La-Net

AGE 203

FOREST MANAGEMENT EDUCATION

Download on the App Store

GET IT ON Google Play

Course video is available on our app

lanetonline.com

Course code: AGE 203

Course title: Forest Management Education

Course credit load: 2 Units

Series 1: Principles of Forest Management

- **Part 1.1: Concepts and Definitions of Forests**
  - Sub Part 1.1.1: Definition and characteristics of a forest
  - Sub Part 1.1.2: Types of forests in Nigeria
  - Sub Part 1.1.3: Functions and values of forests
- **Part 1.2: Forest Ecosystems and Human Interactions**
  - Sub Part 1.2.1: Structure and components of forest ecosystems
  - Sub Part 1.2.2: Human impacts on forest ecosystems
  - Sub Part 1.2.3: Forest ecosystem services in the Nigerian context
- **Part 1.3: Principles and Objectives of Forest Management**
  - Sub Part 1.3.1: Definition and goals of forest management
  - Sub Part 1.3.2: Sustained yield and multiple-use principles
  - Sub Part 1.3.3: Forest mensuration and ecological measurement
- **Part 1.4: Forest Policy and Administration in Nigeria**
  - Sub Part 1.4.1: Historical development of Nigerian forest policy
  - Sub Part 1.4.2: Institutions governing Nigerian forests
  - Sub Part 1.4.3: Forest reserves and game reserves in Nigeria

Introduction

Forests are among the most productive and ecologically significant ecosystems on Earth. They regulate climate, protect watersheds, harbour biodiversity, and supply timber, fuelwood, non-timber forest products, and ecosystem services upon which hundreds of millions of people depend. In Nigeria, forests once covered vast areas of the country but have been severely reduced by agricultural expansion, logging, and urbanisation; the remaining forest estate requires systematic management to sustain its ecological and economic functions.

This Series introduces the foundational concepts of forest management education: the definition and classification of forests, the structure and functioning of forest ecosystems, the principles and objectives of forest management, and the policy and institutional framework governing forests in Nigeria. These concepts underpin all subsequent series in this course.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 1.1** define a forest and distinguish among the major types of forests found in Nigeria (Linked to Part 1.1),
- **SLO 1.2** describe the structure and components of a forest ecosystem and explain the complex interactions between humans and forest ecosystems (Linked to Part 1.2),
- **SLO 1.3** state the principles and objectives of forest management, including sustained yield and multiple use (Linked to Part 1.3),
- **SLO 1.4** describe the historical development of Nigerian forest policy and identify the key institutions responsible for forest governance (Linked to Part 1.4), and
- **SLO 1.5** distinguish between forest reserves and game reserves in Nigeria and explain their legal basis and management objectives (Linked to Part 1.4).

1.1 Concepts and Definitions of Forests

1.1.1 Definition and characteristics of a forest

A forest is a land area dominated by trees, with a canopy cover generally exceeding 10 percent (FAO definition) or 25 percent (some national definitions), in which trees reach a minimum height of 5 m at maturity. Forests are distinguished from woodlands (lower canopy cover, more open structure), savannas (grass-dominated with scattered trees), and plantations (artificially established monocultures of trees). Key characteristics of a natural forest include: a multilayered canopy structure (emergent, main canopy, understorey, and ground layers); high biodiversity of plants, animals, fungi, and microorganisms; complex nutrient cycling; and a continuous process of stand development from seedling to mature and senescent phases.

The Food and Agriculture Organization (FAO) of the United Nations defines forest as land spanning more than 0.5 ha with trees higher than 5 m and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ, excluding land predominantly under agricultural or urban land use. Nigeria uses a national definition requiring a minimum canopy cover of 25 percent for land to be gazetted as forest reserve. Forest area globally is approximately 4.06 billion ha, representing about 31 percent of total land area (FAO Global Forest Resources Assessment 2020).

Fill in the blank: The FAO definition of forest requires a minimum canopy cover of _____ percent and trees able to reach a height of at least 5 metres; land predominantly under agricultural or urban use is excluded.

1.1.2 Types of forests in Nigeria

Nigeria's forests are classified by their ecological zone and origin. Tropical rainforest (lowland rainforest): found in the humid forest zone of southern Nigeria (Cross River, Edo, Ondo, Ogun, Lagos, Rivers, Bayelsa, and Delta states); the most species-rich and structurally complex forest type; receives more than 1,500 mm annual rainfall; supports valuable timbers including Khaya (African mahogany), Entandrophragma (sapele, utile), Milicia excelsa (iroko), and Terminalia

superba (afara). Fresh water swamp forest: found along river floodplains and deltas; seasonally or permanently waterlogged; dominants include Mitragyna ciliata (abura) and Anthocleista species. Mangrove forest: coastal and estuarine; dominated by Rhizophora racemosa, Avicennia germinans, and Laguncularia racemosa; Nigeria has the largest mangrove forest in Africa (approximately 1.0 million ha).

Guinea savanna woodland: covers the large central belt of Nigeria; dominated by Isoberlinia doka, Burkea africana, Daniellia oliveri, and Vitellaria paradoxa (shea butter tree); receives 1,000 to 1,500 mm rainfall; the most extensive vegetation zone in Nigeria. Sudan savanna: northern Nigeria; more arid; trees fewer and shorter; dominated by Acacia species, Balanites aegyptiaca, and Combretum species. Sahel savanna: far north (Sokoto, Katsina, Borno); semi-arid; sparse tree cover; Acacia senegal (gum arabic), Baobab (Adansonia digitata). Montane forest: plateau areas (Jos Plateau, Obudu Plateau, Mambilla Plateau); cooler temperatures; species include Podocarpus milanjianus, Syzygium species, and Hagenia abyssinica.

Fill in the blank: Nigeria has the largest _____ forest in Africa, covering approximately 1.0 million ha along its coastline and estuaries; this forest type is dominated by Rhizophora racemosa and provides critical coastal protection functions.

1.1.3 Functions and values of forests

Forests provide a wide range of goods and services that can be classified as: (1) Productive functions: timber (construction, furniture, paper); fuelwood and charcoal (approximately 70 percent of Nigerian households depend on wood energy); non-timber forest products (NTFPs: bushmeat, honey, medicinal plants, rattan, gum, fruits, leaves); and fodder for livestock. (2) Protective functions: watershed protection (forests maintain water quality and regulate stream flow by intercepting rainfall, reducing surface runoff, and recharging groundwater); soil conservation (tree roots bind soil and leaf litter reduces erosion); microclimate regulation (forests reduce temperature extremes and maintain humidity); and coastal protection (mangroves attenuate storm surges and wave energy).

(3) Social and cultural functions: forests are sacred sites for many Nigerian communities; sources of traditional medicine; recreation and ecotourism destinations; and settings for cultural practices. (4) Environmental (ecological) functions: forests are the largest terrestrial carbon store (tropical forests store approximately 250 tonnes of carbon per ha above and below ground); they are biodiversity hotspots (Nigerian rainforests are part of the Upper Guinean Biodiversity Hotspot); they regulate the global water cycle through evapotranspiration; and they support the livelihoods of forest-dependent communities. Loss of forest cover therefore has cascading consequences for all four categories of forest function.

Fill in the blank: Forests provide _____ functions (timber, fuelwood, NTFPs), protective functions (watershed, soil, microclimate), social and cultural functions, and environmental functions including carbon storage and biodiversity conservation.

Pilot questions 1.1

1. Define a forest according to the FAO definition and state two characteristics that distinguish a forest from a savanna woodland.
2. Name four types of forests found in Nigeria and state one characteristic tree species of each.
3. Distinguish between lowland rainforest and mangrove forest in terms of location, dominant species, and ecological function.
4. List four productive functions and two protective functions of forests relevant to Nigeria.
5. Explain why loss of mangrove forest along the Nigerian coast has serious consequences for both biodiversity and human communities.

1.2 Forest Ecosystems and Human Interactions

1.2.1 Structure and components of forest ecosystems

A forest ecosystem comprises biotic components (living organisms: trees, shrubs, herbs, epiphytes, fungi, bacteria, animals, and microorganisms) and abiotic components (climate: rainfall, temperature, solar radiation; soil: mineral nutrients, organic matter, water-holding

capacity; topography; and hydrology). The biotic community is organised into vertical layers: emergent layer (tallest trees, 40 to 60 m in Nigerian rainforest, e.g. Ceiba pentandra); main canopy (25 to 40 m; Khaya, Entandrophragma, Iroko); understorey (10 to 25 m; Dracaena, Diospyros); shrub layer (2 to 10 m); herb and ground layer (0 to 2 m; ferns, seedlings, mosses).

Energy flows through the ecosystem from primary producers (trees and other green plants that fix solar energy by photosynthesis) through primary consumers (herbivores: insects, rodents, deer, elephants) to secondary consumers (carnivores: snakes, eagles, leopards) and decomposers (fungi and bacteria that break down dead organic matter and return nutrients to the soil). Nutrient cycling in tropical forests is rapid: most nutrients are held in the living biomass rather than the soil; when trees are felled and removed, the nutrient capital of the ecosystem is depleted and recovery is slow. This tight nutrient cycling explains why tropical forest soils, though supporting luxuriant vegetation, are often infertile when the forest is cleared.

Fill in the blank: In a tropical forest ecosystem, most nutrients are held in the living _____ rather than in the soil; when trees are removed by logging, the nutrient capital is depleted and ecological recovery is slow.

1.2.2 Human impacts on forest ecosystems

Human activities affect forest ecosystems through: (1) Deforestation: permanent removal of forest cover for agriculture (shifting cultivation, large-scale plantations), settlement, or infrastructure; Nigeria lost approximately 96 percent of its original forest cover between 1900 and 2000, with the deforestation rate estimated at 3.5 to 5.0 percent per year in the 1990s (one of the highest in the world). (2) Selective logging: removal of only the highest-value timber trees; creates canopy gaps, increases light penetration, and often damages 30 to 60 percent of remaining trees; road construction for log extraction opens forests to further encroachment. (3) Bush burning: widespread in the Guinea savanna of Nigeria; prevents forest regeneration on savanna margins and reduces woody biomass.

(4) Non-timber forest product extraction: unsustainable collection of bushmeat, fuelwood, bark, and medicinal plants depletes populations of target species and disrupts ecosystem processes. (5) Pollution: oil spills in the Niger Delta have destroyed extensive areas of mangrove and freshwater swamp forest; particulate fallout from industrial activities affects forest health in southern Nigeria. (6) Climate change: shifting rainfall patterns, rising temperatures, and increased drought frequency are altering forest composition and productivity across Nigeria's vegetation zones, threatening the survival of species near the limits of their climatic tolerance.

Fill in the blank: Nigeria lost approximately _____ percent of its original forest cover between 1900 and 2000; the main driver was deforestation for agriculture, followed by selective logging, bush burning, and oil pollution in the Niger Delta.

1.2.3 Forest ecosystem services in the Nigerian context

Ecosystem services are the benefits that people derive from ecosystems, classified by the Millennium Ecosystem Assessment (2005) into four categories. Provisioning services: food (bushmeat, fruits, nuts), water, fibre (timber, rattan), fuel (fuelwood, charcoal), and biochemicals (medicines, resins, dyes). Regulating services: climate regulation (carbon sequestration; local rainfall generation through evapotranspiration), flood regulation (forest cover reduces peak runoff in river catchments), water purification, erosion control, and pollination. Cultural services: spiritual and religious values, recreation and ecotourism (e.g. Cross River National Park; Okomu National Park), aesthetic values, and traditional knowledge systems associated with forest species. Supporting services: nutrient cycling, soil formation, primary production, and habitat provision for biodiversity.

