing the precision agriculture cycle from data collection through analysis, variable-rate prescription, field application, and outcome monitoring." Suggested OER search string: "precision agriculture cycle data collection analysis variable rate application OER diagram".
- Figure 1.9: Agricultural DSS diagram Attribution: AI generated using prompt "Generate a diagram showing weather data, market prices, crop models, and farm records feeding into a DSS that generates farm management recommendations." Suggested OER search string: "agricultural decision support system inputs outputs farm management OER diagram".



Course code: AGE 124

Course title: Farm Technology

Course credit load: 2 Units

Series 2: Sources of Farm Power and Tractor Engine Systems

- **Part 2.1: The Agricultural Tractor**

- Sub Part 2.1.1: Definition, types, and uses of the agricultural tractor
- Sub Part 2.1.2: Major systems of the agricultural tractor
- Sub Part 2.1.3: Tractor selection and matching to farm operations

- **Part 2.2: The Internal Combustion Engine**

- Sub Part 2.2.1: Principles and classification of internal combustion engines
- Sub Part 2.2.2: The four-stroke engine: description and operating cycle
- Sub Part 2.2.3: The two-stroke engine: description and comparison with four-stroke

- **Part 2.3: Engine Systems and Their Functions**

- Sub Part 2.3.1: The fuel system
- Sub Part 2.3.2: The cooling and lubrication systems
- Sub Part 2.3.3: The electrical and transmission systems

- **Part 2.4: Tractor Operation and Basic Safety**

- Sub Part 2.4.1: Pre-operation checks and starting procedures
- Sub Part 2.4.2: Field operation techniques
- Sub Part 2.4.3: Tractor safety rules and accident prevention



Introduction

The agricultural tractor and its internal combustion engine are the technological heart of modern mechanised farming. Whether powering a plough, driving an irrigation pump, or operating a thresher through its power take-off shaft, the tractor has transformed the productive capacity of the modern farm. For any agriculture student or professional working with farm machinery, understanding how the tractor and its engine work — and how to operate and maintain them safely — is a foundational competency.

The aim of this Series is to introduce you to the agricultural tractor, its types and major systems, the principles and operating cycles of the internal combustion engine in both its four-stroke and two-stroke forms, the functions of the key engine support systems, and the practical skills of pre-operation checking, field operation, and safety.

We shall commence this Series by examining the agricultural tractor, its classification and major systems. Next, we will study the internal combustion engine, its principles and the four-stroke and two-stroke operating cycles. Following that, we will cover the fuel, cooling, lubrication, electrical, and transmission systems. Finally, we will wrap up with pre-operation checks, field operation techniques, and tractor safety.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 2.1** identify the types of agricultural tractors and describe their major uses (Linked to Part 2.1),
- **SLO 2.2** describe the major systems of the agricultural tractor and explain the function of each (Linked to Part 2.1),
- **SLO 2.3** explain the principles of the internal combustion engine and classify engine types (Linked to Part 2.2),
- **SLO 2.4** describe the four-stroke engine operating cycle and explain what happens in each stroke (Linked to Part 2.2),



- **SLO 2.5** describe the two-stroke engine operating cycle and compare it with the four-stroke engine (Linked to Part 2.2),
- **SLO 2.6** explain the function of the fuel system, cooling system, and lubrication system (Linked to Part 2.3),
- **SLO 2.7** explain the function of the electrical system and the tractor transmission system (Linked to Part 2.3),
- **SLO 2.8** carry out pre-operation checks and describe the correct starting procedure for a tractor (Linked to Part 2.4), and
- **SLO 2.9** apply safe field operation techniques and explain the key tractor safety rules for accident prevention (Linked to Part 2.4).

2.1 The Agricultural Tractor

2.1.1 Definition, types, and uses of the agricultural tractor

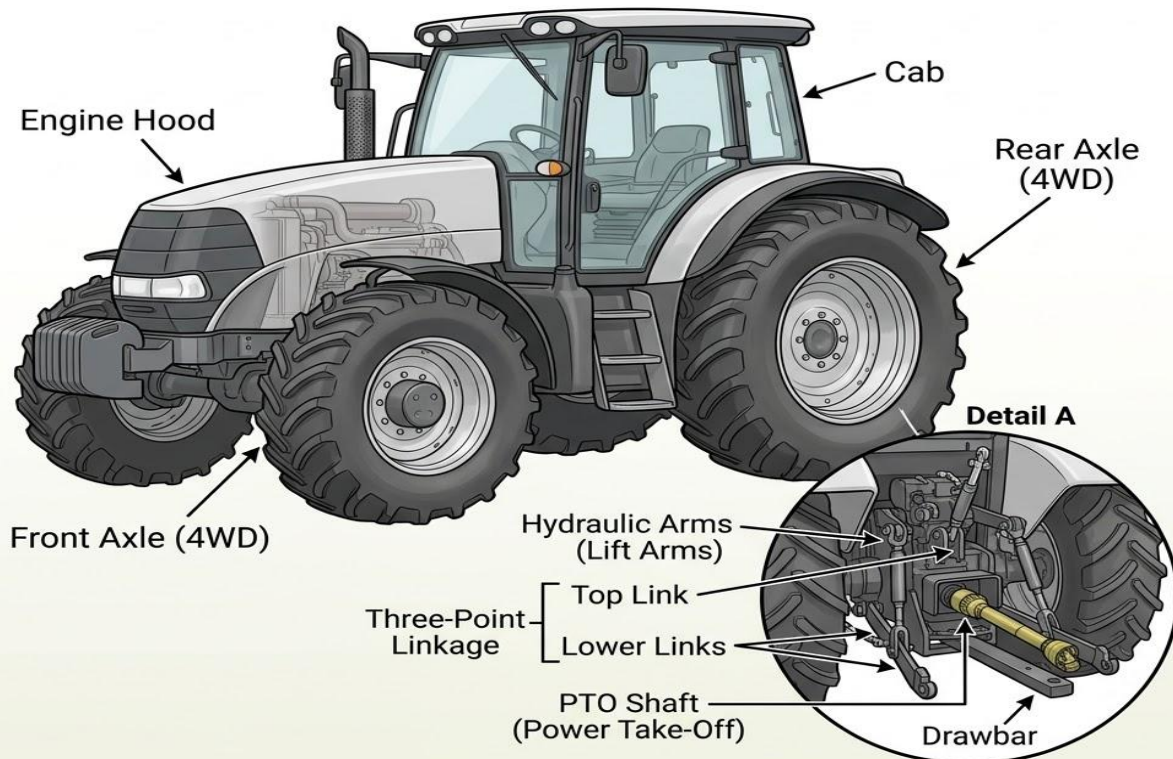
An agricultural tractor is a self-propelled power unit designed to pull, push, or drive mounted, semi-mounted, or trailed farm implements and machines. Its primary role is to convert engine power into either tractive (pulling) effort through its rear wheels or into rotary power for operating implements through the Power Take-Off (PTO) shaft. Tractors are classified by their general-purpose farm work (the most common type in Nigeria), row-crop tractors (with adjustable tread width for inter-row cultivation of crops planted in rows), orchard and vineyard tractors (low-profile for working under trees), and crawler or track tractors (for waterlogged or very soft soils).

Tractors are further classified by power rating into small (below 30 kW), medium (30 to 75 kW), and large (above 75 kW) categories. In Nigeria, the most common tractors used by smallholder and medium-scale farmers in government mechanisation programmes are four-wheel-drive tractors in the 45 to 75 kW range. Two-wheel tractors (power tillers or walking tractors) with 5 to 15 kW engines are suitable for smaller plots and are increasingly used in vegetable production. The uses of tractors span all major farm operations: primary and secondary tillage, planting, fertiliser application, crop protection spraying, harvesting, and transport.



Fill in the blank: The Power Take-Off (PTO) shaft on a tractor converts engine _____ into rotary power to drive mounted or trailed implements such as mowers, threshers, and irrigation pumps.

LABELLED DIAGRAM OF A FOUR-WHEEL-DRIVE AGRICULTURAL TRACTOR (OER)



This is an Open Educational Resource (OER) image.



Figure 2.1: Diagram labelling the main external components of a four-wheel-drive agricultural tractor

2.1.2 Major systems of the agricultural tractor

The agricultural tractor is an integrated machine comprising several interdependent systems.

The **engine system** is the power source, converting chemical energy in fuel into mechanical rotary motion. The **transmission system** transfers engine power through the clutch, gearbox, differential, and final drives to the rear wheels and the PTO shaft. The **hydraulic system** uses



pressurised oil to raise and lower mounted implements through the three-point linkage and to operate remote hydraulic cylinders.

The **steering system** (mechanical or power-assisted) controls direction of travel. The **braking system** (independent rear brakes on each wheel for tight turns plus a parking brake) provides speed control and safety. The **electrical system** powers starting, lighting, instrument panel, and electronic control units. The **fuel system** stores, filters, and delivers fuel to the engine. The **cooling system** maintains the engine at operating temperature. The **lubrication system** protects engine moving parts from wear. Understanding these systems as a whole enables systematic fault diagnosis.

Fill in the blank: The _____ system on a tractor uses pressurised oil to raise and lower mounted implements through the three-point linkage and to power remote hydraulic cylinders.

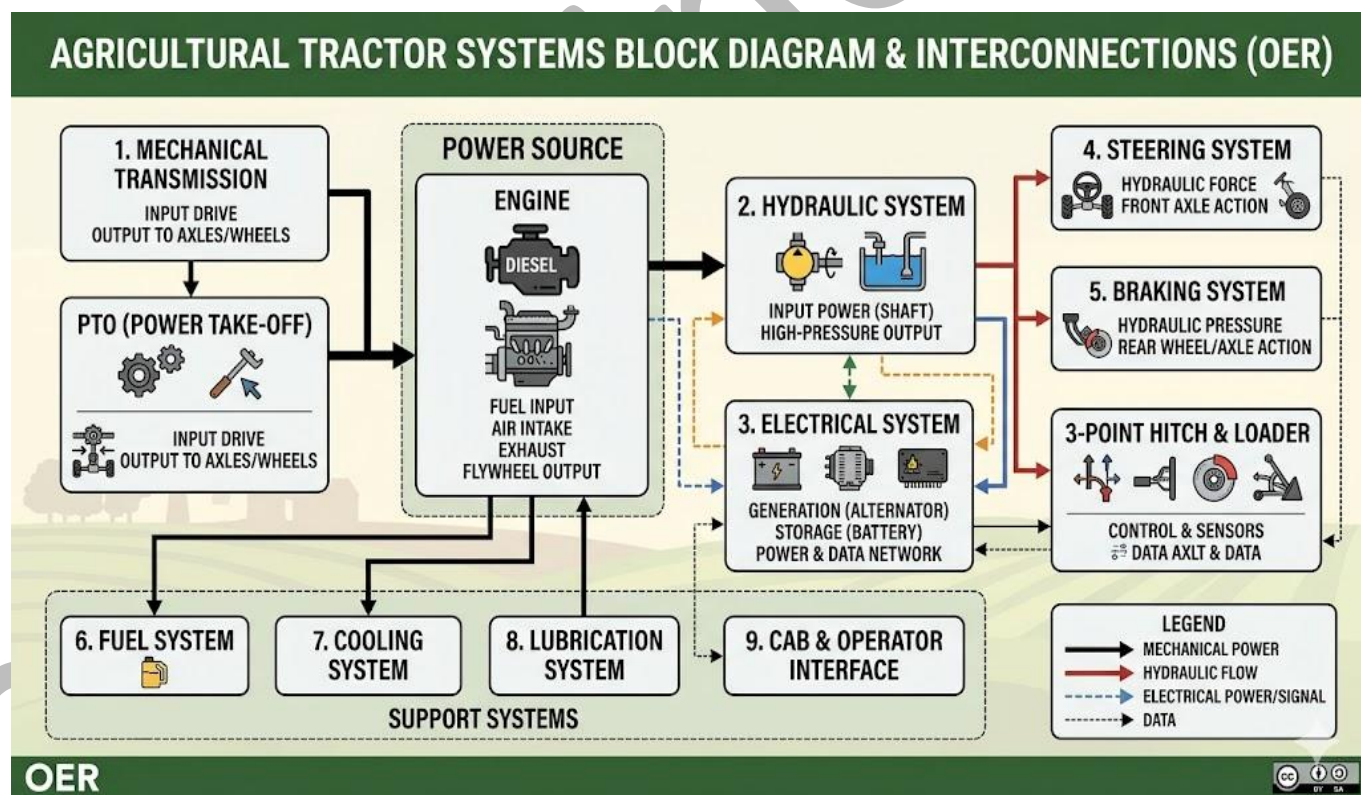


Figure 2.2: Block diagram showing the major systems of the agricultural tractor and their interconnections



2.1.3 Tractor selection and matching to farm operations

Selecting the right tractor for a farm operation requires matching the tractor's power output and physical characteristics to the requirements of the implements it must operate and the conditions of the field. The primary selection criterion is engine power: the tractor must have sufficient engine power (kW) to pull the heaviest implement in the field without excessive wheel slip or engine overloading. A general guideline is that a mouldboard plough with a single 35 cm bottom requires approximately 15 kW of drawbar power; each additional bottom adds approximately the same.

Other selection criteria include tractor weight (a heavier tractor provides better traction but causes more soil compaction), wheelbase and track width (must be compatible with crop row spacing for row-crop operations), three-point linkage category (categories I, II, and III correspond to light, medium, and heavy tractors with different hitch pin dimensions — the implement and tractor linkage categories must match), four-wheel drive versus two-wheel drive (four-wheel drive provides better traction on wet soils and slopes), and cab comfort features (important for operator productivity on large operations requiring long hours of operation). Overspecification (choosing a tractor much larger than needed) wastes capital and operating cost; underspecification leads to poor performance and rapid engine wear.

Fill in the blank: Three-point linkage _____ I, II, and III correspond to light, medium, and heavy tractors respectively, and the tractor and implement categories must match for correct coupling.

Tractor Power Class	Recommended Power Range (HP)	Common Implements / Operations	Matching Criteria
Low-power tractors	15–35 HP	Hand-held ploughs, small ridgers, planters, water pumps	Suitable for smallholder farms, light soils, and short field operations
Medium-power tractors	36–75 HP	Disc ploughs, harrows, seed drills, sprayers	Best for medium-scale farms, mixed soil types, and multipurpose field work



<u>High-power tractors</u>	76–120 HP	Heavy-duty ploughs, rotavators, threshers, trailers	Suitable for large-scale farms, heavier soils, and intensive tillage
<u>Very high-power tractors</u>	121–200+ HP	Combine harvesters, large planters, irrigation systems	Used in commercial mechanised farms; requires large contiguous fields and high capital investment

Table 2.1: Guide for matching tractor power class to implement requirements for common Nigerian farm operations

Pilot questions 2.1

6. Define an agricultural tractor and state its two primary roles on the farm.
7. Name four types of agricultural tractors and describe the conditions for which each is suited.
8. List the major systems of the agricultural tractor and state the function of each.
9. Explain the meaning of three-point linkage category and why it must match between tractor and implement.
10. State three criteria for selecting the correct tractor for a farm operation.

2.2 The Internal Combustion Engine

2.2.1 Principles and classification of internal combustion engines

An internal combustion engine (ICE) is a heat engine in which the combustion of fuel occurs inside the engine cylinder, producing expanding gases that push a piston down the cylinder bore and rotate a crankshaft, converting the chemical energy of the fuel into mechanical rotary motion. The key thermodynamic principle is that heat released by combustion causes rapid gas expansion; this expansion does work on the piston. The piston's reciprocating (back-and-forth) motion is converted into continuous rotary motion by the connecting rod and crankshaft assembly.

Internal combustion engines are classified in several ways: by fuel type (petrol/gasoline engines, diesel engines, and gas engines); by the number of operating strokes per working cycle (four-



stroke and two-stroke); by the method of ignition (spark ignition, SI — in which a spark plug initiates combustion, used in petrol engines; and compression ignition, CI — in which the heat of compressed air ignites the injected diesel fuel automatically, used in diesel engines); and by cylinder arrangement (single cylinder, in-line multi-cylinder, V-type, and horizontally opposed). Agricultural tractors predominantly use multi-cylinder diesel compression ignition engines for their fuel efficiency, durability, and high torque output.

Fill in the blank: In a compression ignition engine, fuel ignites automatically due to the heat of _____ air in the cylinder without the need for a spark plug.

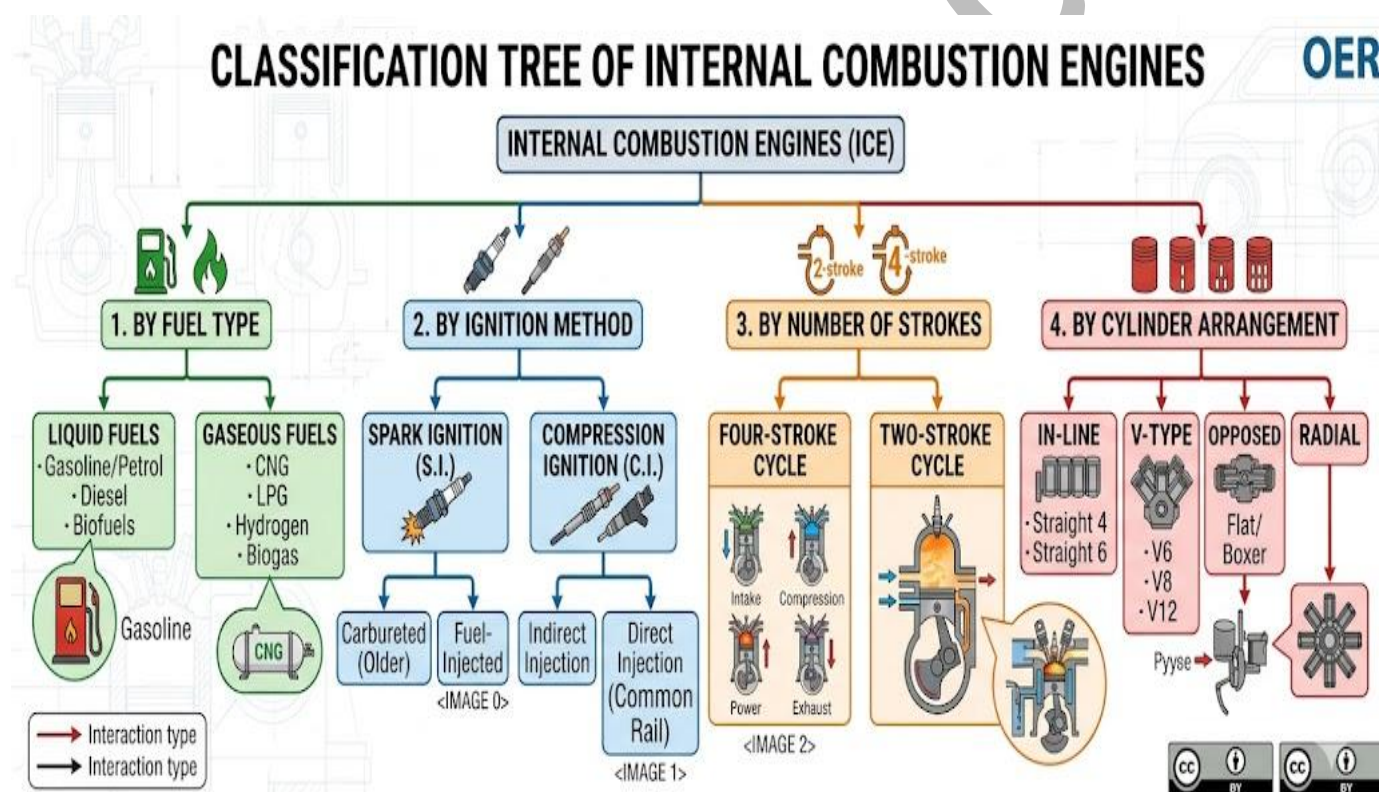


Figure 2.3: Diagram classifying internal combustion engines by fuel type, ignition method, number of strokes, and cylinder arrangement

2.2.2 The four-stroke engine: description and operating cycle

The four-stroke engine completes one full working cycle in four distinct piston strokes (two complete crankshaft revolutions). Each stroke is described by the direction of piston movement and the valve positions. **Stroke 1 — Induction (intake):** the piston moves downward from Top



Dead Centre (TDC) to Bottom Dead Centre (BDC) with the inlet valve open and the exhaust valve closed; the descending piston draws a fresh air-fuel mixture (SI engine) or air only (CI engine) into the cylinder through the open inlet valve.

Stroke 2 — Compression: both valves are closed; the piston moves upward from BDC to TDC, compressing the charge; compression ratios are 8:1 to 12:1 for SI engines and 14:1 to 22:1 for CI engines. **Stroke 3 — Power (expansion):** fuel is ignited (by spark in SI, by compression heat in CI); expanding gases force the piston down from TDC to BDC, producing the power stroke that drives the crankshaft. **Stroke 4 — Exhaust:** the exhaust valve opens; the piston moves up from BDC to TDC, expelling burnt gases through the exhaust valve. The cycle then repeats from stroke 1. Only stroke 3 produces power; the other three are driven by flywheel momentum.

Fill in the blank: In a four-stroke engine, the _____ stroke is the only one that produces power; the other three strokes are driven by the momentum stored in the flywheel.

THE FOUR-STROKE CYCLE (OER DIAGRAM)

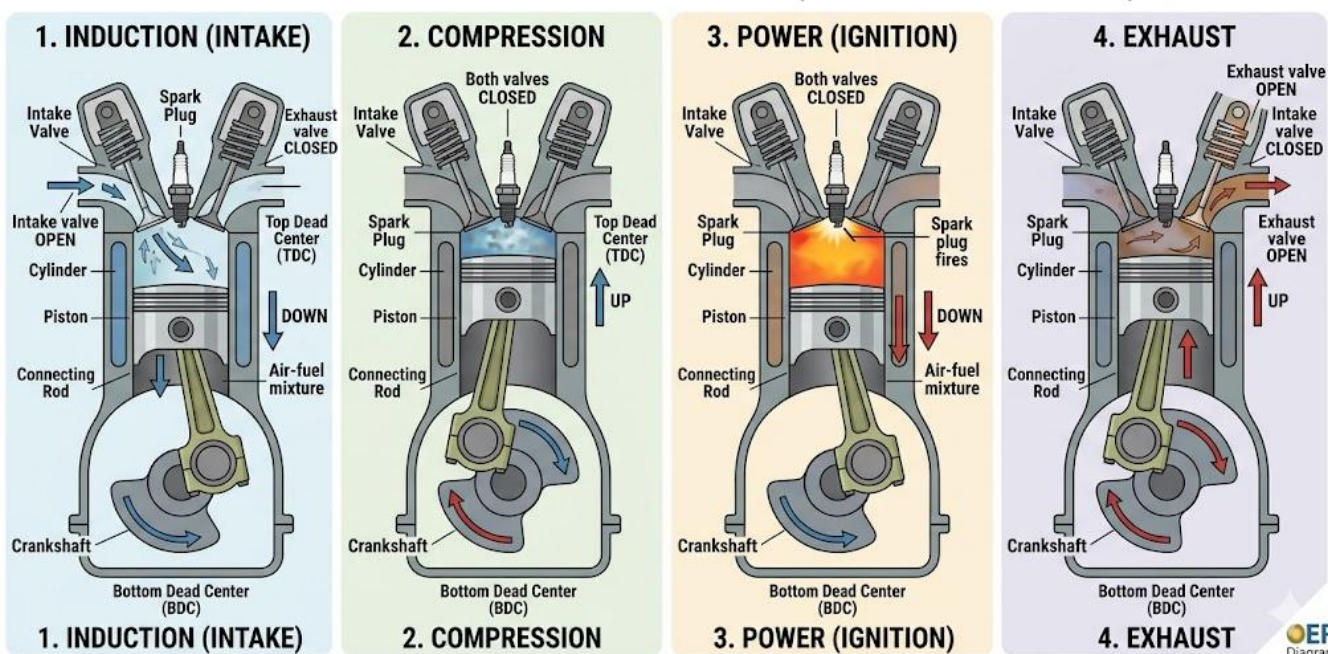


Figure 2.4: Diagram showing the four strokes of the four-stroke engine cycle with piston position, valve states, and events at each stroke



2.2.3 The two-stroke engine: description and comparison with four-stroke

The two-stroke engine completes one full working cycle in just two piston strokes (one complete crankshaft revolution). Instead of separate inlet and exhaust valves, most two-stroke engines use ports (openings in the cylinder wall) that are covered and uncovered by the piston as it moves. **Stroke 1 — Power and exhaust:** combustion drives the piston downward; as the piston descends it first uncovers the exhaust port (allowing burnt gases to escape), then uncovers the transfer port (allowing fresh fuel-air mixture from the crankcase to flow into the cylinder above the piston).

Stroke 2 — Compression and induction: the piston moves upward, covering the transfer and exhaust ports and compressing the charge above, while simultaneously drawing fresh mixture into the crankcase below. At TDC, ignition occurs and the cycle repeats. The two-stroke engine fires once per revolution, giving it a higher power-to-weight ratio than a four-stroke of the same displacement; however, it is less fuel-efficient (some fuel escapes with exhaust gases through the ports), produces more exhaust emissions, and requires oil mixed with the fuel for crankcase lubrication (in simple designs). Two-stroke engines are used in small equipment (chain saws, knapsack sprayer motors, small water pumps) where light weight is more important than fuel economy.

Fill in the blank: The two-stroke engine fires once per _____ revolution, giving it a higher power-to-weight ratio than a four-stroke engine of the same displacement.

Feature	Two-stroke engine	Four-stroke engine
Power strokes per cycle	One power stroke per revolution (every 2 strokes)	One power stroke every 2 revolutions (every 4 strokes)
Fuel efficiency	Less efficient; higher fuel consumption	More efficient; lower fuel consumption
Emissions	Higher emissions due to incomplete combustion	Lower emissions; cleaner combustion
Lubrication	Oil mixed with fuel; frequent refilling	Separate lubrication system; longer-lasting



Complexity	Simple design; fewer parts; lightweight	More complex; heavier; more parts
Agricultural applications	Small machines: sprayers, chainsaws, water pumps	Larger machines: tractors, tillers, irrigation pumps

Table 2.2: Comparison of two-stroke and four-stroke engines across key parameters

Pilot questions 2.2

6. Define an internal combustion engine and explain how it converts fuel energy into mechanical motion.
7. Distinguish between spark ignition and compression ignition engines.
8. Describe what happens during the induction stroke and the compression stroke of a four-stroke engine.
9. Explain why the two-stroke engine has a higher power-to-weight ratio than the four-stroke engine.
10. Give two advantages and two disadvantages of the two-stroke engine compared with the four-stroke.

2.3 Engine Systems and Their Functions

2.3.1 The fuel system

The fuel system delivers clean fuel from the tank to the engine cylinders in the correct quantity and at the correct time for efficient combustion. In a diesel engine the fuel system comprises: the fuel tank (storage), the fuel feed pump (low-pressure transfer from tank to injection pump), primary and secondary fuel filters (removing water and particulates that would damage the precision injection system), the injection pump (which pressurises fuel to very high pressure — 150 to 2,000 bar in modern common rail systems — and meters precise quantities), and the fuel injectors (which spray a fine atomised mist of diesel into the combustion chamber at the correct moment).



Fuel filters are the most maintenance-critical components of the diesel fuel system because diesel injection equipment operates at extremely fine tolerances; even microscopic particles or water droplets can score injector needle seats, causing loss of injection precision, black smoke, and engine damage. Fuel filters must be replaced at intervals specified in the operator's manual, typically every 200 to 500 operating hours. In the petrol (SI) engine, the carburettor or fuel injection system mixes fuel with air in the correct proportion (approximately 14.7:1 air-to-fuel ratio by weight for stoichiometric combustion) before delivery to the cylinder. Fuel system faults — clogged filters, air leaks, or injector wear — are among the most common causes of tractor power loss in Nigerian field conditions.

Fill in the blank: Diesel fuel _____ must be replaced at regular intervals because even microscopic particles can damage injection equipment operating at extremely fine tolerances.

DIESEL ENGINE FUEL SYSTEM FLOWCHART

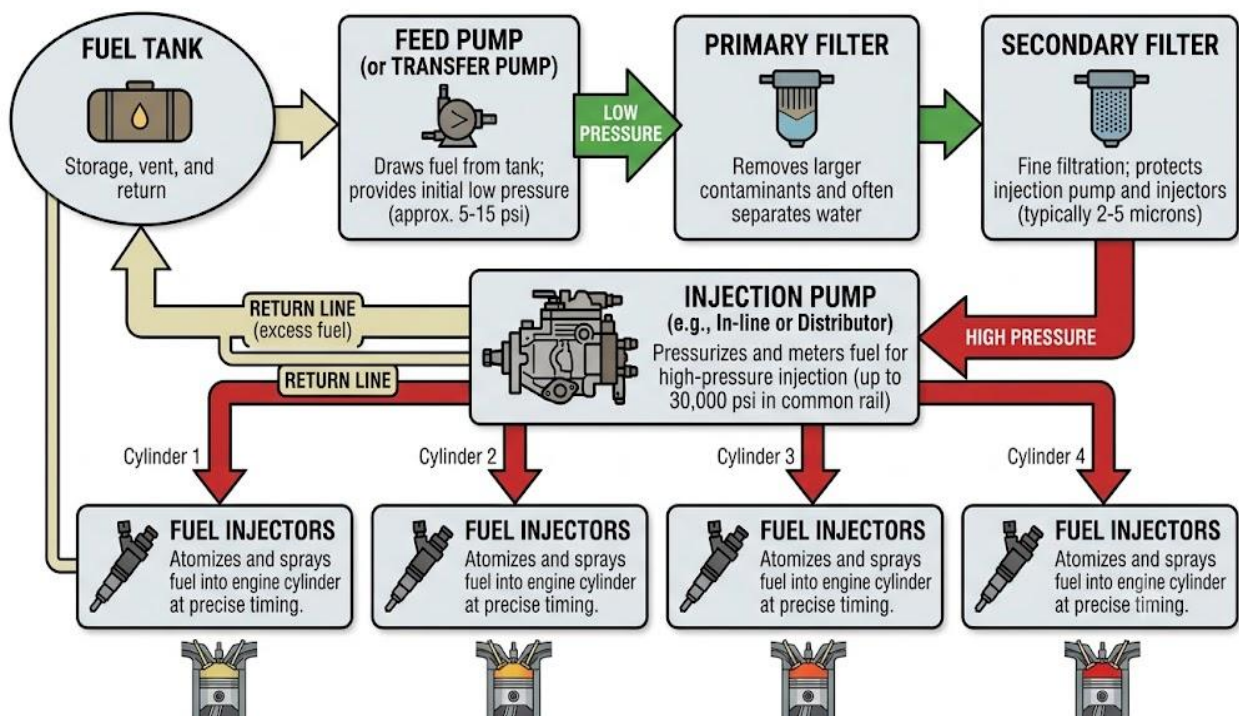


Figure 2.5: Diagram of the diesel engine fuel system from tank through feed pump, filters, injection pump, and injectors to the combustion chamber



2.3.2 The cooling and lubrication systems

The cooling system prevents engine overheating by removing excess heat generated during combustion. Most agricultural tractor engines use a liquid cooling system comprising a water pump (which circulates coolant through passages in the engine block and cylinder head), a radiator (which dissipates heat from the coolant to the passing air stream), a thermostat (which maintains the correct operating temperature of 82 to 95°C by regulating coolant flow to the radiator), a cooling fan (belt-driven or hydraulically driven), and a coolant reservoir. Overheating — caused by low coolant level, blocked radiator fins, failed thermostat, or broken fan belt — is one of the most serious engine hazards and can cause warped cylinder heads and seized pistons.

The lubrication system reduces friction and wear between moving metal surfaces by maintaining a film of pressurised oil between them. The sump (oil pan) stores the engine oil; the oil pump (gear-driven) draws oil from the sump and forces it under pressure through the oil filter to the main and connecting rod bearings, camshaft bearings, and other lubricated surfaces; the oil then drains back to the sump by gravity. The oil pressure gauge on the instrument panel is one of the most critical monitoring instruments: a drop in oil pressure (below approximately 1 bar at idle) indicates pump failure, oil starvation, or a major internal leak and requires immediate engine shutdown to prevent catastrophic bearing failure.

Fill in the blank: The _____ maintains the correct engine operating temperature of 82 to 95°C by regulating the flow of coolant to and from the radiator.



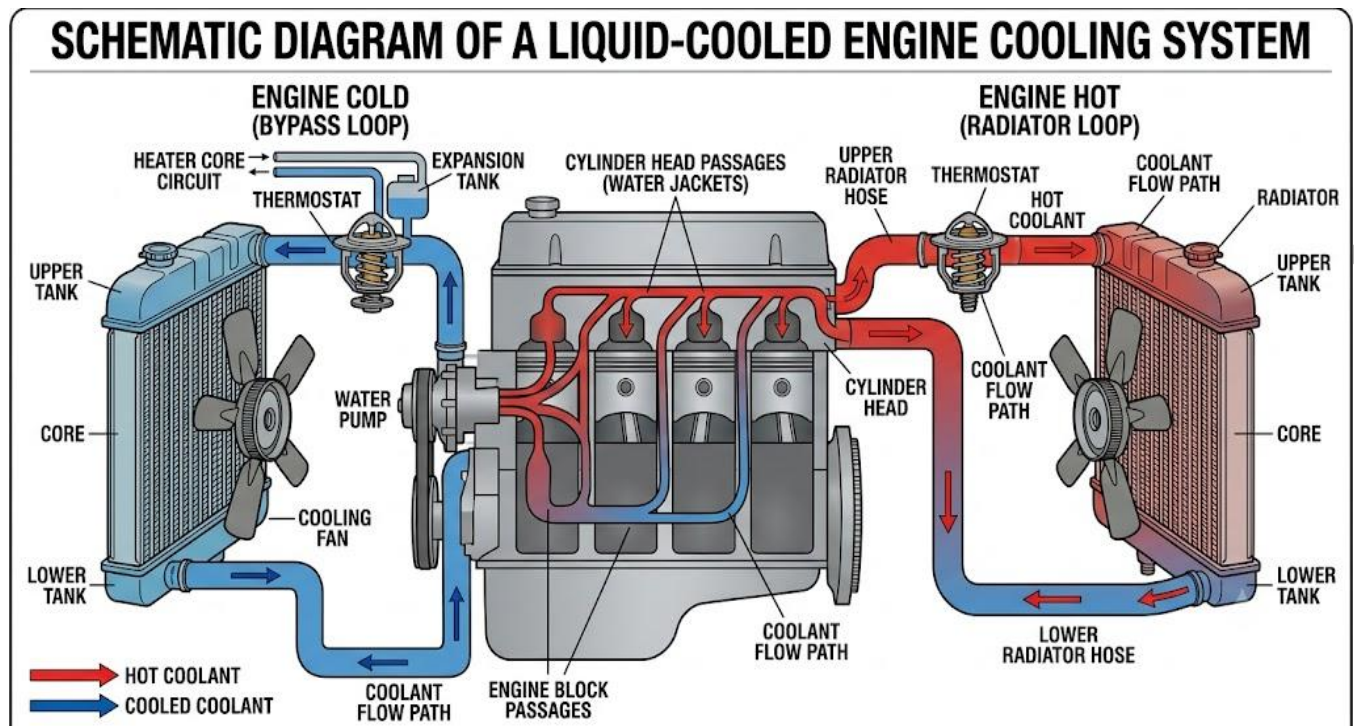


Figure 2.6: Diagram of the engine cooling system showing the water pump, radiator, thermostat, cooling fan, and coolant flow path through the engine block and cylinder head

2.3.3 The electrical and transmission systems

The electrical system on a diesel tractor performs four main functions: starting (a high-current electric starter motor cranks the engine to initiate combustion), charging (the alternator, belt-driven by the engine, recharges the battery and supplies electrical power to all consumers while the engine runs), ignition (not required in diesel engines but essential in petrol engines where the spark plug timing circuit is the heart of the ignition system), and instrumentation and control (the instrument panel displays engine speed, oil pressure, coolant temperature, fuel level, PTO speed, and warning lights that alert the operator to system faults).

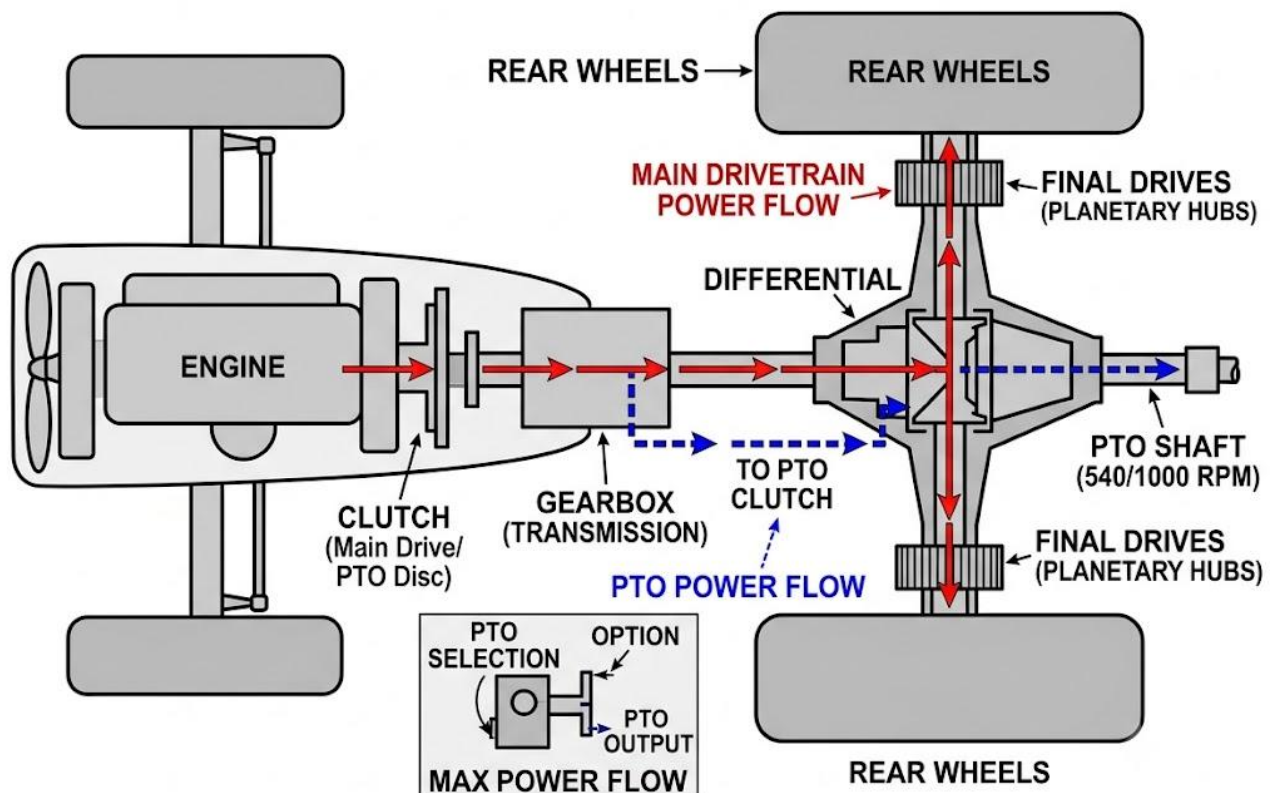
The transmission system transfers engine power to the tractor's drive wheels and PTO shaft. Its main components are: the clutch (a friction disc that temporarily disconnects the engine from the transmission to allow gear changes and implement coupling without stalling the engine), the gearbox (provides a range of forward and reverse gear ratios to match travel speed and tractive effort to the operation), the differential (allows the two rear wheels to rotate at different speeds during turns), the final drives (bevel and spur gears that transmit power from the differential to



the rear wheel axles), and the PTO shaft (a splined output shaft at the rear of the tractor that rotates at 540 or 1,000 rpm to power implements requiring rotary input).

Fill in the blank: The _____ allows the two rear wheels to rotate at different speeds when the tractor turns, preventing tyre scrub and enabling smooth cornering.

SCHEMATIC OF TRACTOR TRANSMISSION POWER FLOW



SCHEMATIC OF TRACTOR TRANSMISSION POWER FLOW

Figure 2.7: Diagram of the tractor transmission system showing the power flow from engine through clutch, gearbox, differential, final drives to rear wheels and PTO shaft

Pilot questions 2.3

1. Describe the components of the diesel engine fuel system in the correct order of fuel flow.
2. Explain why fuel filters are the most maintenance-critical components of the diesel fuel system.



3. Describe the main components of the engine cooling system and explain what happens if the thermostat fails.
4. Explain the function of the oil pump and state the action that must be taken if the oil pressure drops to zero while the engine is running.
5. Explain the function of the differential in the tractor transmission system.

2.4 Tractor Operation and Basic Safety

2.4.1 Pre-operation checks and starting procedures

Pre-operation checks (the daily walk-around inspection) must be performed before every operating session to identify faults before they cause breakdown or injury in the field. The standard pre-operation check covers: engine oil level (dipstick check; oil should be between MIN and MAX marks), coolant level (checked at the radiator cap or expansion tank when the engine is cold), fuel level (fuel gauge or dipstick), air filter condition (check for blockage indicator or visual inspection), tyre pressure and condition (check for cuts, embedded objects, and correct inflation pressure), hydraulic oil level, battery terminals (secure and free of corrosion), all lights, and the condition of the three-point linkage and drawbar.

The starting procedure for a diesel tractor follows these steps: engage the handbrake and place the gearbox in neutral; turn the ignition key to the preheat position and wait until the glow plug warning light goes out (typically 10 to 30 seconds, longer in cold weather, as glow plugs preheat the combustion chambers to ensure reliable cold starting); then turn the key to the start position to engage the starter motor; release the key as soon as the engine fires; allow the engine to warm up at low idle for two to five minutes before moving off or loading the PTO. Never operate the starter motor for more than 15 to 20 seconds continuously to avoid overheating and damaging the starter.

Fill in the blank: Before starting a diesel tractor in cool conditions, the ignition key is first turned to the _____ position to activate the glow plugs and preheat the combustion chambers.



Inspection Item	Standard Check	Assessment Method
Engine oil	Adequate level, clean oil	Dipstick reading, visual check
Coolant	Proper level, no leaks	Radiator cap check, reservoir level
Fuel	Sufficient for operation	Fuel gauge reading
Air filter	Clean, unobstructed	Remove and inspect filter
Tyres	Proper inflation, no damage	Pressure gauge, visual inspection
Hydraulic oil	Adequate level, no leaks	Reservoir dipstick, hose inspection
Battery	Charged, terminals clean	Voltage test, terminal inspection
Lights	Functional headlights, indicators	Switch on and test
Linkage	Secure, no excessive wear	Visual and manual inspection

Box 2.1: Pre-operation daily check checklist for an agricultural tractor

2.4.2 Field operation techniques

Efficient field operation requires selecting the correct gear and engine speed for the implement being used. For tillage operations, the tractor should operate at the engine speed that gives the required PTO speed (typically 540 rpm) or the correct travel speed for draft implement operation, while keeping the engine loaded at 75 to 90 per cent of full rated power for fuel efficiency and engine longevity. Operating at very low engine load wastes fuel; operating continuously at full overload causes overheating and accelerated wear.

Field patterns determine how efficiently the tractor covers the field. The headland turning pattern (operating in parallel strips with turns at the field ends) is the most common for rectangular fields. The round-and-round pattern (working from the outside in or inside out) suits irregular fields. Operator safety during field operations requires: engaging the clutch smoothly when moving off to avoid implement jolting; disengaging the PTO before reversing when implements are attached; reducing speed before turns; engaging four-wheel drive on wet, soft, or sloping ground; lowering the implement before reversing to avoid backing into it; and checking that all bystanders are clear before moving off or engaging the PTO.

Fill in the blank: For fuel efficiency and engine longevity, the tractor should be operated at _____ to 90 per cent of full rated engine power during tillage operations.



2.4.3 Tractor safety rules and accident prevention

Tractor accidents are among the most serious in all of agriculture. The most common fatal accident is tractor overturning (rollover), which occurs most frequently when: operating across steep slopes (side rollover), reversing up a steep slope (rear rollover), turning at excessive speed, or jerking the clutch when a heavy implement is hitched to the drawbar. A Roll-Over Protection Structure (ROPS) — either a two-post bar or a full safety cab — dramatically reduces fatality risk in rollover accidents by creating a survival zone for the operator; a seatbelt must always be worn when a ROPS is fitted.

Other critical safety rules include: never carry passengers on the tractor or implement; never allow anyone to stand near rotating PTO shafts, which must always be shielded with a rotating guard; never attempt to clear a blockage in a PTO-driven machine with the engine running; always engage the handbrake when leaving the tractor unattended; never refuel near a hot exhaust; always shut down the engine and remove the ignition key before servicing; always wear appropriate personal protective equipment (PPE) including safety boots and, when operating sprayers, chemical-resistant gloves, goggles, and a respirator. Thorough pre-operation checks, proper training, and consistent adherence to safety rules are the three pillars of tractor accident prevention.

Fill in the blank: A Roll-Over Protection Structure (ROPS) creates a survival zone in the event of a tractor _____, and its protection is only fully effective when the operator wears the seatbelt.

Safety Rule	Requirement
<u>ROPS and seatbelt</u>	Always use Roll-Over Protective Structure (ROPS) with seatbelt to prevent fatal accidents during rollovers.
<u>No passengers</u>	Tractors are designed for one operator only; carrying passengers increases accident risk.
<u>PTO guard</u>	Ensure Power Take-Off (PTO) shaft is covered with a guard to prevent entanglement injuries.
<u>Engine-off servicing</u>	Switch off engine before maintenance or refueling to avoid burns, shocks, or accidental movement.



<u>Handbrake use</u>	Always engage handbrake when tractor is stationary to prevent unintended rolling.
<u>PPE requirements</u>	Operators must wear protective gear (boots, gloves, helmet, ear protection) to reduce injury risks.

Box 2.2: Key tractor safety rules for preventing accidents and protecting operators

Pilot questions 2.4

1. List five items that must be checked during the daily pre-operation inspection of a tractor.
2. Describe the correct starting procedure for a diesel tractor from engaging the handbrake to moving off.
3. Explain what is meant by operating the tractor at 75 to 90 per cent of rated power and why this is important.
4. State the most common cause of fatal tractor accidents and explain how a ROPS reduces the risk.
5. Give four tractor safety rules that must be followed when operating PTO-driven implements.

Series Summary

This Series has covered the agricultural tractor, the internal combustion engine, and the engine and transmission systems that together make the tractor the most important power unit in modern mechanised farming. We began with the agricultural tractor, defining its purpose, classifying its types by use and power rating, identifying its major systems, and explaining the criteria for matching a tractor to its implements and operations. We then studied the internal combustion engine, distinguishing compression ignition (diesel) from spark ignition (petrol) engines, and describing in detail the four strokes of the four-stroke cycle and the two strokes of the two-stroke cycle, comparing the two engine types across key performance parameters.

Following that, we examined the fuel, cooling, lubrication, electrical, and transmission systems of the tractor engine, explaining the function of each component and highlighting the maintenance-critical items (fuel filters, oil pressure, coolant level, thermostat) whose failure



causes the most field breakdowns. Finally, we covered the practical skills of daily pre-operation checking, diesel tractor starting procedure, efficient field operation patterns, and the essential safety rules for preventing tractor accidents including rollover, PTO entanglement, and refuelling hazards. By completing this Series, you should now be able to achieve all nine Series Learning Outcomes (SLO 2.1 to SLO 2.9).

Glossary of Terms

- **Bottom Dead Centre (BDC):** the lowest position of the piston in the cylinder bore during its stroke; the point at which the piston reverses direction from downward to upward travel.
- **Clutch:** a friction disc assembly that connects and disconnects the engine from the tractor transmission, allowing gear changes and implement coupling without stalling the engine.
- **Compression ignition (CI):** a method of engine ignition in which fuel (diesel) is injected into highly compressed hot air in the cylinder and ignites spontaneously without a spark plug; used in all agricultural tractor diesel engines.
- **Compression ratio:** the ratio of the cylinder volume at Bottom Dead Centre to the cylinder volume at Top Dead Centre; typically 14:1 to 22:1 in diesel engines and 8:1 to 12:1 in petrol engines.
- **Crankshaft:** the rotating shaft in the engine that converts the reciprocating (up-and-down) motion of the pistons into continuous rotary motion transmitted to the transmission and PTO.
- **Differential:** a gear assembly in the tractor rear axle that allows the two rear wheels to rotate at different speeds during turns, preventing tyre scrub and allowing smooth cornering.
- **Drawbar:** a horizontal bar at the rear of the tractor to which trailed implements (trailers, towed tillage equipment) are attached for pulling; distinct from the three-point linkage used for mounted implements.
- **Final drives:** the last stage of the tractor transmission, consisting of reduction gears (bevel and spur gears) that transmit power from the differential to the rear wheel axles at reduced speed and increased torque.



- **Four-stroke engine:** an internal combustion engine that completes its thermodynamic cycle in four piston strokes (two crankshaft revolutions): induction, compression, power, and exhaust.
- **Gearbox:** the part of the tractor transmission that provides a range of selectable gear ratios, allowing the operator to match tractor travel speed and tractive force to the requirements of different operations.
- **Glow plug:** an electric heating element in a diesel engine combustion chamber that preheats the air to assist cold starting; the glow plug warning light on the instrument panel indicates when preheating is complete.
- **Hydraulic system:** the tractor system that uses pressurised oil to raise and lower mounted implements through the three-point linkage and to power remote hydraulic actuators on implements.
- **Injection pump:** the component of the diesel fuel system that pressurises fuel to very high pressure and meters precise quantities to each injector at the correct moment in the engine cycle.
- **Power Take-Off (PTO):** a splined shaft at the rear of the tractor that rotates at 540 or 1,000 rpm to supply rotary power to driven implements such as mowers, threshers, grain augers, and irrigation pumps.
- **ROPS (Roll-Over Protection Structure):** a two-post bar or full cab structure fitted to a tractor to create a survival zone for the operator in the event of a rollover accident; effective only when combined with a seatbelt.
- **Spark ignition (SI):** a method of engine ignition in which an electric spark from a spark plug initiates combustion of the compressed air-fuel mixture in the cylinder; used in petrol engines.
- **Three-point linkage:** a standardised hitch system on the rear of the tractor comprising two lower lift arms and one top link, used to attach and control mounted implements; available in categories I, II, and III for different tractor sizes.
- **Thermostat:** a temperature-sensitive valve in the engine cooling system that regulates coolant flow to the radiator to maintain the engine at its correct operating temperature (82 to 95°C).
- **Top Dead Centre (TDC):** the highest position of the piston in the cylinder bore; the point at which the piston reverses direction from upward to downward travel and at which ignition occurs in both four-stroke and two-stroke engines.



- **Two-stroke engine:** an internal combustion engine that completes its thermodynamic cycle in two piston strokes (one crankshaft revolution), firing once per revolution for a higher power-to-weight ratio than the four-stroke.



Concept Check Questions [Series 2]

Objective Questions

1. The PTO shaft on a tractor rotates at _____ or 1,000 rpm to power driven implements. (Linked to SLO 2.2)
2. In a diesel engine, fuel ignites due to the heat of _____ air, without the need for a spark plug. (Linked to SLO 2.3)
3. In a four-stroke engine, only the _____ stroke produces power; the other three are driven by flywheel momentum. (Linked to SLO 2.4)
4. The _____ allows the two rear wheels to rotate at different speeds during turns, preventing tyre scrub. (Linked to SLO 2.7)
5. A tractor rollover accident is least fatal when the operator wears a seatbelt and the tractor is fitted with a _____. (Linked to SLO 2.9)

Short-Answer Questions

1. Name the major systems of the agricultural tractor and state the function of any three. (Linked to SLO 2.2)
2. Describe the four strokes of the four-stroke engine cycle in the correct order, stating what happens in each stroke. (Linked to SLO 2.4)
3. Compare the two-stroke and four-stroke engines in terms of power-to-weight ratio, fuel efficiency, and typical agricultural applications. (Linked to SLO 2.5)
4. Explain the function of the thermostat in the engine cooling system and describe the consequence of its failure. (Linked to SLO 2.6)
5. State five items on the daily pre-operation tractor check and explain what the operator is looking for in each. (Linked to SLO 2.8)

Long-Answer Questions

1. Analyse the agricultural tractor as a farm power unit, describing its types and classification, its major systems and their functions, and the criteria for selecting the correct tractor for a given Nigerian farm operation. (Linked to SLOs 2.1, 2.2)
2. Discuss the internal combustion engine as used in agricultural tractors, explaining the principles of compression ignition, describing in detail the four-stroke operating cycle,



- comparing it with the two-stroke engine, and identifying the most common engine types used in farm machinery. (Linked to SLOs 2.3, 2.4, 2.5)
3. Evaluate the engine support systems and operational skills required for effective and safe tractor use, covering the fuel, cooling, lubrication, electrical, and transmission systems, and explaining the pre-operation checks, field operation techniques, and safety rules that protect the operator and the machine. (Linked to SLOs 2.6, 2.7, 2.8, 2.9)

Answers to Concept Check Questions [Series 2]

Objective Questions

1. 540.
2. Compressed.
3. Power.
4. Differential.
5. ROPS (Roll-Over Protection Structure).

Short-Answer Questions

1. Major tractor systems: engine (produces power by burning fuel), transmission (transfers power to wheels and PTO), hydraulic (raises/lowers implements), steering (controls direction), braking (controls speed and provides safety), electrical (starting, charging, instrumentation), fuel (stores and delivers fuel), cooling (removes excess heat), lubrication (protects moving parts from wear).
2. Stroke 1 — Induction: piston moves down from TDC to BDC, inlet valve open, air or air-fuel mixture drawn into cylinder. Stroke 2 — Compression: both valves closed, piston moves up to TDC, compressing the charge. Stroke 3 — Power: fuel ignited, expanding gases push piston down from TDC to BDC, driving the crankshaft. Stroke 4 — Exhaust: exhaust valve opens, piston moves up expelling burnt gases; cycle repeats.
3. Two-stroke: fires once per revolution, higher power-to-weight ratio, less fuel efficient (fuel lost with exhaust), higher emissions, requires oil mixed with fuel; used in small light equipment (chain saws, knapsack sprayer motors). Four-stroke: fires once per two



- revolutions, lower power-to-weight ratio, more fuel efficient, lower emissions, separate oil sump lubrication, more complex; used in all agricultural tractors and most farm engines.
4. The thermostat regulates coolant flow to the radiator to keep the engine at 82 to 95°C; if it fails stuck open, the engine runs too cold, fuel combustion is incomplete, and fuel consumption rises; if it fails stuck closed, no coolant reaches the radiator, the engine rapidly overheats, potentially warping the cylinder head and seizing pistons.
 5. Any five: engine oil (dipstick between MIN and MAX — checks for sufficient oil and oil leaks); coolant level (at expansion tank when cold — checks for leaks and adequate cooling capacity); fuel level (avoids running out mid-field); air filter condition (blocked filter starves engine of air, causes black smoke and power loss); tyre pressure (correct pressure ensures traction, stability, and prevents sidewall damage).

Long-Answer Questions

1. Basic response: Types: general-purpose four-wheel-drive (most common in Nigeria, 45 to 75 kW), row-crop, orchard/vineyard, crawler, two-wheel power tiller. Classification: small (<30 kW), medium (30 to 75 kW), large (>75 kW). Systems: engine, transmission, hydraulic, steering, braking, electrical, fuel, cooling, lubrication. Selection criteria: engine power matched to implement draft requirement (15 kW per plough bottom), tractor weight (traction vs compaction), linkage category matching, four-wheel drive for wet soils, cab features for operator comfort.
2. Value-added response: Tractor selection errors are costly in two directions: overspecification wastes capital and operating cost (a 100 kW tractor operating with a two-bottom plough runs chronically underloaded, consuming more fuel per unit work than a correctly matched machine); underspecification leads to chronic overloading (excessive wheel slip, overheating, accelerated wear, and early engine failure). Teaching students to calculate the approximate power requirement of an implement (number of plough bottoms multiplied by approximately 15 kW drawbar power per bottom) and then select a tractor with a 10 to 20 per cent power margin above that requirement is the foundation of sound mechanisation planning.
3. Basic response: Compression ignition (diesel) engines ignite fuel through compressed air heat (no spark plug); compression ratio 14:1 to 22:1. Four-stroke cycle: induction (piston down, inlet open, charge enters), compression (both valves closed, charge compressed), power (ignition, piston driven down), exhaust (exhaust valve open, gases expelled). Two-stroke: completes cycle in two strokes using transfer ports; higher power-to-weight ratio but less efficient. Agricultural tractors use multi-cylinder diesel four-stroke engines for durability and fuel efficiency.



4. Value-added response: Understanding the four-stroke cycle is not merely academic but directly supports engine fault diagnosis. If an engine lacks power, the fault must lie in one of the four strokes: restricted induction (clogged air filter), poor compression (worn rings, valves, or head gasket), poor combustion (dirty injectors, low compression ratio), or restricted exhaust (blocked exhaust or muffler). Teaching students to map symptoms to strokes enables systematic diagnosis rather than random parts replacement, which is the dominant — and costly — fault-finding method currently practised by many Nigerian tractor operators.
5. Basic response: Fuel system: tank, feed pump, filters (primary and secondary), injection pump, injectors — filters are the most maintenance-critical. Cooling: water pump, engine passages, thermostat, radiator, fan — thermostat failure causes overheating or cold running. Lubrication: sump, oil pump, filter, bearing galleries — zero oil pressure requires immediate shutdown. Electrical: starter, alternator, battery, instrument panel. Transmission: clutch, gearbox, differential, final drives, PTO. Pre-operation: oil, coolant, fuel, air filter, tyres, hydraulic oil, battery, lights, linkage. Safety: ROPS and seatbelt, no passengers, PTO guard, engine-off for servicing.
6. Value-added response: The most consequential safety failure in Nigerian tractor operations is the removal or non-use of PTO shaft guards, which are frequently discarded because they make implement attachment slightly more difficult or because they are damaged and not replaced. An unguarded rotating PTO shaft is one of the most dangerous hazards in agriculture: loose clothing, rope, or wire can be caught instantly, pulling the operator into the shaft before any defensive reaction is possible. Making PTO guard integrity a mandatory item on the pre-operation checklist and refusing to operate any tractor whose PTO guard is absent or damaged is the single most important safety habit an agriculture student can develop from this course.

Answers to Pilot Questions [Series 2]

Part 2.1: The Agricultural Tractor

1. An agricultural tractor is a self-propelled power unit designed to pull, push, or drive farm implements and machines; its two primary roles are: (1) providing tractive (pulling) effort through the rear wheels to pull draft implements (ploughs, harrows, seed drills), and (2) providing rotary power through the PTO shaft to drive powered implements (mowers, threshers, irrigation pumps).



2. General-purpose four-wheel-drive tractor (suited to all standard farm operations on open arable land); row-crop tractor (adjustable tread width for inter-row cultivation); orchard/vineyard tractor (low-profile design for operating under tree canopies); crawler/track tractor (suited to waterlogged, soft, or steep terrain where wheeled tractors cannot operate).
3. Engine (produces power), transmission (transfers power to wheels and PTO), hydraulic (raises/lowers implements via three-point linkage), steering (controls direction), braking (speed control and safety), electrical (starting, charging, instrumentation), fuel (stores and delivers fuel), cooling (removes combustion heat), lubrication (reduces friction and wear between engine parts).
4. Three-point linkage category refers to the standardised size of the hitch pins and link arms (Category I for small tractors up to approximately 45 kW, Category II for medium 45 to 90 kW, Category III for large above 90 kW); the category must match because the implement's lower link hitch pins must fit the tractor's lower link ends precisely for secure coupling and correct implement geometry.
5. Any three: engine power matched to implement draft or PTO requirement; tractor weight appropriate to the soil conditions (traction needed vs compaction risk); three-point linkage category compatible with intended implements; four-wheel drive vs two-wheel drive based on soil and slope conditions; tractor power rating matched to the farm scale for economic operation.

Part 2.2: The Internal Combustion Engine

1. An internal combustion engine burns fuel inside a cylinder; the heat released by combustion causes rapid expansion of gases; expanding gases push a piston down the cylinder bore; the piston's reciprocating (up-and-down) linear motion is converted into continuous rotary motion by the connecting rod and crankshaft assembly, which is then transmitted to the tractor's transmission and PTO.
2. Spark ignition engines use an electric spark from a spark plug to ignite a compressed air-fuel mixture at a precisely timed moment; used in petrol engines. Compression ignition engines have no spark plug; fuel is injected into air that has been compressed so highly that its temperature is sufficient to ignite the fuel spontaneously; used in all agricultural tractor diesel engines.



3. Induction stroke: the piston moves from TDC to BDC with the inlet valve open and the exhaust valve closed; the expanding cylinder volume draws a fresh charge of air (CI) or air-fuel mixture (SI) through the open inlet valve into the cylinder. Compression stroke: both inlet and exhaust valves are closed; the piston moves from BDC to TDC compressing the charge to a fraction of its original volume; compression heats the charge significantly.
4. The two-stroke engine fires (produces a power stroke) once every revolution of the crankshaft, whereas the four-stroke engine fires only once every two revolutions; therefore for the same engine displacement and speed, the two-stroke produces twice as many power strokes per unit time, yielding more power per unit of engine mass and displacement.
5. Two-stroke advantages: higher power-to-weight ratio (more power per kg of engine mass); simpler construction (no separate valvetrain, fewer moving parts). Two-stroke disadvantages: lower fuel efficiency (some unburned fuel-air mixture escapes through exhaust ports with exhaust gas); higher exhaust emissions (unburned hydrocarbons); requires oil mixed with fuel for lubrication in simple crankcase-scavenged designs.

Part 2.3: Engine Systems and Their Functions

1. Fuel tank, feed pump (low-pressure transfer), primary fuel filter, secondary fuel filter, injection pump (high-pressure metering and pressurisation), fuel injectors (atomised spray into combustion chamber).
2. Diesel injection equipment operates at extremely fine mechanical tolerances (injector needle seat clearances in the micrometre range); even microscopic solid particles or water droplets in the fuel can score the precision surfaces of the injector needle and seat, causing loss of injection pressure, poor atomisation, black smoke, misfiring, and progressive injector damage requiring expensive replacement.
3. Components: water pump (circulates coolant), engine block and cylinder head passages (absorb heat), thermostat (regulates coolant flow to radiator), radiator (dissipates heat to air stream), cooling fan (enhances air flow through radiator), expansion tank (accommodates coolant volume changes). If the thermostat fails stuck closed, no coolant reaches the radiator, the engine overheats rapidly, potentially warping the cylinder head or seizing pistons.
4. The oil pump draws oil from the sump and forces it under pressure through the oil filter to all lubricated engine bearings and surfaces; if the oil pressure gauge drops to zero while the engine is running, the operator must immediately shut down the engine (turn off ignition



- key), because continued operation without oil pressure will destroy the main and connecting rod bearings within seconds, causing catastrophic engine failure.
5. The differential is a gear assembly in the rear axle housing that allows the two rear wheels to rotate at different speeds during turns; when a tractor turns, the outer wheel must travel a greater arc than the inner wheel and therefore must rotate faster; without a differential, both wheels would be forced to turn at the same speed, causing the inside tyre to scrub (slip sideways) on the ground, making tight turns difficult and causing tyre wear.

Part 2.4: Tractor Operation and Basic Safety

1. Any five: engine oil level (dipstick check between MIN and MAX); coolant level (at radiator or expansion tank when cold); fuel level (gauge or dipstick); air filter condition (restriction indicator or visual check for blockage); tyre pressure and condition (inflation pressure with gauge, visual check for cuts); hydraulic oil level; battery terminal security and corrosion; all lights functional; three-point linkage and drawbar condition; safety guards in place.
2. Engage handbrake and place gearbox in neutral; turn ignition key to preheat position and wait for glow plug warning light to extinguish (10 to 30 seconds); turn key to start position to engage starter motor; release key as soon as engine fires; allow engine to warm up at low idle for two to five minutes before applying load or moving off; never crank starter motor for more than 15 to 20 seconds continuously.
3. Operating at 75 to 90 per cent of rated power means the engine is working at a load that is high enough to be thermally efficient (combustion is complete, fuel consumption per kW is minimised) but not so high as to cause continuous overloading; at very low loads the engine runs inefficiently and deposits carbon; at continuous overload the engine overheats, wears rapidly, and may suffer premature failure; the 75 to 90 per cent range represents the sweet spot of fuel efficiency and longevity.
4. Tractor rollover (overturning) is the most common cause of fatal tractor accidents; it occurs on steep side slopes, when reversing up slopes, at excessive speed during turns, or when a heavy drawbar load jerks the tractor rearward; a ROPS creates a structural survival space around the operator that prevents the cab structure from collapsing onto the operator in a rollover; the seatbelt must be worn to keep the operator within this survival space; without the seatbelt the operator may be thrown clear of the ROPS zone and crushed.



5. Any four: always ensure the PTO shaft guard (plastic rotating cover) is securely fitted before engaging the PTO; never reach across or stand close to a rotating PTO shaft; disengage the PTO before reversing or making sharp turns when a PTO-driven implement is attached; never attempt to clear a blockage in a PTO-driven machine with the engine running; wear close-fitting clothing with no loose sleeves or dangling strings when operating near PTO shafts.

References and Attributions [Series 2]

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Figures, Plates, Tables, and Boxes

- Figure 2.1: Agricultural tractor labelled diagram Attribution: AI generated using prompt "Generate a labelled diagram of a four-wheel-drive agricultural tractor identifying the engine hood, cab, rear axle, PTO shaft, three-point linkage, hydraulic arms, and drawbar." Suggested OER search string: "agricultural tractor labelled diagram main components PTO three-point linkage OER".
- Figure 2.2: Tractor systems block diagram Attribution: AI generated using prompt "Generate a block diagram showing the major tractor systems and how they interconnect, including engine,



transmission, hydraulic, steering, braking, electrical, and support systems." Suggested OER search string: "agricultural tractor systems block diagram interconnections OER".

- Table 2.1: Tractor-implement power matching table Attribution: AI generated using prompt "Generate a table matching tractor power classes to Nigerian farm implements and operations showing recommended power range and matching criteria." Suggested OER search string: "tractor power matching implement operations Nigeria table OER".
- Figure 2.3: ICE classification tree Attribution: AI generated using prompt "Generate a classification tree diagram for internal combustion engines showing categories by fuel type, ignition method, number of strokes, and cylinder arrangement." Suggested OER search string: "internal combustion engine classification types fuel ignition strokes OER diagram".
- Figure 2.4: Four-stroke engine cycle diagram Attribution: AI generated using prompt "Generate a four-panel diagram showing the four strokes of a four-stroke engine: induction, compression, power, and exhaust, with piston position and valve states." Suggested OER search string: "four-stroke engine cycle induction compression power exhaust diagram OER".
- Table 2.2: Two-stroke vs four-stroke comparison Attribution: AI generated using prompt "Generate a table comparing two-stroke and four-stroke engines on power strokes, fuel efficiency, emissions, lubrication, and agricultural applications." Suggested OER search string: "two-stroke four-stroke engine comparison table agricultural applications OER".
- Figure 2.5: Diesel fuel system diagram Attribution: AI generated using prompt "Generate a flowchart diagram of the diesel engine fuel system showing the sequence: fuel tank, feed pump, primary filter, secondary filter, injection pump, and fuel injectors." Suggested OER search string: "diesel engine fuel system diagram tank injection pump filters OER".
- Figure 2.6: Engine cooling system diagram Attribution: AI generated using prompt "Generate a schematic diagram of a liquid-cooled engine cooling system showing the water pump, engine passages, thermostat, radiator, cooling fan, and coolant flow path." Suggested OER search string: "engine cooling system diagram water pump radiator thermostat coolant flow OER".
- Figure 2.7: Tractor transmission power flow diagram Attribution: AI generated using prompt "Generate a schematic diagram showing the tractor transmission power flow from engine through clutch, gearbox, differential, final drives to rear wheels and PTO shaft." Suggested OER search string: "tractor transmission system power flow clutch gearbox differential PTO OER diagram".
- Box 2.1: Tractor pre-operation check checklist Attribution: AI generated using prompt "Generate a checklist box listing the daily pre-operation inspection items for an agricultural tractor including engine oil, coolant, fuel, air filter, tyres, hydraulic oil, battery, and lights." Suggested OER search string: "tractor pre-operation daily check checklist inspection OER box".



- Figure 2.8: Tractor field operation patterns Attribution: AI generated using prompt "Generate a two-panel diagram showing the headland turning pattern and round-and-round pattern for tractor field operations." Suggested OER search string: "tractor field operation patterns headland round-and-round diagram OER".
- Box 2.2: Tractor safety rules box Attribution: AI generated using prompt "Generate a safety rules box listing key tractor safety requirements including ROPS and seatbelt, no passengers, PTO guard, engine-off servicing, handbrake use, and PPE." Suggested OER search string: "tractor safety rules accident prevention ROPS PTO guard seatbelt OER box".



Course code: AGE 124

Course title: Farm Technology

Course credit load: 2 Units

Series 3: Farm Implements, Tillage Equipment, and Crop Protection Tools

- **Part 3.1: Primary Tillage Implements**

- Sub Part 3.1.1: The mouldboard plough: description and operation
- Sub Part 3.1.2: The disc plough: description, operation, and comparison with mouldboard
- Sub Part 3.1.3: Subsoilers and chisel ploughs

- **Part 3.2: Secondary Tillage and Inter-row Cultivation Implements**

- Sub Part 3.2.1: Disc harrows and tine harrows
- Sub Part 3.2.2: Rotary tillers and ridgers
- Sub Part 3.2.3: Cultivators: types and uses

- **Part 3.3: Planting and Fertiliser Application Equipment**

- Sub Part 3.3.1: Seed drills and planters
- Sub Part 3.3.2: Fertiliser distributors and spreaders
- Sub Part 3.3.3: Transplanting equipment

- **Part 3.4: Crop Protection Equipment**

- Sub Part 3.4.1: Sprayers: types and operating principles
- Sub Part 3.4.2: Nozzles, calibration, and spray quality
- Sub Part 3.4.3: Safe use and maintenance of crop protection equipment



Introduction

The range of implements and machines used between tractor and crop is vast, covering every operation from breaking the soil for the first time to protecting the standing crop from pests and diseases. Knowing what each implement does, how it works, and when to use it is as important as knowing how to drive the tractor that pulls it. A tractor paired with the wrong implement, or an implement set up incorrectly, produces poor results regardless of how powerful the engine or how skilled the operator.

The aim of this Series is to introduce you to the design, function, and correct use of the main tillage implements, secondary tillage and cultivation tools, planting and fertiliser application equipment, and crop protection sprayers used in Nigerian mechanised agriculture.

We shall commence this Series by examining primary tillage implements, the ploughs and subsoilers that break and invert the soil. Next, we will study secondary tillage implements and cultivators. Following that, we will cover seed drills, planters, and fertiliser application equipment. Finally, we will wrap up with sprayer types, nozzle selection, calibration, and the safe use and maintenance of crop protection equipment.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 3.1** describe the mouldboard plough and explain its design features, adjustments, and operation (Linked to Part 3.1),
- **SLO 3.2** describe the disc plough and compare it with the mouldboard plough in terms of design and application (Linked to Part 3.1),
- **SLO 3.3** explain the purpose and operation of subsoilers and chisel ploughs (Linked to Part 3.1),
- **SLO 3.4** describe the types and uses of secondary tillage implements including disc harrows, tine harrows, rotary tillers, ridgers, and cultivators (Linked to Part 3.2),
- **SLO 3.5** explain the design and operation of seed drills, row planters, and fertiliser distributors (Linked to Part 3.3),



- **SLO 3.6** describe the types of sprayers and explain the principles of their operation (Linked to Part 3.4),
- **SLO 3.7** explain nozzle types, spray quality, and sprayer calibration (Linked to Part 3.4), and
- **SLO 3.8** describe the safe use and maintenance of sprayers and other crop protection equipment (Linked to Part 3.4).