In Nigeria, the economic value of forest ecosystem services is substantial but largely unquantified and therefore undervalued in national accounts. The Cross River rainforest provides watershed services to communities along the Cross River and supplies NTFPs to hundreds of thousands of people. Mangroves in the Niger Delta protect shorelines, support fisheries (as nursery habitats for commercially important fish and crustaceans), and store large quantities of

carbon in their waterlogged soils (blue carbon). Quantifying these services is a key challenge for forest managers and policymakers seeking to justify investment in forest conservation.

Fill in the blank: The Millennium Ecosystem Assessment classifies ecosystem services into provisioning, regulating, _____, and supporting services; the regulating services of Nigerian forests include carbon sequestration, flood regulation, and erosion control.

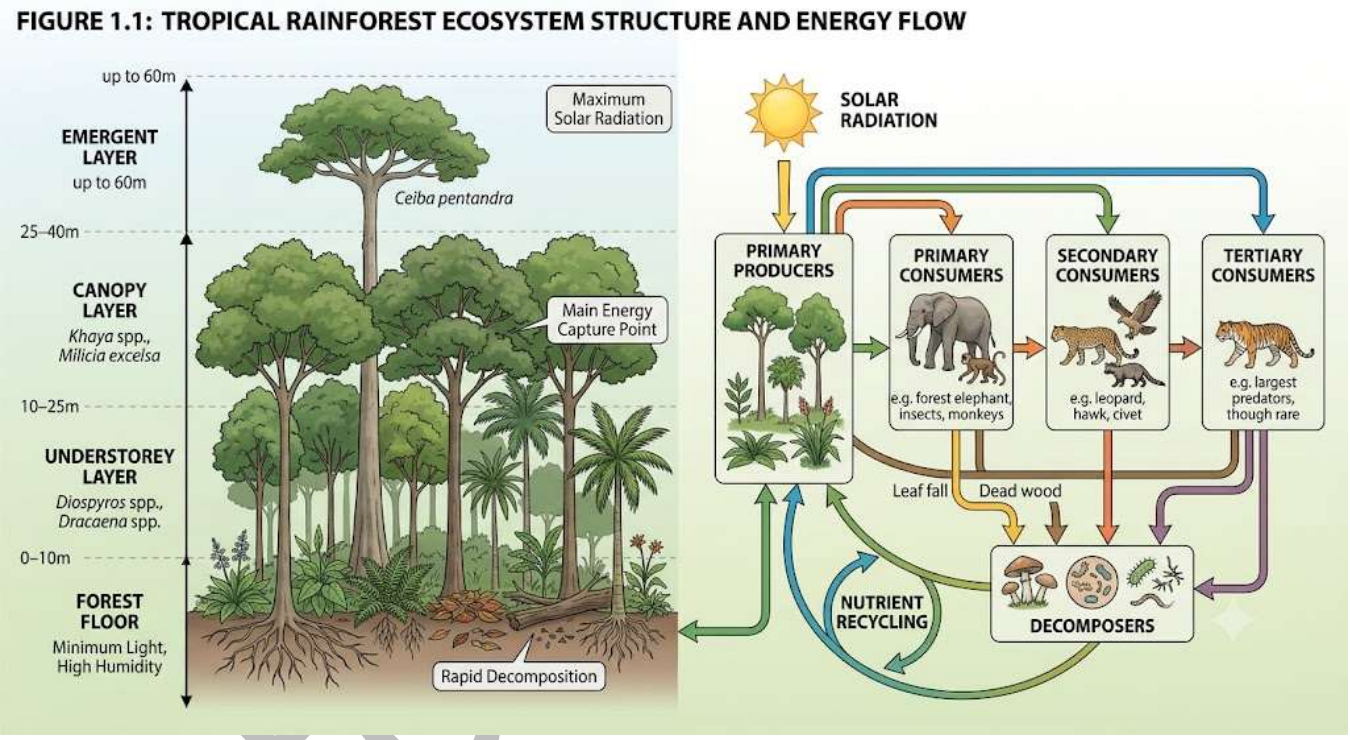

Figure 1.1: Structure and energy flow in a Nigerian tropical rainforest ecosystem

Pilot questions 1.2

1. Describe the vertical layers of a Nigerian tropical rainforest and name one tree species characteristic of each layer.
2. Explain why tropical forest soils are often infertile when the forest is cleared, using the concept of nutrient cycling.
3. List four human activities that cause degradation of Nigerian forests and briefly describe the impact of each.
4. Explain what is meant by ecosystem services and give two examples each of provisioning and regulating services provided by Nigerian forests.

5. Describe the ecological importance of mangrove forests in the Niger Delta under two headings: fisheries and carbon storage.

1.3 Principles and Objectives of Forest Management

1.3.1 Definition and goals of forest management

Forest management is the process of planning and implementing practices for the stewardship and use of forests to meet specific environmental, economic, social, and cultural objectives while maintaining the forest's long-term ecological integrity and productivity. The principal goals of forest management include: (1) sustained production of timber and non-timber forest products; (2) maintenance and enhancement of biodiversity; (3) protection of watershed and soil functions; (4) sequestration of carbon and mitigation of climate change; (5) provision of social benefits including employment, recreation, and cultural values; and (6) maintenance of the forest as a functional ecosystem capable of continued productivity across multiple rotations.

Forest management is inherently long-term: decisions made today (species planted, harvesting systems adopted, areas protected) will determine the state of the forest decades hence. This long time horizon requires planning tools (forest inventories, growth and yield models, management plans with 10 to 50 year horizons) that are not needed in annual crop agriculture. It also requires institutional continuity: changes in government policy or management objectives can disrupt management plans whose effects span generations of trees.

Fill in the blank: Forest management is a long-term process requiring planning tools such as forest _____, growth and yield models, and management plans with horizons of 10 to 50 years; institutional continuity is essential because decisions made today affect forest condition for decades.

1.3.2 Sustained yield and multiple-use principles

Sustained yield is the guiding principle of classical forest management: the annual harvest of timber (or other forest products) should not exceed the annual increment (growth) of the forest, so that the productive capacity of the forest is maintained indefinitely. Mathematically: allowable annual cut (AAC) = total standing volume / rotation age, adjusted for growth rate. If a forest contains 500,000 m3 of timber and the rotation age is 50 years, the AAC = 500,000/50 = 10,000 m3/year. Exceeding this cut draws down the growing stock and eventually reduces future yields. Nigeria's forest reserves were established specifically to provide a sustained yield of timber for domestic consumption and export.

Multiple use is the principle that forests should be managed to provide a range of goods and services simultaneously, not timber alone: watershed protection, biodiversity conservation, NTFPs, grazing, recreation, and carbon sequestration can all be provided from the same forest area if managed appropriately. Multiple-use management requires zoning: some areas are designated for intensive timber production; others for biodiversity conservation or watershed protection; others for NTFP harvesting; and buffer zones separate incompatible uses. The concept of sustainable forest management (SFM), promoted by the Forest Stewardship Council (FSC) and international agreements (UNCED 1992; Convention on Biological Diversity), extends sustained yield to encompass environmental, social, and economic sustainability simultaneously.

Fill in the blank: The allowable annual cut (AAC) in sustained yield management equals the total standing volume divided by the _____ age; this ensures that the annual harvest does not exceed annual increment and the productive capacity of the forest is maintained indefinitely.

1.3.3 Forest mensuration and ecological measurement

Forest mensuration is the science of measuring forest trees and stands to provide the data needed for management decisions. Key measurements include: diameter at breast height (DBH; measured at 1.3 m above ground using a diameter tape or calipers; units: cm); total height and merchantable height (using a hypsometer, Suunto clinometer, or Vertex ultrasonic instrument; units: m); basal area (cross-sectional area of a tree stem at 1.3 m = pi/4 x DBH2; units: m2; stand

basal area summed over all trees per ha); volume (calculated from DBH and height using volume tables or taper equations; units: m3); and age (from tree rings in temperate species or from planting records in plantations).

Stand-level measurements derived from individual tree data include: stand density (number of trees per ha); basal area per ha (sum of individual tree basal areas; typical values 20 to 50 m2/ha in tropical rainforest); mean annual increment (MAI = total volume / age; used to determine optimal rotation); and current annual increment (CAI = increment during the current year; the rotation is optimised when MAI = CAI). Ecological measurements in forest management extend beyond timber: floristic surveys (species richness, diversity indices), wildlife transect surveys, soil sampling, and stream flow measurement are all part of comprehensive forest monitoring in Nigeria.

Fill in the blank: Diameter at breast height (DBH) is measured at _____ m above ground using a diameter tape or calipers; it is the primary measurement used to calculate basal area and estimate timber volume in forest inventories.

Pilot questions 1.3

1. Define forest management and state four goals that a forest management plan should address.
2. Explain the sustained yield principle. If a forest reserve contains 800,000 m3 of standing timber and the rotation is 40 years, what is the allowable annual cut?
3. Distinguish between sustained yield and multiple-use principles in forest management.
4. Define DBH, basal area, and mean annual increment (MAI) and explain how each is used in forest management decisions.
5. Explain what sustainable forest management (SFM) means and name one international organisation that certifies sustainably managed forests.

1.4 Forest Policy and Administration in Nigeria

1.4.1 Historical development of Nigerian forest policy

The formal management of Nigerian forests began during the colonial period. The first Nigerian Forest Ordinance was enacted in 1901, establishing the legal basis for forest reservation. By 1930, the Forestry Department had been established in all regions and a network of forest reserves was being gazetted. The primary objective of colonial forest policy was to ensure a sustained supply of timber for export and for local use in railway construction and public works. Forest reserves were demarcated, local communities were excluded from reserved areas (often without adequate compensation), and concessions were granted to European timber companies.

At independence (1960) and during the 1970s oil boom, forest policy was subordinated to agricultural development; large areas of forest were converted to cocoa, rubber, and food crop farms with government encouragement. The 1988 National Policy on Environment acknowledged the importance of forest conservation and called for reforestation, but implementation was weak. The 2006 National Forest Policy (revised in 2011) set targets for increasing forest cover, promoting community forestry, and strengthening forest law enforcement. The National REDD+ (Reducing Emissions from Deforestation and Forest Degradation) programme, supported by the UN-REDD Programme since 2012, aims to provide financial incentives for forest conservation by quantifying and rewarding carbon sequestration services.

Fill in the blank: The first Nigerian Forest Ordinance was enacted in _____, establishing the legal basis for forest reservation; the colonial forest policy aimed primarily to ensure a sustained supply of timber for export and for use in railway construction.

1.4.2 Institutions governing Nigerian forests

Forest management in Nigeria is a concurrent responsibility shared between federal and state governments under the 1999 Constitution. Federal institutions: the Federal Ministry of Environment (FMEnv) is responsible for national forest policy; the Forestry Research Institute of Nigeria (FRIN), headquartered in Ibadan, conducts research on forest species, silviculture, and forest products and manages federal forest reserves; the National Park Service (NPS) manages

Nigeria's seven national parks. State governments manage the bulk of the forest estate through State Forestry Commissions or Departments of Forestry.

Key federal agencies: FRIN (established 1954 as the Forest Research Station Ibadan; current mandate: research, training, and advisory services in forestry); the National Park Service NPS (established 1991; manages Yankari, Cross River, Gashaka-Gumti, Kainji Lake, Old Oyo, Chad Basin, and Okomu national parks); and the Federal Department of Forestry (FDF) under FMEnv (coordinates national forest policy implementation). Non-governmental organisations active in Nigerian forest conservation include the Nigerian Conservation Foundation (NCF), WWF-Nigeria, Wildlife Conservation Society (WCS), and A Rocha Nigeria. International bodies with roles in Nigerian forest governance include FAO, UN-REDD, and the African Timber Organisation (ATO).