3.1 Primary Tillage Implements

3.1.1 The mouldboard plough: description and operation

The mouldboard plough is the classic primary tillage implement, designed to cut a furrow slice of soil, lift it, and invert it so that surface crop residues and weeds are buried and the freshly exposed subsoil is turned to the surface. Its main components are: the **share** (a hardened steel cutting blade that severs the furrow slice horizontally from the unploughed land), the **mouldboard** (the curved steel plate above the share that lifts, twists, and inverts the furrow slice), the **landside** (the flat steel plate on the land side that resists the lateral thrust of the soil and keeps the plough running straight), and the **frog** (the main body to which all other parts are bolted).

The mouldboard plough is adjusted for furrow width (the horizontal width of soil cut, typically 25 to 40 cm) and furrow depth (typically 15 to 30 cm for general tillage). On a tractor-mounted plough, depth is controlled by the hydraulic top link and depth wheels; width is set by the position of the share relative to the previous furrow. The mouldboard plough performs best in medium-textured soils free of large stones; it wraps and buries trash effectively and produces a good tilth after secondary tillage. It is the most widely used primary tillage implement in Nigeria for cereal and legume production.

Fill in the blank: The _____ of the mouldboard plough is the curved steel plate that lifts, twists, and inverts the furrow slice to bury surface residues and expose fresh subsoil.



LABELLED DIAGRAM OF A MOULDBOARD PLOUGH IN OPERATION

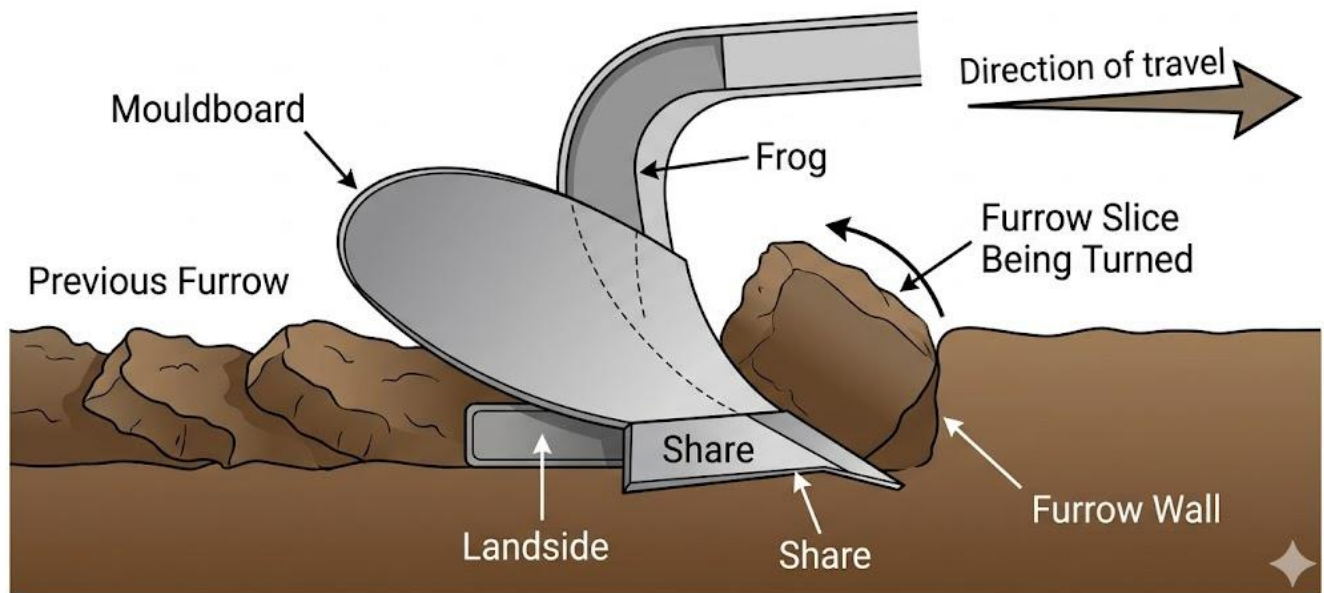


Figure 3.1: Labelled diagram of a mouldboard plough showing the share, mouldboard, landside, frog, and furrow slice

3.1.2 The disc plough: description, operation, and comparison with mouldboard

The disc plough uses a series of large, concave, spherical steel discs (typically 60 to 75 cm diameter) mounted on a common axle or on individual bearings at an angle to the direction of travel (disc angle: 40 to 45 degrees) and tilted from the vertical (tilt angle: 15 to 25 degrees). As the plough moves forward, the disc rolls and cuts into the soil, lifting and inverting the furrow slice outwards to one side. Unlike the mouldboard plough, the disc plough has no landside and relies on the angled disc to provide the lateral reaction force.

The disc plough excels in conditions where the mouldboard plough struggles: hard, dry soils (where disc ploughs can penetrate with less draught); sticky, wet soils (where soil does not stick to rotating discs as it does to a mouldboard); trashy soils with heavy crop residues (discs cut through trash rather than wrapping it under as the mouldboard does); and rocky or stumpy land (discs deflect rather than breaking on hard obstructions). The disc plough's limitations are that it does not bury trash as thoroughly as the mouldboard plough and that it leaves a rougher furrow



surface. In Nigeria, disc ploughs are widely used in the savanna zones where soils are hard and dry at the onset of land preparation.

Fill in the blank: The disc plough excels in hard, dry soils and rocky conditions because the discs _____ rather than break when they encounter hard obstructions, reducing implement damage.

 Feature	<u>Mouldboard Plough</u>	<u>Disc Plough</u>
Soil conditions	Best for light to medium soils; struggles in hard, dry, or stony soils	Performs well in hard, dry, stony, and sticky soils
Trash burial	Excellent burial of crop residues and weeds	Moderate burial; leaves some trash on surface
Draught requirement	Higher draught; requires more power	Lower draught; easier to pull
Soil type suitability	Suitable for loamy and sandy soils	Suitable for clayey, heavy, and stony soils
Maintenance	More frequent maintenance due to wear on mouldboards	Less maintenance; discs are durable and self-cleaning
Nigerian farming applications	Used in southern Nigeria for root crops and lighter soils	Common in northern Nigeria for cereals and tougher soils

Table 3.1: Comparison of mouldboard plough and disc plough across key design and performance parameters

3.1.3 Subsoilers and chisel ploughs

Subsoilers are deep-working tillage implements designed to break up the subsoil hardpan (a compacted layer below normal ploughing depth) without inverting the soil. They consist of one or more heavy, narrow, curved tines (shanks) that penetrate to depths of 40 to 80 cm and shatter the compacted layer, improving drainage, reducing waterlogging, and allowing deeper root penetration. Subsoiling does not mix or invert soil horizons; it fractures the compacted zone in situ. Heavy tractors (minimum 60 to 90 kW) are required because subsoiling draught forces are very high.

Chisel ploughs use multiple narrow, flexible or rigid tines (chisels) spaced 20 to 35 cm apart to till the soil to a depth of 20 to 35 cm without full inversion. They break and loosen the topsoil,



partially incorporate surface residues, and leave a rough mulch on the surface that reduces erosion and conserves moisture. Chisel ploughing is used as an alternative to mouldboard ploughing in conservation tillage systems, where complete soil inversion and residue burial is intentionally avoided to maintain a protective surface cover. In Nigeria, chisel ploughs are used on large commercial farms adopting conservation agriculture practices in the Guinea savanna.

Fill in the blank: Subsoilers penetrate to depths of 40 to 80 cm to break up the _____, a compacted layer below normal ploughing depth that restricts drainage and root penetration.

SOIL PROFILE COMPARISON: THREE TILLAGE OPERATIONS

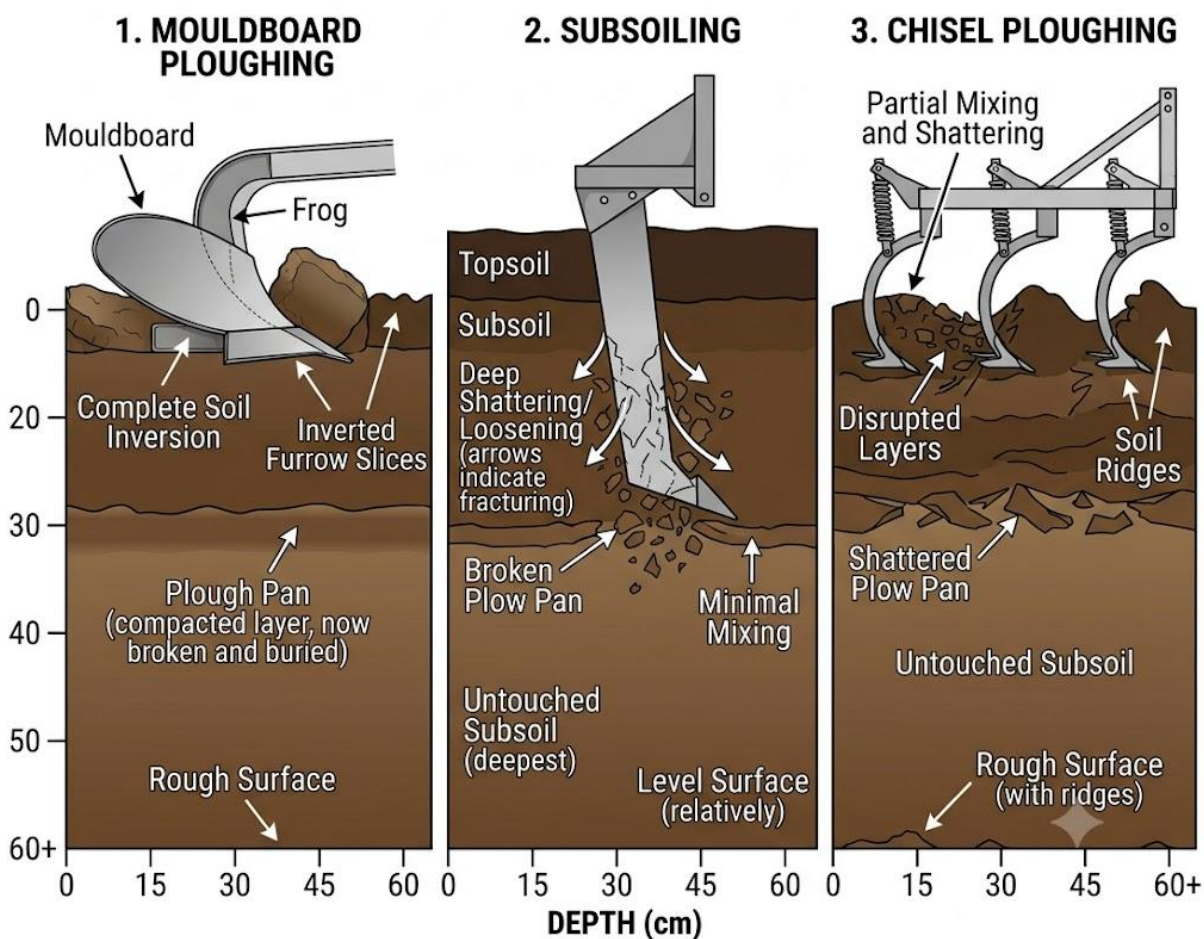


Figure 3.2: Diagram comparing the soil profiles produced by mouldboard ploughing, subsoiling, and chisel ploughing



Pilot questions 3.1

1. Name the four main components of a mouldboard plough and state the function of each.
2. Explain how furrow depth is controlled on a tractor-mounted mouldboard plough.
3. Describe two soil conditions in which the disc plough performs better than the mouldboard plough.
4. Explain the purpose of subsoiling and state the minimum tractor power required.
5. Distinguish between subsoiling and chisel ploughing in terms of depth and soil disturbance.

3.2 Secondary Tillage and Inter-row Cultivation Implements

3.2.1 Disc harrows and tine harrows

Secondary tillage refines the seedbed after primary tillage by breaking down large clods, levelling the surface, and incorporating residues or amendments. The **disc harrow** consists of gangs of concave steel discs (typically 40 to 60 cm diameter) arranged on axles in two or four gangs; the front gangs are angled to throw soil outward and the rear gangs are angled to throw it inward, producing a mixing and levelling action. Disc harrows can be offset (all gangs on one side for working close to obstacles) or tandem (two pairs of gangs in line). They work well in hard and trashy conditions.

Tine harrows use rows of rigid or flexible steel tines (spring tines, S-tines, or chain links with tines) dragged through the soil at shallow depth to break clods, uproot small weeds, and create a fine seedbed surface. Spring-tine harrows are the most widely used type for seedbed preparation before planting cereals; their flexible tines follow the ground surface well and leave a fine, uniform tilth. Chain harrows (a mesh of interlocked steel links dragged flat) level the soil surface and are used after disc harrowing to remove ridges and fill hollows. Tine harrowing depth is typically 3 to 8 cm and requires relatively low draught.

Fill in the blank: The disc harrow uses gangs of concave discs angled to produce a _____ and levelling action on the soil, breaking down clods after primary tillage.



COMPARATIVE DIAGRAM: TILLAGE IMPLEMENTS AND SOIL DISTURBANCE

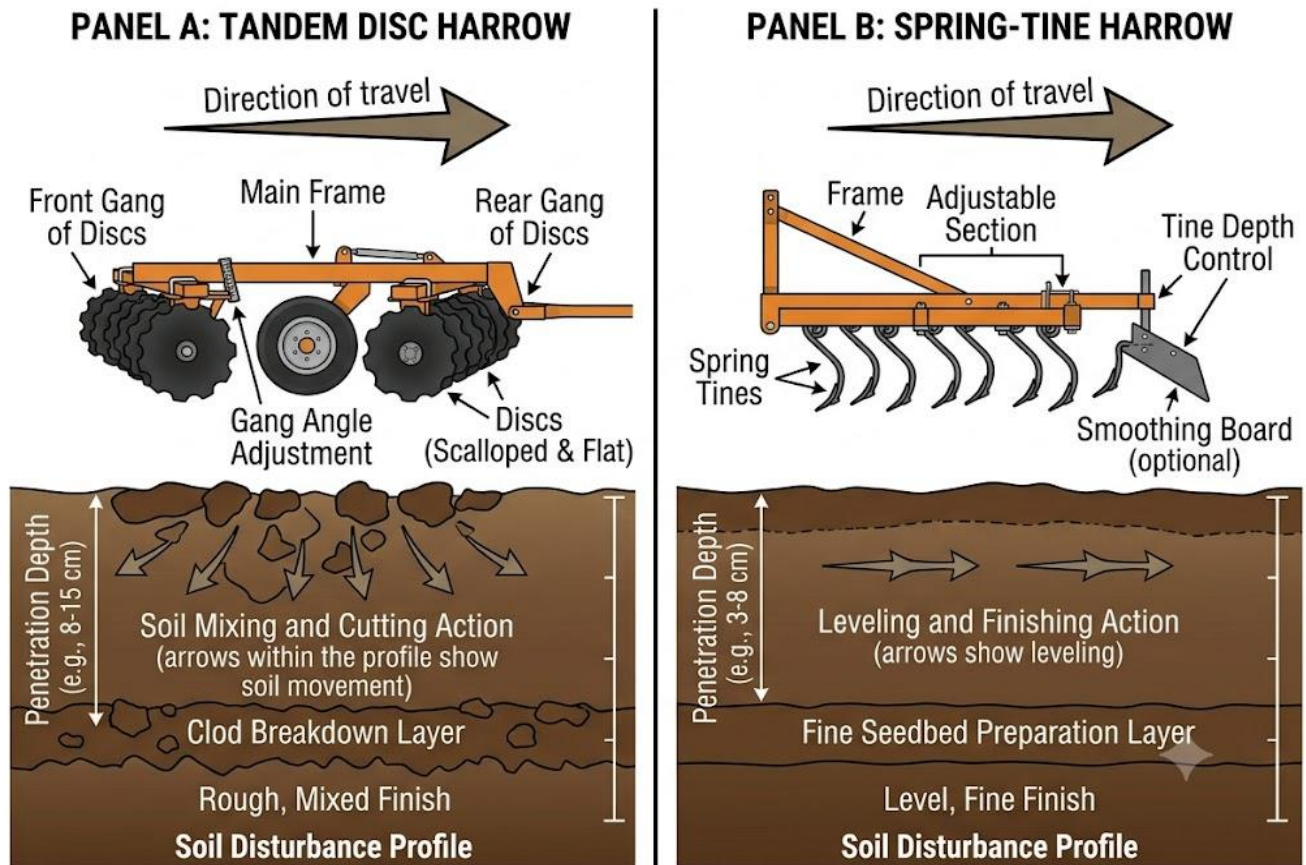


Figure 3.3: Diagram showing the tandem disc harrow and spring-tine harrow in operation with soil disturbance profiles

3.2.2 Rotary tillers and ridgers

The rotary tiller (rotavator) is a PTO-driven secondary tillage implement in which a horizontal shaft fitted with L-shaped or C-shaped blades rotates at high speed (200 to 300 rpm) to cut, break, and mix the soil in a single pass. It produces a very fine, uniform tilth suitable for direct seeding or transplanting and simultaneously incorporates crop residues and soil amendments. The working depth is 10 to 20 cm, controlled by the rear roller or depth skid. Because the rotary tiller does the work of both ploughing and harrowing in one pass, it saves time and fuel on small plots; however, it consumes more PTO power per unit area than draft implements.



The ridger (ridging body) creates raised ridges of soil with furrows between them, which is the dominant seedbed preparation method for root crops (yam, cassava) and for surface drainage management in the Nigerian Guinea savanna. A ridger is essentially a double mouldboard share assembly that throws soil to both sides, forming a ridge typically 20 to 40 cm high. Ridging is done after primary tillage; the furrow spacing is set to match the crop row spacing (typically 75 to 100 cm for yam and cassava). A toolbar carrying multiple ridging bodies can ridge an entire field in one tractor pass, replacing the enormous hand labour traditionally required for ridge formation.

Fill in the blank: The rotary tiller produces a fine, uniform tilth in a single pass by rotating _____ blades at high speed to cut, break, and mix the soil.

3.2.3 Cultivators: types and uses

Cultivators are inter-row tillage implements used after crop emergence to control weeds, break surface crusts, and incorporate fertiliser between crop rows without damaging the standing crop. They are designed with narrow tines or sweeps set on a toolbar at spacings that match the crop row spacing, so the cultivator passes between the rows without touching the plants. The **spring-tine cultivator** uses flexible tines that vibrate in the soil, uprooting weeds and breaking crusts; it is used for shallow inter-row cultivation at 5 to 10 cm depth in cereals and legumes.

The sweep cultivator uses flat, horizontal blade attachments (sweeps) that undercut weeds just below the soil surface, slicing through weed root systems without disturbing the soil structure as much as tine cultivators. Row-crop cultivators are mounted on adjustable toolbars that allow the spacing between cultivator units to be set to any row width, making them versatile across a range of crop configurations. In Nigerian mechanised farming, inter-row cultivation is still predominantly done by hand hoe; however, tractor-mounted row-crop cultivators are increasingly used on maize and soybean farms in the middle belt, where weed pressure is high and manual labour is expensive.

Fill in the blank: Cultivators are designed with tines or sweeps set at spacings that match the crop _____ spacing so they pass between the crop rows without damaging the standing plants.



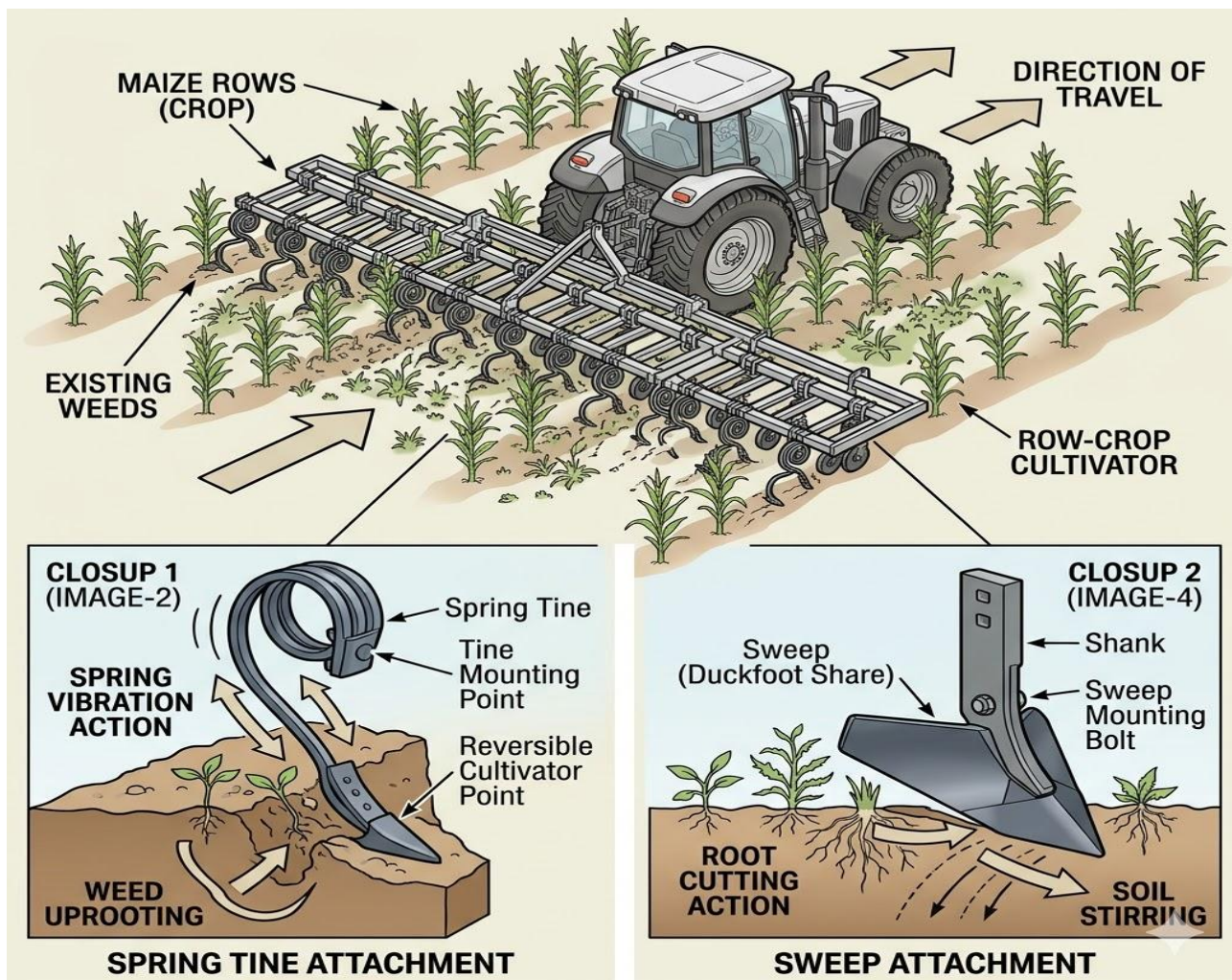


Figure 3.4: Diagram showing a row-crop cultivator in operation between maize rows, with tine and sweep attachment options labelled crop cultivator passing between maize rows with close-up views of spring tine and sweep attachments for weed control

Pilot questions 3.2

11. Distinguish between disc harrows and tine harrows in terms of design and soil action.
12. Explain the advantage and limitation of a rotary tiller compared with conventional ploughing and harrowing.
13. Describe the purpose of ridging and explain why it is important in Nigerian root crop production.
14. Define a cultivator and explain what it is designed to do.
15. Explain the difference between a spring-tine cultivator and a sweep cultivator.



3.3 Planting and Fertiliser Application Equipment

3.3.1 Seed drills and planters

Seed drills are machines that place seed in the soil at a controlled depth, spacing, and seeding rate in continuous rows. The main components of a seed drill are: the seed hopper (stores the seed), the seed metering mechanism (measures the volume or number of seeds released per unit distance; common types are fluted roller meters for small grains and finger pickup plates for large seeds), the furrow opener (creates a slot in the soil into which the seed is dropped; types include disc openers, hoe openers, and tine openers), and the press wheel or covering board (closes the furrow over the seed and ensures seed-to-soil contact for good germination).

Row planters are designed for large-seeded crops (maize, soybean, cowpea, sunflower) and place individual seeds at precise inter-seed spacings within the row, producing a stand of known plant population. Precision planters use positive seed singulation mechanisms (plate cells, finger pickups, or vacuum pneumatic systems) to ensure that exactly one seed is placed at each intended spacing, avoiding doubles (two seeds in one spot) or skips (empty spaces). Seeding rate, spacing, and depth are all adjustable. Modern planters are fitted with electronic seed rate monitors that alert the operator to blockages or metering failures in any row unit in real time.

Fill in the blank: The _____ mechanism on a seed drill measures the volume or number of seeds released per unit distance of travel to ensure the correct seeding rate is achieved.



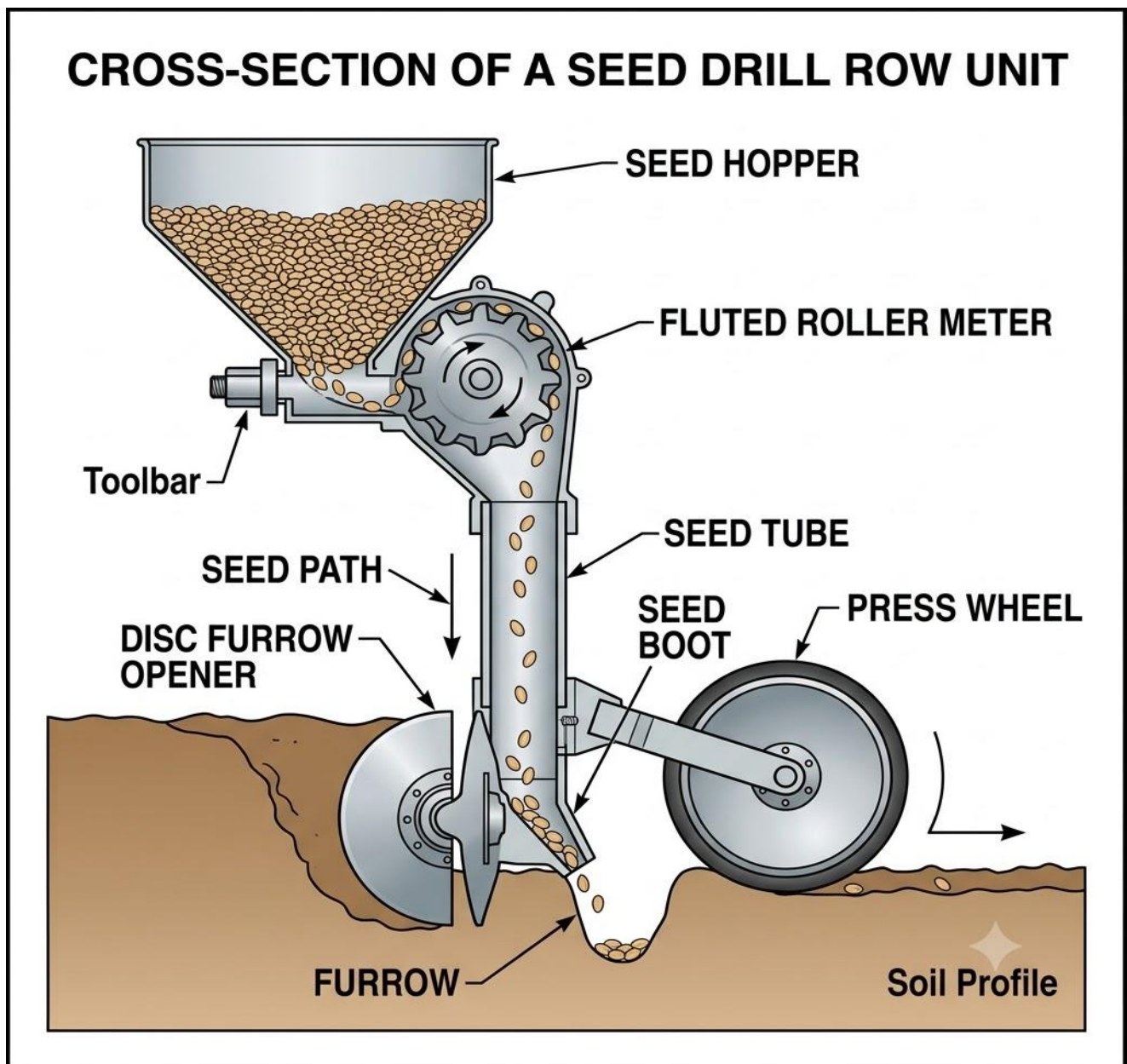


Figure 3.5: Diagram of a seed drill row unit showing the seed hopper, fluted roller meter, disc furrow opener, seed tube, and press wheel

3.3.2 Fertiliser distributors and spreaders

Fertiliser application equipment must apply the correct quantity of fertiliser uniformly across the field at the correct time. **Broadcast spreaders** (also called centrifugal or spinning disc spreaders) use one or two rotating discs driven by the PTO or by a ground-wheel drive to throw granular fertiliser uniformly over a wide swath (10 to 24 m). They are fast and economical for



top-dressing large areas but have limited accuracy at field edges and do not place fertiliser precisely relative to the crop row.

Band applicators (fertiliser coulters) place granular fertiliser in a narrow band at a controlled depth and distance from the seed row during planting; band application reduces fertiliser waste and the risk of seed burning compared with broadcast application of the same rate. Liquid fertiliser applicators (knife applicators or injectors) inject liquid nitrogen fertiliser (UAN, aqueous ammonia) directly into the soil at prescribed depths and spacings. The application rate of all fertiliser distributors must be calibrated before field use by collecting and weighing the output from a measured number of wheel revolutions or PTO shaft turns and comparing it against the target application rate in kg per hectare.

Fill in the blank: Broadcast _____ spreaders use rotating discs to throw granular fertiliser uniformly over a wide swath during top-dressing operations.



COMPARISON OF FERTILISER APPLICATION METHODS: PLACEMENT PATTERN

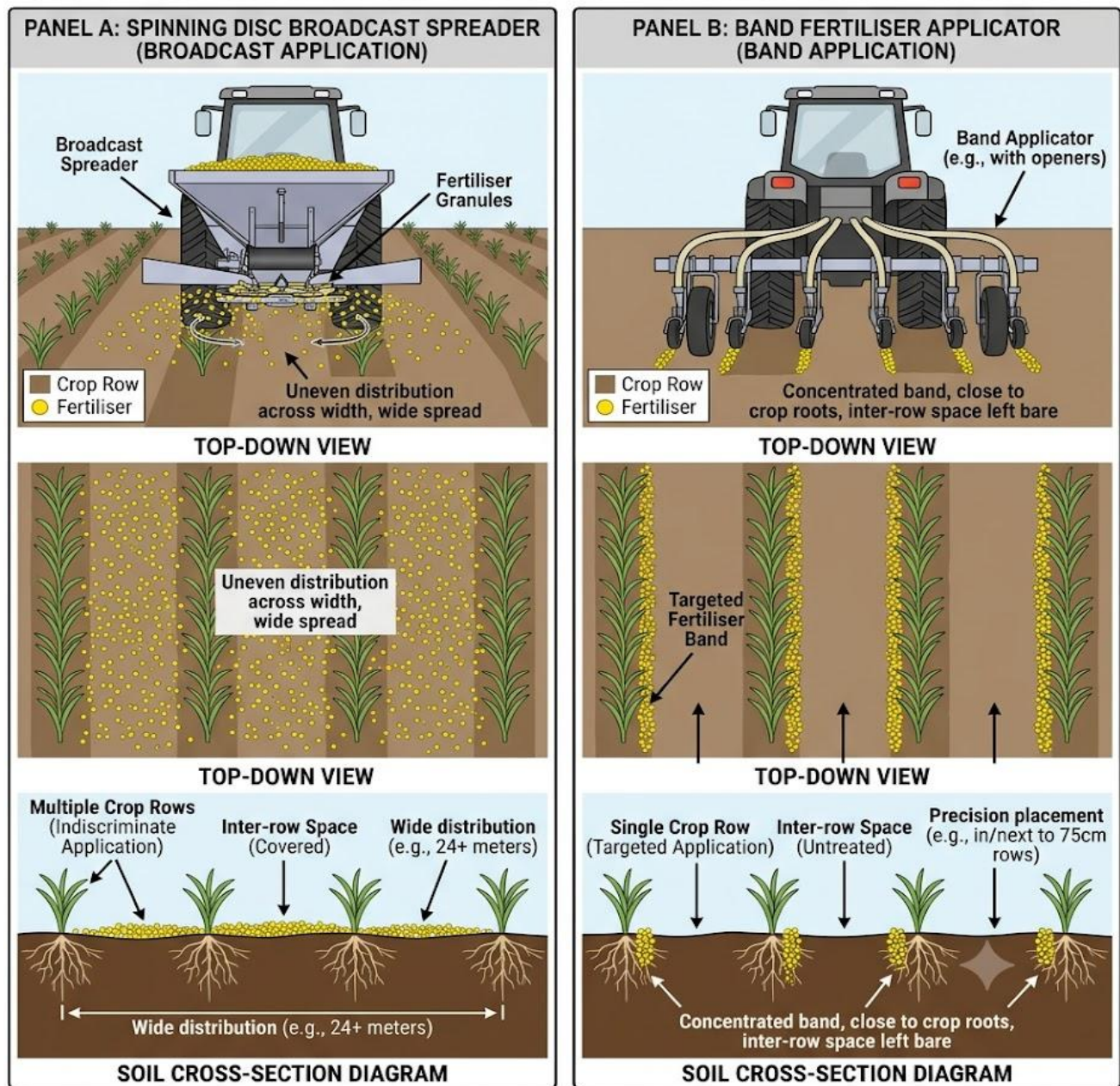


Figure 3.6: Diagram comparing broadcast spinning disc spreader and band applicator for fertiliser placement relative to the crop row

3.3.3 Transplanting equipment

Transplanting machines mechanise the labour-intensive operation of moving seedlings from a nursery into the field at precise spacing and depth. Semi-automatic transplanting machines



require an operator seated on the machine to feed individual seedlings into a rotating planting mechanism; the machine opens a furrow, the operator drops a seedling into it, and the machine closes and firms the soil around the root. Fully automatic transplanters use cell-tray seedlings (plugs) and a mechanical or pneumatic pickup mechanism that extracts individual seedlings from the tray and places them in the opened furrow without human handling of each plant.

In Nigeria, transplanting machines are most relevant for vegetables (tomato, pepper, onion, cabbage, lettuce) where the high value of the crop justifies the capital cost of the machine and where hand transplanting is a major labour bottleneck. Two-row and four-row tractor-mounted transplanters are available for vegetable production. The key performance criteria for a transplanting machine are transplanting depth consistency (the seedling should be set at the same depth as it grew in the nursery), spacing accuracy (deviation from target spacing should be less than 5 per cent), and transplant survival rate (above 95 per cent within seven days of field transplanting).

Fill in the blank: Semi-automatic transplanting machines require a seated _____ to feed individual seedlings into the planting mechanism, while fully automatic machines use cell-tray plugs picked up mechanically.





Plate 3.2: A two-row semi-automatic transplanting machine in operation transplanting tomato seedlings into prepared ridges

Pilot questions 3.3

6. Name the four main components of a seed drill row unit and state the function of each.
7. Explain the difference between a seed drill and a row planter.
8. Describe what a precision planter does and explain why precision seed singulation is important.
9. Compare broadcast fertiliser spreaders and band applicators in terms of placement, accuracy, and crop safety.
10. Explain why transplanting machines are particularly appropriate for vegetable production in Nigeria.



3.4 Crop Protection Equipment

3.4.1 Sprayers: types and operating principles

Sprayers are machines that apply liquid pesticides (herbicides, insecticides, fungicides, and foliar fertilisers) to crops or soil in the form of fine droplets. All sprayers consist of the same basic components: a tank (stores the spray solution), a pump (pressurises the liquid), agitation (keeps the spray mixture in suspension), a pressure regulator (maintains consistent operating pressure), boom and pipes (distribute liquid to the nozzles), and nozzles (break the liquid into droplets of the desired size and apply them at the correct rate).

The main types of sprayers used in Nigerian agriculture are: the knapsack sprayer (a 10 to 20 litre manually pumped or motorised unit carried on the operator's back, suitable for small plots and spot treatments), the wheel-barrow sprayer (a 100 to 200 litre tank on a two-wheeled frame with a petrol-engine pump, pushed by an operator), the tractor-mounted boom sprayer (a 200 to 1,000 litre tank with a boom 6 to 18 m wide mounted on the tractor three-point linkage, suitable for large field operations), and the aerial sprayer (drone or fixed-wing aircraft fitted with a spray system, used for large-scale and difficult-to-access areas). The operating principle in all these types is that the pump supplies liquid at the required pressure to the boom, which distributes it to the nozzles.

Fill in the blank: A tractor-mounted boom sprayer consists of a tank, pump, pressure regulator, boom, and _____, which break the spray liquid into droplets of the required size and distribute them at the target rate.



AGRICULTURAL SPRAYERS: COMPARATIVE DIAGRAM OF TYPES AND APPLICATIONS

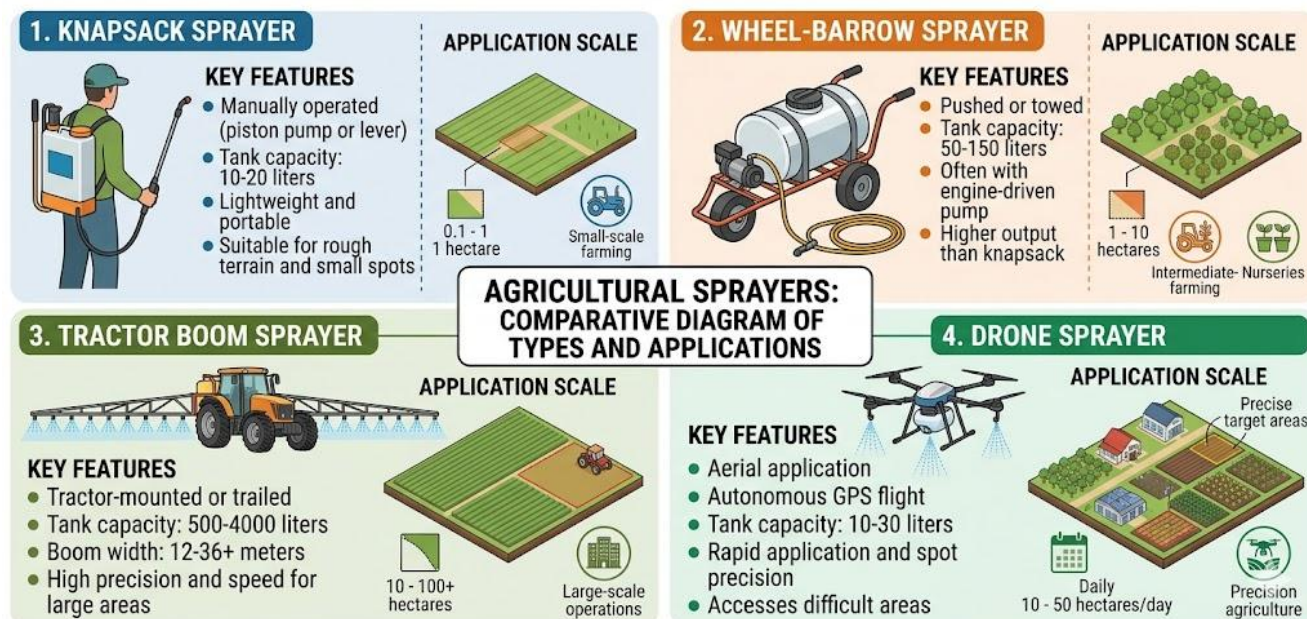


Figure 3.7: Diagram showing the main types of sprayers used in Nigerian agriculture from knapsack to tractor boom sprayer

3.4.2 Nozzles, calibration, and spray quality

Nozzles are the most critical components of the sprayer because they determine droplet size, spray pattern, and application rate. The main nozzle types used in agriculture are: **flat fan nozzles** (produce a flat elliptical spray pattern at angles of 80 to 120 degrees; the standard choice for herbicide application), **hollow cone nozzles** (produce a ring of droplets in a cone pattern; used for insecticide and fungicide applications requiring good canopy penetration and coverage of leaf undersides), and **flood jet nozzles** (produce large droplets in a wide pattern; used for soil-incorporated herbicides where drift must be minimised).

Droplet size is described by volume median diameter (VMD) in micrometres: fine droplets (VMD 100 to 200 μm) give better coverage but are highly prone to drift; medium droplets (VMD 200 to 400 μm) give the best balance of coverage and drift resistance for most applications; coarse droplets (VMD above 400 μm) minimise drift but may give incomplete coverage. Sprayer calibration is the process of measuring and adjusting the actual output of the sprayer to match the target application rate (litres per hectare). Calibration involves measuring



the nozzle output at a set pressure over one minute, calculating the effective swath width, and adjusting travel speed or nozzle size to achieve the target rate. Poorly calibrated sprayers over-apply (wasting expensive chemicals and causing crop damage or environmental contamination) or under-apply (giving inadequate pest control).

Fill in the blank: _____ fan nozzles produce a flat elliptical spray pattern and are the standard choice for applying herbicides over a uniform soil or crop canopy surface.

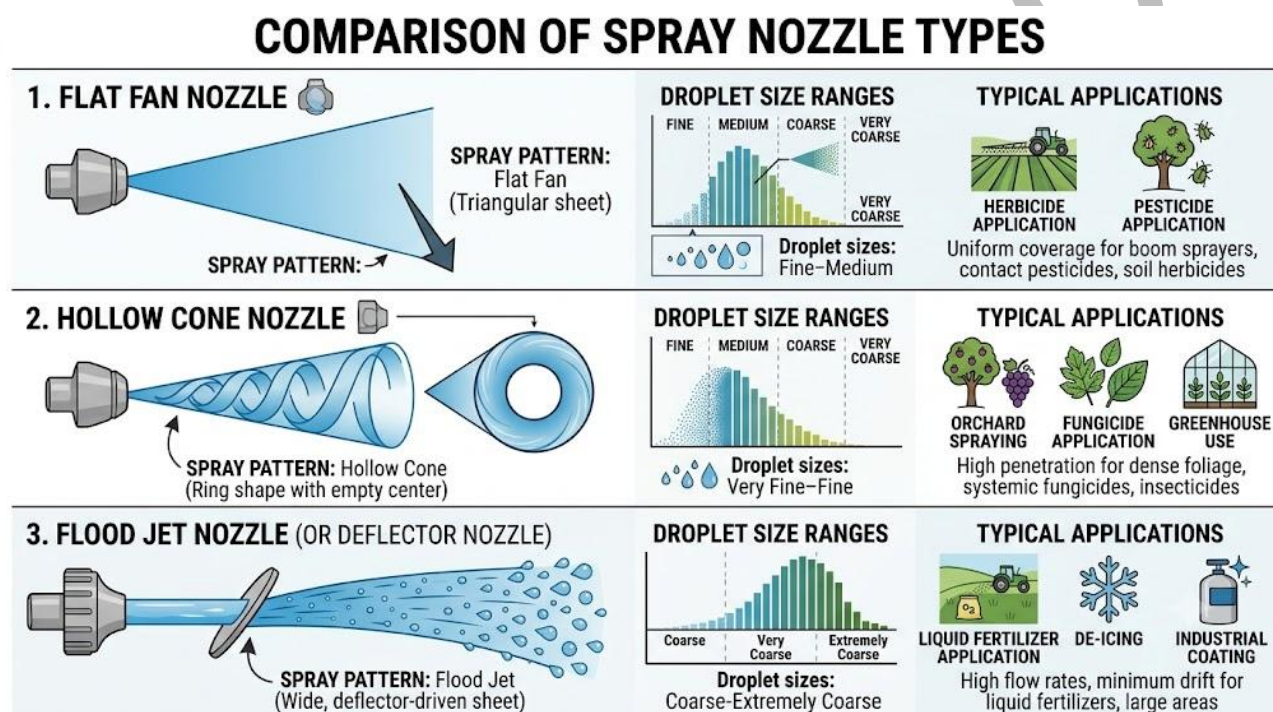


Figure 3.8: Diagram showing the spray patterns and droplet size ranges of flat fan, hollow cone, and flood jet nozzles

3.4.3 Safe use and maintenance of crop protection equipment

Safe use of crop protection equipment begins before mixing begins. The operator must read and understand the pesticide label, which specifies the correct dose, dilution rate, crops and pests for which the product is registered, pre-harvest interval, and personal protective equipment (PPE) required. PPE for spraying operations typically includes: a chemical-resistant coverall, rubber gloves, rubber boots, a face shield or goggles, and a respiratory mask for highly toxic products.



Mixing concentrated pesticide in a confined space without respiratory protection is one of the most common causes of acute pesticide poisoning in Nigerian agriculture.

Sprayer maintenance is critical for consistent performance and operator safety. After each use, the tank, boom, and nozzles must be triple-rinsed with clean water and the rinsate applied to a treated area or disposed of according to the label instructions, never discarded near water sources. Nozzles must be inspected regularly for wear: a worn nozzle delivering more than 10 per cent above its rated output must be replaced, as worn nozzles cause uneven application and pesticide drift. Filters (in-line and nozzle body filters) must be cleaned after every use. Pressure gauges and diaphragms must be checked for accuracy and leaks. Sprayer hoses and boom joints are common leak points and must be inspected before each use.

Fill in the blank: A nozzle delivering more than _____ per cent above its rated output due to wear must be replaced to maintain accurate application rates and prevent drift.

Safety Requirement	Standard Practice
<u>PPE requirements</u>	Wear coveralls, gloves, boots, goggles, and respirator to protect against chemical exposure.
<u>ROPS and seatbelt</u>	If spraying with tractor-mounted equipment, ensure rollover protection and seatbelt use.
<u>No passengers</u>	Do not carry passengers during spraying to avoid exposure and accidents.
<u>Triple rinse</u>	Rinse sprayer tank three times after use to remove chemical residues.
<u>Filter cleaning</u>	Remove and clean filters to prevent clogging and ensure proper spray distribution.
<u>Nozzle inspection</u>	Check nozzles for wear, blockage, or damage; replace if necessary.
<u>Rinsate disposal</u>	Dispose of rinsate safely, following environmental guidelines (e.g., dilute and apply to designated field areas).

Box 3.1: PPE requirements and post-use sprayer maintenance checklist for crop protection operations



Pilot questions 3.4

1. Name the six basic components shared by all types of sprayers.
2. Describe the knapsack sprayer and state the scale of operations for which it is suitable.
3. Explain the difference between a flat fan nozzle and a hollow cone nozzle and state when each is used.
4. Describe the sprayer calibration process and explain why it is important.
5. State four safety rules that must be observed during spraying operations.



Series Summary

This Series has covered the design, function, and use of the main implements and equipment used from primary tillage through to crop protection in Nigerian mechanised farming. We began with primary tillage implements, describing the mouldboard plough with its share, mouldboard, landside, and frog, and its adjustments for depth and width; comparing it with the disc plough and identifying the conditions in which each is preferred; and explaining the deep-working function of subsoilers and the conservation tillage role of chisel ploughs. We then studied secondary tillage and cultivation, covering disc and tine harrows, the rotary tiller and ridger, and the spring-tine and sweep cultivators used for inter-row weed control.

Following that, we examined planting and fertiliser application equipment, explaining the components of seed drills and the precision singulation principles of row planters, comparing broadcast spinning disc spreaders with band applicators for fertiliser placement, and describing the design and performance criteria of transplanting machines for vegetable production. Finally, we covered crop protection equipment, classifying sprayers from knapsack to tractor boom, explaining nozzle types and the determination of droplet size, describing the sprayer calibration process, and establishing the PPE requirements, post-use maintenance procedures, and environmental safety obligations for all spraying operations. By completing this Series, you should now be able to achieve all eight Series Learning Outcomes (SLO 3.1 to SLO 3.8).

Glossary of Terms

- **Band application:** the placement of fertiliser or herbicide in a narrow band at a set depth and distance from the seed row, improving placement efficiency and reducing the risk of seed burning.
- **Chisel plough:** a conservation tillage implement using multiple narrow tines to loosen and partially mix the topsoil without full inversion, leaving residues at or near the surface to protect against erosion.
- **Coulter:** a sharp disc or blade that runs ahead of the plough share to cut vertically through soil and crop residues, reducing draught and improving furrow quality in trashy soils.



- **Cultivator:** an inter-row tillage implement fitted with tines or sweeps at row-crop spacings to control weeds, break surface crusts, and incorporate fertiliser between growing crop rows.
- **Disc harrow:** a secondary tillage implement comprising gangs of concave discs angled to mix, break, and level the soil after primary tillage.
- **Disc plough:** a primary tillage implement using large angled concave discs to cut and partially invert soil; performs well in hard, dry, and trashy soils where mouldboard ploughs struggle.
- **Draught:** the horizontal pull force required to move a tillage implement through the soil at a given speed and depth; the primary factor determining tractor power requirement for tillage.
- **Flat fan nozzle:** a spray nozzle that produces a flat elliptical spray pattern at 80 to 120 degrees; the standard nozzle type for herbicide application over a uniform surface.
- **Frog:** the main body casting of a mouldboard plough to which the share, mouldboard, landside, and beam attachment are all bolted.
- **Furrow opener:** the component of a seed drill or planter that creates a slot or trench in the soil into which seed is dropped; types include disc, hoe, and tine openers.
- **Hardpan:** a compacted layer in the subsoil below normal ploughing depth that restricts water drainage and root penetration; broken up by subsoiling.
- **Hollow cone nozzle:** a spray nozzle that produces droplets in a ring-shaped cone pattern; used for insecticides and fungicides requiring good canopy penetration.
- **Knapsack sprayer:** a 10 to 20 litre manually or motor-pump sprayer carried on the operator's back; the most widely used crop protection equipment by Nigerian smallholder farmers.
- **Landside:** the flat steel plate on the land side of the mouldboard plough that resists the lateral force of the soil and keeps the plough tracking straight.
- **Mouldboard:** the curved steel plate above the share of the mouldboard plough that lifts, twists, and inverts the furrow slice to bury surface residues.
- **Nozzle:** the final outlet component of a sprayer that breaks the liquid into droplets of a controlled size and distributes them at the required application rate and spray angle.
- **Precision planter:** a row planter that uses positive singulation mechanisms to place exactly one seed at each intended spacing, avoiding doubles or skips.



- **Press wheel:** a wheel behind the furrow opener of a seed drill that closes the furrow over the seed and firms the soil to ensure good seed-to-soil contact.
- **Ridger:** a tillage implement consisting of double mouldboard shares that throw soil to both sides to form raised ridges with furrows between them.
- **Rotary tiller (rotavator):** a PTO-driven tillage implement with rotating L-shaped or C-shaped blades that cuts, breaks, and mixes soil in a single pass, producing a fine seedbed.
- **Share:** the hardened steel cutting blade at the bottom of the mouldboard plough that severs the furrow slice horizontally from the unploughed land.
- **Subsoiler:** a deep-working tillage implement with narrow curved tines that penetrate to 40 to 80 cm to shatter compacted subsoil hardpan without inverting soil horizons.
- **VMD (Volume Median Diameter):** a measure of spray droplet size in micrometres; the droplet diameter below which 50 per cent of the spray volume falls; used to characterise spray quality.

Concept Check Questions [Series 3]

Objective Questions

1. The _____ of the mouldboard plough is the curved steel plate that lifts and inverts the furrow slice to bury surface residues. (Linked to SLO 3.1)
2. The disc plough excels in hard, dry soils because its discs _____ rather than break when they hit hard obstructions. (Linked to SLO 3.2)
3. Subsoilers penetrate to depths of 40 to 80 cm to break up the subsoil _____, which restricts drainage and root penetration. (Linked to SLO 3.3)
4. The rotary tiller is driven by the tractor _____ shaft and produces a fine seedbed in a single pass. (Linked to SLO 3.4)
5. A nozzle delivering more than _____ per cent above its rated output must be replaced to maintain correct application rates. (Linked to SLO 3.7)

Short-Answer Questions



1. Compare the mouldboard plough and disc plough, stating two conditions in which each performs better. (Linked to SLOs 3.1, 3.2)
2. Explain the purpose of a cultivator and describe how it avoids damaging the growing crop. (Linked to SLO 3.4)
3. Describe the components of a seed drill row unit and explain the function of each. (Linked to SLO 3.5)
4. Explain the difference between flat fan nozzles and hollow cone nozzles and state the application for which each is suited. (Linked to SLO 3.7)
5. Describe the PPE that must be worn during spraying operations and explain why each item is necessary. (Linked to SLO 3.8)

Long-Answer Questions

1. Analyse the range of tillage implements available for Nigerian farming systems, covering primary tillage (mouldboard plough, disc plough, subsoiler, chisel plough) and secondary tillage and cultivation implements (disc harrow, tine harrow, rotary tiller, ridger, cultivator), explaining the design, soil action, and appropriate application of each. (Linked to SLOs 3.1, 3.2, 3.3, 3.4)
2. Discuss planting and fertiliser application equipment, describing the components and operating principles of seed drills and precision planters, comparing broadcast and band fertiliser application methods, and explaining the design and use of transplanting machines for vegetable production. (Linked to SLO 3.5)
3. Evaluate crop protection sprayers as a technology, classifying the main sprayer types from knapsack to tractor boom, explaining nozzle types and their effect on droplet size and spray quality, describing the calibration process, and establishing the safety and maintenance requirements for responsible sprayer operation. (Linked to SLOs 3.6, 3.7, 3.8)

Answers to Concept Check Questions [Series 3]

Objective Questions

1. Mouldboard.
2. Deflect.



3. Hardpan.
4. PTO (Power Take-Off).
5. 10.

Short-Answer Questions

1. Mouldboard plough performs better in: medium-textured soils free of stones (complete inversion and good trash burial); soils that require thorough weed burial before planting. Disc plough performs better in: hard, dry soils where its discs can penetrate with less draught; rocky or stumpy land where discs deflect rather than break; heavy-trash fields where the disc cuts through residues; sticky wet soils where soil does not adhere to rotating discs.
2. A cultivator is an inter-row tillage implement used after crop emergence to control weeds, break surface crusts, and incorporate fertiliser between crop rows; it avoids crop damage by having its tines or sweeps set on a toolbar at spacings exactly matching the crop row spacing, so the working tools pass through the inter-row spaces without contacting the plant stems or root zones.
3. Seed hopper (stores the seed bulk for metering); seed metering mechanism (measures and releases a controlled number or volume of seeds per unit of travel distance to achieve the target seeding rate); furrow opener (creates a slot or trench in the soil at the correct depth for seed placement); press wheel or covering board (closes the furrow over the seed and firms the soil to ensure intimate seed-to-soil contact for rapid germination).
4. Flat fan nozzles produce a flat elliptical spray pattern at 80 to 120 degrees, delivering medium to coarse droplets uniformly across a swath; they are the standard choice for herbicide applications over a uniform soil surface or low crop canopy. Hollow cone nozzles produce a ring of droplets in a hollow cone pattern with finer droplets, providing good coverage of leaf undersides and canopy penetration; they are used for insecticide and fungicide applications on leafy crops where thorough coverage of leaf surfaces is required.
5. Chemical-resistant coverall: prevents pesticide absorption through the skin, which is the main route of chronic exposure; rubber gloves: protect hands during mixing and application, when pesticide concentration is highest; rubber boots: prevent absorption through feet and lower legs when walking through treated crops; face shield or goggles: protect eyes from spray drift and splashing during mixing; respiratory mask: prevents inhalation of pesticide vapours and fine droplets, particularly important for highly toxic products applied in still air.

Long-Answer Questions



1. Basic response: Mouldboard plough — share severs, mouldboard inverts; best in medium soils free of stones; adjustable for depth (15 to 30 cm) and width (25 to 40 cm). Disc plough — angled concave discs (60 to 75 cm); best in hard, dry, trashy, rocky soils; less thorough trash burial. Subsoiler — narrow curved tines 40 to 80 cm deep; breaks hardpan without inversion; requires 60 to 90 kW tractor. Chisel plough — multiple narrow tines 20 to 35 cm; partial loosening, surface residue retained; conservation tillage. Disc harrow — gangs of concave discs; clod breaking and levelling. Tine/spring-tine harrow — shallow 3 to 8 cm; fine seedbed. Rotary tiller — PTO-driven rotating blades; fine tilth in one pass, high PTO demand. Ridger — double mouldboard forms ridges; root crop seedbeds. Cultivators — inter-row, tine or sweep, avoids crop damage.
2. Value-added response: The choice of tillage system is not fixed but should respond to the farming context. In the Nigerian Guinea savanna, where soils are hard at the start of the rains and carry substantial crop residues, the disc plough is frequently the first choice for primary tillage because mouldboard ploughs require excessive draught in the hard soil and frequently break on concealed stones. However, the disc plough's incomplete trash burial means secondary tillage with a disc harrow is essential to break down large clods and create the seedbed fineness required by small-seeded crops. Teaching students to sequence implements logically — primary, secondary, and seedbed preparation — rather than defaulting to a single implement builds the systems thinking that characterises a skilled farm machinery manager.
3. Basic response: Seed drill components: hopper, fluted roller meter or finger pickup, furrow opener (disc, hoe, or tine), press wheel. Seed drill vs precision planter: drill places seed continuously in a row; planter spaces individual seeds precisely (positive singulation, electronic monitoring). Fertiliser application: broadcast spinning disc spreader (fast, wide swath, less precise placement); band applicator (precise placement alongside seed row, reduces fertiliser use and seed burn risk; calibration required for both). Transplanting machines: semi-automatic (operator feeds seedlings); fully automatic (cell tray plugs); criteria: depth consistency, spacing accuracy $\pm 5\%$, survival rate $>95\%$; most applicable for high-value vegetables.
4. Value-added response: The economics of planting and fertiliser application equipment investments are particularly favourable for Nigerian farmers because the labour cost of hand planting and fertiliser application is high and increasing as rural labour migrates to urban areas. A four-row maize planter that plants 1 to 2 hectares per hour at precise 75×25 cm spacing replaces the equivalent of 20 to 40 person-days of hand planting per hectare, with more consistent spacing and depth and therefore better crop stands. The fertiliser saving from



- precision band application compared with broadcast top-dressing (which loses a significant fraction to volatilisation and runoff on broadcast applications) can repay the machine cost within a few seasons on a medium-scale farm.
5. Basic response: Sprayer types: knapsack (10 to 20 L, backpack, small plots); wheelbarrow (100 to 200 L, engine pump, medium plots); tractor boom (200 to 1,000 L, 6 to 18 m boom, large fields); aerial/drone (large scale). Common components: tank, pump, agitation, pressure regulator, boom, nozzles. Nozzle types: flat fan (herbicides, 80 to 120 degree pattern); hollow cone (insecticides/fungicides, canopy penetration); flood jet (soil herbicides, coarse droplets, low drift). Droplet size: fine 100 to 200 μm (good coverage, high drift risk); medium 200 to 400 μm (balance); coarse above 400 μm (low drift). Calibration: measure nozzle output, calculate swath and speed, adjust to target L/ha. PPE: coverall, gloves, boots, goggles, respirator. Maintenance: triple rinse, filter cleaning, nozzle inspection, leak checks.
 6. Value-added response: The most persistent source of crop protection equipment failure in Nigerian smallholder agriculture is not equipment breakdown but poor calibration. A knapsack sprayer operator who walks at variable speed, operates the lever at irregular stroke frequency, and uses worn nozzles may be applying anywhere from 50 to 200 per cent of the label rate, with all the consequences of under-efficacy or crop damage that implies. Teaching calibration as a practical skill — not just a theoretical concept — and encouraging students to calibrate before every crop and every field prepares them to address one of the most concrete and correctable causes of pesticide waste and crop protection failure in Nigerian field conditions.

Answers to Pilot Questions [Series 3]

Part 3.1: Primary Tillage Implements

1. Share: severs the furrow slice horizontally from the unploughed land. Mouldboard: lifts, twists, and inverts the furrow slice to bury residues. Landside: resists lateral soil thrust and keeps the plough tracking straight. Frog: the main body casting to which share, mouldboard, landside, and beam attachment are bolted.
2. On a tractor-mounted plough, furrow depth is controlled primarily by the tractor hydraulic top link (adjusting the angle of the implement relative to the tractor and raising or lowering the share point) and by depth wheels (gauge wheels that run on the unploughed land surface



and set the maximum penetration depth by supporting the weight of the implement at the desired working depth).

3. Hard, dry soils: disc ploughs can penetrate with less draught because the rolling disc cuts through hard soil more easily than the static mouldboard share; rocky or stumpy soils: discs deflect when they hit hard obstructions rather than breaking, unlike the mouldboard share which can shear or break bolts when it hits a rock.
4. Subsoiling breaks up the subsoil hardpan below normal ploughing depth to improve drainage, reduce waterlogging, and allow deeper root penetration into the subsoil; minimum tractor power required is 60 to 90 kW because draught forces for deep subsoil penetration are very high.
5. Subsoiling: works to 40 to 80 cm depth; shatters the compacted hardpan in situ without mixing or inverting soil horizons; uses one or a few heavy narrow tines. Chisel ploughing: works to 20 to 35 cm depth (within the topsoil zone); loosens and partially mixes topsoil; leaves surface residues largely intact; uses multiple closely spaced lighter tines.

Part 3.2: Secondary Tillage and Inter-row Cultivation Implements

1. Disc harrow: uses gangs of concave steel discs that cut and mix the soil with a chopping and rolling action; effective in hard, cloddy, or trashy conditions; works to 10 to 15 cm depth. Tine harrow: uses rows of rigid or flexible steel tines dragged through the soil at shallow depth (3 to 8 cm); produces a fine seedbed by breaking small clods and uprooting small weeds; less effective in very cloddy or trashy conditions.
2. Advantage: performs both primary loosening and seedbed preparation in a single pass, saving time, fuel, and multiple field operations; produces a very fine, uniform tilth suitable for direct seeding or transplanting. Limitation: consumes considerably more PTO power per unit area than draft tillage implements; blade wear is high in stony or abrasive soils; can create a tillage pan if used repeatedly at the same depth.
3. Ridging creates raised beds of soil separated by furrows, which are the standard seedbed for root crops (yam, cassava) because ridges improve drainage around the tuber zone, concentrate organic matter and loosened soil for tuber expansion, facilitate earthing-up, and make harvesting easier by reducing the depth of soil through which tubers must be dug; in the Nigerian Guinea savanna, ridge formation has traditionally required very large amounts of hand labour that tractor-mounted ridgers can replace very efficiently.



4. A cultivator is an inter-row tillage implement used after crop emergence to control weeds between crop rows, break surface crusts that impede water infiltration, and optionally incorporate fertiliser applied as a top-dressing; it is designed so that its working tools (tines or sweeps) operate only in the inter-row spaces and do not disturb the crop plants or their root zones.
5. Spring-tine cultivator: uses flexible vibrating tines that stir and uproot weeds at 5 to 10 cm depth; best for shallow inter-row cultivation in cereals and legumes on relatively clean soils. Sweep cultivator: uses flat horizontal blade attachments (sweeps) that undercut weeds just below the soil surface, slicing through root systems; more effective on larger weeds and leaves the soil surface less disturbed than tine cultivation.

Part 3.3: Planting and Fertiliser Application Equipment

1. Seed hopper: stores the seed bulk and feeds it to the metering mechanism. Seed metering mechanism: measures and controls the number or volume of seeds released per unit of travel to achieve the target seeding rate. Furrow opener: creates the soil slot or trench at the correct depth and width into which the seed is deposited. Press wheel or covering board: closes the furrow over the seed and firms the surrounding soil to ensure good seed-to-soil contact for reliable germination.
2. A seed drill places seed in a continuous stream in rows at a set seeding rate (kg/ha) without precise individual seed spacing; it is used for small-seeded cereals (wheat, rice, sorghum) sown at high plant populations. A row planter is designed for large-seeded crops (maize, soybean, cowpea) and places individual seeds at precise inter-seed spacings within the row to achieve a target plant population per hectare.
3. A precision planter uses a positive singulation mechanism (plate cells, finger pickups, or vacuum pneumatic systems) to ensure exactly one seed is placed at each intended position in the row; precision singulation is important because doubles (two seeds at one position) create plant competition that reduces individual plant yield, while skips (empty positions) reduce plant population and total yield; both cause significant yield loss relative to the target population.
4. Broadcast spinner spreader: applies granular fertiliser uniformly over a wide swath (10 to 24 m) at high speed; good for top-dressing large areas; less accurate at field edges; does not place fertiliser precisely relative to the crop row and some fertiliser may fall on leaves. Band



- applicator: places fertiliser in a narrow band at a set depth and distance from the seed row; more efficient use of fertiliser (roots encounter high local concentration); reduces risk of seed burning; slower and more complex.
5. Vegetable crops are high-value, justifying the capital cost of a transplanting machine; transplanting is one of the most labour-intensive operations in vegetable production (hand transplanting tomato at 50,000 plants/ha is a severe bottleneck); vegetable seedlings are propagated in nurseries and transplanted as plugs, which is the ideal format for mechanised transplanting; the transplanting machine's consistency of depth and spacing improves crop uniformity and marketable yield compared with hand transplanting.

Part 3.4: Crop Protection Equipment

1. Tank (stores the spray solution); pump (pressurises the liquid to the operating pressure); agitation system (keeps the spray mixture in suspension to prevent settling or separation); pressure regulator (maintains consistent operating pressure regardless of pump speed variation); boom and distribution pipes (carry the pressurised liquid from the pump to the nozzles); nozzles (break the liquid into droplets of the desired size and apply them at the correct rate and pattern).
2. The knapsack sprayer is a 10 to 20 litre tank carried on the operator's back with a manually pumped or small motor-driven pump and a hand-held lance fitted with a nozzle; it is suitable for small plot operations (under 1 hectare), spot treatment of weeds or disease outbreaks, nursery spraying, and any operation where tractor access is not possible; it is the most widely used crop protection equipment by Nigerian smallholder farmers because of its low cost and versatility.
3. Flat fan nozzle: produces a flat elliptical pattern at 80 to 120 degrees; delivers medium to coarse droplets for uniform coverage of soil or low canopy surfaces; used for pre-emergence and post-emergence herbicide applications. Hollow cone nozzle: produces a ring of droplets in a cone shape; generates finer droplets that penetrate the crop canopy and cover leaf undersides; used for insecticide and fungicide applications on leafy crops where thorough leaf surface coverage is critical for efficacy.
4. Sprayer calibration is the process of measuring and adjusting the actual output of the sprayer to match the target application rate in litres per hectare; the process involves: measuring the output of each nozzle at the set operating pressure over one minute; measuring the effective



boom swath width; calculating travel speed; then calculating the actual application rate = $(\text{nozzle output L/min} \times 600) / (\text{travel speed km/h} \times \text{swath width m})$; if actual rate differs from target, travel speed or nozzle size is adjusted; calibration is important because uncalibrated sprayers over-apply (wasting chemicals and risking crop damage) or under-apply (giving inadequate pest or disease control).

5. Any four: read and understand the pesticide label before mixing; wear the full PPE (coverall, gloves, boots, goggles, and respirator for toxic products); never eat, drink, or smoke during mixing or spraying; do not spray in windy conditions that cause drift onto non-target areas or adjacent crops; check that all nozzles, filters, and hose connections are leak-free before starting; never spray near water sources or beehives; wash hands, face, and exposed skin thoroughly with soap and water immediately after completing spraying operations.



References and Attributions [Series 3]

Textual References (Books and External Sources)

- Srivastava, A. K., Goering, C. E., Rohrbach, R. P., & Buckmaster, D. R. (2006). Engineering principles of agricultural machines (2nd ed.). ASABE.
- Kepner, R. A., Bainer, R., & Barger, E. L. (1978). Principles of farm machinery (3rd ed.). AVI Publishing.
- Matthews, G. A. (2000). Pesticide application methods (3rd ed.). Blackwell Science.
- FAO (Food and Agriculture Organization of the United Nations). (2013). Agricultural mechanization: A key input for sub-Saharan African smallholders. FAO.
- ASABE (American Society of Agricultural and Biological Engineers). (2009). ASABE standards: Agricultural machinery management data. ASABE.
- FAO (Food and Agriculture Organization of the United Nations). (2025). Guidelines for sustainable agriculture. FAO.

Figures, Plates, Tables, and Boxes

- Figure 3.1: Mouldboard plough labelled diagram Attribution: AI generated using prompt "Generate a labelled diagram of a mouldboard plough showing the share, mouldboard, landside, frog, and the furrow slice being turned." Suggested OER search string: "mouldboard plough labelled diagram share mouldboard landside frog OER".
- Table 3.1: Mouldboard vs disc plough comparison Attribution: AI generated using prompt "Generate a table comparing the mouldboard plough and disc plough on soil conditions, trash burial, draught, soil type, maintenance, and Nigerian farming applications." Suggested OER search string: "mouldboard plough disc plough comparison table soil conditions trash burial OER".
- Figure 3.2: Tillage implement soil profile comparison Attribution: AI generated using prompt "Generate a three-panel cross-section diagram showing soil profiles produced by mouldboard ploughing, subsoiling, and chisel ploughing." Suggested OER search string: "soil tillage profile mouldboard plough subsoiler chisel plough comparison OER diagram".
- Figure 3.3: Disc harrow and spring-tine harrow diagram Attribution: AI generated using prompt "Generate a two-panel diagram showing a tandem disc harrow and a spring-tine harrow with their



soil disturbance profiles." Suggested OER search string: "disc harrow spring tine harrow secondary tillage soil profile OER diagram".

- Plate 3.1: Rotary tiller in operation Attribution: AI generated using prompt "Generate an image of a tractor-mounted PTO-driven rotary tiller working in a farm field producing a fine tilled seedbed." Suggested OER search string: "rotary tiller rotavator PTO driven field operation seedbed OER image".
- Figure 3.4: Row-crop cultivator diagram Attribution: AI generated using prompt "Generate a diagram showing a row-crop cultivator passing between maize rows with close-up views of spring tine and sweep attachments." Suggested OER search string: "row-crop cultivator maize tine sweep inter-row weed control OER diagram".
- Figure 3.6: Fertiliser spreader comparison diagram Attribution: AI generated using prompt "Generate a two-panel diagram comparing a spinning disc broadcast spreader and a band fertiliser applicator showing their placement pattern relative to the crop row." Suggested OER search string: "fertiliser spreader band applicator comparison distribution crop row OER diagram".
- Plate 3.2: Semi-automatic transplanting machine Attribution: AI generated using prompt "Generate an image of a tractor-mounted two-row semi-automatic transplanting machine with seated operators transplanting tomato seedlings into prepared ridges." Suggested OER search string: "semi-automatic transplanting machine tomato seedlings tractor-mounted OER image".
- Figure 3.7: Sprayer types diagram Attribution: AI generated using prompt "Generate a four-panel diagram showing knapsack sprayer, wheel-barrow sprayer, tractor boom sprayer, and drone sprayer with key features and application scale." Suggested OER search string: "sprayer types knapsack boom sprayer Nigeria crop protection OER diagram".
- Figure 3.8: Nozzle types spray pattern diagram Attribution: AI generated using prompt "Generate a three-panel diagram showing the spray patterns of flat fan, hollow cone, and flood jet nozzles with droplet size ranges and applications." Suggested OER search string: "sprayer nozzle types flat fan hollow cone flood jet spray pattern droplet OER".
- Box 3.1: Sprayer PPE and maintenance checklist Attribution: AI generated using prompt "Generate a box listing PPE requirements for spraying operations and post-use maintenance steps including triple rinse, filter cleaning, nozzle inspection, and rinsate disposal." Suggested OER search string: "sprayer PPE maintenance checklist post-use rinse nozzle filter safety OER".