Fill in the blank: The Forestry Research Institute of Nigeria (FRIN), headquartered in _____, conducts research on forest species, silviculture, and forest products and manages federal forest reserves; it was established in 1954 as the Forest Research Station.

1.4.3 Forest reserves and game reserves in Nigeria

A forest reserve is an area of land formally gazetted under state or federal law for the purpose of maintaining forest cover and providing a sustained supply of timber and other forest products. Nigeria has approximately 1,134 forest reserves covering about 9.6 million ha (approximately 10.4 percent of Nigeria's land area); however, effective management covers far less due to encroachment, illegal logging, and inadequate funding. Forest reserves are managed by state forestry departments on a multiple-use basis; limited settlement, farming on degraded areas, and NTFP collection may be permitted in some zones under community forestry arrangements.

A game reserve (wildlife sanctuary) is a protected area established primarily for the conservation of wildlife species and their habitats; hunting and settlement are prohibited or strictly regulated. Nigeria's game reserves include the Borgu Game Reserve (Kwara and Niger states), Hadejia-Nguru Wetlands, and the Sambisa Game Reserve (Borno State; now better known for other

reasons). National parks are the highest category of protected area in Nigeria; they are established by federal law, exclude settlement and extractive activities, and are managed by the National Park Service for biodiversity conservation, research, and ecotourism. The seven Nigerian national parks cover approximately 2.4 million ha. All are included in the IUCN protected area system and several are recognised internationally (Cross River National Park contains part of the Cameroon Highlands biodiversity hotspot).

Fill in the blank: Nigeria has approximately 1,134 forest _____ covering about 9.6 million ha, managed by state forestry departments; national parks are managed by the federal National Park Service and are the highest category of protected area in Nigeria.

Feature	Forest Reserve	Game Reserve	National Park
Legal Basis	State forest laws and regulations	State or federal wildlife laws	Federal National Parks Decree (1991)
Primary Objective	Sustained timber and non-timber forest-product production; forest conservation	Wildlife protection and habitat conservation	Biodiversity conservation, research, and ecotourism
Managing Authority	State Forestry Departments or Commissions	State Wildlife Departments or Agencies	National Park Service (Federal Ministry of Environment)
Extractive Activities	Limited logging, NTFP collection, and controlled farming	Hunting restricted or prohibited; minimal extraction	No extractive activities permitted
Human Settlement	Limited or regulated under community forestry schemes	Generally prohibited	Strictly prohibited
Current Number and Area	About 1,134 reserves covering ~9.6 million ha	Around 12 reserves nationwide	Seven national parks covering ~2.4 million ha

Box 1.1: Comparison of forest reserves, game reserves, and national parks in Nigeria

Pilot questions 1.4

1. Outline the historical development of Nigerian forest policy from the colonial period (1901) to the 2006 National Forest Policy.
2. Describe the role of FRIN in Nigerian forest management and state two research functions it performs.
3. Distinguish between a forest reserve and a national park in Nigeria in terms of legal basis, managing authority, and permitted activities.
4. Name three Nigerian national parks and state the state(s) in which each is located.
5. Explain what REDD+ means and why it is relevant to Nigerian forest policy.

Series Summary

This Series examined the major forest types found in Nigeria, including lowland rainforest, freshwater swamp forest, mangrove forest, Guinea savanna woodland, Sudan–Sahel savanna, and montane forest. Forests provide timber, fuelwood, medicinal plants, foods, and other non-timber products. They also protect soil and watersheds, regulate local climate, store carbon, conserve biodiversity, and support cultural and recreational activities. Forest ecosystems contain biotic components such as trees, animals, and decomposers, as well as abiotic factors such as climate, soil, and topography.

The Series also discussed threats to Nigerian forests, including deforestation, logging, bush burning, overharvesting, oil pollution, and climate change. Sustainable forest management aims to maintain timber production, biodiversity, watershed protection, carbon storage, and community benefits through sustained-yield and multiple-use practices. Important forest measurements include DBH, basal area, standing volume, and mean annual increment. Forest administration in Nigeria involves the Federal Ministry of Environment, FRIN, the National Park Service, and state forestry departments, supported by national forest policies, reserves, national parks, and REDD+ programmes.

Glossary of Terms

- **Allowable annual cut (AAC):** the maximum volume of timber that can be harvested from a forest each year without depleting the growing stock; in sustained yield management, AAC = total standing volume / rotation age.
- **Basal area:** the cross-sectional area of a tree stem at breast height (1.3 m); calculated as pi/4 x DBH2; stand basal area is the sum of individual tree basal areas per hectare (m2/ha).
- **Deforestation:** the permanent removal of forest cover and conversion to non-forest land use (agriculture, settlement, or infrastructure); the primary cause of forest loss in Nigeria.

- **Diameter at breast height (DBH):** the diameter of a tree stem measured at 1.3 m above ground using a diameter tape or calipers; the primary measurement used to calculate basal area and estimate timber volume.
- **Ecosystem services:** the benefits that people derive from ecosystems; classified by the Millennium Ecosystem Assessment into provisioning, regulating, cultural, and supporting services.
- **Forest reserve:** an area of land formally gazetted under state or federal law for maintaining forest cover and providing timber and forest products; managed by state forestry departments in Nigeria.
- **Forest mensuration:** the science of measuring forest trees and stands (DBH, height, basal area, volume, age) to provide data for forest management planning and decision-making.
- **FRIN (Forestry Research Institute of Nigeria):** a federal research institution headquartered in Ibadan; established in 1954; conducts research on forest species, silviculture, and forest products and manages federal forest reserves.
- **Mangrove forest:** a coastal and estuarine forest type dominated by salt-tolerant trees (Rhizophora, Avicennia, Laguncularia); Nigeria has the largest mangrove forest in Africa (approximately 1.0 million ha).
- **Mean annual increment (MAI):** the average volume increment per year over the life of a tree or stand, calculated as total volume divided by age; the rotation is optimised when MAI equals current annual increment.
- **Multiple use:** the principle that forests should be managed to provide a range of goods and services simultaneously, including timber, NTFPs, biodiversity, watershed protection, and recreation.
- **National Park Service (NPS):** the federal agency established in 1991 to manage Nigeria's seven national parks for biodiversity conservation, research, and ecotourism.
- **REDD+:** Reducing Emissions from Deforestation and Forest Degradation; an international mechanism that provides financial incentives to developing countries for conserving forests and reducing forest-based greenhouse gas emissions.

- **Sustained yield:** the principle that the annual harvest of forest products should not exceed the annual increment, so that the productive capacity of the forest is maintained indefinitely across multiple rotations.
- **Tropical rainforest:** the most species-rich and structurally complex forest type; found in southern Nigeria (Cross River, Edo, Ondo states); receives more than 1,500 mm annual rainfall; supports high-value timbers including Khaya, Entandrophragma, and Milicia excelsa.

Concept Check Questions [Series 1]

Objective Questions

1. The FAO definition of forest requires a minimum canopy cover of _____ percent and trees able to reach a height of at least 5 m. (Linked to SLO 1.1)
2. Nigeria has the largest _____ forest in Africa, covering approximately 1.0 million ha along its coastline and estuaries. (Linked to SLO 1.1)
3. DBH is measured at _____ m above ground and is the primary measurement used in forest inventory to estimate timber volume. (Linked to SLO 1.3)
4. The Forestry Research Institute of Nigeria (FRIN) is headquartered in _____ and was established in 1954 as the Forest Research Station. (Linked to SLO 1.4)
5. The allowable annual cut (AAC) in sustained yield management equals the total standing volume divided by the _____ age. (Linked to SLO 1.3)

Short-Answer Questions

6. Define a forest and distinguish it from a savanna woodland using two criteria. (Linked to SLO 1.1)
7. Name four types of forests in Nigeria and state one dominant tree species for each. (Linked to SLO 1.1)
8. Explain the sustained yield principle and calculate the AAC for a forest with 600,000 m3 of standing timber and a 30-year rotation. (Linked to SLO 1.3)
9. Describe the role of FRIN and the National Park Service in Nigerian forest governance. (Linked to SLO 1.4)
10. Distinguish between a forest reserve and a national park in Nigeria under the headings of legal basis, managing authority, and permitted activities. (Linked to SLO 1.5)

Long-Answer Questions

11. Describe the types of forests found in Nigeria, their geographical distribution, dominant species, and the ecological and economic functions they provide. (Linked to SLOs 1.1, 1.2)
12. Explain the principles of forest management (sustained yield and multiple use), describe the key mensuration measurements used in forest inventories, and outline the

development of Nigerian forest policy and the institutions responsible for forest governance. (Linked to SLOs 1.3, 1.4, 1.5)

Answers to Concept Check Questions [Series 1]

Objective Questions

1. 10.
2. Mangrove.
3. 1.3.
4. Ibadan.
5. Rotation.

Short-Answer Questions

6. A forest is land with more than 10 percent canopy cover and trees able to reach a minimum height of 5 m (FAO). It differs from savanna woodland in: (1) canopy cover exceeding 10 percent versus the more open savanna structure; (2) a multilayered canopy with emergent, main canopy, understorey, and ground layers, compared with a single discontinuous tree layer over grass in savanna.
7. Lowland rainforest (south; Khaya senegalensis/Milicia excelsa); mangrove forest (coast; Rhizophora racemosa); Guinea savanna woodland (central belt; Isoberlinia doka); Sudan savanna (north; Acacia senegal).
8. Sustained yield means the annual harvest must not exceed annual increment, maintaining forest productivity indefinitely. AAC = 600,000 / 30 = 20,000 m3 per year.
9. FRIN (Forestry Research Institute of Nigeria; Ibadan): conducts research on forest species, silviculture, and forest products; manages federal forest reserves; provides training and advisory services to state forestry departments. National Park Service (NPS): established 1991; manages Nigeria's seven national parks for biodiversity conservation, research, and ecotourism; excludes settlement and extractive activities.
10. Forest reserve: gazetted under state forest law; managed by state forestry departments; limited timber extraction, NTFP collection, and farming on degraded areas may be permitted. National park: established by federal law (National Parks Decree 1991); managed by the National Park Service; settlement and extraction prohibited; conservation, research, and ecotourism are the primary objectives.

Long-Answer Questions

11. Nigeria has seven main forest types. Lowland tropical rainforest (south: Cross River, Edo, Ondo, Delta; above 1,500 mm rainfall; Khaya, Entandrophragma, Milicia excelsa, Terminalia superba; most species-rich; supplies high-value timber). Freshwater swamp forest (river floodplains; seasonally waterlogged; Mitragyna ciliata, Anthocleista; watershed function). Mangrove forest (coastline and estuaries; largest in Africa, 1.0 million ha; Rhizophora racemosa, Avicennia germinans; coastal protection, fisheries nursery, blue carbon). Guinea savanna woodland (central belt; 1,000 to 1,500 mm rainfall; Isoberlinia doka, Daniellia oliveri, Vitellaria paradoxa; most extensive zone; fuelwood, shea butter). Sudan savanna (northern Nigeria; Acacia, Balanites aegyptiaca; gum arabic, fuelwood). Sahel savanna (far north; semi-arid; Acacia senegal, Adansonia digitata; gum arabic). Montane forest (Jos, Obudu, Mambilla plateaus; Podocarpus milanjianus; biodiversity refugia). Functions: productive (timber, fuelwood, NTFPs for 70% of households); protective (watershed, soil conservation, coastal protection); cultural (sacred sites, traditional medicine, recreation); environmental (carbon storage 250 t/ha; biodiversity hotspot; water cycle regulation).
12. Sustained yield: annual harvest must not exceed annual increment; AAC = standing volume / rotation; maintains productive capacity indefinitely. Multiple use: forests managed for several simultaneous objectives (timber, NTFPs, biodiversity, watershed, recreation, carbon) through zoning; sustainable forest management (SFM) extends this to environmental and social sustainability. Key mensuration measurements: DBH (diameter at 1.3 m; diameter tape; cm); height (hypsometer or Suunto clinometer; m); basal area (pi/4 x DBH2; m2; stand basal area summed per ha); volume (from DBH and height using volume tables; m3); MAI (volume / age; used to set rotation). Forest policy history: 1901 Forest Ordinance (colonial; legal basis for reservation); 1930s Forestry Department in all regions; 1960s and 1970s oil boom (forest converted to agriculture); 1988 National Policy on Environment (called for reforestation); 2006/2011 National Forest Policy (targets for cover increase and community forestry); REDD+ since 2012 (financial incentives for carbon conservation). Institutions: FMEnv (national policy); FRIN Ibadan (research; federal reserves); National Park Service (7 national parks; 2.4 million ha); state forestry departments (1,134 forest reserves; 9.6 million ha). Forest reserve vs national

park: legal basis (state law vs federal decree); managing authority (state vs NPS); extraction (limited vs prohibited); settlement (limited vs prohibited).