Course code: AGE 124

Course title: Farm Technology

Course credit load: 2 Units

Series 4: Harvesting, Spraying, and Processing Equipment in Agriculture

- **Part 4.1: Grain Harvesting Equipment**

- Sub Part 4.1.1: Grain harvesting methods and the combine harvester
- Sub Part 4.1.2: Components and operation of the combine harvester
- Sub Part 4.1.3: Threshers and grain handling equipment

- **Part 4.2: Root Crop and Vegetable Harvesting Equipment**

- Sub Part 4.2.1: Cassava and yam harvesting equipment
- Sub Part 4.2.2: Groundnut and soybean harvesting equipment
- Sub Part 4.2.3: Vegetable and fruit harvesting tools and equipment

- **Part 4.3: Agricultural Processing Equipment**

- Sub Part 4.3.1: Grain milling and threshing machines
- Sub Part 4.3.2: Oil extraction equipment: palm and groundnut
- Sub Part 4.3.3: Cassava processing machines

- **Part 4.4: Irrigation Equipment**

- Sub Part 4.4.1: Types and components of irrigation systems
- Sub Part 4.4.2: Pumps and water conveyance equipment
- Sub Part 4.4.3: Irrigation scheduling and water use efficiency



Introduction

The value of a crop is not realised until it is harvested, handled, processed, and delivered without loss. From the combine harvester cutting its first swathe to processed palm oil sealed for market, machinery determines the speed, efficiency, and quality of post-field agricultural production. Irrigation equipment extends the production season and stabilises yields against erratic rainfall. Together, harvesting, processing, and irrigation equipment represent the most capital-intensive machinery investments in the agricultural sector.

The aim of this Series is to introduce you to the design, operation, and principles of grain and root crop harvesting machines, the processing equipment used for grain milling and oil and cassava product production, and the irrigation systems and equipment used to supply water to crops.

We shall commence this Series by examining grain harvesting equipment including the combine harvester. Next, we will study root crop and vegetable harvesting. Following that, we will cover grain milling, oil extraction, and cassava processing machines. Finally, we will wrap up with irrigation system types, pumps, and irrigation scheduling for water use efficiency.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 4.1** describe the design, main components, and operating principles of the combine harvester (Linked to Part 4.1),
- **SLO 4.2** describe the types and operation of grain threshers and grain handling equipment (Linked to Part 4.1),
- **SLO 4.3** describe the harvesting equipment and methods used for cassava, yam, groundnut, soybean, and vegetables (Linked to Part 4.2),
- **SLO 4.4** describe grain milling machines and explain their operating principles (Linked to Part 4.3),



- **SLO 4.5** explain the operation of palm oil and groundnut oil extraction equipment (Linked to Part 4.3),
- **SLO 4.6** describe the cassava processing machines used for grating, pressing, and frying (Linked to Part 4.3),
- **SLO 4.7** classify irrigation systems and describe the components of each type (Linked to Part 4.4), and
- **SLO 4.8** explain the selection of pumps, water conveyance systems, and irrigation scheduling for water use efficiency (Linked to Part 4.4).

4.1 Grain Harvesting Equipment

4.1.1 Grain harvesting methods and the combine harvester

Grain crops (maize, rice, sorghum, wheat, soybean) can be harvested by hand, by reaper-binders that cut and bind stalks for separate threshing, or by combine harvesters that cut, thresh, clean, and collect grain in a single field pass. The combine harvester is the most efficient machine for large-scale grain harvesting and is the dominant technology for commercial grain production worldwide.

In Nigeria, combine use has been limited by small farm sizes, mixed cropping systems, inadequate roads, and high capital cost. Government mechanisation service centres and contractor hire have expanded access to medium-scale farms producing rice, maize, sorghum, and soybean in the savanna zones. Self-propelled combine harvesters are the most common type; tractor-pulled models suit lower-budget operations. The key performance indicator for a combine harvester is grain loss: total field losses from cutting, threshing, and separation should be below 3 per cent of the standing crop yield.

Fill in the blank: The key performance indicator for a combine harvester is grain _____, which should be kept below 3 per cent of the standing crop yield for efficient operation.





Plate 4.1: A self-propelled combine harvester harvesting maize in a Nigerian savanna commercial farm

4.1.2 Components and operation of the combine harvester

The **combine harvester** performs five consecutive operations. The **cutting platform (header)** gathers standing crop using a reel, a reciprocating cutterbar, and a conveyor auger feeding the feeder house. The **feeder house** is a chain-and-slat elevator carrying cut crop into the threshing cylinder. The **threshing cylinder and concave** beat grain free from straw: the rotating rasp-bar cylinder beats crop against the curved concave grate, dislodging grain through the concave openings.

The **straw walkers** (oscillating sieves) carry straw rearward while remaining grain falls through for recovery. The **cleaning shoe** (upper and lower sieves with a fan air blast) removes chaff and weed seeds, directing clean grain into the **grain tank** for periodic unloading via the grain auger into a trailer. Only the power stroke produces work; the other components are driven by the engine to maintain continuous crop flow through the machine.



Fill in the blank: In the combine harvester, the threshing _____ and concave work together to beat grain free from the straw as the rotating cylinder impacts the crop against the curved concave grate.

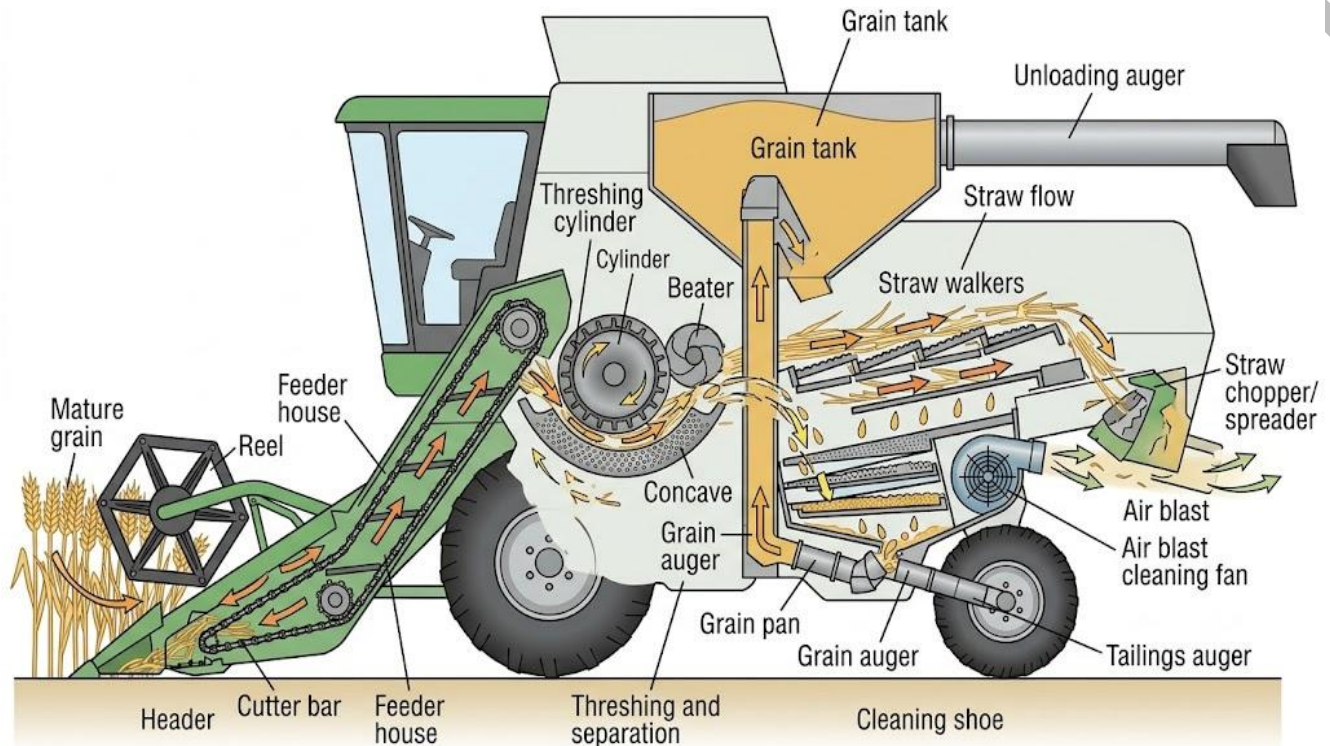


Figure 4.1: Cross-section diagram showing crop flow through the five main systems of a combine harvester

4.1.3 Threshers and grain handling equipment

Standalone threshers are used where combine harvesters are unavailable or where grain is harvested manually. The most common type in Nigeria is the **axial-flow thresher** in which crop is fed parallel to the rotation axis of a drum fitted with rasp bars or spike teeth; grain is separated through concave openings as the crop spirals around the drum. Axial-flow threshers can be powered by a diesel engine (5 to 15 kW), electric motor, or PTO shaft and process 500 to 1,500 kg of paddy rice or maize per hour.

After threshing, grain must be handled efficiently to reduce losses. Grain augers (screw conveyors) transfer grain from threshers into storage bags or bins; portable belt or bucket



elevators raise grain into high-sided vehicles or elevated silos. Grain driers reduce moisture to safe storage levels (below 13 per cent for cereals) using heated air from diesel burners or direct solar drying on raised platforms. Accurate weighing using platform scales at the threshing point is essential for record keeping, market transactions, and yield assessment.

Fill in the blank: Axial-flow threshers feed crop _____ to the rotation axis of the drum, allowing grain to be separated through concave openings as the crop spirals around the inside of the drum.

Pilot questions 4.1

1. State three operations that a combine harvester performs that a standalone thresher does not.
2. Name the five main component systems of the combine harvester and state the function of each.
3. Define grain loss in combine harvester operation and state the acceptable target.
4. Describe the operating principle of the axial-flow thresher.
5. Explain why grain must be dried before storage and state the safe moisture level for cereal grain.

4.2 Root Crop and Vegetable Harvesting Equipment

4.2.1 Cassava and yam harvesting equipment

Cassava harvesting is one of the most labour-intensive operations in Nigerian crop production because roots are buried 15 to 30 cm deep and must be extracted without breaking, since broken roots deteriorate rapidly. Hand harvesting using a hoe or digging fork remains the most common method on smallholder farms. Tractor-mounted cassava harvesters use a subsoil lifting bar that runs under the root zone and breaks the soil to loosen the roots, which are then pulled out by hand or by conveyor.

Fully mechanised cassava harvesters combine a subsoil lifter with conveyors that lift and shake roots free of soil, depositing them in windrows or directly into a trailer. A key challenge in



cassava mechanisation is variation in root size, depth, and soil conditions across Nigerian farming systems. Yam harvesting is even more challenging because tubers grow very deep (30 to 60 cm), are highly irregular in shape, and extremely fragile; mechanical yam harvesters remain at the experimental stage in Nigeria.

Fill in the blank: Tractor-mounted cassava harvesters use a subsoil lifting _____ that runs beneath the root zone to loosen the soil before roots are pulled out manually or by conveyor.



Plate 4.3: A tractor-mounted cassava harvester with a subsoil lifting bar loosening roots for manual collection

4.2.2 Groundnut and soybean harvesting equipment

Groundnut harvesting involves two stages: digging and threshing. On smallholder farms, plants are uprooted by hand or with a hand-pushed groundnut digger blade, allowed to wilt in windrows for two to three days, and then threshed by beating against a metal grate or using a small petrol-engine thresher. Tractor-mounted groundnut diggers use a share to undercut the pods and an elevator web to bring loosened plants to the surface.



Soybean harvesting is well suited to combine operation because plants are relatively uniform in height, pods are at a consistent height above ground, and the crop lodges less than other legumes. The header height must be set very low (10 to 15 cm above ground) to capture the lowest pods. A flex header whose cutterbar flexes to follow ground contours reduces pod shatter losses on uneven ground. After harvesting, soybeans require drying to below 13 per cent moisture and careful handling to prevent seed coat damage that causes aflatoxin susceptibility and reduces oil content.

Fill in the blank: A flex _____ on a combine harvester flexes to follow ground contours during soybean harvesting, reducing pod shatter losses on uneven fields.

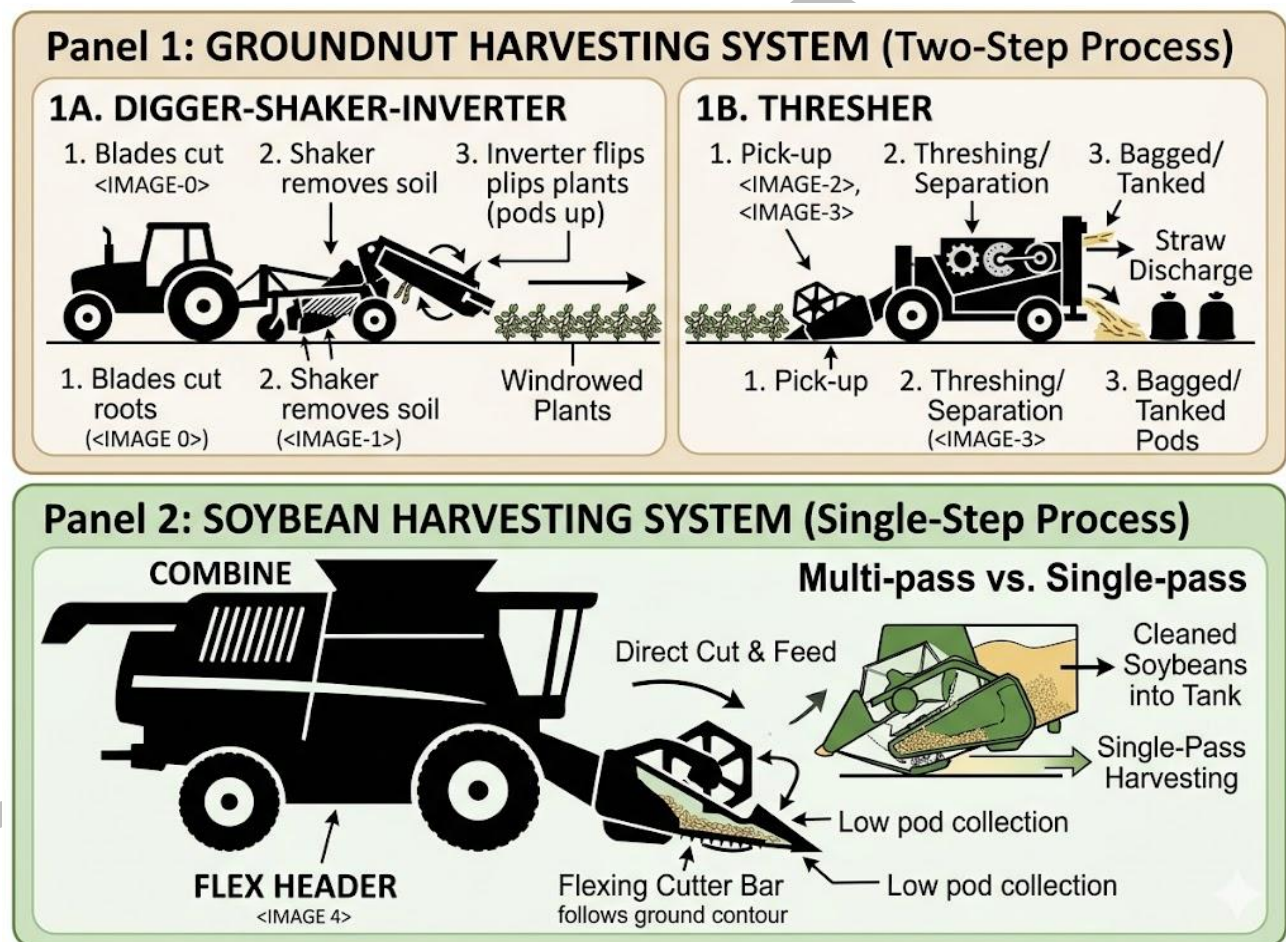


Figure 4.2: Diagram comparing groundnut harvesting (digger and thresher) and soybean harvesting (combine with flex header)



4.2.3 Vegetable and fruit harvesting tools and equipment

Vegetables and fruits are predominantly harvested by hand throughout Nigeria because their high fragility, irregular maturation, and the need for selective picking make full mechanisation difficult. Hand harvesting tools include harvesting knives (for tomato and cucumber stem cutting), secateurs and pruning shears (for pepper, aubergine, and okra), bean hooks (for cowpea pod picking), and harvesting baskets and field crates for collecting and transporting produce to the packaging area.

Post-harvest handling equipment is as important as the harvesting tool for maintaining vegetable quality. Gentle handling to avoid bruising, immediate shade to remove field heat, and prompt precooling (immersion in cool water or forced-air cooling) dramatically extend shelf life. Field packinghouses fitted with sorting tables, grading lines, and weighing scales allow produce to be graded at the farm before transport, reducing the number of handling steps and mechanical damage. Mobile cold stores and evaporative coolers maintain the cold chain from harvest. For export vegetables, adherence to quality and food safety standards from harvest to pack is essential.

Fill in the blank: Immediate _____ of harvested vegetables by moving them into shade or cool water removes field heat and dramatically extends shelf life and market quality.

Step Number	Post-Harvest Step	Description
1	Harvesting	Careful removal of vegetables from the field at the appropriate maturity stage to maintain quality.
2	Precooling	Rapid removal of field heat to slow down respiration, microbial growth, and ripening.
3	Grading and Sorting	Separating produce based on size, color, weight, and quality standards, and removing damaged items.



Step Number	Post-Harvest Step	Description
4	Packing	Placing produce into appropriate containers to provide physical protection and facilitate handling.
5	Cold Storage	Maintaining optimal temperature and humidity to extend shelf life and preserve nutrient content.
6	Transport	Moving the final product to the market while maintaining the cold chain to minimize losses.

Box 4.1: Recommended post-harvest handling steps for fresh vegetables from harvest to market

Pilot questions 4.2

16. Explain why cassava harvesting is labour-intensive and describe how a tractor-mounted harvester reduces this labour.
17. Describe the two stages of groundnut harvesting and the equipment used at each stage.
18. Explain why soybean is better suited to combine harvesting than most other grain legumes.
19. Name four hand harvesting tools used for vegetables and state which crop each is used for.
20. Explain why immediate precooling after harvest is important for vegetable quality.

4.3 Agricultural Processing Equipment

4.3.1 Grain milling and threshing machines

Grain milling reduces dry grain into flour, meal, or grits for human consumption or animal feed. The two most common mill types in Nigeria are the **hammer mill** and the **plate mill (disc mill)**. The hammer mill uses a rotating shaft carrying free-swinging hardened steel hammers that shatter grain against a perforated screen; product fineness is controlled by the screen hole size and the mill is versatile across grain types including maize, sorghum, and dried cassava. The



plate mill uses two closely set grooved metal discs (one fixed, one rotating) that grind grain between them into flour.

Dehulling machines remove the outer bran layer from grain before milling. Paddy rice processing requires a rice husker (rubber rollers remove the outer husk) followed by a rice whitener (abrasion against a whitening stone polishes the dehulled brown rice). Maize shellers mechanically strip grain from the cob before milling. All grain milling equipment must be operated with grain dried to below 13 per cent moisture to prevent screen and plate clogging, and processing areas must be regularly cleared of dust and screenings that create fire and explosion hazards.

Fill in the blank: The _____ mill uses free-swinging steel hammers rotating at high speed to shatter grain against a perforated screen, producing flour whose fineness is controlled by the screen hole size.

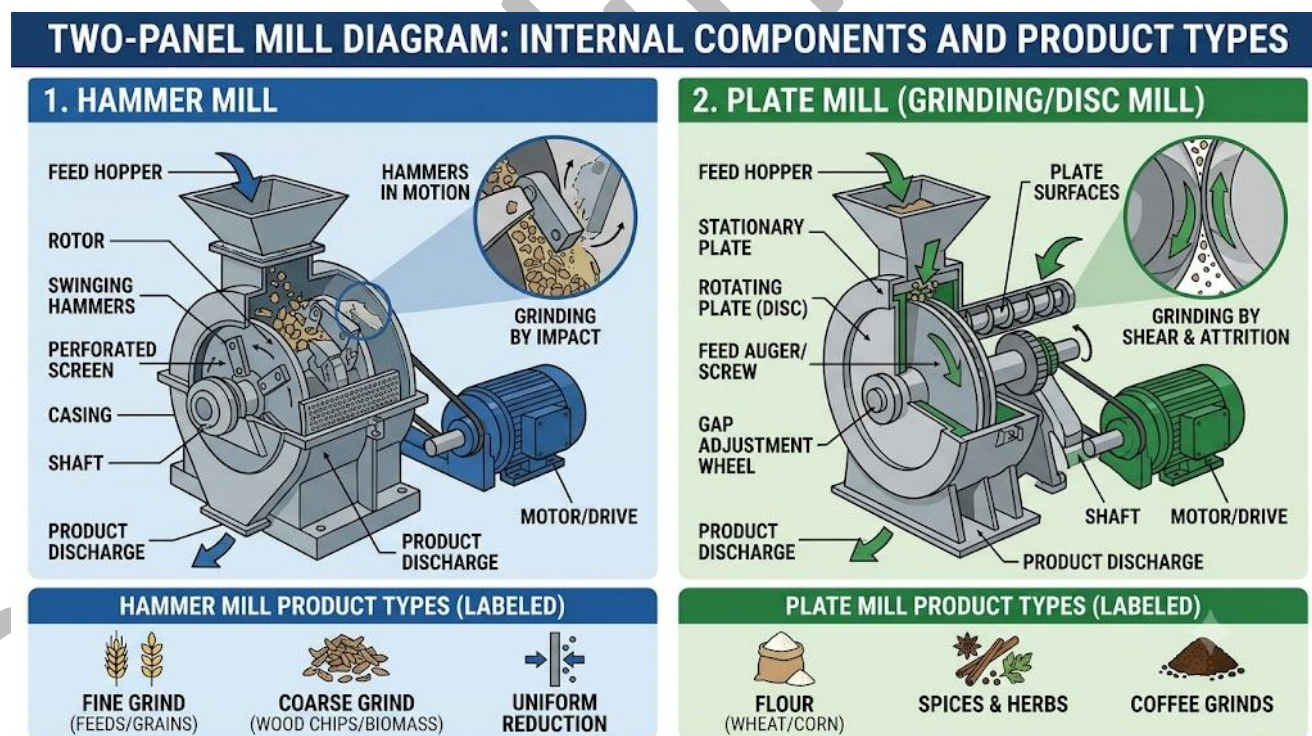


Figure 4.3: Diagram showing the internal components of a hammer mill and a plate mill



4.3.2 Oil extraction equipment: palm and groundnut

Small-scale palm oil processing equipment mechanises the most labour-intensive steps. The **mechanical digester** (a steam-jacketed cylinder with rotating paddles) macerates steamed palm fruit to release oil from the mesocarp fibre. The **mechanical screw press** then expresses oil from the pulp under high mechanical pressure, achieving 80 to 90 per cent oil extraction efficiency compared with 50 to 60 per cent for the traditional hand method.

After pressing, crude palm oil is purified by clarification: the oil is heated to 90 to 95°C in a clarification tank, causing it to separate into three layers (oil on top, water in the middle, and sludge at the bottom); the oil layer is decanted and dried by further heating. For groundnut oil, the expeller press extracts oil after roasting kernels at 120 to 140°C, achieving 80 to 85 per cent extraction from a typical 48 per cent oil content kernel. Both palm and groundnut oil must be dried after extraction and stored in clean, sealed, opaque containers away from heat and light to prevent rancidity.

Fill in the blank: The mechanical screw _____ expresses palm oil from macerated fruit pulp under high pressure, achieving 80 to 90 per cent oil extraction efficiency compared with the traditional manual method.



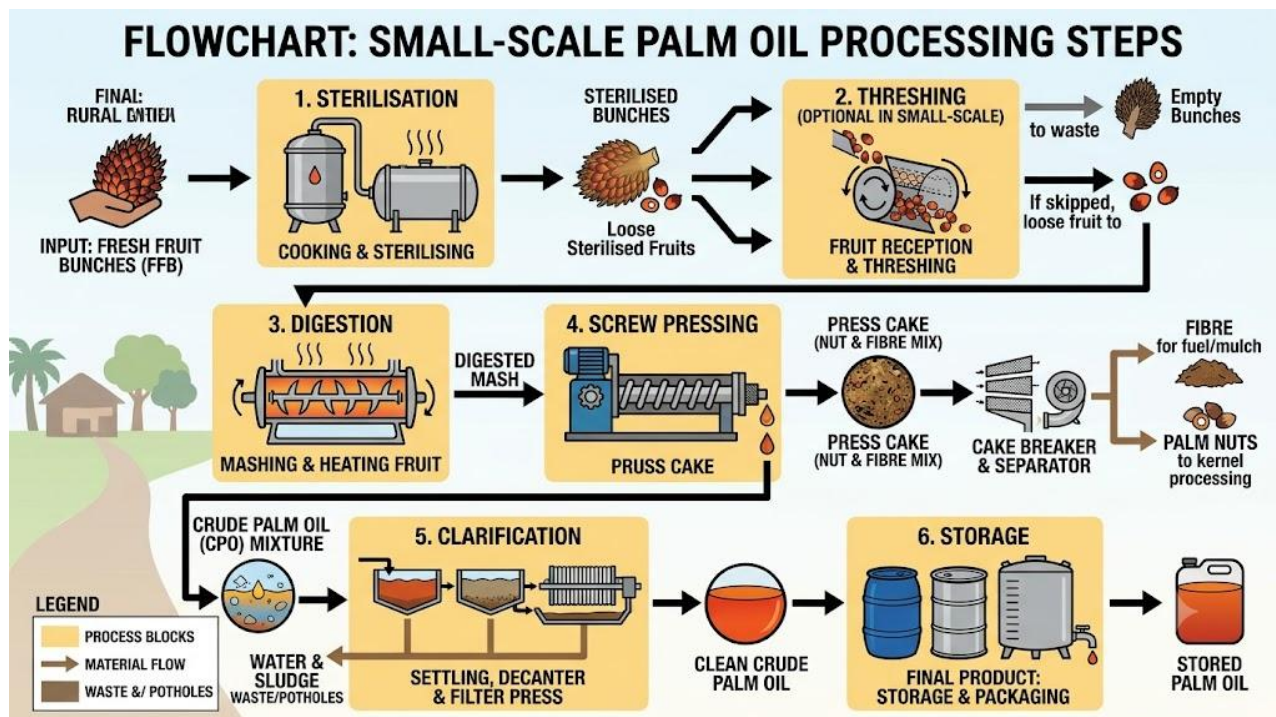


Figure 4.4: Palm oil processing flowchart from sterilisation through digestion, pressing, clarification, and storage

4.3.3 Cassava processing machines

Mechanised cassava processing replaces the most labour-intensive hand operations in garri and cassava flour production. The **mechanical cassava grater** uses a motor-driven drum covered with a rasping surface (punched spikes or studded rubber) that reduces peeled cassava roots to a wet mash in seconds, replacing hand grating. A typical motorised grater processes 500 to 2,000 kg of peeled cassava per hour depending on drum size and motor power (1.5 to 5.5 kW).

After grating, the wet mash is loaded into a hydraulic or screw-type cassava press that applies continuous pressure to express water and hydrogen cyanide from bitter varieties, reducing mash moisture from approximately 70 per cent to 40 to 45 per cent before fermentation and frying. The garri frying machine (mechanical garification drum) is a motorised rotating drum with external heating (gas or firewood) and internal paddles that continuously stir the sieved mash during frying, producing uniformly toasted garri without intense hand labour. Capacities range from 50 to 500 kg of dry garri per hour.



Fill in the blank: The mechanical cassava _____ uses a motor-driven studded drum to reduce peeled roots to a wet mash, replacing the slow and labour-intensive hand grating process.

MECHANISED CASSAVA PROCESSING FLOWCHART

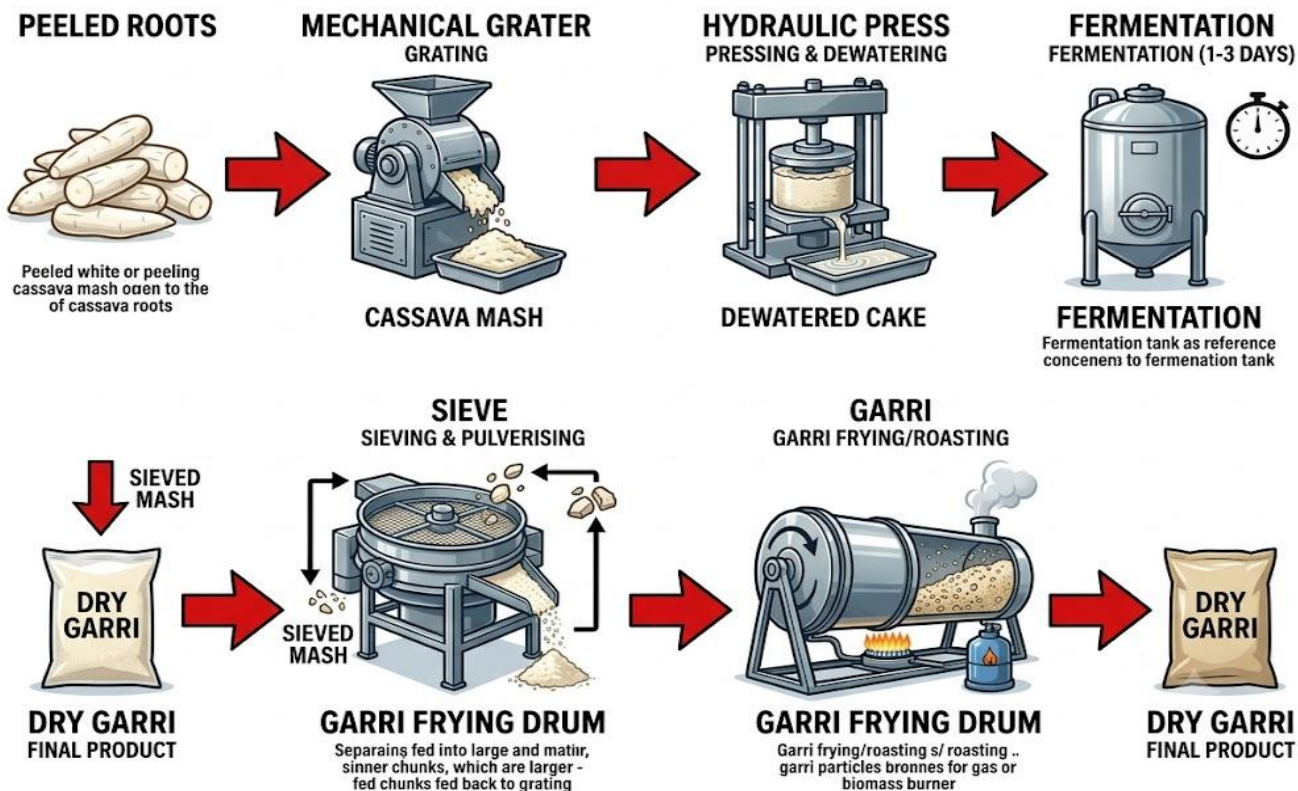


Figure 4.5: Mechanised cassava processing flowchart from peeled roots through grater, press, fermentation, sieve, and frying drum to garri

Pilot questions 4.3

1. Distinguish between a hammer mill and a plate mill in terms of operating principle and product type.
2. Describe the operating principle of the mechanical screw press in palm oil extraction.
3. Explain the clarification step in palm oil processing and describe how it separates oil from impurities.
4. Describe the mechanical cassava grater and explain how it improves on hand grating.
5. Explain the function of the cassava hydraulic press and state what it removes from the mash.



4.4 Irrigation Equipment

4.4.1 Types and components of irrigation systems

Irrigation systems supply water to crops to supplement or replace rainfall. The three main categories used in Nigeria are **surface irrigation** (water released at the surface and distributed by gravity along furrows or across basins), **sprinkler irrigation** (water pressurised and distributed through rotating or fixed sprinkler heads that spray water over the crop like artificial rain), and **drip (trickle) irrigation** (water delivered at low pressure directly to the root zone of each plant through emitters on lateral pipes, minimising evaporation and runoff losses).

Surface irrigation is the least capital-intensive and most widely used method for large-scale irrigated rice and sugarcane in Nigeria but has low water use efficiency (50 to 60 per cent). Sprinkler systems achieve 70 to 80 per cent efficiency and are suitable for a wide range of crops and terrain. Drip irrigation achieves the highest efficiency (85 to 95 per cent) and is most cost-effective for high-value vegetables, fruit orchards, and greenhouse crops; it also allows fertigation — the delivery of dissolved fertiliser through the drip lines.

Fill in the blank: Drip irrigation achieves water use efficiency of 85 to _____ per cent, the highest of any irrigation method, by delivering water directly to the root zone through emitters.



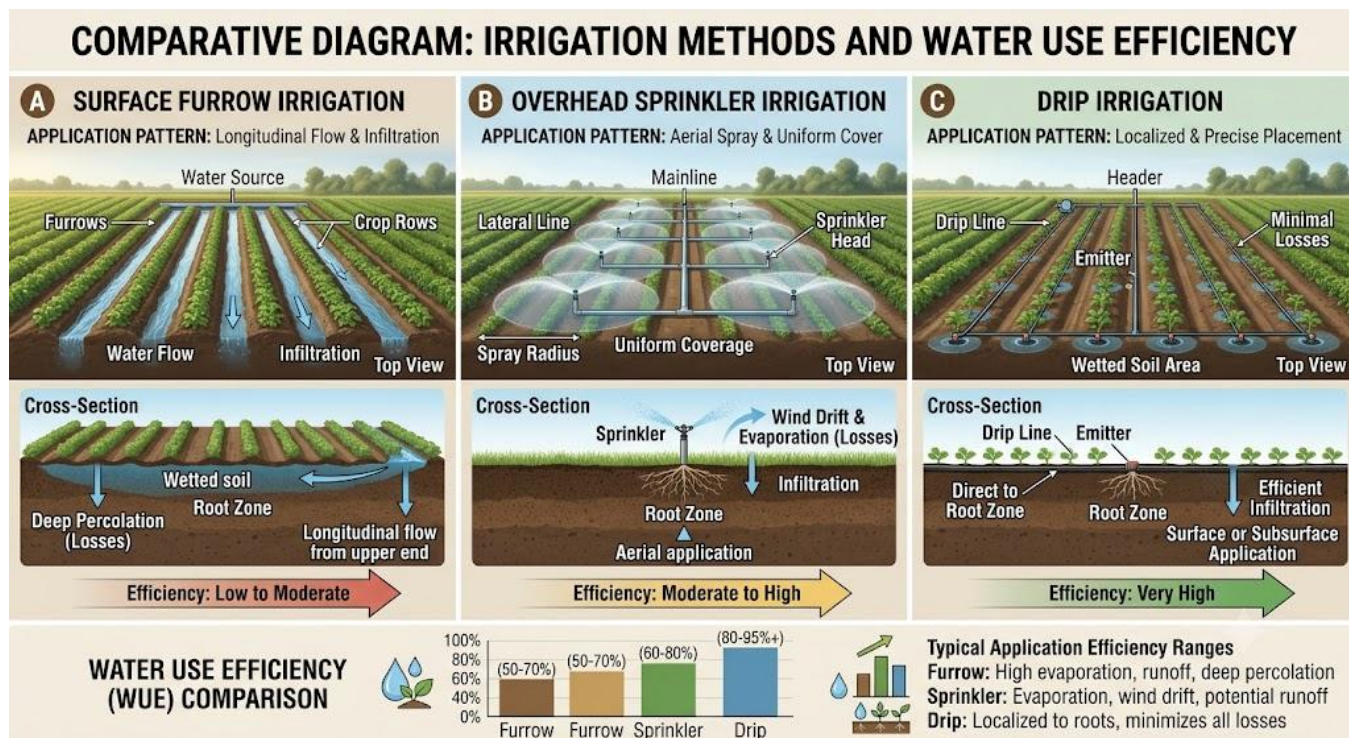


Figure 4.6: Diagram comparing surface, sprinkler, and drip irrigation systems showing application patterns and efficiency ranges

4.4.2 Pumps and water conveyance equipment

Pumps are the primary power conversion devices in irrigation, converting mechanical energy into hydraulic energy to lift and convey water from source to field. The main pump types used in Nigerian irrigation are **centrifugal pumps** (the most widely used; a rotating impeller flings water outward by centrifugal force, creating pressure and continuous flow for high flow rates at moderate to high heads), **submersible pumps** (sealed motor-pump units lowered into boreholes; eliminate priming and suit deep water sources), and **solar pumps** (DC motor-driven pumps powered by solar photovoltaic panels; increasingly common for small-scale Nigerian dry-season vegetable irrigation).

Water conveyance equipment carries water from the pump to the field. Open channels (earthen or concrete-lined) are used for large-scale surface irrigation schemes but lose water to seepage and evaporation. Gated pipes (portable aluminium or PVC pipes with outlet gates) distribute water along furrow irrigated fields. Mainlines, submains, and lateral pipes (rigid or flexible PVC



or polyethylene) form the distribution network for pressurised sprinkler and drip systems. Filters (screen, disc, and sand filters) are essential upstream of drip emitters to remove particles that would cause emitter clogging; even clean borehole water must be filtered before entering a drip system.

Fill in the blank: _____ pumps are the most widely used type in Nigerian irrigation, using a rotating impeller to generate pressure and continuous flow for high flow rate applications.

SCHEMATIC DIAGRAM OF A DRIP IRRIGATION SYSTEM

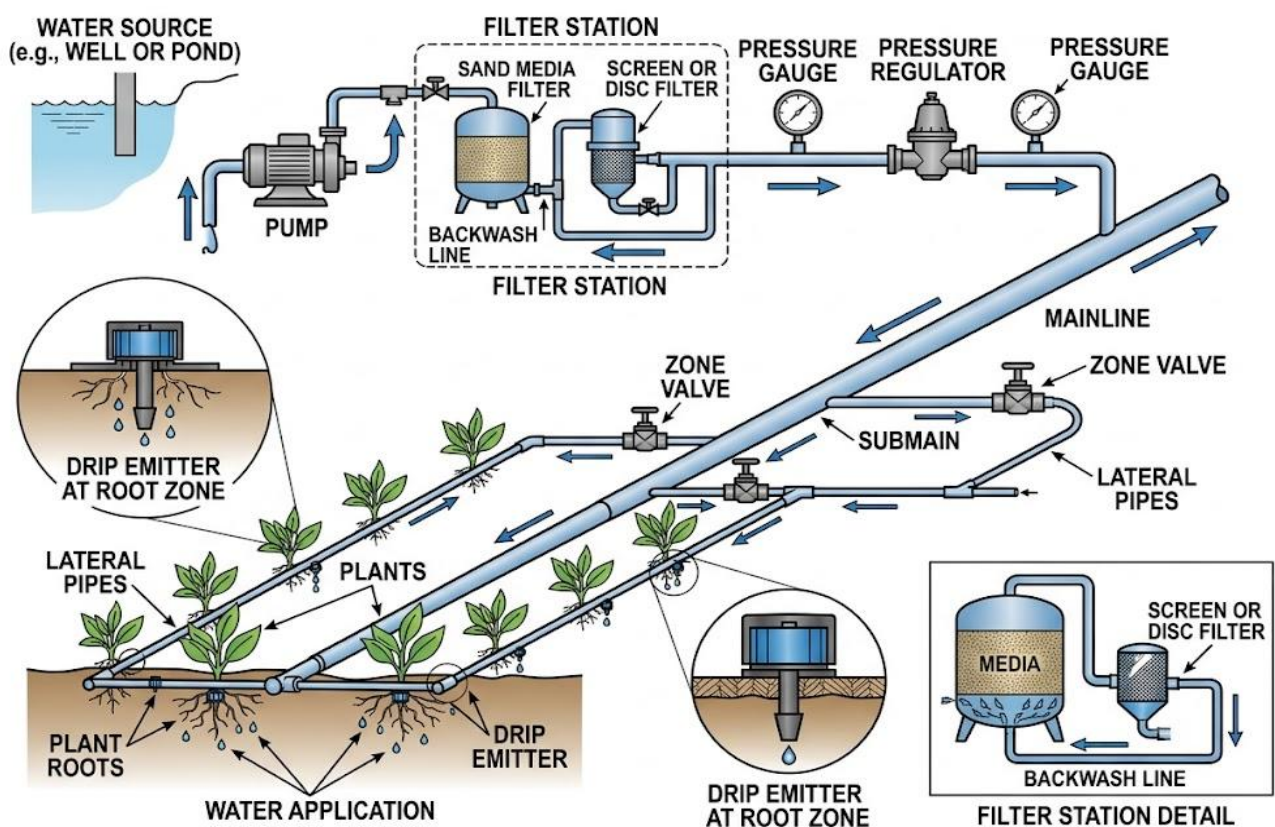


Figure 4.7: Schematic diagram of a drip irrigation system from pump and filter station to emitters at plant roots

4.4.3 Irrigation scheduling and water use efficiency

Irrigation scheduling determines when to irrigate and how much water to apply to optimise crop growth while minimising waste. The two fundamental concepts are **crop water**



requirement (ETc) — the water a crop uses through evapotranspiration per day (mm/day), calculated as reference evapotranspiration (ETo) multiplied by a crop coefficient (Kc) that varies by crop and growth stage — and **soil water deficit** — the difference between field capacity (the maximum water the soil holds after drainage) and the current soil water content, which determines how much water must be applied to return the soil to field capacity.

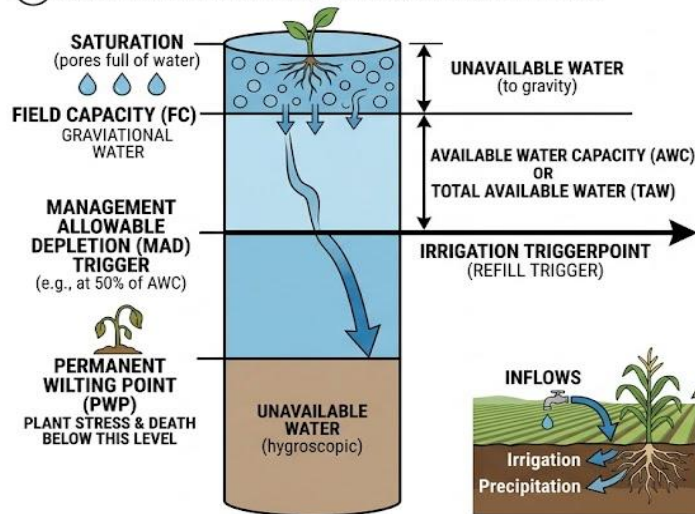
Irrigation should be triggered when the soil water deficit reaches the management allowable depletion (MAD), typically 40 to 50 per cent of plant available water capacity. This is determined by tensiometers (sensors measuring soil water tension at root depth) or estimated from weather-based ETo calculations combined with soil water balance accounting. Water use efficiency (WUE) is the crop yield produced per unit of water applied; it is improved by irrigating at optimal crop growth stages, applying the correct amount per event without over-irrigating, using high-efficiency systems (drip and sprinkler over surface), and keeping the system free of leaks and blockages.

Fill in the blank: Irrigation should be triggered when the soil water deficit reaches the management allowable _____ (MAD), typically 40 to 50 per cent of the plant available water capacity.

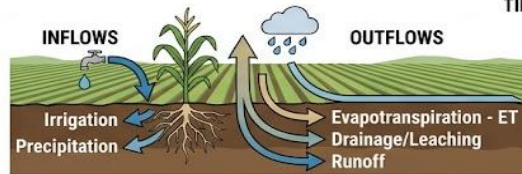
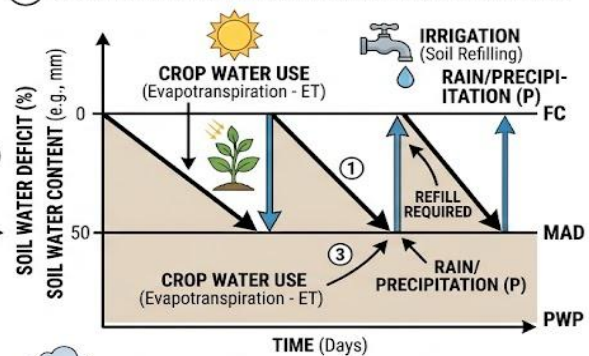


SOIL WATER BALANCE AND IRRIGATION SCHEDULING DIAGRAM

① SOIL WATER RESERVOIR AND CRITICAL LEVELS.



② SOIL WATER BALANCE DYNAMICS OVER TIME.



③ SYSTEM INPUTS AND OUTPUTS (OVERVIEW)

CHANGE IN SOIL WATER
= INFLOWS - OUTFLOWS

Figure 4.8: Soil water balance diagram showing field capacity, management allowable depletion trigger, and permanent wilting point

Pilot questions 4.4

1. Name the three main irrigation system categories and state the water use efficiency of each.
2. Explain why drip irrigation is most cost-effective for high-value vegetable production.
3. Describe the operating principle of the centrifugal pump.
4. Explain why filters are essential upstream of drip emitters.
5. Define crop water requirement (ETc) and explain how irrigation scheduling uses it.



Series Summary

This Series has covered the harvesting, processing, and irrigation equipment that constitute the post-production and water supply technology of the agricultural sector. We began with grain harvesting, describing the five operating systems of the combine harvester (header, feeder house, threshing cylinder and concave, straw walkers, and cleaning shoe with grain tank), and explaining standalone axial-flow threshers, grain augers, and grain driers. We then examined root crop and vegetable harvesting, describing the challenges and mechanisation approaches for cassava and yam, the two-stage groundnut harvesting system, the combine harvesting of soybean with a flex header, and the hand tools and precooling practices for fresh vegetable quality.

Following that, we covered agricultural processing equipment: hammer mills and plate mills for grain milling; the mechanical digester, screw press, and clarification process for palm oil; the expeller press for groundnut oil; and the mechanical cassava grater, hydraulic press, and motorised garification drum for garri production. Finally, we introduced irrigation systems, comparing surface, sprinkler, and drip methods; describing centrifugal, submersible, and solar pumps and distribution networks; and establishing the concepts of crop water requirement, soil water deficit, and management allowable depletion for irrigation scheduling. By completing this Series, you should now be able to achieve all eight Series Learning Outcomes (SLO 4.1 to SLO 4.8).

Glossary of Terms

- **Axial-flow thresher:** a threshing machine in which crop is fed parallel to the rotation axis of the drum, spiralling around the drum interior for grain separation through concave openings.
- **Centrifugal pump:** a pump using a rotating impeller to fling water outward by centrifugal force, creating pressure and continuous flow; the most common pump in Nigerian irrigation.
- **Clarification:** the separation of crude palm oil from water and sludge by heating to 90 to 95°C and gravity-settling the three phases before decanting the oil layer.



- **Combine harvester:** a self-propelled or trailed machine that cuts standing grain, threshes grain from straw, cleans the grain, and deposits it in a tank in a single field pass.
- **Concave:** the curved grate below the threshing cylinder through which grain passes after being dislodged from the straw by the rotating cylinder.
- **Crop coefficient (Kc):** a dimensionless factor relating reference evapotranspiration (E_{To}) to actual crop water requirement (E_{Tc}); varies by crop type and growth stage.
- **Crop water requirement (E_{Tc}):** the water used by a crop through evapotranspiration per unit time (mm/day), calculated as E_{To} multiplied by the crop coefficient K_c .
- **Drip irrigation:** an irrigation system delivering water at low pressure directly to the root zone through emitters on lateral pipes; achieves 85 to 95 per cent water use efficiency.
- **Feeder house:** the chain-and-slat elevator on a combine harvester that carries cut crop from the header rearward and upward into the threshing cylinder.
- **Fertigation:** the delivery of dissolved fertiliser through the irrigation system (typically drip), combining irrigation and fertiliser application in a single operation.
- **Field capacity (FC):** the soil water content after excess water has drained by gravity, typically one to three days after saturation; represents the maximum useful water storage.
- **Flex header:** a combine harvester cutting platform whose cutterbar flexes vertically to follow ground contours, reducing pod shatter losses during soybean harvesting.
- **Grain loss:** the proportion of standing crop yield not recovered during harvesting; should be below 3 per cent of standing crop yield for efficient combine harvesting.
- **Hammer mill:** a grain milling machine in which rotating free-swinging steel hammers shatter grain against a perforated screen; product fineness is controlled by screen hole size.
- **Management allowable depletion (MAD):** the level of soil water depletion at which irrigation should be triggered, typically 40 to 50 per cent of plant available water capacity.
- **Mechanical digester:** a cylindrical vessel with rotating paddles used in palm oil processing to macerate steamed fruit and release oil from the mesocarp fibre before pressing.
- **Plate mill (disc mill):** a grain milling machine using two closely set grooved discs (one fixed, one rotating) to grind grain between them; produces fine, uniform flour.



- **Screw press (expeller):** a machine applying continuous mechanical pressure to extract oil from oilseed or palm fruit pulp using a rotating screw that forces material against a perforated cage.
- **Sprinkler irrigation:** an irrigation system that pressurises water and distributes it through rotating or fixed sprinkler heads; achieves 70 to 80 per cent water use efficiency.
- **Straw walker:** a series of oscillating perforated platforms in a combine harvester that carry straw rearward while allowing remaining grain to fall through for recovery.
- **Submersible pump:** a sealed motor-pump unit lowered directly into a borehole or well; eliminates priming requirements and suits deep water sources for irrigation.
- **Surface irrigation:** an irrigation method in which water is released at the surface and distributed by gravity along furrows or basins; efficiency 50 to 60 per cent.
- **Tensiometer:** a soil water measurement device installed at root depth that measures soil water tension to determine when to trigger irrigation.

Concept Check Questions [Series 4]

Objective Questions

6. Total grain loss for efficient combine harvester operation should be below _____ per cent of the standing crop yield. (Linked to SLO 4.1)
7. The threshing _____ and concave work together in the combine to beat grain free from the straw. (Linked to SLO 4.1)
8. The _____ mill uses free-swinging steel hammers to shatter grain against a perforated screen for flour production. (Linked to SLO 4.4)
9. Drip irrigation achieves water use efficiency of 85 to _____ per cent, the highest of any system. (Linked to SLO 4.7)
10. Irrigation should be triggered at management allowable _____ (MAD), typically 40 to 50 per cent of plant available water capacity. (Linked to SLO 4.8)

Short-Answer Questions



11. Name the five main systems of the combine harvester and describe the function of each. (Linked to SLO 4.1)
12. Describe the two-stage process of groundnut harvesting and name the equipment used at each stage. (Linked to SLO 4.3)
13. Explain the clarification step in small-scale palm oil processing. (Linked to SLO 4.5)
14. Compare surface and drip irrigation in terms of water use efficiency and crop suitability. (Linked to SLO 4.7)
15. Define crop water requirement (ET_c) and explain how it is calculated. (Linked to SLO 4.8)

Long-Answer Questions

14. Analyse grain harvesting technology, describing the combine harvester in detail, explaining standalone threshers and grain handling equipment, and assessing the constraints on combine adoption in Nigeria. (Linked to SLOs 4.1, 4.2)
15. Discuss the agricultural processing equipment used for grain milling, palm oil extraction, and cassava processing in Nigeria, explaining operating principles and how mechanisation improves on traditional hand methods. (Linked to SLOs 4.4, 4.5, 4.6)
16. Evaluate the irrigation systems available for Nigerian agriculture, comparing main system types and efficiency, describing pumps and conveyance equipment for pressurised systems, and explaining irrigation scheduling principles for optimal crop production and water use efficiency. (Linked to SLOs 4.7, 4.8)

Answers to Concept Check Questions [Series 4]

Objective Questions

1. 3.
2. Cylinder.
3. Hammer.
4. 95.
5. Depletion.

Short-Answer Questions



1. Header (gathers and cuts standing crop with reel, cutterbar, and auger); feeder house (chain-and-slat elevator carries cut material to threshing cylinder); threshing cylinder and concave (rotating cylinder beats grain from straw through concave openings); straw walkers (oscillating sieves carry straw rearward while grain falls through); cleaning shoe (sieves with fan air blast remove chaff and direct clean grain to grain tank).
2. Stage 1 — digging: a tractor-mounted groundnut digger blade undercuts the taproot below the pod zone and an elevator web brings loosened plants to the surface for windrow deposition; hand uprooting with a digging fork on smallholder farms. Stage 2 — threshing: after two to three days wilting, the dry plants are threshed by a petrol-engine groundnut thresher that strips pods from stems, or by hand-beating against a metal grate for smaller quantities.
3. After pressing, crude palm oil contains water and sludge; the mixture is heated to 90 to 95°C in a clarification tank, which reduces viscosity and causes separation into three layers: clean oil on top, muddy water in the middle, and settled sludge at the bottom; the oil layer is decanted and further heated to remove residual moisture, producing clear purified crude palm oil.
4. Surface irrigation: water flows by gravity in furrows or basins; efficiency 50 to 60 per cent; low capital cost; suitable for large-scale rice, sugarcane, and cereals on flat land. Drip irrigation: emitters deliver water to individual root zones; efficiency 85 to 95 per cent; highest capital cost per hectare; most cost-effective for high-value vegetables, fruit trees, and greenhouse crops where water saving and fertigation justify the investment.
5. Crop water requirement (ET_c) is the water used by a crop through evapotranspiration per unit time (mm/day); it is calculated as $ET_c = ET_o \times K_c$, where ET_o is reference evapotranspiration estimated from weather data and K_c is the crop coefficient, a dimensionless factor varying by crop type and growth stage (typically 0.3 to 0.4 at early growth, rising to 1.0 to 1.2 at peak, then declining at maturity).

Long-Answer Questions

1. Basic response: Combine harvester systems — header (reel, cutterbar, auger), feeder house (chain conveyor), threshing cylinder and concave, straw walkers, cleaning shoe (sieves plus fan, grain tank and auger). Grain loss target: below 3 per cent. Standalone axial-flow threshers: 500 to 1,500 kg/h, diesel or PTO-driven; grain augers for transfer; driers for moisture reduction to below 13 per cent. Nigerian constraints: small farm size, mixed cropping, poor roads, high capital cost; solution: mechanisation service centres and contractor hire.



2. Value-added response: The most impactful combine adjustment in Nigerian conditions is the threshing cylinder speed and concave clearance. Under-threshing (cylinder too slow or clearance too wide) leaves grain on straw, increasing straw walker losses. Over-threshing (cylinder too fast or clearance too narrow) causes grain breakage and high cleaning losses. Operators who can diagnose loss type and make the correct adjustment are far more valuable to a mechanisation programme than those who can only operate in ideal conditions.
3. Basic response: Grain milling — hammer mill (rotating hammers, screen controls fineness, versatile); plate mill (two grooved discs, fine flour); rice husker plus whitener; maize sheller; dry grain below 13 per cent required. Palm oil — mechanical digester (maceration) plus screw press (80 to 90 per cent efficiency) plus clarification (heating to 90 to 95°C, three-layer separation, decanting, drying). Groundnut oil — roasting (120 to 140°C), expeller press (80 to 85 per cent). Cassava — mechanical grater (studded drum, 500 to 2,000 kg/h), hydraulic press (removes water and HCN), garification drum (50 to 500 kg dry garri/h).
4. Value-added response: The economic case for mechanising cassava processing is among the strongest in Nigerian agri-processing because grating, pressing, and garification replace the three most physically demanding, time-consuming, and scalability-limiting steps in traditional garri production. A motorised grater replaces 20 to 40 person-days of hand grating per tonne; a hydraulic press eliminates prolonged manual squeezing; and a garification drum allows one operator to produce output requiring multiple people at an open fire. Together these three machines transform garri from a subsistence activity into a scalable agribusiness enterprise.
5. Basic response: Irrigation types — surface (50 to 60 per cent efficiency, gravity, furrows and basins); sprinkler (70 to 80 per cent, rotating heads); drip (85 to 95 per cent, emitters at root zone, fertigation). Pumps — centrifugal (impeller, high flow, most common); submersible (sealed, in borehole, no priming needed); solar PV-driven (DC motor, smallholder dry-season vegetables). Conveyance — open channels (surface, high seepage); gated pipe (furrow distribution); PVC mains and laterals (pressurised systems); filters (mandatory before drip emitters). Scheduling — $ET_c = ET_o \times K_c$; irrigate at MAD (40 to 50 per cent depletion); tensiometers for trigger; WUE maximised by timing, quantity, and system maintenance.
6. Value-added response: The economic gap between surface and drip irrigation is largest for high-value dry-season vegetable production: water is scarce, vegetables are highly water-sensitive, and quality premiums are significant. A drip system using 40 per cent less water than furrow irrigation to produce the same tomato yield generates savings on pumping fuel and may allow additional cropping cycles from water saved. Teaching students to calculate



simple payback period for a drip system upgrade (capital cost divided by annual fuel and labour savings) transforms irrigation selection from a technology preference into a financial decision grounded in real numbers.

Answers to Pilot Questions [Series 4]

Part 4.1: Grain Harvesting Equipment

1. Three operations: cutting the standing crop in the field (the standalone thresher processes already-cut crop); cleaning the threshed grain by removing chaff and weed seeds with air blast and sieves; collecting and storing clean grain in an on-machine tank for bulk transfer rather than into bags at a fixed point.
2. Header: gathers and cuts standing crop using reel, cutterbar, and cross auger. Feeder house: chain-and-slat elevator carries cut material to the threshing cylinder. Threshing cylinder and concave: rotating cylinder beats grain free from straw through concave grate openings. Straw walkers: oscillating sieves carry straw rearward while remaining grain falls through for recovery. Cleaning shoe: upper and lower sieves with fan air blast separate clean grain from chaff and direct it to the grain tank.
3. Grain loss is the proportion of the total standing crop yield not recovered during harvesting, comprising header losses (shatter before cutting), threshing losses (grain left on straw), separation losses (grain exiting with straw), and cleaning losses (grain discharged with chaff); the acceptable target is below 3 per cent of standing crop yield.
4. Crop is fed into the drum opening parallel to its rotation axis; the rotating drum carries crop in a spiral path around the inside of the cylindrical concave; rasp bars or spike teeth beat the crop and dislodge grain through concave perforations as it spirals; separated grain falls through to the collection tray while threshed straw exits at the rear.
5. Grain moisture above 13 per cent supports *Aspergillus* mould growth producing aflatoxins, toxic compounds that contaminate grain and can kill livestock; high moisture also accelerates insect reproduction and grain respiration, both of which consume stored grain; drying to below 13 per cent removes the conditions necessary for mould, insect, and respiratory activity.

Part 4.2: Root Crop and Vegetable Harvesting Equipment



1. Cassava roots are buried 15 to 30 cm deep across a large area and must be extracted individually without breaking because broken roots deteriorate within 24 to 72 hours; a tractor-mounted harvester runs a subsoil lifting bar beneath the root zone at tractor travel speed, loosening all root stocks in a row simultaneously so farmworkers following can pull roots with much less effort and in much less time than hand digging.
2. Stage 1 — digging: tractor-mounted digger runs a blade below the pod zone to sever the taproot, and an elevator web lifts plants to the surface for windrow deposition; plants wilt for two to three days. Stage 2 — threshing: dry plants are fed into a petrol-engine or PTO-driven groundnut thresher that separates pods from stems by impact and agitation, or hand-beaten against a metal grate for smaller quantities.
3. Soybean plants are relatively uniform in height; pods are at consistent heights above the ground allowing a set header height; the crop lodges less than other legumes so it remains accessible to the cutterbar; and the seed coat is more resistant to combine threshing damage than fragile seeds of crops like cowpea.
4. Any four: harvesting knife (tomato, cucumber — cutting fruit stem); secateurs or pruning shears (pepper, aubergine, okra — cutting mature fruits); bean hook (cowpea — hooking and separating pods); harvesting basket (all crops — collecting and transporting from field); field crate or vented container (tomatoes, peppers — carrying to packing area without bruising).
5. Vegetables continue to respire after harvest, generating heat; accumulated field heat raises temperature, increasing respiration rate, ethylene production, and microbial decay; moving to shade or cool water immediately after harvest removes this heat, lowering respiration rate and slowing all deterioration, extending shelf life from hours without precooling to days or weeks with proper cold chain maintenance.

Part 4.3: Agricultural Processing Equipment

1. Hammer mill: rotating free-swinging hammers shatter grain by high-speed impact against a perforated screen; screen hole diameter controls product fineness; versatile, produces meal or flour. Plate mill: two grooved discs (one fixed, one rotating) grind grain by attrition as it passes between them; disc gap controls fineness; produces finer, more uniform flour; less effective with very hard or wet grains.
2. The screw press feeds macerated palm fruit pulp or oilseed into a cylindrical cage housing a rotating screw (helix); as the material is conveyed forward the taper of the screw increases compression pressure; this squeezes oil out through cage perforations into a collection tray



- while the de-oiled press cake exits at the far end; the screw applies continuous mechanical pressure achieving 80 to 90 per cent oil extraction efficiency.
3. Crude palm oil after pressing contains approximately 30 to 50 per cent water and sludge; the mixture is heated to 90 to 95°C in a clarification tank, reducing viscosity and promoting phase separation; the heated mixture separates into three layers: oil (lightest, top), muddy water (middle), and settled sludge (bottom); the clean oil layer is decanted and further heated to evaporate residual water, producing dry, clear crude palm oil.
 4. The mechanical cassava grater has a motor-driven drum covered with a rasping surface (metal studs or punched spikes); peeled cassava roots fed against the rotating drum surface are torn into fine wet particles that fall into a collection trough; the motorised grater processes 500 to 2,000 kg of peeled cassava per hour compared with less than 20 to 30 kg per hour by hand grating, eliminating one of the most exhausting bottlenecks in garri production.
 5. The cassava hydraulic press applies continuous mechanical pressure to bags or frames containing wet grated cassava mash, squeezing out the liquid fraction; the expelled liquid contains water (reducing mash moisture from about 70 per cent to 40 to 45 per cent) and dissolved hydrogen cyanide from bitter varieties; removing this liquid is a critical food safety step, reducing HCN to levels further lowered to safe limits during fermentation and frying.

Part 4.4: Irrigation Equipment

1. Surface irrigation: 50 to 60 per cent efficiency (gravity, furrows or basins). Sprinkler irrigation: 70 to 80 per cent efficiency (pressurised, rotating or fixed heads). Drip irrigation: 85 to 95 per cent efficiency (emitters at root zone).
2. Drip is most cost-effective for high-value vegetables because: the 30 to 50 per cent water saving over surface irrigation significantly reduces pumping fuel costs (the dominant operating expense in dry-season irrigation); precise root zone delivery enables fertigation, reducing fertiliser loss; drier surface between rows reduces weed growth and fungal disease; and higher yield and quality from stress-free water supply justify the higher capital cost per hectare.
3. A centrifugal pump uses a rotating impeller on a shaft; when the impeller spins, water is flung outward by centrifugal force, creating a low pressure zone at the centre (eye) that draws more water in from the suction pipe; water flung to the outer edge gains kinetic energy converted to pressure in the spiral casing (volute); pressurised water exits through the discharge pipe to the distribution system.



4. Drip emitters have very small outlet orifices (0.5 to 1.5 mm diameter) operating at low pressure; even small particles of sand, algae, minerals, or organic matter can block these orifices, stopping water delivery to individual plants; blocked emitters starve plants while adjacent plants receive normal water, creating visible dry spots; filters (screen, disc, and sand filters rated to 120 to 200 mesh) remove blocking particles before water enters the drip laterals.
5. ET_c is the volume of water used by a crop through evapotranspiration per unit time (mm/day); it is calculated as $ET_c = ET_o \times K_c$, where ET_o is reference evapotranspiration estimated from weather parameters and K_c is the crop coefficient for the specific crop and growth stage; irrigation scheduling uses ET_c to calculate daily soil water depletion; when accumulated depletion reaches MAD (40 to 50 per cent of plant available water capacity), an irrigation event is triggered to refill soil to field capacity.



References and Attributions [Series 4]

Textual References (Books and External Sources)

- Srivastava, A. K., Goering, C. E., Rohrbach, R. P., & Buckmaster, D. R. (2006). Engineering principles of agricultural machines (2nd ed.). ASABE.
- Doorenbos, J., & Pruitt, W. O. (1977). Crop water requirements. FAO Irrigation and Drainage Paper No. 24. FAO.
- FAO (Food and Agriculture Organization of the United Nations). (2004). Small-scale palm oil processing in Africa. FAO Agricultural Services Bulletin No. 148. FAO.
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- Nakayama, F. S., & Bucks, D. A. (1986). Trickle irrigation for crop production. Elsevier.
- FAO (Food and Agriculture Organization of the United Nations). (2025). Guidelines for sustainable agriculture. FAO.

Figures, Plates, Tables, and Boxes

- Plate 4.1: Combine harvester harvesting maize in Nigeria Attribution: AI generated using prompt "Generate an image of a self-propelled combine harvester harvesting maize in a large flat field in the Nigerian Guinea savanna zone." Suggested OER search string: "combine harvester maize harvest Nigeria savanna zone commercial farm OER image".
- Figure 4.1: Combine harvester crop flow diagram Attribution: AI generated using prompt "Generate a cross-section diagram of a combine harvester showing crop flow from header through feeder house, threshing cylinder, straw walkers, cleaning shoe, and grain tank." Suggested OER search string: "combine harvester cross-section diagram crop flow threshing cleaning grain tank OER".
- Plate 4.2: Axial-flow rice thresher in operation Attribution: AI generated using prompt "Generate an image of a diesel-powered axial-flow rice thresher with operators feeding rice sheaves and collecting bagged grain." Suggested OER search string: "axial-flow rice thresher diesel powered operators feeding grain OER image".
- Plate 4.3: Tractor-mounted cassava harvester Attribution: AI generated using prompt "Generate an image of a tractor-mounted cassava harvesting implement with a subsoil lifting bar loosening



cassava roots as farmworkers collect the uprooted tubers." Suggested OER search string: "tractor-mounted cassava harvester subsoil lifting bar Nigeria farm OER image".

- Figure 4.2: Groundnut and soybean harvesting comparison Attribution: AI generated using prompt "Generate a two-panel diagram showing the groundnut harvesting system with digger and thresher and the soybean system with combine harvester and flex header." Suggested OER search string: "groundnut digger thresher soybean combine flex header harvesting OER diagram".
- Box 4.1: Fresh vegetable post-harvest handling steps Attribution: AI generated using prompt "Generate a text box listing post-harvest handling steps for fresh vegetables from harvest through precooling, grading, packing, cold storage, and transport." Suggested OER search string: "fresh vegetable post-harvest handling steps precooling grading packing OER box".
- Figure 4.3: Hammer mill and plate mill diagrams Attribution: AI generated using prompt "Generate a two-panel diagram showing the internal components of a hammer mill and a plate mill with their product types." Suggested OER search string: "hammer mill plate mill grain milling internal components diagram OER".
- Figure 4.4: Palm oil processing flowchart Attribution: AI generated using prompt "Generate a flowchart showing small-scale palm oil processing steps from fresh fruit bunches through sterilisation, digestion, screw pressing, clarification, and storage." Suggested OER search string: "palm oil processing flowchart digestion screw press clarification OER".
- Figure 4.5: Mechanised cassava processing flowchart Attribution: AI generated using prompt "Generate a flowchart showing mechanised cassava processing from peeled roots through grater, press, fermentation, sieve, and garri frying drum." Suggested OER search string: "mechanised cassava processing flowchart grater press fermentation garri frying OER".
- Figure 4.6: Irrigation systems comparison Attribution: AI generated using prompt "Generate a three-panel diagram comparing surface furrow irrigation, sprinkler irrigation, and drip irrigation showing application patterns and efficiency." Suggested OER search string: "irrigation systems comparison surface sprinkler drip efficiency OER diagram".
- Figure 4.7: Drip irrigation system schematic Attribution: AI generated using prompt "Generate a schematic diagram of a drip irrigation system showing pump, filter station, pressure regulator, mainline, submain, lateral pipes, and drip emitters at plant roots." Suggested OER search string: "drip irrigation system components pump filter mainline lateral emitters OER diagram".
- Figure 4.8: Soil water balance for irrigation scheduling Attribution: AI generated using prompt "Generate a diagram of the soil water balance showing field capacity, management allowable depletion trigger, and permanent wilting point with crop water use and irrigation refilling."



Suggested OER search string: "soil water balance irrigation scheduling field capacity MAD wilting point OER".



Course code: AGE 124

Course title: Farm Technology

Course credit load: 2 Units

Series 5: Maintenance and Economics of Agricultural Mechanisation

- **Part 5.1: Principles and Types of Farm Equipment Maintenance**

- Sub Part 5.1.1: Importance and objectives of farm equipment maintenance
- Sub Part 5.1.2: Types of maintenance: preventive, corrective, and predictive
- Sub Part 5.1.3: Maintenance planning and record keeping

- **Part 5.2: Maintenance Procedures for Key Farm Machines**

- Sub Part 5.2.1: Tractor maintenance schedules and procedures
- Sub Part 5.2.2: Maintenance of tillage implements and sprayers
- Sub Part 5.2.3: Storage and end-of-season care of farm equipment

- **Part 5.3: Farm Equipment Costing and Economic Analysis**

- Sub Part 5.3.1: Costs of owning and operating farm machinery
- Sub Part 5.3.2: Machine capacity, field efficiency, and work rate
- Sub Part 5.3.3: Economic analysis of mechanisation decisions

- **Part 5.4: Economics of Agricultural Mechanisation in Nigeria**

- Sub Part 5.4.1: Mechanisation policy and investment framework in Nigeria
- Sub Part 5.4.2: Mechanisation service centres and equipment hire
- Sub Part 5.4.3: Sustainability and future directions of farm mechanisation



Introduction

A farm machine that breaks down at the critical moment of land preparation or harvesting can cost the farmer an entire season of income. Maintenance is not a cost that can be deferred: it is an investment in the reliability of the production system. At the same time, mechanisation decisions are economic decisions — the cost of owning and operating machinery must be justified by the value it adds to farm output. Understanding both the technical and economic dimensions of farm mechanisation is essential for any agriculture professional advising on or managing mechanised farming systems.

The aim of this Series is to equip you with the principles and practices of farm equipment maintenance, the procedures for maintaining tractors, tillage implements, and sprayers, and the economic tools for costing machinery and evaluating mechanisation investments in the Nigerian context.

We shall commence this Series by examining the principles and types of farm equipment maintenance. Next, we will study maintenance procedures for tractors, implements, and sprayers. Following that, we will cover farm equipment costing and economic analysis. Finally, we will wrap up with the economics of agricultural mechanisation in Nigeria, including policy, service centres, and future directions.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 5.1** explain the importance and objectives of farm equipment maintenance and describe the types of maintenance (Linked to Part 5.1),
- **SLO 5.2** develop a maintenance plan and explain the role of maintenance records (Linked to Part 5.1),
- **SLO 5.3** describe the maintenance schedules and procedures for agricultural tractors (Linked to Part 5.2),



- **SLO 5.4** describe the maintenance procedures for tillage implements and sprayers (Linked to Part 5.2),
- **SLO 5.5** explain end-of-season storage procedures for farm equipment (Linked to Part 5.2),
- **SLO 5.6** calculate the fixed and variable costs of owning and operating farm machinery (Linked to Part 5.3),
- **SLO 5.7** explain machine capacity, field efficiency, and work rate, and use them in economic analysis (Linked to Part 5.3),
- **SLO 5.8** describe the mechanisation policy framework in Nigeria and explain the role of mechanisation service centres (Linked to Part 5.4), and
- **SLO 5.9** discuss the sustainability and future directions of agricultural mechanisation in Nigeria (Linked to Part 5.4).