Answers to Pilot Questions [Series 1]

Part 1.1

1. FAO definition: forest is land spanning more than 0.5 ha with trees above 5 m and canopy cover exceeding 10 percent, excluding land under agricultural or urban use. Two distinctions from savanna woodland: (1) canopy cover exceeds 10 percent in forest versus below 10 percent in savanna woodland; (2) forest has a multilayered canopy (emergent, main canopy, understorey, ground) versus the single discontinuous tree layer typical of savanna woodland.
2. Lowland tropical rainforest (southern Nigeria; Khaya senegalensis/African mahogany). Mangrove forest (coastal/estuarine; Rhizophora racemosa). Guinea savanna woodland (central belt; Isoberlinia doka). Sudan savanna (northern Nigeria; Acacia senegal).
3. Lowland rainforest: found in the humid southern zone (Cross River, Edo, Ondo); dominant species include Khaya, Entandrophragma, and Milicia excelsa; functions include timber production, carbon storage, and biodiversity conservation. Mangrove forest: found along the coast and in the Niger Delta estuaries; dominant species Rhizophora racemosa and Avicennia germinans; functions include coastal protection, fisheries nursery habitat, and blue carbon storage.
4. Four productive functions: (1) timber for construction and furniture; (2) fuelwood and charcoal (70 percent of Nigerian households); (3) NTFPs (bushmeat, medicinal plants, honey, rattan); (4) fodder for livestock. Two protective functions: (1) watershed protection (regulates stream flow, reduces runoff, recharges groundwater); (2) soil conservation (tree roots bind soil; leaf litter reduces erosion).
5. Loss of mangrove forest reduces coastal protection, exposing shoreline communities to storm surge and erosion. It also destroys nursery habitats for commercially important fish and crustaceans, reducing fisheries productivity on which Niger Delta communities

depend. Additionally, mangrove soils store large quantities of blue carbon; their destruction releases stored carbon as greenhouse gases.

Part 1.2

1. Emergent layer (40 to 60 m; Ceiba pentandra/kapok). Main canopy (25 to 40 m; Khaya senegalensis/African mahogany). Understorey (10 to 25 m; Dracaena species). Shrub and ground layer (0 to 10 m; ferns, seedlings, mosses).
2. In tropical forests, most nutrients are held in the living biomass (trees, shrubs, and roots) rather than in the soil. Nutrient cycling is rapid: dead organic matter is quickly decomposed by fungi and bacteria and nutrients are immediately re-absorbed by tree roots. When trees are felled and removed, the nutrient capital leaves with the logs; the remaining soil is nutrient-poor and supports only a limited second crop before productivity declines further.
3. Deforestation (clears forest permanently; destroys biodiversity and watershed function). Selective logging (damages 30 to 60 percent of remaining trees; opens forest to encroachment). Bush burning (prevents forest regeneration; reduces woody biomass in savanna-forest margins). Oil pollution (destroys mangrove and swamp forest in Niger Delta; kills aquatic organisms).
4. Ecosystem services are benefits people obtain from ecosystems. Provisioning: food (bushmeat, fruits, nuts) and fibre (timber, rattan). Regulating: climate regulation through carbon sequestration and local rainfall generation via evapotranspiration; flood regulation by reducing peak runoff in river catchments.
5. Fisheries: mangroves serve as nursery habitats for commercially important fish species (e.g. Ethmalosa fimbriata, Mugil cephalus) and crustaceans (shrimps, crabs); loss of mangrove directly reduces offshore fishery productivity. Carbon storage: waterlogged mangrove soils accumulate large amounts of organic matter that cannot decompose under anaerobic conditions; these blue carbon stores can contain more carbon per hectare than upland tropical forests.

Part 1.3

1. Forest management is the planning and implementation of practices for stewardship and use of forests to meet environmental, economic, social, and cultural objectives while

maintaining ecological integrity. Four goals: (1) sustained timber and NTFP production; (2) biodiversity maintenance; (3) watershed and soil protection; (4) carbon sequestration and climate change mitigation.

2. Sustained yield means annual harvest must not exceed annual growth increment, so forest productivity is maintained indefinitely. AAC = 800,000 / 40 = 20,000 m3 per year.
3. Sustained yield focuses specifically on maintaining the productive output (timber or NTFPs) at a constant level indefinitely by matching harvest to increment. Multiple use extends the concept to managing the same forest area for several objectives simultaneously (timber, wildlife, water, recreation, NTFPs), requiring spatial zoning to separate compatible and incompatible activities.
4. DBH: diameter of tree stem at 1.3 m above ground; used to calculate basal area and estimate volume in forest inventory. Basal area: cross-sectional area of stem at 1.3 m = pi/4 x DBH2; stand basal area (m2/ha) indicates stocking density and is used to set thinning and harvesting intensity. MAI (mean annual increment): total volume / age; the optimal rotation is the age at which MAI is maximised (where MAI = current annual increment).
5. Sustainable forest management (SFM) is the management of forests to meet current needs without compromising the ability of future generations to meet their needs; it integrates economic (timber, NTFPs), environmental (biodiversity, carbon, watershed), and social (community livelihoods, cultural values) objectives. The Forest Stewardship Council (FSC) certifies forests managed according to SFM principles.

Part 1.4

1. 1901: first Forest Ordinance enacted; legal basis for forest reservation established. 1930s: Forestry Department established in all regions; network of forest reserves being gazetted; primary goal was sustained timber supply for export and public works. 1960s to 1970s: at independence and during the oil boom, forests were converted to agriculture (cocoa, rubber, food crops) with government encouragement. 1988: National Policy on Environment called for reforestation but implementation was weak. 2006/2011: National Forest Policy set targets for increasing forest cover, promoting community forestry, and

strengthening law enforcement. 2012 onwards: REDD+ programme launched, providing financial incentives for forest carbon conservation.

2. FRIN (Forestry Research Institute of Nigeria; Ibadan): conducts research on forest species, silviculture, and wood utilisation; provides training for forestry professionals; manages federal forest reserves; and offers advisory services to state forestry departments. Two research functions: (1) developing improved planting stock and silvicultural techniques for plantation establishment; (2) characterising the properties of Nigerian timber species to inform utilisation and marketing.
3. Forest reserve: gazetted under state forest law; managed by state forestry departments; limited timber extraction, NTFP collection, and farming in degraded zones may be permitted. National park: established by Federal National Parks Decree 1991; managed by the National Park Service; human settlement and all extractive activities (logging, farming, hunting) are prohibited; objectives are biodiversity conservation, research, and ecotourism.
4. Yankari National Park (Bauchi State). Cross River National Park (Cross River State). Gashaka-Gumti National Park (Adamawa and Taraba States).
5. REDD+ stands for Reducing Emissions from Deforestation and Forest Degradation plus the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks. It is an international climate finance mechanism under the UNFCCC that pays developing countries for verified reductions in forest carbon emissions. It is relevant to Nigeria because the country has high deforestation rates; if forest conservation can be quantified and credited, it provides an additional financial incentive for both government and local communities to protect forests beyond the value of extractive uses.

References and Attributions [Series 1]

Textual References (Books and External Sources)

- FAO. (2020). Global forest resources assessment 2020. Food and Agriculture Organization of the United Nations, Rome.
- Ola-Adams, B. A. (1993). Forestry in Nigeria: History and development. Forestry Research Institute of Nigeria, Ibadan.
- Chukwu, O., & Oladele, A. T. (2015). Status of forest reserves in Nigeria. Journal of Forestry Research and Management, 12(1), 1-18.
- Millennium Ecosystem Assessment. (2005). Ecosystems and human well-being: Synthesis. Island Press, Washington, DC.
- National Forest Policy of Nigeria. (2006, revised 2011). Federal Ministry of Environment, Abuja.

Figures, Plates, Tables, and Boxes

- Figure 1.1: Structure and energy flow in a Nigerian tropical rainforest ecosystem. Attribution: AI generated. Suggested OER search string: “tropical rainforest ecosystem layers energy flow Nigeria diagram OER”.
- Box 1.1: Comparison of forest reserves, game reserves, and national parks in Nigeria. Attribution: AI generated. Suggested OER search string: “Nigeria forest reserve game reserve national park comparison protected area categories OER”.

Course code: AGE 203

Course title: Forest Management Education

Course credit load: 2 Units

Series 2: Renewable Resources and Distribution

- **Part 2.1: Concept of Natural Resources**
  - Sub Part 2.1.1: Definition and classification of natural resources
  - Sub Part 2.1.2: Renewable versus non-renewable resources
  - Sub Part 2.1.3: Importance of natural resources to Nigeria
- **Part 2.2: Renewable Forest Resources**
  - Sub Part 2.2.1: Timber as a renewable forest resource
  - Sub Part 2.2.2: Non-timber forest products (NTFPs)
  - Sub Part 2.2.3: Water and soil as forest-dependent renewable resources
- **Part 2.3: Distribution of Forest Resources in Nigeria**
  - Sub Part 2.3.1: Geographical distribution of Nigerian forest resources
  - Sub Part 2.3.2: Factors determining resource distribution
  - Sub Part 2.3.3: Forest resource mapping and inventory in Nigeria
- **Part 2.4: Sustainability and Conservation of Renewable Resources**
  - Sub Part 2.4.1: Threats to renewable resource sustainability
  - Sub Part 2.4.2: Conservation strategies for forest resources
  - Sub Part 2.4.3: Community-based natural resource management in Nigeria

Introduction

Natural resources are the raw materials and environmental conditions provided by nature upon which human survival and economic development depend. Among the most important of these are forest resources: timber, non-timber forest products, water, biodiversity, and the ecological processes that sustain them. Understanding the nature, distribution, and sustainable management of renewable forest resources is central to the work of the forest manager.

This Series examines the concept of renewable natural resources with emphasis on forest resources in Nigeria. It covers the classification of natural resources, the character and economic value of Nigeria's major forest resources, their geographical distribution and the factors that determine this distribution, the threats they face, and the conservation and community-based management strategies available to sustain them for future generations.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 2.1** define natural resources and distinguish between renewable and non-renewable resources with examples from Nigeria (Linked to Part 2.1),
- **SLO 2.2** describe the major renewable forest resources of Nigeria, including timber, NTFPs, water, and soil (Linked to Part 2.2),
- **SLO 2.3** describe the geographical distribution of forest resources across Nigeria and explain the factors that determine this distribution (Linked to Part 2.3),
- **SLO 2.4** identify the principal threats to renewable resource sustainability in Nigeria (Linked to Part 2.4), and
- **SLO 2.5** describe conservation strategies and community-based natural resource management approaches relevant to Nigerian forest resources (Linked to Part 2.4).

2.1 Concept of Natural Resources

2.1.1 Definition and classification of natural resources

A natural resource is any material or energy source found in the natural environment that is useful to humans and can be extracted or harvested for economic or subsistence purposes. Natural resources are classified in several ways. By origin: biotic resources (derived from living organisms: timber, wildlife, fish, NTFPs) and abiotic resources (derived from non-living matter: minerals, soil, water, solar energy, wind). By availability: stock resources (finite quantities accumulated over geological time: coal, petroleum, mineral ores) and flow resources (renewed continuously by natural processes: solar radiation, wind, flowing water, tidal energy). By renewability: renewable resources (can be replenished naturally within a human time frame if not overexploited) and non-renewable resources (cannot be replenished within a human time frame once depleted).

A further classification recognises: actual resources (currently known and economically exploitable with existing technology: petroleum in the Niger Delta, timber in Cross River State) and potential resources (known to exist but not yet economically exploitable due to lack of technology or infrastructure: deep-sea minerals; sub-Saharan solar energy at commercial scale). Ubiquitous resources (found everywhere: air, sunlight) are distinguished from localised resources (restricted to specific geological or ecological settings: tropical hardwood timber; crude oil). This classification framework helps planners allocate resources efficiently and prioritise conservation efforts.

Fill in the blank: Natural resources are classified by renewability as _____ resources (replenishable within a human time frame) and non-renewable resources (depleted permanently once used); examples of the former in Nigeria include timber and NTFPs, while petroleum is an example of the latter.

2.1.2 Renewable versus non-renewable resources

Renewable resources are those that are regenerated by natural ecological or biogeochemical processes at rates sufficient to sustain continued human use, provided the rate of extraction does not exceed the rate of renewal. Examples from Nigeria: timber (trees grow back if the forest is not cleared; sustained yield harvesting maintains long-term productivity); freshwater (replenished by rainfall and hydrological cycling; watershed forests maintain recharge); fish (populations recover if harvested below maximum sustainable yield); NTFPs such as honey, rattan, and medicinal plants; fertile soil (rebuilt by organic matter decomposition and mineral weathering over decades to centuries); and biodiversity (species populations recover if habitat is maintained and hunting is controlled).

Non-renewable resources, once consumed, cannot be replaced within any practical human time frame. Nigerian examples: crude petroleum (the Niger Delta oil fields took millions of years to form; at current extraction rates reserves will last only decades); natural gas; coal (Enugu coal fields); and mineral ores (iron ore at Itakpe; limestone; tin ore from the Jos Plateau). The distinction between renewable and non-renewable is not always sharp: soil can be renewable over centuries but non-renewable on a human agricultural time scale if eroded; groundwater in deep aquifers is effectively non-renewable; fisheries collapse permanently if pushed beyond the point of no return.

Fill in the blank: Freshwater is a _____ resource because it is replenished continuously by rainfall and the hydrological cycle; however, if forest cover that maintains watershed recharge is removed, the effective availability of freshwater may decline permanently.

2.1.3 Importance of natural resources to Nigeria

Nigeria is richly endowed with natural resources that underpin its economy and the livelihoods of its people. Petroleum and natural gas (Niger Delta; Akwa Ibom, Rivers, Delta, Bayelsa, Ondo, Edo states): Nigeria is Africa's largest oil producer and holds the largest proven natural gas reserves on the continent; oil and gas revenues account for approximately 70 to 90 percent of government revenue and 90 percent of export earnings, making the Nigerian economy highly dependent on a non-renewable resource. Solid minerals: tin ore (Jos Plateau); coal (Enugu);

limestone (Ewekoro, Yandev, Ashaka; basis of the cement industry); iron ore (Itakpe, Ajaokuta); gold (Zamfara, Kebbi, Niger State); and gemstones (Plateau State).

Agricultural land and forests: Nigeria has approximately 70.8 million ha of land; approximately 34 million ha are arable; forests and woodlands cover approximately 9 to 12 million ha (depending on definition). These are the primary natural resource base for approximately 70 percent of the Nigerian population who depend on agriculture and forestry for food and income. Freshwater resources: Nigeria's major river systems (Niger, Benue, Cross River, Ogun, Osun, Sokoto, Hadejia) and lakes (Lake Chad, Kainji Reservoir) support fisheries, irrigation, municipal water supply, and hydroelectric power. The sustainable management of these renewable resources is critical to Nigeria's long-term development, reducing dependence on petroleum revenue.

Fill in the blank: Petroleum and natural gas account for approximately _____ percent of Nigeria's export earnings, making the country highly dependent on a non-renewable resource; diversification into sustainable management of renewable resources (agriculture, forestry, fisheries) is a national development priority.

Pilot questions 2.1

1. Define a natural resource and distinguish between biotic and abiotic resources with two Nigerian examples of each.
2. Explain the difference between renewable and non-renewable resources. Give three examples of each from Nigeria.
3. Distinguish between actual and potential natural resources with one Nigerian example of each.
4. Explain why soil can be regarded as both renewable and non-renewable depending on the time scale considered.
5. State four natural resources found in Nigeria and explain the economic importance of each to the national economy.

2.2 Renewable Forest Resources

2.2.1 Timber as a renewable forest resource

Timber is wood harvested from forests for use in construction, furniture, pulp and paper, fuel, and industrial processing. It is a renewable resource because trees regenerate naturally from seeds and resprouting stumps after harvesting, provided sufficient seed trees remain and the site is not converted to another land use. The renewability of timber depends critically on management: under sustained yield forestry (Series 1), the allowable annual cut is limited to the annual increment, ensuring permanent productivity. Under unmanaged exploitation, repeated high-grade logging rapidly depletes the most valuable species, leaving a degraded forest incapable of producing commercial timber.

Nigeria's principal commercial timber species, their properties, and uses: Khaya senegalensis and K. ivorensis (African mahogany; reddish-brown; fine grain; furniture, panelling, boat-building; most heavily exploited Nigerian species); Entandrophragma cylindricum (sapele; interlocked grain; furniture, veneer, flooring); Entandrophragma utile (utile; less interlocked than sapele; furniture, joinery); Milicia excelsa (iroko; very durable; outdoor construction, bridge decking; comparable to teak); Terminalia superba (afara/limba; light-coloured; plywood, furniture); Triplochiton scleroxylon (obeche/wawa; lightweight; plywood, packing cases, interior joinery); and Nauclea diderrichii (opepe; orange-yellow; very durable; heavy construction, marine piling). Nigeria's timber export peaked in the 1960s and has since collapsed due to deforestation and overexploitation.

Fill in the blank: Milicia excelsa, known commercially as _____, is a highly durable Nigerian timber species comparable to teak; it is widely used in outdoor construction and bridge decking and is among the most valuable commercial timber species in West Africa.

2.2.2 Non-timber forest products (NTFPs)

Non-timber forest products (NTFPs) are all forest-derived goods other than timber: plant products (fruits, seeds, leaves, bark, roots, resins, gums, dyes, latex, medicinal plants, rattan, bamboo) and animal products (bushmeat, honey, insects, snails, fish from forest streams). NTFPs are economically and nutritionally vital to rural communities across Nigeria: they provide food security (bushmeat is the primary protein source for many forest-edge communities in southern

Nigeria), cash income (rattan furniture, medicinal herb trade, honey), and traditional medicines (an estimated 80 percent of Nigerians rely primarily on plant-based traditional medicine). The NTFP trade in Nigeria is largely informal and unquantified but estimated to be worth billions of naira annually.

Important NTFPs in Nigeria: Irvingia gabonensis (African mango/bush mango; seeds used for ogbono soup; fruit flesh edible; widely traded across southern Nigeria); Garcinia kola (bitter kola; seeds chewed as a stimulant and used in traditional medicine; highly valued); Cola nitida and C. acuminata (kola nut; stimulant; ceremonial use; important in Yoruba and Igbo cultural traditions); Vitellaria paradoxa (shea butter; Butyrospermum parkii; kernel fat used in food, cosmetics, and pharmaceuticals; primary income source for women in the Nigerian Guinea savanna); Acacia senegal (gum arabic; sap used as food additive, adhesive, and pharmaceutical excipient; Sahelian Nigeria); rattan (Calamus species; widely harvested for furniture; Ondo, Ogun, Cross River states); and honey (Apis mellifera; harvested from wild and kept colonies throughout Nigeria).

Fill in the blank: Vitellaria paradoxa, commonly known as the _____ tree, produces kernel fat that is extracted as shea butter; it is the primary income source for women in Nigeria's Guinea savanna zone and is used in food, cosmetics, and pharmaceutical products.

2.2.3 Water and soil as forest-dependent renewable resources

Forests play a critical role in maintaining the quality and quantity of freshwater resources. Forest canopies intercept rainfall, reducing the kinetic energy of raindrops and preventing soil surface sealing. Deep tree roots create macropores that enhance soil infiltration, reducing surface runoff and increasing groundwater recharge. Evapotranspiration from forest canopies returns moisture to the atmosphere, contributing to local and regional rainfall patterns (approximately 40 to 60 percent of Amazonian rainfall is generated by the forest itself; similar processes operate in the Congo Basin and in the Nigerian rainforest zone). Riverine (riparian) forests along stream banks filter sediment and nutrients from agricultural runoff before they reach watercourses, maintaining water quality downstream.

Soil is a renewable resource over the long term but can be irreversibly degraded by deforestation. Forest litter (leaf fall, dead wood, bark) forms a continuous layer on the forest floor that protects the mineral soil surface from raindrop impact and surface flow, maintains soil organic matter content, and supports a diverse decomposer community (earthworms, fungi, bacteria) that maintains soil structure and fertility. When forest is cleared, the litter layer disappears, soil organic matter oxidises within a few years, surface runoff increases, and erosion by water accelerates. In southern Nigeria, highly weathered, iron-rich Ultisol and Oxisol soils under cleared forest are particularly susceptible to gully erosion (oke-orite); in the north, harmattan winds erode exposed sandy soils in cleared savanna.

Fill in the blank: Forest canopies intercept rainfall and deep tree roots enhance soil _____, increasing groundwater recharge and reducing surface runoff; when forests are cleared, infiltration declines, runoff increases, and soil erosion accelerates rapidly.