5.1 Principles and Types of Farm Equipment Maintenance

5.1.1 Importance and objectives of farm equipment maintenance

Farm equipment maintenance is the set of planned and unplanned activities performed to keep agricultural machinery in safe, reliable, and efficient working condition throughout its service life. The importance of maintenance is threefold: it preserves machine reliability (preventing breakdowns at critical operational periods), extends machine service life (reducing the rate of wear and corrosion that would otherwise shorten the useful life of expensive equipment), and protects operator safety (ensuring that brakes, guards, hitching devices, and safety systems remain in working order).

The economic importance of maintenance is underscored by the high cost of replacing farm equipment in Nigeria. A breakdown during land preparation or harvesting, when timeliness is critical, can result in crop losses that far exceed the cost of the maintenance that could have prevented the breakdown. Research in sub-Saharan Africa consistently shows that poor maintenance is one of the leading causes of premature equipment abandonment, with tractors in government mechanisation programmes often retiring after only 3 to 5 years of service rather than the 10 to 15 years achievable with proper maintenance. Developing a maintenance culture



in which regular service is treated as an investment rather than a cost is one of the most important behavioural changes the agricultural engineering profession can promote.

Fill in the blank: The three core objectives of farm equipment maintenance are preserving machine _____, extending service life, and protecting operator safety.

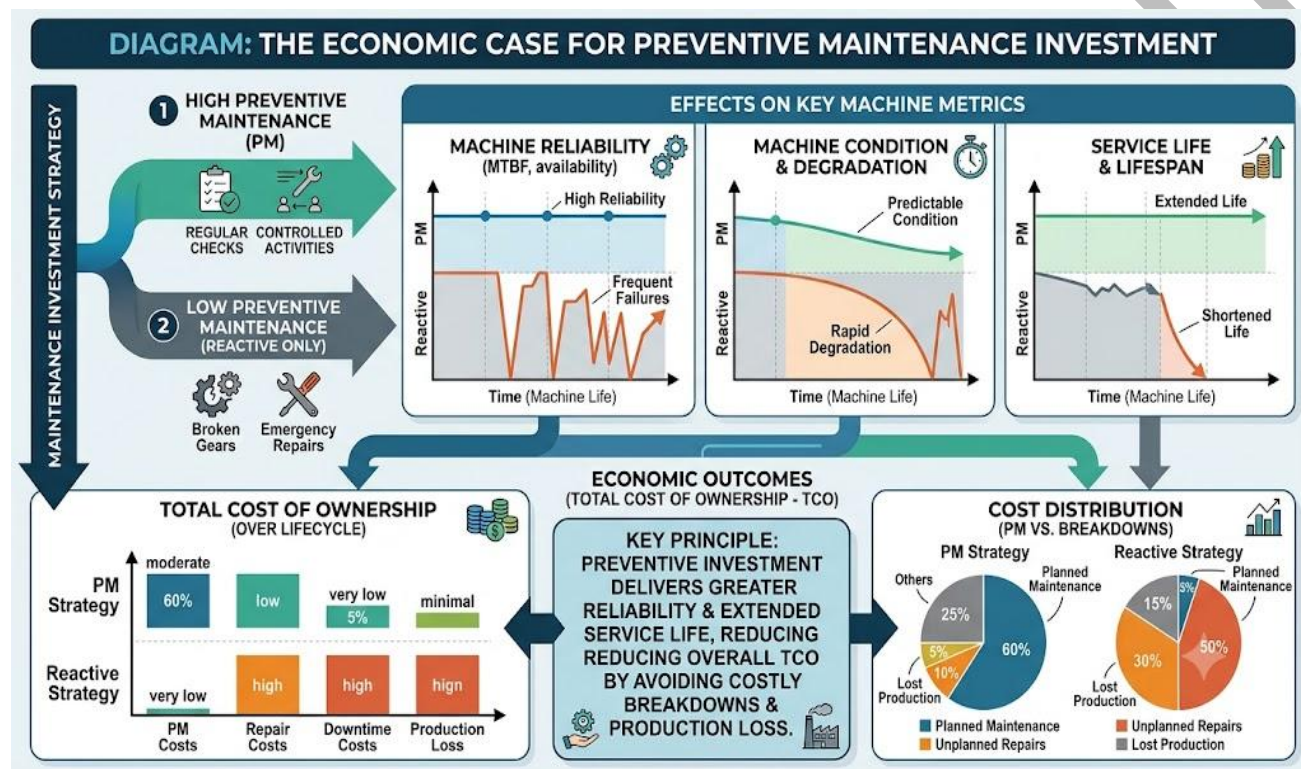


Figure 5.1: Diagram showing the relationship between maintenance investment and machine reliability, service life, and total cost of ownership

5.1.2 Types of maintenance: preventive, corrective, and predictive

Preventive maintenance (PM) is scheduled maintenance performed at regular intervals (by time or operating hours) regardless of apparent machine condition, with the objective of preventing failures before they occur. It includes daily checks (fluid levels, tyre pressure, visual inspection), periodic services (engine oil and filter change every 250 hours, air filter service every 100 hours, gear oil change every 500 hours), and seasonal inspections. Preventive maintenance is the most cost-effective type because it keeps the machine in good condition at predictable, budgeted cost and prevents expensive emergency repairs.



Corrective maintenance is the repair of a machine after a failure has occurred; it is by definition unplanned and typically more expensive than the preventive maintenance that could have prevented it, because emergency repair parts are expensive, downtime occurs at the worst time, and secondary damage to other components often occurs before the failure is detected.

Predictive maintenance uses condition monitoring technologies (vibration analysis, oil analysis, thermal imaging, noise level monitoring) to detect early signs of component deterioration before failure occurs, allowing maintenance to be scheduled at the most convenient and least costly time. Predictive maintenance is used on expensive, high-utilisation machines where the cost of condition monitoring is justified by the cost of failure.

Fill in the blank: _____ maintenance is performed at regular intervals regardless of machine condition, with the objective of preventing failures before they occur.

Maintenance Type	Timing	Cost	Planning Requirement	Nigerian Applicability	Examples
Preventive maintenance	Scheduled at regular intervals before breakdown	Moderate; avoids costly repairs	Requires structured schedule and discipline	Highly applicable; reduces downtime in peak farming seasons	Oil changes, filter replacement, tyre checks
Corrective maintenance	After breakdown or failure occurs	High; includes repair and lost time	Minimal planning; reactive approach	Common in Nigeria due to limited funds and poor planning	Engine overhaul, replacing broken parts
Predictive maintenance	Based on monitoring equipment condition and performance	Initially high (technology cost), but reduces long-term expenses	Requires sensors, data analysis, and skilled operators	Emerging; limited adoption due to cost and skill gaps	Vibration analysis, oil analysis, sensor-based monitoring



Table 5.1: Comparison of preventive, corrective, and predictive maintenance types for farm equipment

5.1.3 Maintenance planning and record keeping

A maintenance plan is a structured schedule of all maintenance tasks required for each machine on the farm, with their frequencies (daily, weekly, every 100 hours, every 250 hours, annually) and the responsible person. It is derived from the manufacturer's operator's manual, which contains the authoritative maintenance schedule for each specific machine. The maintenance plan should also include a parts inventory list (the minimum stock of consumable parts — oil filters, air filters, fan belts, spark plugs, fuses — that must be kept on hand to avoid service interruptions when a scheduled maintenance event falls due).

Maintenance records are the historical log of all maintenance activities performed on each machine. A complete maintenance record shows the date, odometer reading or operating hours, work performed, parts replaced, quantities of lubricants and fluids used, name of the person performing the maintenance, and the cost. Maintenance records serve multiple functions: they provide evidence that the manufacturer's maintenance schedule has been followed (important for warranty claims), allow the farm manager to track maintenance costs per machine and per hectare, reveal patterns of repeated failure that indicate underlying problems requiring engineering attention, and provide the data needed to calculate machine depreciation and residual value at disposal. In Nigeria, the absence of maintenance records is a major constraint to effective farm equipment management in both private and public sector mechanisation programmes.

Fill in the blank: The manufacturer's _____ manual contains the authoritative maintenance schedule for each specific machine and is the primary source for developing a farm maintenance plan.



TRACTOR MAINTENANCE RECORD & SERVICE LOG								
TRACTOR MODEL: FORD 6600				OWNER/FARM: GREEN VALLEY FARMS				
SERIAL NO: F2130987				DATE PURCHASED: 15 OCT 2021				
DATE	HOUR METER	SERVICE TYPE INTERVAL (HR)	DESCRIPTION OF WORK / PARTS REPLACED	OIL QUANTITIES & TYPE	TECHNICIAN / SHOP	PARTS COST	LABOR COST	TOTAL COST
18 APR 2022	105 HR	1st FREE SERVICE	Changed engine oil & filter, fuel filter. Greased all points. Check fan belt.	Engine Oil: 10L (15W-40)	R. MILLER / Dealer	125.50	FREE	125.50
12 SEPT 2022	402 HR	400 HR SERVICE	Changed engine oil & filter, fuel filters, air filter. Adjusted brakes.	Engine Oil: 10L (15W-40)	R. MILLER / Dealer	280.75	160.00	440.75
30 APR 2023	705 HR	700 HR SERVICE	Changed engine oil & filter, transmission/hyd oil & filters. Replaced fan belt. Replaced 1 front tire.	Engine Oil: 10L (15W-40), Trans/Hyd: 60L (UTTO)	A. DAVIS / Davis Agric.	850.10	240.00	1,090.10
15 OCT 2023	1003 HR	1000 HR SERVICE	Full service. Changed all oils & filters. Checked injectors & tappet clearance. Installed rear work light.	Engine Oil: 10L (15W-40), Trans/Hyd: 60L (UTTO), Final Drive: 2L (80W-90)	R. MILLER / Dealer	1,150.00	320.00	1,470.00
10 MAR 2024	1301 HR	1300 HR SERVICE	Routine service. Changed engine oil & filter. Tightened wheel bolts. Checked battery.	Engine Oil: 10L (15W-40)	S. CHEN / Chen Farms	140.20	80.00	220.20

Figure 5.2: Example of a completed machine maintenance record card showing service intervals, parts replaced, and oil quantities for a farm tractor

Pilot questions 5.1

1. State three objectives of farm equipment maintenance and explain why each is important.
2. Define preventive maintenance and explain why it is the most cost-effective maintenance type.
3. Distinguish between corrective maintenance and predictive maintenance.
4. Describe the contents of a farm maintenance plan.
5. State four types of information that must be recorded in a machine maintenance record.

5.2 Maintenance Procedures for Key Farm Machines

5.2.1 Tractor maintenance schedules and procedures

Tractor maintenance follows a structured schedule based on operating hours. **Daily (every 8 to 10 hours):** check engine oil level with dipstick; check coolant level; check fuel level; inspect



tyre condition and pressure; check air filter restriction indicator; inspect for fluid leaks; check all lights and safety guards; grease all grease nipples on the three-point linkage, drawbar, and front axle. **Every 50 hours:** change engine oil and oil filter for the first service on a new tractor; inspect battery terminals; check hydraulic oil level; check all belts for tension and wear.

Every 250 hours: change engine oil and filter; service air filter (clean or replace the primary element, replace the safety element if the restriction indicator has tripped); check and clean fuel filters; check and adjust valve clearances if specified; check cooling system hoses and clamps; lubricate all bearings and pivot points. Every 500 hours: change engine oil and filter; replace fuel filters; change hydraulic oil and filter; change transmission and differential gear oils; check and adjust brakes; inspect the clutch for wear. Every 1,000 hours (annual service): drain, flush, and refill the cooling system with fresh coolant; check the injection pump timing; inspect the electrical system; check tyres for sidewall cracking and replace if necessary.

Fill in the blank: Tractor engine oil and filter should be changed every _____ operating hours as part of the routine preventive maintenance schedule.

Service Interval	Tasks	Consumable Parts
<u>Daily</u>	Check engine oil, coolant, fuel, tyre pressure, lights, battery, linkage, hydraulic oil	Top-up fluids (engine oil, coolant, fuel), grease fittings
<u>50-hour</u>	Grease all fittings, check air filter, inspect belts and hoses, tighten bolts	Grease, air filter cleaning/replacement
<u>250-hour</u>	Change engine oil and filter, clean fuel filter, check brake adjustment, inspect hydraulic system	Engine oil, oil filter, fuel filter
<u>500-hour</u>	Replace hydraulic oil and filter, check transmission fluid, inspect clutch, adjust valve clearance	Hydraulic oil, hydraulic filter, transmission fluid
<u>1,000-hour</u>	Major service: replace fuel injectors, check alternator, overhaul cooling system, inspect PTO shaft	Fuel injectors, coolant, belts, PTO parts



Table 5.2: Tractor preventive maintenance schedule showing tasks at daily, 50-hour, 250-hour, 500-hour, and 1,000-hour intervals

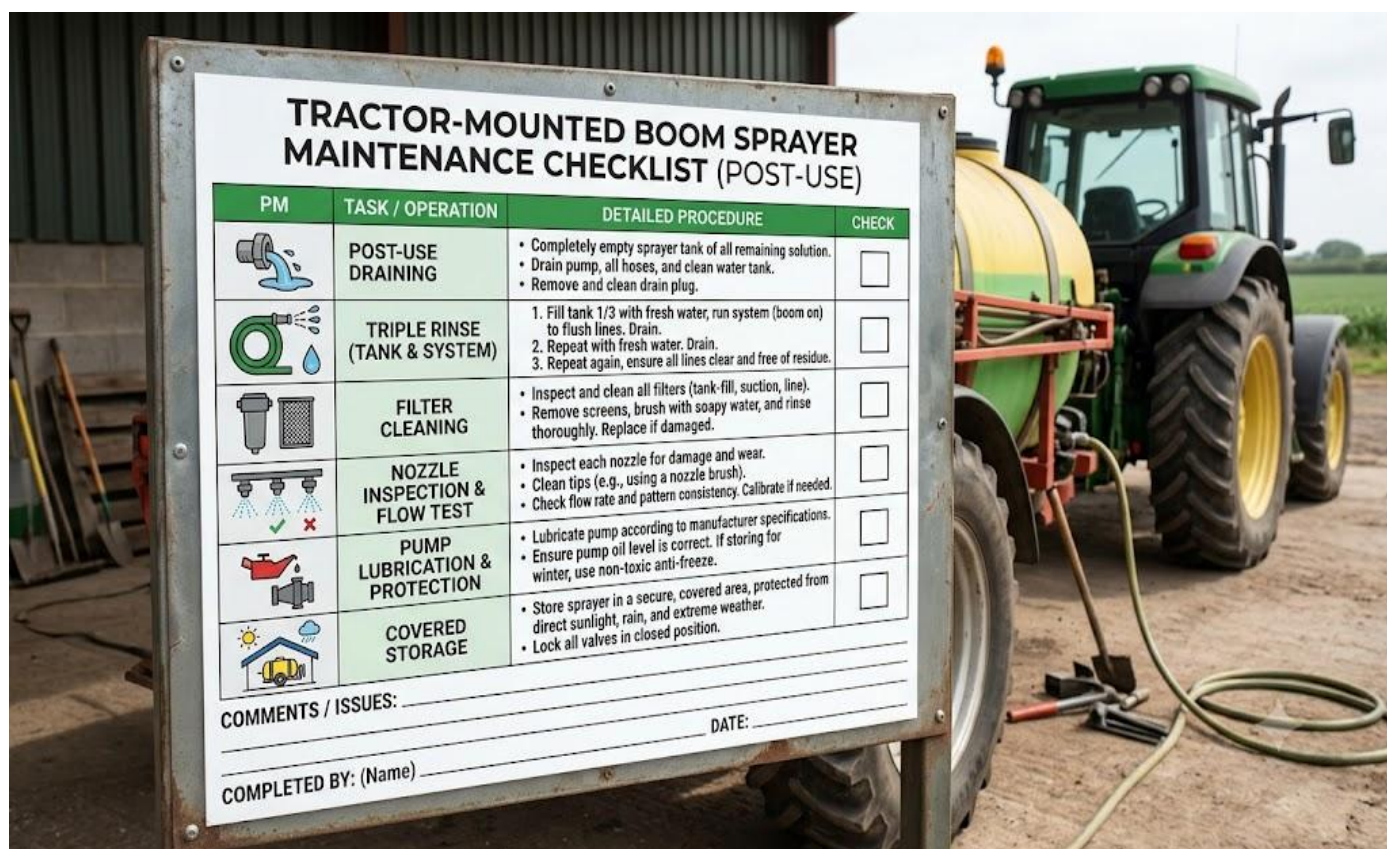
5.2.2 Maintenance of tillage implements and sprayers

Tillage implement maintenance focuses on controlling wear and corrosion on the cutting surfaces that contact soil. Mouldboard plough shares and disc plough discs wear down with use; when the cutting edge becomes rounded and thick (more than 3 to 4 mm thick), the draught force required increases significantly and penetration quality falls; worn shares and discs must be resharpened or replaced. Coulters must be kept sharp and free-running on their bearings. After each field use, all soil must be removed from metal surfaces and a light coat of waste oil applied to prevent rust during idle periods.

Sprayer maintenance is critical for accurate pesticide application and operator safety. After each use: drain the tank completely; rinse the tank, boom, and nozzles three times with clean water, spraying the rinsate onto a treated field; check and clean all in-line and nozzle body filters; inspect all hoses and boom joints for leaks and chafing; check pressure gauge accuracy; inspect all nozzles for wear (replace any nozzle delivering more than 10 per cent above its rated output); lubricate the pump diaphragm or piston; store in a protected area away from direct sunlight, which degrades rubber seals and plastic components. Annual maintenance should include a full pressure test of all seals, diaphragms, and hose connections.

Fill in the blank: Mouldboard plough shares must be resharpened or replaced when the cutting edge becomes more than _____ to 4 mm thick, because blunt shares require excessive draught force and give poor furrow quality.





Box 5.1: Post-use maintenance checklist for a tractor-mounted boom sprayer

5.2.3 Storage and end-of-season care of farm equipment

End-of-season storage preparation is one of the most important maintenance operations for farm equipment in Nigeria's seasonal climate, where machines are often idle for three to five months during the dry season. Tractors prepared for storage should have: the engine oil changed (old oil contains combustion acids that attack bearing surfaces during long storage); the cooling system flushed and filled with fresh coolant and corrosion inhibitor; the fuel tank filled to the top (to prevent condensation inside the tank) or completely drained; the battery removed and stored in a cool, dry place or connected to a maintenance charger; and all exposed metal surfaces lightly coated with grease or oil.

Tillage implements stored for the season should be cleaned thoroughly of all soil and plant material, metal cutting surfaces oiled or greased, any cracked or broken components repaired before storage rather than left for the following season, and the implement stored off the ground



on wooden blocks where possible to prevent moisture contact. Sprayers should be drained, triple-rinsed, and have all rubber seals and diaphragms lubricated with a suitable rubber preservative before storage. All implements and equipment should be stored under cover — in a shed or at minimum under a waterproof tarpaulin — to protect from sun, rain, and biological attack. Storing equipment in the open is the single most preventable cause of premature corrosion and deterioration in Nigerian farming conditions.

Fill in the blank: Tractor engine oil must be _____ at the start of end-of-season storage because old oil contains combustion acids that attack bearing surfaces during extended idle periods.

Pilot questions 5.2

1. List the daily tractor maintenance tasks that must be performed before each operating session.
2. State at what operating hour interval tractor engine oil and filter should be changed and explain why this interval is important.
3. Explain how to determine when a mouldboard plough share needs resharpener or replacement.
4. Describe the post-use maintenance procedure for a tractor-mounted boom sprayer.
5. Explain why end-of-season oil change is more important than mid-season oil change for preserving tractor engine life.

5.3 Farm Equipment Costing and Economic Analysis

5.3.1 Costs of owning and operating farm machinery

The total annual cost of farm machinery is divided into **fixed costs** (costs incurred whether the machine is used or not) and **variable costs** (costs that depend on the amount the machine is used). Fixed costs include: **depreciation** (the annual loss in machine value due to age and use, typically calculated as straight-line depreciation = (Purchase price - Salvage value) / Useful life in years), **interest** (the opportunity cost of capital tied up in the machine or the cost of borrowed



funds, typically 10 to 20 per cent of the average machine value per year), and **insurance and housing** (premiums and storage facility cost, typically 1 to 2 per cent of machine value per year).

Variable costs (operating costs) include: fuel (the largest operating cost for tractors and self-propelled machines, calculated as specific fuel consumption in litres per kWh multiplied by engine power and annual use hours), lubricants (approximately 10 to 15 per cent of fuel cost), repairs and maintenance (typically 5 to 10 per cent of purchase price per year for a well-maintained machine, rising to 15 to 20 per cent for poorly maintained equipment), and labour (operator wages and benefits). The total cost per hectare (or per tonne of product processed) is calculated by dividing total annual cost by annual use in hectares, and is the key economic indicator for comparing machinery options and justifying mechanisation investments.

Fill in the blank: Straight-line _____ is calculated as the purchase price minus salvage value divided by the useful life in years, and is the largest single fixed cost item for most farm machines.

Cost Component	Basis of Calculation	Estimated Annual Cost (₹)	Notes / Examples
<u>Depreciation</u>	Tractor value ÷ useful life (e.g., 10 years)	1,200,000	Based on purchase price of ₹12 million
<u>Interest</u>	10% of average investment	600,000	Opportunity cost of capital
<u>Insurance</u>	2–3% of tractor value	300,000	Covers theft, fire, accident
<u>Fuel</u>	8 L/hr × 500 hrs × ₹800/L	3,200,000	Diesel consumption
<u>Lubricants</u>	15% of fuel cost	480,000	Engine oil, hydraulic oil, grease
<u>Repairs</u>	10% of depreciation	120,000	Routine repairs and parts
<u>Labour</u>	Operator wage ₹25,000/month	300,000	Tractor driver/operator
Total Annual Cost	Sum of all above	6,200,000	—
Cost per hectare	Total ÷ 200 ha serviced	₹31,000/ha	Assuming 200 ha annual coverage



Table 5.3: Example annual machinery cost calculation for a 55 kW four-wheel-drive tractor at 600 hours annual use

5.3.2 Machine capacity, field efficiency, and work rate

Theoretical field capacity (TFC) is the area a machine would cover per hour if it operated continuously at its rated speed and full working width, with no time lost to turning at field ends, refilling, or breakdowns. It is calculated as: $TFC \text{ (ha/h)} = \text{working width (m)} \times \text{travel speed (km/h)} / 10$. A tractor pulling a 2.4 m disc harrow at 8 km/h has a $TFC = 2.4 \times 8 / 10 = 1.92 \text{ ha/h}$. **Effective field capacity (EFC)** is the actual area covered per hour in the field, accounting for all time losses; it is always less than TFC.

Field efficiency (FE) is the ratio of effective to theoretical field capacity, expressed as a percentage: $FE = (EFC / TFC) \times 100$. Typical field efficiency values are 75 to 85 per cent for disc harrows, 65 to 80 per cent for seed drills, and 60 to 75 per cent for combine harvesters (the lowest because of frequent unloading stops and greater variation in crop conditions). Field efficiency is reduced by time lost to: turning at headlands, overlapping between passes, filling seed hoppers or fertiliser bins, unloading grain tanks, adjusting implements, and operator rest breaks. Improving field efficiency through better field organisation (longer fields reduce turning time) and better logistics (seed and fertiliser delivery to the field to reduce refill stoppages) directly reduces cost per hectare.

Fill in the blank: Field efficiency is calculated as the ratio of effective field capacity to _____ field capacity, expressed as a percentage, and reflects the time lost to turns, refilling, and other non-work activities.



DIAGRAM ILLUSTRATING FIELD CAPACITY & EFFICIENCY CONCEPTS

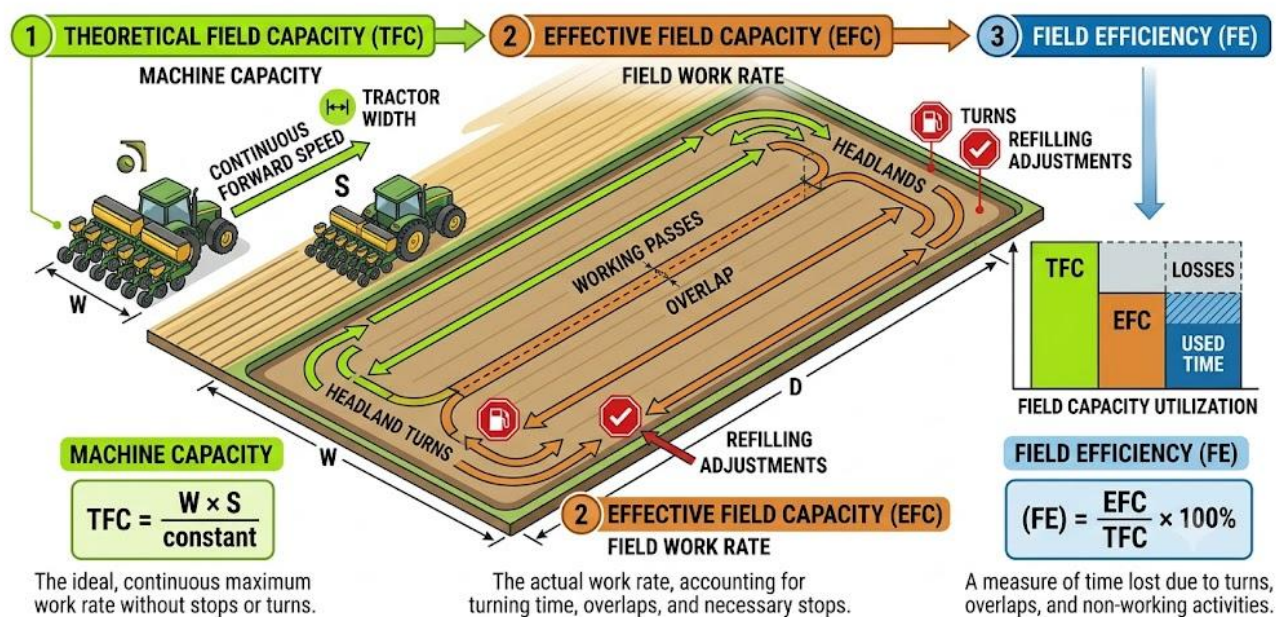


Figure 5.3: Diagram illustrating the concepts of theoretical field capacity, effective field capacity, and field efficiency with a worked example

5.3.3 Economic analysis of mechanisation decisions

The fundamental mechanisation decision is whether the income generated by using a machine exceeds its total annual cost. The **break-even analysis** determines the minimum annual use (in hectares or hours) at which the machine becomes economically viable: break-even area = Total fixed costs per year / (Income per hectare - Variable cost per hectare). Below the break-even area, the machine is not economically justified and hiring a contract service is preferable; above it, ownership is economically superior.

Complementary economic analysis tools include the benefit-cost ratio (BCR = total annual benefits / total annual costs; BCR above 1.0 indicates economic viability), the payback period (the number of years required for cumulative net benefits to repay the initial investment), and the net present value (NPV, which discounts future cash flows to present value to account for the time value of money). In the Nigerian context, sensitivity analysis is particularly important: because fuel prices, crop prices, and interest rates are highly volatile, the economic viability of a mechanisation investment must be tested across a range of these parameters, not just at a single



assumed value. Students who can perform these analyses provide genuinely valuable advisory services to farmers and agribusinesses.

Fill in the blank: Break-even analysis determines the minimum annual _____ area at which a machine becomes economically viable; below this area, hiring a contract service is preferable to ownership.

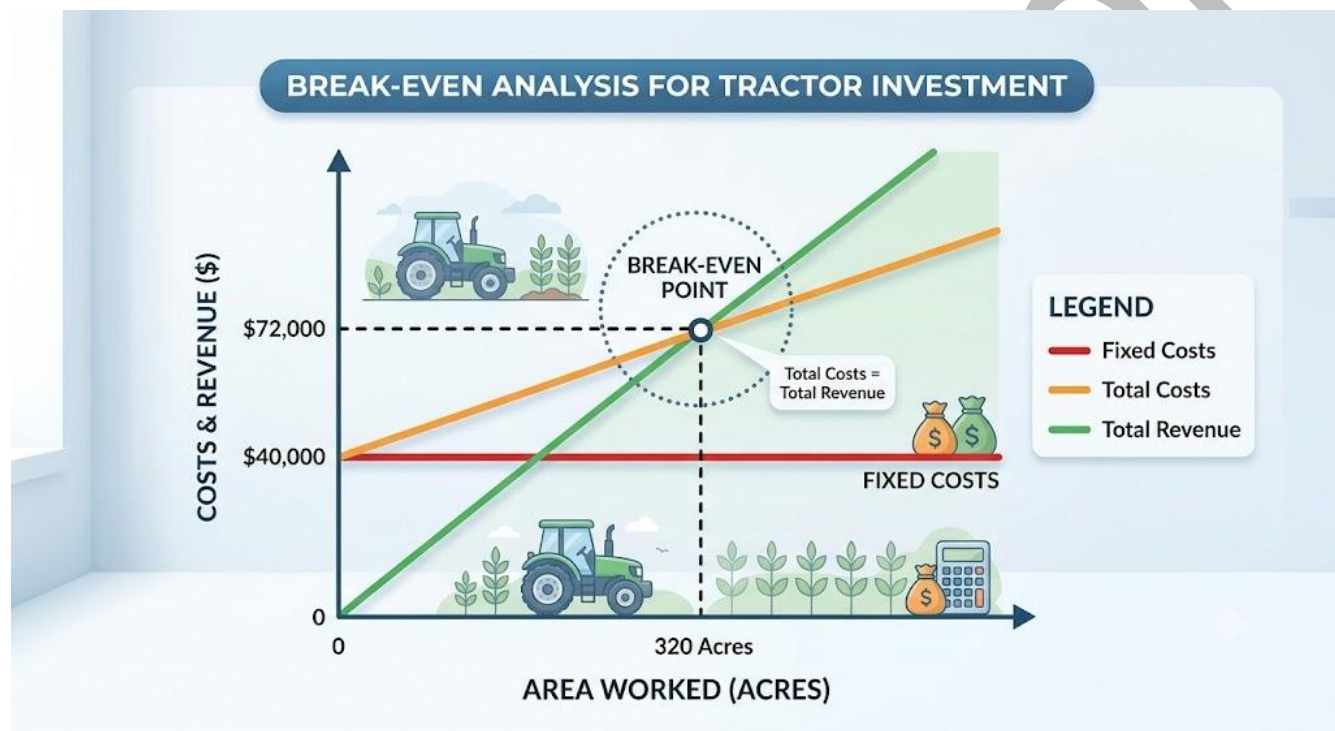


Figure 5.4: Break-even analysis graph for a tractor investment showing total cost and total revenue lines crossing at the break-even point

Pilot questions 5.3

11. Distinguish between fixed costs and variable costs of farm machinery and give two examples of each.
12. Explain how straight-line depreciation is calculated and give a numerical example.
13. Define theoretical field capacity and calculate the TFC for a 3.6 m wide disc harrow operating at 6 km/h.
14. Explain what field efficiency means and give two reasons why it is always less than 100 per cent.
15. Explain the break-even analysis method for evaluating a machinery investment decision.



5.4 Economics of Agricultural Mechanisation in Nigeria

5.4.1 Mechanisation policy and investment framework in Nigeria

Agricultural mechanisation policy in Nigeria has evolved through several phases. The first government tractorisation programmes began in the 1970s under the Operation Feed the Nation and Green Revolution initiatives, which supplied subsidised tractors to state governments. The establishment of the Agricultural Development Programmes (ADPs) from the late 1970s brought a more systematic approach to mechanisation extension. The National Agricultural Land Development Authority (NALDA) operated large-scale mechanised farms in the 1990s. The current framework under the Federal Ministry of Agriculture and Rural Development (FMARD) emphasises private sector-led mechanisation with government support through the Anchor Borrowers Programme (ABP) and the Agricultural Credit Guarantee Scheme Fund (ACGSF).

The key policy challenges for mechanisation investment in Nigeria include: the fragmented smallholder land ownership structure (which makes individual investment in large machinery uneconomic), the high cost and unreliability of diesel fuel supply (which raises operating costs unpredictably), limited access to long-term credit for machinery investment (most agricultural loans in Nigeria are short-term and too expensive for capital equipment), weak rural infrastructure (roads and electricity), limited supply of trained mechanics and spare parts in rural areas, and inconsistent government policy (frequent changes in subsidy programmes and import duty regimes create investor uncertainty). Addressing these structural constraints requires coordinated policy action across multiple government agencies and the private sector.

Fill in the blank: The _____ Borrowers Programme (ABP) is one of the current government frameworks supporting private sector-led agricultural mechanisation and input access in Nigeria.



TIMELINE OF KEY NIGERIAN AGRICULTURAL MECHANISATION POLICY MILESTONES

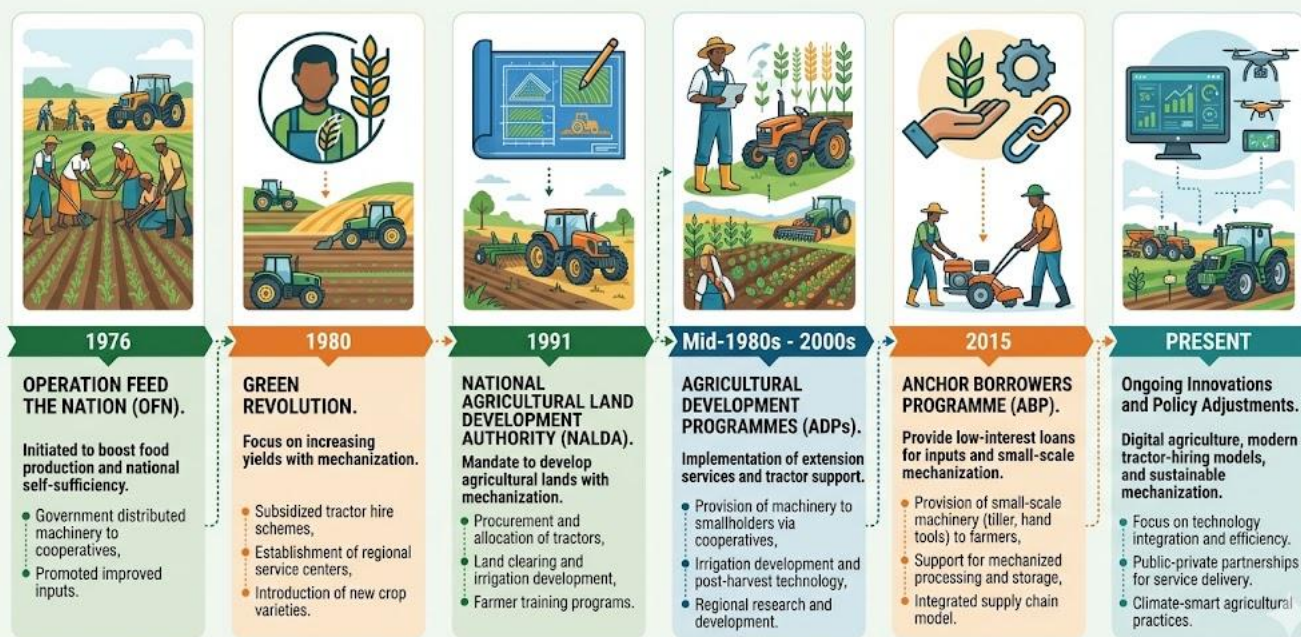


Figure 5.5: Timeline of Nigerian agricultural mechanisation policy milestones from the 1970s to the present

5.4.2 Mechanisation service centres and equipment hire

Mechanisation service centres (MSCs) are facilities that own, maintain, and hire out farm equipment to smallholder and medium-scale farmers who cannot afford to own machinery individually. By pooling equipment across many clients, MSCs spread the fixed cost of ownership over a larger area of use, reducing the cost per hectare below what individual ownership would cost. MSCs provide: tractor hire for land preparation (ploughing and harrowing), combine harvester hire for grain crops, thresher hire, irrigation pump hire, and in some cases processing machine hire for garri, palm oil, or grain milling.