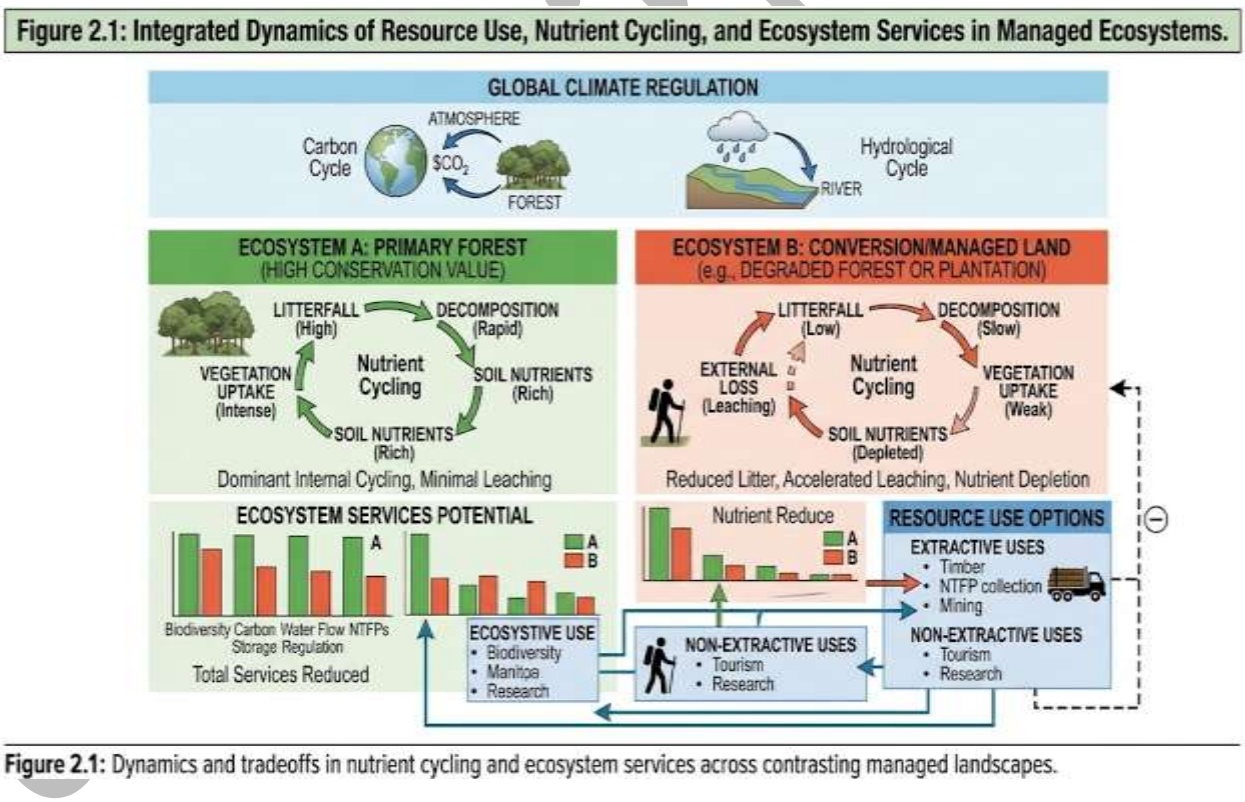

Figure 2.1: Hydrological functions of a Nigerian forest catchment compared with a deforested catchment

Pilot questions 2.2

1. Define timber as a renewable resource and state the condition under which its renewability is maintained.
2. Name five Nigerian commercial timber species and state one characteristic property and one major use of each.
3. Define NTFPs and give four examples of plant NTFPs and two examples of animal NTFPs important in Nigeria.
4. Explain two economic roles that NTFPs play in rural Nigerian communities.
5. Describe three ways in which forests maintain the quality and quantity of freshwater in Nigerian river catchments.

2.3 Distribution of Forest Resources in Nigeria

2.3.1 Geographical distribution of Nigerian forest resources

Nigeria's forest resources are unevenly distributed, reflecting the country's strong north-south rainfall gradient and the associated vegetation zones described in Series 1. Timber resources: concentrated in the humid forest states of the south (Cross River, Edo, Ondo, Ogun, Delta, Rivers, Bayelsa, Lagos, Ekiti, Osun, and Oyo states); Cross River State contains the largest remaining block of lowland tropical rainforest in Nigeria (approximately 900,000 ha including Cross River National Park and surrounding forest reserves); Edo State (Okomu National Park; Omo Forest Reserve) and Ondo State (Omo-Shasha-Oluwa Forest Reserve) also contain significant timber resources. The south-south and south-west geopolitical zones account for more than 80 percent of Nigeria's remaining closed-canopy forest.

NTFPs: distributed across all vegetation zones but species composition varies by zone. Shea butter (Vitellaria paradoxa) is concentrated in the Guinea savanna of Kwara, Kogi, Niger, Oyo, Osun, Ekiti, Benue, Nasarawa, and Plateau states; gum arabic (Acacia senegal) in Sokoto, Kebbi, Zamfara, Katsina, Kano, Jigawa, Yobe, and Borno states; kola nut (Cola nitida) in Ondo, Ogun, Osun, and Cross River states; bitter kola (Garcinia kola) in Cross River and Edo states; rattan in Ondo, Ogun, Oyo, and Cross River states. Medicinal plants are harvested throughout the country

but the highest diversity is in the southern rainforest zone. Bushmeat is most intensively harvested in the forest-savanna transition zones of Kwara, Oyo, Benue, and Cross River states.

Fill in the blank: Cross River State contains the largest remaining block of lowland tropical rainforest in Nigeria, covering approximately _____ ha including Cross River National Park and surrounding forest reserves; it has the highest timber species diversity in the country.

2.3.2 Factors determining resource distribution

The distribution of forest resources across Nigeria is determined by a combination of climatic, edaphic (soil), topographic, and human factors. Climate: rainfall amount and seasonality is the primary determinant; the southern humid zone (more than 1,500 mm/year; 9 to 12 wet months) supports closed rainforest with high timber diversity; the Guinea savanna (1,000 to 1,500 mm/year; 6 to 8 wet months) supports woodland with shea butter and other savanna species; the Sudan and Sahel savannas (below 1,000 mm/year; 3 to 5 wet months) support sparse tree cover with Acacia and gum-producing species. Temperature: forests at higher elevations on the Jos Plateau, Obudu Plateau, and Mambilla Plateau are cooler and support different species assemblages (Podocarpus, Syzygium) from those of the lowlands.

Soil type: deep, well-drained Ultisols and Oxisols of the south support closed rainforest; shallow, seasonally waterlogged soils support freshwater swamp forest (Mitragyna); saline and waterlogged mangrove soils support mangrove communities. Topography: valley bottoms and river floodplains support swamp forests; upland ridges support drier forest types; steep slopes maintain forest because they are less accessible to farmers. Human factors: areas near roads and settlements have been cleared for agriculture; traditional and customary protection (sacred groves, community forests) has preserved patches of forest in otherwise cleared landscapes; colonial forest reservation protected large blocks in the south while the north was largely left unprotected.

Fill in the blank: The primary climatic factor determining the distribution of forest types across Nigeria is annual _____ amount and seasonality; areas receiving more than 1,500 mm per

year with 9 to 12 wet months support closed rainforest, while drier areas support woodland and savanna vegetation.

2.3.3 Forest resource mapping and inventory in Nigeria

Accurate information on the distribution, quantity, and condition of forest resources is essential for management planning, policy formulation, and investment decisions. Forest resource mapping in Nigeria uses: (1) Remote sensing: satellite imagery (Landsat, Sentinel-2, MODIS) is used to map vegetation cover, monitor deforestation rates, and identify forest degradation at national and state scales; the National Space Research and Development Agency (NASRDA) and the Forestry Research Institute of Nigeria (FRIN) use satellite data to produce national land cover maps. (2) Forest inventory: systematic sampling of trees within plots to estimate standing timber volumes, species composition, basal area per ha, and stem density; Nigerian forest reserves have been inventoried using systematic grid or strip sampling with plots of 0.1 to 0.25 ha at intervals of 250 to 500 m.

(3) Geographic Information Systems (GIS): spatial databases combining remotely sensed imagery with field inventory data, administrative boundaries, topographic maps, and soil maps to produce forest resource maps for planning. (4) National forest assessment: the FAO Global Forest Resources Assessment collects country-level data from Nigeria every five years; the most recent data (2020) estimate Nigeria's total forest area at approximately 6.6 million ha (7.2 percent of land area), compared with an estimated 17 million ha in 1990, indicating a loss of approximately 10.4 million ha over 30 years. These assessments document the severity of Nigeria's deforestation problem and provide the baseline data needed for REDD+ carbon accounting.

Fill in the blank: Satellite imagery from platforms such as Landsat and Sentinel-2 is used by NASRDA and FRIN to map vegetation cover and monitor _____ rates at national and state scales in Nigeria; this remote sensing data is combined with field inventory data using GIS for forest management planning.

Pilot questions 2.3

1. Name three states in Nigeria with the largest remaining areas of closed-canopy tropical rainforest and state one important forest reserve or national park in each.
2. Explain how rainfall amount and seasonality determines the distribution of forest types across Nigeria from south to north.
3. State three states where shea butter (Vitellaria paradoxa) is commercially important and explain why it is concentrated in this zone.
4. Describe two methods used for forest resource mapping and inventory in Nigeria and state one advantage of each.
5. What does the FAO 2020 estimate of Nigeria's forest area indicate about the rate of deforestation since 1990?

2.4 Sustainability and Conservation of Renewable Resources

2.4.1 Threats to renewable resource sustainability

Nigeria's renewable forest resources face multiple, overlapping threats. (1) Deforestation and land conversion: agricultural expansion (subsistence farming, large-scale plantations of oil palm, cassava, and cocoa) is the primary driver; Nigeria's deforestation rate was approximately 400,000 ha per year in the early 2000s (World Bank), one of the highest globally. (2) Overexploitation of timber: selective high-grading (removing only the most valuable species at each logging entry) has eliminated commercially viable stocks of Khaya, Entandrophragma, and Milicia from most accessible forest reserves; log export bans (first imposed in 1976) have been inconsistently enforced. (3) Overexploitation of NTFPs: bushmeat hunting using wire snares and firearms has driven many mammal species (forest elephants, chimpanzees, forest buffaloes, African grey parrots) to local extinction in most Nigerian forests; unsustainable harvest of rattan, medicinal plants, and fuelwood depletes stocks faster than they regenerate.

(4) Bush burning: annual burning of savanna and forest margins during the dry season suppresses tree regeneration, maintains grass dominance, and prevents the southward advance of forest into savanna; it also kills wildlife and destroys NTFP-producing plants. (5) Charcoal production: the demand for charcoal as a cooking fuel in Nigerian cities (Lagos, Abuja, Kano, Port Harcourt)

drives large-scale harvesting of woody biomass from savanna woodlands; an estimated 50 to 70 million tonnes of fuelwood and charcoal are consumed annually in Nigeria. (6) Climate change: altered rainfall patterns, prolonged dry seasons, and increased frequency of extreme weather events are reducing forest productivity and shifting vegetation zone boundaries northward, threatening the survival of forest-dependent species and communities.

Fill in the blank: Nigeria's deforestation rate was approximately _____ ha per year in the early 2000s, driven primarily by agricultural expansion; this rate is among the highest globally and has resulted in the loss of approximately 10.4 million ha of forest between 1990 and 2020.

2.4.2 Conservation strategies for forest resources

Conservation of Nigeria's renewable forest resources requires a combination of in situ (on-site) and ex situ (off-site) strategies. In situ conservation: (1) Protected area network: Nigeria's 7 national parks, 12 game reserves, and 1,134 forest reserves provide in situ protection for forest biodiversity and resources; however, effective management of most reserves is compromised by inadequate funding, staffing, and enforcement. (2) Sustainable forest management (SFM): applying reduced-impact logging (RIL) techniques within timber concessions (pre-harvest inventory, directional felling, extraction road planning, slash disposal) reduces the collateral damage of logging; FSC certification provides market incentives for SFM. (3) Reforestation and afforestation: planting trees on degraded forest land (reforestation) or on non-forest land (afforestation) to restore ecosystem functions; Nigeria's Green Wall Sahara Initiative plants drought-resistant species along the Sahel border to combat desertification.

Ex situ conservation: gene banks, botanical gardens (University of Ibadan Botanical Garden; Obafemi Awolowo University Botanical Garden; Federal College of Forestry Ibadan arboretum), and seed orchards maintain planting material of threatened or commercially important forest tree species. Policy and legal instruments: the National Forest Policy (2006/2011) sets the framework; CITES (Convention on International Trade in Endangered Species) regulates trade in

threatened species (e.g. African rosewood Pterocarpus erinaceus; listed CITES Appendix II); REDD+ provides financial incentives for carbon conservation. Economic instruments: payment for ecosystem services (PES) schemes reward landowners and communities for maintaining forest cover that provides watershed services or carbon storage; ecotourism revenues from national parks provide an alternative income stream.

Fill in the blank: Reduced-impact logging (RIL) techniques include pre-harvest _____, directional felling, and planned extraction road layouts; these practices reduce the collateral damage caused by conventional logging and are required for Forest Stewardship Council (FSC) certification.

2.4.3 Community-based natural resource management in Nigeria

Community-based natural resource management (CBNRM) involves giving local communities rights, responsibilities, and incentives to manage natural resources sustainably. The rationale is that communities living adjacent to forests have the greatest stake in their long-term productivity and the most detailed knowledge of local ecology; if they receive tangible benefits from conservation, they are more likely to protect forest resources than if management decisions are imposed from outside. CBNRM approaches in Nigerian forestry: community forestry (legally designated areas in which local communities have harvesting and management rights under supervision of state forestry departments); collaborative forest management (joint management between state forestry authority and local communities, with revenue-sharing arrangements); sacred groves (traditional community conservation of forest patches with spiritual significance; widely practised in Yoruba, Igbo, and Ijaw communities).

Successful Nigerian examples: the Ekuri Community Forest (Cross River State; 33,600 ha; managed by Ekuri communities since the 1990s; one of the largest community forests in Africa; provides timber, NTFPs, and watershed services); the Omo Forest Reserve collaborative management scheme (Ogun and Oyo states; IITA involvement in NTFP valuation and

community benefit-sharing). CBNRM faces challenges in Nigeria: weak land tenure security (most community lands are not legally registered); elite capture (NTFP revenues may be appropriated by community leaders rather than distributed equitably); and conflict between forest-dependent communities and the state over resource rights. Strengthening land tenure, transparent governance, and equitable benefit-sharing are prerequisites for effective CBNRM.

Fill in the blank: The Ekuri Community Forest in Cross River State covers _____ ha and is one of the largest community forests in Africa; it has been managed by Ekuri communities since the 1990s, providing timber, NTFPs, and watershed services to local populations.

Conservation Strategy	Nigerian Example
Protected Areas	Cross River National Park (biodiversity hotspot managed by National Park Service)
Sustainable Forest Management	Omo Forest Reserve (managed for timber, NTFPs, and biodiversity under multiple-use principles)
Reforestation	Great Green Wall Programme (tree planting in northern Nigeria to combat desertification)
Community-Based NRM	Ekuri Community Forest Project (Cross River State; local community manages forest sustainably)
Payment for Ecosystem Services	UN-REDD+ Programme (financial incentives for carbon sequestration in Nigerian forests)
Ex Situ Conservation	Forestry Research Institute of Nigeria (FRIN) arboretum and gene banks conserving indigenous species outside natural habitats

Box 2.1: Conservation strategies for renewable forest resources in Nigeria with examples

Pilot questions 2.4

1. List four threats to the sustainability of renewable forest resources in Nigeria and briefly describe the impact of each.
2. Distinguish between in situ and ex situ conservation of forest resources and give one Nigerian example of each.
3. Explain the principle of community-based natural resource management (CBNRM) and state one advantage and one challenge of this approach in Nigeria.

4. Describe the Green Wall Sahara Initiative and explain what it aims to achieve in northern Nigeria.
5. Explain how REDD+ can provide a financial incentive for forest conservation in Nigeria.

Series Summary

This Series examined the classification, distribution, use, and conservation of natural resources in Nigeria. Natural resources may be biotic or abiotic, renewable or non-renewable, and actual or potential. Renewable resources such as timber, non-timber forest products, freshwater, soil, and fish can regenerate when properly managed, while petroleum, natural gas, coal, and mineral ores are finite. Important timber species include mahogany, sapele, iroko, obeche, and opepe, while major non-timber forest products include bush mango, bitter kola, kola nut, shea butter, gum arabic, rattan, and honey. Forests also support water and soil conservation by promoting infiltration, groundwater recharge, erosion control, organic-matter formation, and nutrient cycling.

Forest resources are unevenly distributed according to rainfall, soil, topography, vegetation zone, and human activities. Timber resources are concentrated mainly in southern Nigeria, while products such as shea butter and gum arabic are more common in the savanna and Sahel zones. Their distribution and condition are assessed through field inventories, remote sensing, and GIS. Major threats include deforestation, excessive logging, bush burning, charcoal production, bushmeat hunting, and climate change. Conservation measures include protected areas, sustainable forest management, reduced-impact logging, reforestation, community-based forest management, REDD+, botanical gardens, CITES controls, and payment for ecosystem services. These measures are essential for maintaining biodiversity, rural livelihoods, freshwater supplies, soil productivity, and long-term economic development.

Glossary of Terms

- **Acacia senegal:** a leguminous tree of the Sahelian zone of northern Nigeria that produces gum arabic (acacia gum), widely used as a food additive, adhesive, and pharmaceutical excipient.
- **Bushmeat:** wild animal meat harvested from forests and savannas; a major protein source for rural communities and a significant income earner in Nigeria; unsustainable harvest threatens many mammal species.

- **CBNRM (community-based natural resource management):** an approach that gives local communities rights, responsibilities, and incentives to manage natural resources sustainably; includes community forests, collaborative management, and sacred groves.
- **CITES:** the Convention on International Trade in Endangered Species of Wild Fauna and Flora; an international agreement regulating trade in threatened species; relevant to Nigerian timber exports (e.g. Pterocarpus erinaceus listed on Appendix II).
- **Deforestation:** the permanent conversion of forest land to another land use; the primary threat to Nigeria's forest resources, occurring at approximately 400,000 ha per year in the early 2000s.
- **Ekuri Community Forest:** a 33,600 ha community-managed forest in Cross River State; one of the largest community forests in Africa; managed by Ekuri communities since the 1990s for timber, NTFPs, and watershed services.
- **Green Wall Sahara Initiative:** an African Union-led afforestation programme planting a belt of drought-resistant trees and vegetation across the Sahel from Senegal to Djibouti to combat desertification; Nigeria participates through planting in Sokoto, Kebbi, and other northern states.
- **Irvingia gabonensis:** a forest tree of southern Nigeria known as African mango or bush mango; its seeds are used to make ogbono soup and the fruit flesh is edible; an important NTFP widely traded across the south.
- **Milicia excelsa:** commonly known as iroko; a highly durable Nigerian timber species comparable in quality to teak; used in outdoor construction, bridge decking, and heavy joinery; one of the most valuable West African timbers.
- **Non-timber forest products (NTFPs):** all forest-derived goods other than timber; includes plant products (fruits, seeds, bark, resins, medicinal plants, rattan) and animal products (bushmeat, honey, snails); vital to rural livelihoods and food security in Nigeria.
- **Payment for ecosystem services (PES):** an economic instrument that compensates landowners or communities for managing land in ways that provide ecosystem services (watershed protection, carbon sequestration, biodiversity conservation) to downstream or global beneficiaries.
- **REDD+:** Reducing Emissions from Deforestation and Forest Degradation; an international climate finance mechanism providing financial incentives to developing countries for verified reductions in forest carbon emissions through conservation and sustainable management.

- **Reduced-impact logging (RIL):** a set of logging practices that minimise collateral damage to the residual forest; includes pre-harvest inventory, directional felling, planned skid trail layout, and controlled road construction; required for FSC certification.
- **Renewable resource:** a natural resource that is regenerated by natural ecological or biogeochemical processes at rates sufficient to sustain human use, provided the rate of extraction does not exceed the rate of renewal.
- **Vitellaria paradoxa:** the shea butter tree; a savanna species of the Guinea savanna zone of Nigeria; its kernel fat (shea butter) is extracted for food, cosmetics, and pharmaceuticals; the primary income source for women in northern and central Nigeria.

Concept Check Questions [Series 2]

Objective Questions

1. Resources that can be replenished within a human time frame are called _____ resources; petroleum is an example of the opposite category. (Linked to SLO 2.1)
2. Milicia excelsa, known commercially as _____, is a highly durable Nigerian timber comparable to teak and used in outdoor construction. (Linked to SLO 2.2)
3. Vitellaria paradoxa (shea butter tree) is concentrated in Nigeria's _____ savanna zone and is the primary income source for women in that region. (Linked to SLOs 2.2, 2.3)
4. The FAO 2020 Global Forest Resources Assessment estimated Nigeria's forest area at approximately _____ million ha, down from 17 million ha in 1990. (Linked to SLO 2.3)
5. The Ekuri Community Forest in Cross River State covers _____ ha and is one of the largest community forests in Africa. (Linked to SLO 2.5)

Short-Answer Questions

6. Define a renewable resource and give three examples from Nigerian forests. (Linked to SLO 2.1)
7. Name four Nigerian commercial timber species and state one major use of each. (Linked to SLO 2.2)
8. Explain three ways in which forests maintain the quantity and quality of freshwater in Nigerian river catchments. (Linked to SLO 2.2)
9. Describe how rainfall amount and seasonality determines the distribution of forest resources from southern to northern Nigeria. (Linked to SLO 2.3)
10. Explain CBNRM and state one advantage and one challenge of applying it in Nigeria. (Linked to SLO 2.5)

Long-Answer Questions

11. Define and classify natural resources. Describe the major renewable forest resources of Nigeria (timber, NTFPs, water, soil), their economic importance, and the factors determining their geographical distribution. (Linked to SLOs 2.1, 2.2, 2.3)
12. Describe the main threats to renewable forest resource sustainability in Nigeria and explain the conservation strategies and community-based management approaches used to address them. (Linked to SLOs 2.4, 2.5)

Answers to Concept Check Questions [Series 2]

Objective Questions

1. Renewable.
2. Iroko.
3. Guinea.
4. 6.6.
5. 33,600.

Short-Answer Questions

6. A renewable resource is one regenerated by natural ecological processes at rates sufficient for sustained human use. Three examples from Nigerian forests: timber (trees regrow after harvesting if the site is not converted); freshwater (replenished by rainfall and maintained by forest watershed functions); NTFPs such as shea butter nuts (produced annually by Vitellaria trees that regenerate if not cleared).
7. Khaya senegalensis/ivorensis (African mahogany; furniture and panelling). Entandrophragma cylindricum (sapele; veneer and flooring). Milicia excelsa (iroko; outdoor construction and bridge decking). Triplochiton scleroxylon (obeche; plywood and interior joinery).
8. Three ways: (1) canopy interception reduces raindrop impact and surface sealing, increasing soil infiltration and groundwater recharge; (2) evapotranspiration returns moisture to the atmosphere, contributing to local rainfall recycling; (3) riparian forest filters sediment and nutrients from agricultural runoff before they enter watercourses, maintaining downstream water quality.
9. The south (above 1,500 mm/year; 9 to 12 wet months) supports closed tropical rainforest with the highest timber diversity (Khaya, Milicia, Entandrophragma). The Guinea savanna zone (1,000 to 1,500 mm; 6 to 8 wet months) supports open woodland with shea butter (Vitellaria) and Isoberlinia. The Sudan and Sahel savannas (below 1,000 mm; 3 to 5 wet months) support sparse tree cover with Acacia senegal (gum arabic) and Baobab.
10. CBNRM gives local communities rights and responsibilities to manage natural resources sustainably. Advantage: communities with secure resource rights have strong incentives to protect forests, as they receive the direct benefits; their local ecological knowledge improves management outcomes. Challenge: weak land tenure in Nigeria means community resource rights are insecure; elite capture of NTFP revenues by community leaders undermines equitable benefit-sharing and reduces community-wide incentives for conservation.