Equipment hire pricing is set to cover the operating cost of the machine plus a contribution to fixed costs, at a rate competitive enough to attract farmers away from hand tools or animal traction. In Nigeria, both government-operated MSCs (operated by ADPs and state ministries of agriculture) and private MSCs (operated by agribusinesses and farmer cooperatives) exist. The digital equipment hire model pioneered by Hello Tractor (a GPS-enabled tractor hire platform



that connects tractor owners with smallholder farmers needing services) represents a significant innovation in mechanisation service delivery that uses mobile phones to match supply and demand in real time. Students entering the agricultural sector have strong entrepreneurial opportunities in establishing and managing MSCs at the local and regional level.

Fill in the blank: Mechanisation service centres spread the fixed cost of equipment ownership over a larger area of use, reducing the _____ per hectare below what individual ownership would cost for smallholder farmers.

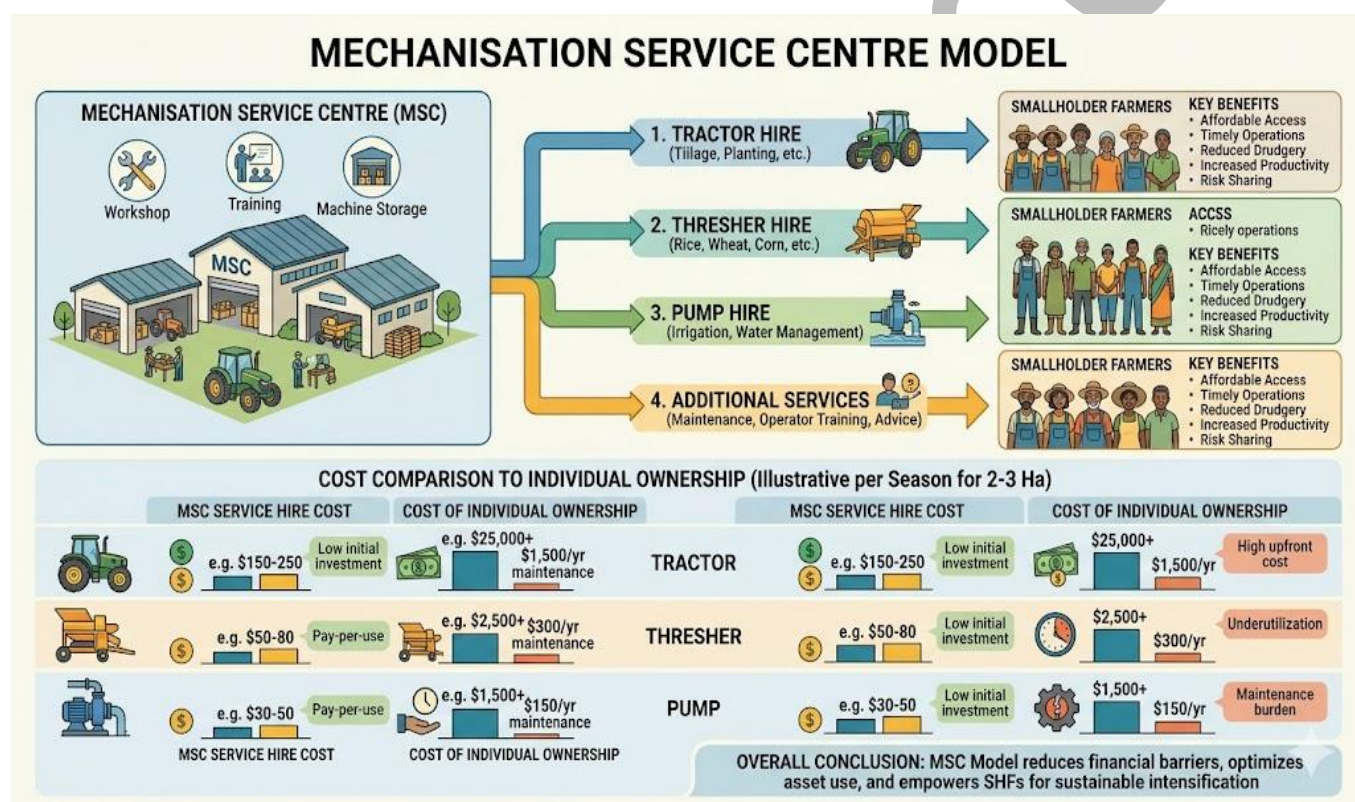


Figure 5.6: Diagram showing the equipment hire model of a mechanisation service centre and its benefits to smallholder farmers

5.4.3 Sustainability and future directions of farm mechanisation

Sustainable mechanisation seeks to achieve the productivity and labour-saving benefits of mechanisation while minimising the negative environmental and social effects identified in Series 1. Key principles of sustainable mechanisation in the Nigerian context include:

appropriate scale (matching machine size and power to the farming system rather than



defaulting to large-scale equipment), **conservation-compatible tillage** (adopting reduced or minimum tillage systems that maintain soil organic matter and reduce erosion), **renewable energy integration** (expanding the use of solar-powered irrigation and processing equipment), and **local manufacturing and repair capacity** (supporting the development of Nigerian fabricators who can build and maintain appropriate machinery locally).

The future directions of agricultural mechanisation in Nigeria are shaped by four converging trends. First, the rapid decline in solar PV and battery costs is making solar-powered irrigation, electric tractors, and autonomous field robots increasingly economically viable. Second, ICT and mobile connectivity are enabling precision agriculture and equipment hire platforms to reach previously inaccessible rural areas. Third, demographic pressure and urbanisation are reducing rural labour availability, creating a structural demand pull for labour-saving mechanisation across all farm sizes. Fourth, climate change is intensifying the need for irrigation and post-harvest infrastructure to buffer production against erratic rainfall. Together these trends create a compelling case for an accelerated and well-designed mechanisation investment in Nigeria over the coming decade.

Fill in the blank: Reducing rural _____ availability due to urbanisation creates a structural demand pull for labour-saving mechanisation across all farm sizes in Nigeria.



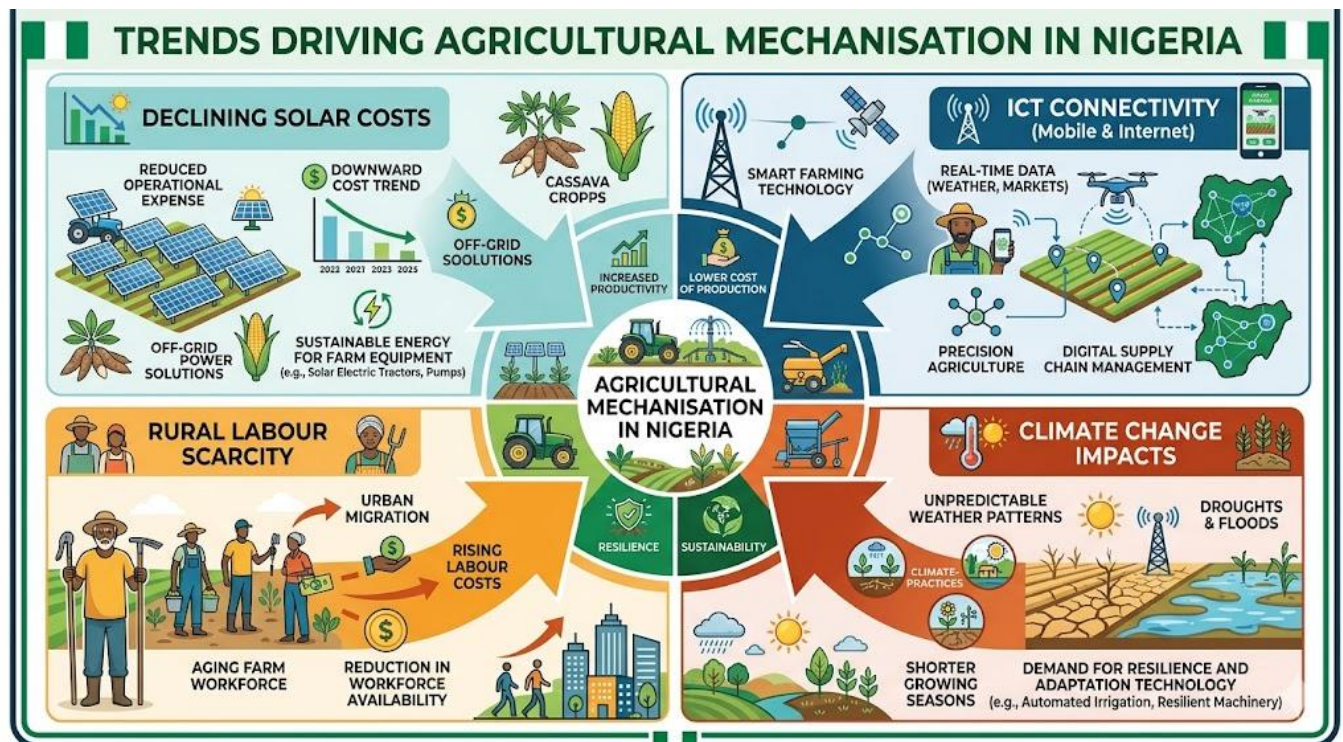


Figure 5.7: Diagram showing the four converging trends driving the future of agricultural mechanisation in Nigeria

Pilot questions 5.4

1. Name three key policy challenges constraining agricultural mechanisation investment in Nigeria.
2. Explain the economic principle behind mechanisation service centres and describe how they benefit smallholder farmers.
3. Describe the Hello Tractor model and explain why it represents a significant innovation in mechanisation service delivery.
4. Explain what is meant by appropriate-scale technology in the context of sustainable mechanisation.
5. State the four converging trends shaping the future direction of agricultural mechanisation in Nigeria.



Series Summary

This final Series has completed the course by covering the maintenance and economics of agricultural mechanisation. We began with the principles and types of maintenance, explaining the three objectives of maintenance (reliability, service life, operator safety), comparing preventive, corrective, and predictive maintenance types, and describing the structure and content of maintenance plans and maintenance records. We then covered the maintenance procedures for tractors (daily, 50-hour, 250-hour, 500-hour, and 1,000-hour service schedules), tillage implements (share sharpness, corrosion prevention), and sprayers (triple rinse, filter and nozzle inspection, seal lubrication), and described end-of-season storage procedures for both tractors and implements.

Following that, we developed the economic analysis framework for farm machinery, distinguishing fixed costs (depreciation, interest, insurance) from variable costs (fuel, lubricants, repairs, labour), explaining theoretical and effective field capacity and field efficiency, and describing break-even analysis, benefit-cost ratios, payback periods, and NPV as tools for evaluating mechanisation investments. Finally, we placed mechanisation economics in the Nigerian context, tracing the history of mechanisation policy, explaining the role of mechanisation service centres and the Hello Tractor digital hire model, and identifying the four trends — declining solar costs, ICT connectivity, rural labour scarcity, and climate change — that will drive the future of mechanisation in Nigeria. By completing this Series and the course as a whole, you should now be able to achieve all nine Series Learning Outcomes (SLO 5.1 to SLO 5.9) and all seven course learning outcomes.

Glossary of Terms

- **Anchor Borrowers Programme (ABP):** a Central Bank of Nigeria programme that provides loans to smallholder farmers for the purchase of inputs and equipment, intended to stimulate domestic agricultural production and reduce food imports.



- **Benefit-cost ratio (BCR):** the ratio of total annual benefits to total annual costs of a project or investment; a BCR above 1.0 indicates that the investment generates more value than it costs and is economically viable.
- **Break-even analysis:** an economic technique that determines the minimum level of output (area, hours, or tonnes) at which total revenue equals total cost, indicating the point at which an investment becomes economically justified.
- **Corrective maintenance:** unplanned repair or replacement of components that have already failed; typically more expensive and disruptive than the preventive maintenance that could have prevented the failure.
- **Depreciation:** the annual reduction in the value of a machine due to age, use, and obsolescence; a fixed cost that must be recovered over the useful life of the machine.
- **Effective field capacity (EFC):** the actual area covered per hour by a field machine, accounting for all time losses including turning, refilling, adjustments, and breakdowns; always less than theoretical field capacity.
- **Field efficiency (FE):** the ratio of effective field capacity to theoretical field capacity, expressed as a percentage; reflects the proportion of field time actually spent on productive work.
- **Fixed costs:** machinery costs that are incurred regardless of how much the machine is used, including depreciation, interest on capital, insurance, and housing.
- **Hello Tractor:** a Nigerian digital platform that uses GPS-enabled tractors and a mobile app to connect tractor owners with smallholder farmers requiring mechanisation services, acting as an equipment hire marketplace.
- **Mechanisation service centre (MSC):** a facility that owns, maintains, and hires out farm equipment to farmers, spreading the fixed cost of ownership across many users to reduce cost per hectare below the level achievable through individual ownership.
- **Net present value (NPV):** the sum of all discounted future cash flows from an investment minus the initial investment cost; a positive NPV indicates that the investment creates value in present-day terms.
- **Operator's manual:** the manufacturer's written guide for operating, adjusting, and maintaining a specific machine; the primary authoritative source for the maintenance schedule.



- **Payback period:** the time required for cumulative net benefits from an investment to recover the initial capital cost; a shorter payback period indicates lower investment risk.
- **Predictive maintenance:** maintenance that uses condition monitoring technologies (vibration analysis, oil analysis, thermal imaging) to detect early signs of component deterioration before failure, allowing maintenance to be scheduled at the most convenient time.
- **Preventive maintenance (PM):** scheduled maintenance performed at regular intervals (by time or operating hours) regardless of apparent machine condition, with the objective of preventing failures before they occur.
- **Salvage value:** the estimated residual value of a machine at the end of its useful life; used in depreciation calculations to determine the amount of value to be recovered over the machine's service life.
- **Sensitivity analysis:** an economic technique that tests how the outcome of an investment analysis (such as NPV or BCR) changes when key input assumptions (fuel price, crop price, interest rate) are varied, revealing which parameters most affect viability.
- **Straight-line depreciation:** the simplest depreciation method, which assumes that a machine loses value at a constant rate each year; calculated as (Purchase price minus Salvage value) divided by Useful life in years.
- **Theoretical field capacity (TFC):** the area a field machine would cover per hour if it operated continuously at its rated speed and full working width with no time losses; calculated as working width (m) multiplied by travel speed (km/h) divided by 10.
- **Variable costs:** machinery costs that depend on the extent of machine use, including fuel, lubricants, repairs, maintenance, and operator labour.



Concept Check Questions [Series 5]

Objective Questions

1. The three objectives of farm equipment maintenance are reliability, extended service life, and operator _____. (Linked to SLO 5.1)
2. _____ maintenance is performed at regular intervals regardless of machine condition to prevent failures before they occur. (Linked to SLO 5.1)
3. Straight-line depreciation is calculated as purchase price minus _____ value divided by useful life in years. (Linked to SLO 5.6)
4. Theoretical field capacity (ha/h) is calculated as working width (m) multiplied by travel speed (km/h) divided by _____. (Linked to SLO 5.7)
5. A benefit-cost ratio above _____ indicates that an investment generates more value than it costs. (Linked to SLO 5.7)

Short-Answer Questions

1. Compare preventive and corrective maintenance and explain why preventive maintenance is preferred. (Linked to SLO 5.1)
2. List the daily tractor maintenance tasks that must be completed before each operating session. (Linked to SLO 5.3)
3. Explain the difference between fixed costs and variable costs of farm machinery and give two examples of each. (Linked to SLO 5.6)
4. Define field efficiency and explain two factors that reduce it below 100 per cent. (Linked to SLO 5.7)
5. Describe the mechanisation service centre model and explain how it benefits smallholder farmers. (Linked to SLO 5.8)

Long-Answer Questions

1. Analyse the maintenance requirements of farm equipment, explaining the importance and objectives of maintenance, comparing the three types of maintenance, describing a maintenance plan and records system, and outlining the specific maintenance schedules for tractors, tillage implements, and sprayers. (Linked to SLOs 5.1, 5.2, 5.3, 5.4)



2. Discuss the economic analysis of farm machinery investment, explaining the fixed and variable cost components, the concepts of field efficiency and effective field capacity, and the use of break-even analysis, benefit-cost ratios, and net present value in evaluating mechanisation decisions. (Linked to SLOs 5.6, 5.7)
3. Evaluate the economics and future prospects of agricultural mechanisation in Nigeria, describing the policy framework and investment constraints, the role of mechanisation service centres and digital hire platforms, and the four trends driving the future direction of mechanisation in the country. (Linked to SLOs 5.8, 5.9)

Answers to Concept Check Questions [Series 5]

Objective Questions

1. Safety.
2. Preventive.
3. Salvage.
4. 10.
5. 1.0.

Short-Answer Questions

1. Preventive maintenance is performed on schedule regardless of machine condition, preventing failures before they occur at predictable, budgeted cost; it keeps machines reliable, extends service life, and avoids the higher cost of emergency repair. Corrective maintenance is unplanned repair after a failure, typically more expensive because parts are sourced urgently, downtime occurs at the worst moment, and secondary damage to other components often occurs; preventive maintenance is preferred because it converts uncertain emergency costs into predictable scheduled costs.
2. Daily tractor maintenance tasks: check engine oil level with dipstick (should be between MIN and MAX marks); check coolant level in radiator or expansion tank; check fuel level; inspect tyre condition and inflation pressure; check air filter restriction indicator; inspect for any fluid leaks under the tractor; check all lights and safety guards are functional; grease all grease nipples on three-point linkage, drawbar, and front axle.



3. Fixed costs are incurred regardless of how much the machine is used; examples: depreciation (annual value loss over useful life), interest on capital (opportunity cost or loan repayment). Variable costs depend on the extent of use; examples: fuel (consumed in proportion to hours worked and engine load), repair and maintenance labour (increases with hours of use).
4. Field efficiency is the ratio of effective field capacity (actual area covered per hour) to theoretical field capacity (maximum area if working continuously at full width and speed), expressed as a percentage; it is always below 100 per cent because time is lost to: turning at field headlands (significant in short fields), refilling seed hoppers, fertiliser bins, or spray tanks, overlapping between passes, implement adjustments, and operator rest breaks.
5. A mechanisation service centre owns farm equipment and hires it out to farmers by the hour or hectare; by operating across many clients, the centre spreads fixed ownership costs (depreciation, interest, insurance) over a large total area of use, reducing cost per hectare below what individual ownership would cost a smallholder; farmers benefit by accessing mechanisation without the capital burden of ownership, with hire available at short notice to meet seasonal timeliness requirements.

Long-Answer Questions

1. Basic response: Maintenance objectives: reliability, service life extension, operator safety. Types: preventive (scheduled, prevents failure, most cost-effective); corrective (after failure, expensive, disruptive); predictive (condition monitoring, scheduled on fault indicators). Maintenance plan: manufacturer's schedule as basis, frequency list by task, parts inventory. Maintenance records: date, hours, tasks, parts, costs. Tractor schedule: daily (oil, coolant, fuel, tyres, leaks, grease); 250 hours (oil and filter change, air filter, valve clearances); 500 hours (all fluids including gearbox and hydraulics); 1,000 hours (cooling system flush, injection pump). Tillage implements: share sharpness check (replace when edge exceeds 3 to 4 mm), soil removal after use, oiling metal surfaces. Sprayers: triple rinse after use, filter cleaning, nozzle inspection (replace at 10 per cent wear), pump lubrication, covered storage.
2. Value-added response: The most commonly neglected maintenance task in Nigerian farm operations is the 250-hour engine oil and filter change, because oil visually appears clean for much longer than its effective service life; operators see clear oil on the dipstick and conclude that a change is unnecessary, while the oil's additive package (acid neutralisers, anti-wear agents, dispersants) has long since been depleted. Teaching operators to maintain an operating hours log and change oil strictly by hours (not by visual appearance) is the single maintenance habit change that most extends engine life in Nigerian tractor fleets.



3. Basic response: Fixed costs: depreciation (straight-line = (Purchase price minus Salvage value) / Useful life); interest (10 to 20 per cent of average machine value/year); insurance and housing. Variable costs: fuel (largest operating cost, specific fuel consumption x power x hours); lubricants (10 to 15 per cent of fuel cost); repairs (5 to 10 per cent of purchase price/year); labour. Cost per hectare = total annual cost / annual use area. $TFC (ha/h) = \text{width (m)} \times \text{speed (km/h)} / 10$. $EFC = TFC \times FE$. Field efficiency 60 to 85 per cent typical. Break-even area = Fixed costs / (Revenue per hectare minus Variable cost per hectare). $BCR = \text{Benefits} / \text{Costs}$ (above 1.0 = viable). Payback period = Investment / Annual net benefit. NPV uses discounted cash flows.
4. Value-added response: The practical skill most needed in Nigerian agricultural advisory work is the ability to calculate cost per hectare for a specific machine in a specific farming context and compare it honestly with the alternative of contract hire. Farmers who can see that their tractor (poorly utilised at 150 hours per year) costs 3 to 4 times per hectare what a well-run MSC charges are empowered to make rational decisions about ownership versus hire. Graduates who can perform this analysis — and explain it in simple terms without jargon — provide genuinely valuable advisory services that change investment decisions and improve farm profitability.
5. Basic response: Policy challenges: fragmented smallholder land ownership; high and volatile diesel fuel costs; limited long-term credit access; weak rural infrastructure; shortage of trained mechanics; inconsistent government policy. Policy history: Operation Feed the Nation (1970s), Green Revolution (1980s), ADPs, NALDA, ABP and ACGSF (current). MSCs: spread fixed costs across many users, government-operated (ADPs) and private; hire pricing covers operating costs plus fixed cost contribution. Hello Tractor: GPS-enabled tractor hire platform, mobile app matching tractor owners with farmers, digital innovation in service delivery. Future trends: declining solar costs (electric tractors, solar irrigation); ICT connectivity (precision agriculture, hire platforms); labour scarcity due to urbanisation; climate change intensifying irrigation and storage needs.
6. Value-added response: The most transformative structural change available to Nigerian agricultural mechanisation is not a new technology but a new ownership and operating model. The Hello Tractor model, which aggregates utilisation of existing tractors through a digital platform, turns tractors that were underutilised at 200 hours per year (because individual owners lacked the client base to fill their calendars) into machines working 600 to 800 hours per year (because the platform connects them to a continuous pipeline of clients). This tripling of



utilisation reduces cost per hour by 40 to 50 per cent, making mechanisation accessible to smallholder farms that could not afford it at individual-ownership prices. Scaling this model nationwide, with government support for platform development and tractor-owner financing, represents the most cost-effective path to broad-based mechanisation in Nigeria.

Answers to Pilot Questions [Series 5]

Part 5.1: Principles and Types of Farm Equipment Maintenance

1. Machine reliability: ensures machines are available and functional when needed at critical operational periods such as land preparation and harvesting; unreliable machines cause yield losses that far exceed the cost of maintenance. Service life extension: proper maintenance slows the rate of wear and corrosion, enabling machines to reach their design service life of 10 to 15 years rather than being retired prematurely after 3 to 5 years as commonly seen in Nigerian mechanisation programmes. Operator safety: maintains brakes, guards, safety hitching devices, and lighting systems in working order, reducing the risk of accidents and injuries during field operations.
2. Preventive maintenance is performed at regular intervals (by calendar time or operating hours) regardless of apparent machine condition, with the objective of preventing failures before they occur; it is the most cost-effective type because: the cost of scheduled service (known, budgeted, planned) is consistently lower than the cost of emergency repair after failure (unexpected, disruptive, often involving secondary damage); machines remain available during scheduled maintenance but break down at the worst moments if maintenance is deferred; and spare parts can be ordered in advance at normal prices rather than purchased urgently at premium prices.
3. Corrective maintenance is unplanned repair performed after a component has already failed; it is typically more expensive and disruptive than preventive maintenance because downtime occurs at operationally critical moments, spare parts must be sourced urgently, and secondary damage to other components often occurs. Predictive maintenance uses condition monitoring technologies (vibration sensors, oil analysis, thermal cameras) to detect early signs of component deterioration before failure, allowing maintenance to be scheduled at a convenient time; it is appropriate for expensive, high-utilisation machines where the cost of monitoring is justified by the savings from avoiding unexpected failure.



4. A maintenance plan contains: a list of all machines on the farm; for each machine, a schedule of all required maintenance tasks listed by frequency (daily, every 50 hours, every 250 hours, every 500 hours, annually); the specific task description and consumable parts required at each service interval; the responsible person for each task; and a minimum spare parts inventory list specifying the consumables (filters, belts, fuses) that must be kept in stock to avoid service interruptions.
5. Any four: date of maintenance; operating hours or odometer reading at time of service; specific tasks performed; parts replaced (part numbers and quantities); quantities of lubricants and fluids used; name of person performing the maintenance; cost of parts and labour.

Part 5.2: Maintenance Procedures for Key Farm Machines

1. Check engine oil level with dipstick (between MIN and MAX marks); check coolant level in radiator or expansion tank when engine is cold; check fuel level; inspect tyre condition (cuts, embedded objects) and inflation pressure; check air filter restriction indicator; inspect under the tractor for fluid leaks (oil, coolant, hydraulic fluid); check all lights and safety guards are in place and functional; grease all grease nipples on three-point linkage, drawbar, and front axle.
2. Engine oil and filter should be changed every 250 operating hours (after the initial 50-hour first service on a new machine); this interval is important because diesel engine oil degrades through: thermal oxidation (high temperatures break down oil molecules); contamination (combustion blowby gases introduce acidic products and soot particles); and additive depletion (anti-wear, dispersant, and acid-neutralising additives are consumed); beyond 250 hours the oil's protective properties are significantly diminished and continued use accelerates bearing and cylinder liner wear.
3. A mouldboard plough share needs sharpening or replacement when: the cutting edge has worn from its original thin, sharp profile (approximately 1 to 2 mm thick) to a blunt, rounded edge more than 3 to 4 mm thick; this can be assessed by running a finger along the cutting edge (a sharp share feels knife-like) or by measuring the edge thickness with a calliper; additional indicators include increased tractor engine load (requiring higher gear or more throttle for the same field conditions), reduced penetration depth, and poor furrow quality (ragged walls, incomplete trash burial).



4. After each use: drain the tank completely; triple-rinse the tank, boom, and nozzles with clean water, spraying the rinsate onto a treated field area; clean all in-line and nozzle body filters; inspect all hoses and boom joints for leaks and wear; check pressure gauge accuracy; inspect each nozzle output (replace any nozzle delivering more than 10 per cent above its rated output); lubricate the pump diaphragm or piston with the manufacturer-specified lubricant; store in a covered area away from direct sunlight to protect rubber seals and plastic components.
5. During the engine's operating season, fresh oil is continuously replenished by the regular 250-hour change before it becomes heavily contaminated with acids; however, if the old oil is left in the engine during long idle storage (3 to 5 months), the combustion acids and soot particles in it continue to attack bearing surfaces throughout the storage period; fresh oil changed at the start of storage contains full additive package including acid neutralisers that protect bearings during the idle period; this makes the pre-storage oil change more protective than the mid-season change, which is immediately followed by dilution with incoming combustion products.

Part 5.3: Farm Equipment Costing and Economic Analysis

1. Fixed costs are incurred regardless of machine use: depreciation (annual value loss, e.g. a tractor depreciating at 200,000 naira per year whether used or idle), interest on capital (cost of funds tied up in the machine, e.g. 15 per cent of average machine value per year). Variable costs depend on extent of use: fuel (consumed only when the machine runs, e.g. 8 to 12 litres per hour for a 55 kW tractor), repairs and maintenance labour (increases with operating hours, e.g. rising from 5 per cent to 15 per cent of purchase price per year as the machine ages and accumulates use).
2. Straight-line depreciation = (Purchase price minus Salvage value) / Useful life in years.
Example: a tractor purchased at 15 million naira with a salvage value of 1.5 million naira and a useful life of 10 years has an annual depreciation of $(15,000,000 \text{ minus } 1,500,000) / 10 = 1,350,000$ naira per year.
3. Theoretical field capacity (TFC) is the area a machine would cover per hour if it operated continuously at its rated speed and full working width with no time losses; $\text{TFC (ha/h)} = \text{working width (m)} \times \text{travel speed (km/h)} / 10$. For a 3.6 m disc harrow at 6 km/h: $\text{TFC} = 3.6 \times 6 / 10 = 2.16$ ha/h.



4. Field efficiency is the ratio of effective field capacity (actual area covered per hour) to theoretical field capacity, expressed as a percentage; it is always below 100 per cent because: time is lost to turning at headland ends (proportion depends on field length; longer fields have lower turning time as a percentage of total time); time is lost to refilling the seed hopper, fertiliser bin, or spray tank; time is lost to implement adjustments, overlapping between passes, and operator rest and personal breaks.
5. Break-even analysis determines the minimum annual use area at which total revenue equals total cost: $\text{break-even area} = \text{Total fixed costs per year} / (\text{Charge per hectare for the service} - \text{Variable cost per hectare})$; below this area, hiring a contract service is economically preferable to owning the machine (fixed costs are not fully recovered); above it, ownership is cheaper than hiring because the fixed cost per hectare is diluted over a larger area while the variable cost per hectare remains approximately constant; the analysis helps investors decide whether their anticipated annual use justifies the capital investment.

Part 5.4: Economics of Agricultural Mechanisation in Nigeria

1. Any three: fragmented smallholder land ownership makes individual investment in large machinery uneconomic for most farmers; limited access to long-term credit at affordable interest rates (most agricultural loans are short-term and too expensive for capital equipment); high and volatile diesel fuel prices raise operating costs unpredictably and can quickly turn a viable mechanisation investment into an unviable one.
2. An MSC pools equipment ownership across many clients, spreading the high fixed costs (depreciation, interest, insurance) over a much larger total annual use area than any individual smallholder could achieve; this reduces fixed cost per hectare dramatically; farmers benefit because they access mechanisation at hire rates that are affordable and competitive with hand or animal-power costs, without needing to invest capital in equipment, maintain it, or source spare parts; they also benefit from the timeliness advantage of hiring machinery when it is needed rather than waiting for their own machine to be repaired.
3. Hello Tractor is a GPS-enabled digital platform that uses a mobile app to connect tractor owners (who register their tractors on the platform) with smallholder farmers seeking tractor hire for land preparation; the platform handles booking, payment, and job tracking in real time; it is significant because it dramatically increases tractor utilisation (turning tractors that were used only 200 hours per year into machines used 600 to 800 hours), reduces cost per



hectare, extends mechanisation access to farmers in remote areas who previously had no way of locating and booking a tractor, and creates a transparent market price for mechanisation services.

4. Appropriate-scale technology refers to equipment that is matched in size, power, complexity, and cost to the actual scale and farming system of the target users; in Nigeria this means machines accessible and economical for farms of 1 to 10 hectares: two-wheel power tillers rather than 100 kW four-wheel tractors; motorised knapsack sprayers rather than large boom sprayers; small-scale threshers and processing machines that can be owned by individual farmers or small cooperatives rather than only by large commercial operations.
5. The four trends: declining solar PV and battery costs (making solar irrigation, electric tractors, and autonomous field robots increasingly viable); ICT and mobile connectivity expansion (enabling precision agriculture tools and digital hire platforms to reach rural areas); declining rural labour availability due to urbanisation (creating structural demand for labour-saving mechanisation at all farm sizes); climate change impacts (intensifying the need for irrigation and post-harvest storage infrastructure to buffer production against erratic and more extreme weather).



References and Attributions [Series 5]

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- FAO (Food and Agriculture Organization of the United Nations). (2025). Guidelines for sustainable agriculture. FAO.

Figures, Plates, Tables, and Boxes

- Figure 5.1: Maintenance investment vs reliability diagram Attribution: AI generated using prompt "Generate a diagram showing the relationship between maintenance investment and machine reliability, service life, and total cost of ownership." Suggested OER search string: "farm equipment maintenance investment reliability service life total cost OER diagram".
- Table 5.1: Maintenance types comparison table Attribution: AI generated using prompt "Generate a table comparing preventive, corrective, and predictive maintenance types for farm equipment on timing, cost, Nigerian applicability, and examples." Suggested OER search string: "preventive corrective predictive maintenance comparison table farm equipment OER".
- Figure 5.2: Maintenance record card example Attribution: AI generated using prompt "Generate an image of a completed machine maintenance record card showing service intervals, parts replaced, oil quantities, and cost entries for a farm tractor." Suggested OER search string: "farm equipment maintenance record card log book service intervals OER".
- Table 5.2: Tractor preventive maintenance schedule Attribution: AI generated using prompt "Generate a table listing tractor maintenance tasks by service interval: daily, 50-hour, 250-hour,



500-hour, and 1,000-hour services." Suggested OER search string: "tractor maintenance schedule daily 250 500 1000 hours service intervals table OER".

- Box 5.1: Boom sprayer post-use maintenance checklist Attribution: AI generated using prompt "Generate a maintenance checklist box for a tractor-mounted boom sprayer covering post-use draining, triple rinse, filter cleaning, nozzle inspection, pump lubrication, and covered storage." Suggested OER search string: "boom sprayer post-use maintenance checklist filters nozzles rinse storage OER box".
- Box 5.2: End-of-season storage checklist Attribution: AI generated using prompt "Generate a checklist box listing end-of-season storage steps for tractors and farm implements including oil change, coolant, battery, metal protection, soil removal, and covered storage." Suggested OER search string: "end-of-season storage checklist tractor implements maintenance OER box".
- Table 5.3: Annual machinery cost calculation table Attribution: AI generated using prompt "Generate an annual machinery cost calculation table for a 55 kW tractor showing depreciation, interest, insurance, fuel, lubricants, repairs, and labour costs." Suggested OER search string: "tractor annual machinery cost calculation depreciation fuel repairs table OER".
- Figure 5.3: Field capacity and efficiency diagram Attribution: AI generated using prompt "Generate a diagram illustrating theoretical field capacity, effective field capacity, and field efficiency with a rectangular field showing working passes and headland turns." Suggested OER search string: "field capacity efficiency farm machinery theoretical effective worked example OER".
- Figure 5.4: Break-even analysis graph Attribution: AI generated using prompt "Generate a break-even analysis graph for a tractor investment showing fixed costs, total costs increasing with area, and total revenue with the break-even point labelled." Suggested OER search string: "tractor break-even analysis graph fixed costs total revenue OER diagram".
- Figure 5.5: Nigerian mechanisation policy timeline Attribution: AI generated using prompt "Generate a timeline diagram showing key Nigerian agricultural mechanisation policy milestones from Operation Feed the Nation through Green Revolution, NALDA, ADPs, and Anchor Borrowers Programme." Suggested OER search string: "Nigerian agricultural mechanisation policy history timeline milestones OER".
- Figure 5.6: Mechanisation service centre model diagram Attribution: AI generated using prompt "Generate a diagram showing a mechanisation service centre with arrows to smallholder farmers receiving tractor, thresher, and pump hire services." Suggested OER search string: "mechanisation service centre equipment hire smallholder farmers Nigeria OER diagram".



- Figure 5.7: Future mechanisation trends diagram Attribution: AI generated using prompt "Generate a four-arrow convergence diagram showing declining solar costs, ICT connectivity, rural labour scarcity, and climate change as trends driving agricultural mechanisation in Nigeria." Suggested OER search string: "future agricultural mechanisation Nigeria trends solar ICT labour climate OER".