Long-Answer Questions

11. Natural resources are materials found in nature useful to humans. Classification: biotic (timber, wildlife, fish, NTFPs) vs abiotic (minerals, water, solar energy); renewable (timber, water, NTFPs, soil) vs non-renewable (petroleum, coal, mineral ores); actual vs potential. Timber: renewable under sustained yield; key species: Khaya (mahogany; furniture), Entandrophragma (sapele; veneer), Milicia excelsa (iroko; outdoor construction), Triplochiton (obeche; plywood), Nauclea (opepe; heavy construction); Nigeria's timber export collapsed after 1960s due to overexploitation. NTFPs: Irvingia gabonensis (bush mango; food), Garcinia kola (bitter kola; medicine), Cola nitida (kola nut; ceremony), Vitellaria paradoxa (shea butter; income for women), Acacia senegal (gum arabic; food additive), rattan, honey; vital to rural food security and cash income. Water: forests maintain freshwater through canopy interception, infiltration enhancement, evapotranspiration, groundwater recharge, and riparian filtration. Soil: forest litter protects mineral soil from erosion; organic matter maintains fertility; decomposer community maintains structure; cleared forest soils are prone to gully erosion (southern Nigeria) and wind erosion (north). Distribution: timber concentrated in south (Cross River, Edo, Ondo; Cross River block 900,000 ha); shea butter in Guinea savanna; gum arabic in Sahel. Factors: rainfall amount and seasonality (primary); soil type; topography; human settlement history.
12. Threats: deforestation (400,000 ha/year; agricultural expansion primary driver); timber overexploitation (high-grading depleted Khaya, Milicia from accessible reserves); bushmeat hunting (wire snares and firearms; elephants, chimpanzees, forest buffaloes locally extinct in most reserves); bush burning (suppresses tree regeneration; destroys NTFP plants); charcoal demand (50 to 70 million tonnes of wood fuel annually); climate change (shifting rainfall; longer dry seasons; northward movement of vegetation zones). Conservation strategies: (1) Protected areas (7 national parks; 1,134 forest reserves; Cross River NP; Okomu NP; inadequately funded). (2) SFM with RIL (pre-harvest inventory; directional felling; planned roads; FSC certification incentive). (3) Reforestation/afforestation (Green Wall Sahara Initiative in Sokoto, Kebbi; drought-resistant species). (4) CBNRM (Ekuri Community Forest 33,600 ha; Omo collaborative scheme; sacred groves; transparent revenue-sharing needed). (5) REDD+ (financial incentives for verified carbon conservation; pilot projects in Cross River and Edo). (6) Policy and legal (National Forest Policy 2006/2011; CITES for threatened species; log export ban). (7) Ex situ (botanical gardens; seed orchards at FRIN; gene banks). Challenges: inadequate funding; encroachment; weak law enforcement; insecure community land tenure.

Answers to Pilot Questions [Series 2]

Part 2.1

1. A natural resource is any material or energy source found in the natural environment that is useful to humans. Biotic: timber (forest trees) and fish (freshwater rivers). Abiotic: crude petroleum (Niger Delta) and water (River Niger and River Benue).
2. Renewable resources are regenerated by natural processes within a human time frame if not overexploited. Examples: timber (Cross River rainforest); freshwater (rivers recharged by rainfall); shea butter nuts (annual production by Vitellaria trees). Non-renewable: crude petroleum (Niger Delta); coal (Enugu State); tin ore (Jos Plateau).
3. Actual resource: crude petroleum in the Niger Delta (currently known and exploited with existing technology). Potential resource: deep-sea polymetallic nodules in Nigeria's Exclusive Economic Zone (known to exist but not yet economically exploitable due to lack of deep-sea mining technology).
4. On a century scale, soil is renewable: organic matter from decomposing litter, mineral weathering, and biological activity gradually rebuild soil structure and fertility. On a human agricultural time scale (decades), soil is effectively non-renewable: once the protective forest litter is removed and topsoil is eroded by rain (as in southern Nigerian gully erosion), recovery takes centuries, far exceeding the planning horizon of any farmer or policymaker.
5. Timber (Cross River, Edo, Ondo states): raw material for construction, furniture, and plywood; once a major export earner. Petroleum (Niger Delta): accounts for 70 to 90 percent of government revenue and 90 percent of export earnings; funds national development. Agricultural land (throughout Nigeria): supports livelihoods of approximately 70 percent of the population through food crop and cash crop production. Freshwater (Niger, Benue, Cross River systems): supports fishing, irrigation, hydroelectric power (Kainji, Shiroro dams), and municipal water supply.

Part 2.2

1. Timber is renewable because trees grow back from seeds and stump sprouts after harvesting. Its renewability is maintained only when the annual harvest does not exceed the annual increment (sustained yield principle) and when the forest site is not permanently converted to agriculture or urban use after logging.
2. Khaya senegalensis/ivorensis (African mahogany; reddish-brown; fine grain; furniture and panelling). Entandrophragma cylindricum (sapele; interlocked grain; veneer and flooring). Milicia excelsa (iroko; very durable; outdoor construction). Triplochiton scleroxylon (obeche;

lightweight; plywood). Nauclea diderrichii (opepe; very durable; heavy construction and marine piling).

3. Plant NTFPs: Irvingia gabonensis (bush mango seeds; ogbono soup); Garcinia kola (bitter kola; traditional medicine); Vitellaria paradoxa (shea butter; food and cosmetics); rattan (Calamus species; furniture). Animal NTFPs: bushmeat (wild mammals and reptiles; protein source); honey (Apis mellifera; food and cash income).
4. Food security: bushmeat is the primary protein source for many rural communities in southern and central Nigeria, particularly in forest-edge villages where livestock are scarce. Cash income: NTFPs such as shea butter, kola nuts, bitter kola, and rattan are traded at local and regional markets, providing cash income for households, particularly women, who have few alternative sources of earnings.
5. Three ways: (1) canopy interception reduces rainfall kinetic energy, preventing soil surface sealing, and deep tree roots create macropores that enhance infiltration and groundwater recharge; (2) evapotranspiration from the canopy returns water to the atmosphere and contributes to local rainfall recycling, maintaining regional moisture balance; (3) riparian (riverine) forest strips along stream banks filter sediment, nutrients, and agrochemicals from agricultural runoff, maintaining downstream water quality for communities and aquatic life.

Part 2.3

1. Cross River State (Cross River National Park; Boshi-Okwango Forest Reserve). Edo State (Okomu National Park; Ologbo Forest Reserve). Ondo State (Omo-Shasha-Oluwa Forest Reserve complex).
2. The south receives above 1,500 mm of rainfall annually with 9 to 12 wet months, supporting dense closed rainforest with high timber species diversity (Khaya, Milicia, Entandrophragma). The Guinea savanna of central Nigeria receives 1,000 to 1,500 mm with 6 to 8 wet months, supporting open woodland with shea butter and Isoberlinia. The Sudan savanna of the north receives 600 to 1,000 mm with only 3 to 5 wet months, supporting sparse tree cover with Acacia and gum-producing species. The Sahel in the far north receives below 500 mm, supporting only scattered shrubs and trees.
3. Three Guinea savanna states: Kwara, Kogi, and Niger States. Shea butter is concentrated there because Vitellaria paradoxa is adapted to the seasonal rainfall (1,000 to 1,500 mm; 6 to 8 wet months) and well-drained soils of the Guinea savanna; it cannot survive in the wetter rainforest zone (too humid; competition from taller canopy trees) or the drier Sudan savanna (insufficient moisture for fruiting).

4. Remote sensing (satellite imagery: Landsat, Sentinel-2): advantage: covers large areas rapidly and repeatedly at low cost, enabling detection of deforestation and forest degradation at national scale. Field forest inventory (systematic plot sampling): advantage: provides accurate ground-truth data on species composition, timber volumes, and basal area that remote sensing alone cannot supply; essential for management planning and REDD+ carbon accounting.
5. The FAO 2020 estimate of 6.6 million ha (7.2 percent of land area) compared with 17 million ha in 1990 indicates a loss of approximately 10.4 million ha over 30 years, equivalent to an average deforestation rate of approximately 347,000 ha per year. This represents one of the most severe rates of forest loss in the world and indicates that Nigeria's forest resources are being depleted far faster than they are being regenerated or protected.

Part 2.4

1. Deforestation (agricultural expansion permanently removes forest; eliminates habitat and timber stocks). Timber overexploitation (high-grading removes most valuable species; leaves degraded residual forest incapable of future commercial production). Bushmeat overhunting (wire snares and firearms drive forest mammals to local extinction; disrupts ecosystem function). Bush burning (prevents tree regeneration; destroys NTFP-producing plants; maintains grass dominance at the expense of forest cover).
2. In situ conservation: protecting resources in their natural habitat. Example: Cross River National Park (in situ conservation of rainforest biodiversity and timber species). Ex situ conservation: maintaining resources away from their natural habitat. Example: the arboretum and seed orchards at FRIN Ibadan (ex situ conservation of planting material of commercially important and threatened forest tree species).
3. CBNRM gives communities adjacent to forests the rights and responsibilities to manage resources sustainably, based on the principle that communities with secure resource rights have stronger incentives to protect them. Advantage: communities possess detailed local ecological knowledge and are most affected by resource degradation; giving them management authority and equitable benefit-sharing aligns their interests with sustainable conservation. Challenge: weak and insecure land tenure in Nigeria means communities do not legally own the forests they depend on; the state can withdraw management rights at any time, reducing community investment in long-term conservation.
4. The Green Wall Sahara Initiative is an African Union-led programme that aims to plant a mosaic of trees, vegetation, and land restoration measures 15 km wide across the entire width of Africa along the southern edge of the Sahara desert, from Senegal in the west to Djibouti in the east. In

Nigeria, it aims to halt and reverse desertification in Sokoto, Kebbi, Zamfara, Katsina, Kano, Jigawa, Yobe, and Borno states by planting drought-resistant indigenous tree species (Acacia species, Baobab, Ziziphus mauritiana) to stabilise sandy soils, restore degraded land, and improve rural livelihoods in the Sahel belt.

5. REDD+ (Reducing Emissions from Deforestation and Forest Degradation) provides financial payments to developing countries from international climate funds (Green Climate Fund, bilateral donors) in return for verified reductions in deforestation rates and measured increases in forest carbon stocks. In Nigeria, REDD+ pilot projects in Cross River and Edo states pay communities and state governments for quantified carbon stored in conserved forests, making conservation financially competitive with logging or conversion to agriculture; this creates an economic incentive for forest protection at both government and community level.

References and Attributions [Series 2]

Textual References (Books and External Sources)

- FAO. (2020). Global forest resources assessment 2020. Food and Agriculture Organization of the United Nations, Rome.
- Adegbehin, J. O. (1993). Non-timber forest products in Nigeria: Potential and constraints. Journal of Tropical Forest Science, 5(4), 564-576.
- World Bank. (2006). Nigeria development report: Creating the conditions for growth. World Bank, Washington, DC.
- Ojo, L. O. (2004). The fate of a tropical rainforest in Nigeria: Abeku sector of Omo Forest Reserve. Global Nest: The International Journal, 6(2), 116-130.
- Millennium Ecosystem Assessment. (2005). Ecosystems and human well-being: Synthesis. Island Press, Washington, DC.

Figures, Plates, Tables, and Boxes

- Figure 2.1: Hydrological functions of a Nigerian forest catchment compared with a deforested catchment. Attribution: AI generated. Suggested OER search string: “forest hydrology watershed functions infiltration runoff groundwater recharge comparison deforestation diagram OER”.

- Box 2.1: Conservation strategies for renewable forest resources in Nigeria with examples. Attribution: AI generated. Suggested OER search string: “conservation strategies renewable forest resources Nigeria community forestry REDD protected areas table OER”.

Course code: AGE 203

Course title: Forest Management Education

Course credit load: 2 Units

Series 3: Forest Trees and Wildlife

- **Part 3.1: Classification of Important Forest Trees**
  - Sub Part 3.1.1: Botanical classification and nomenclature of forest trees
  - Sub Part 3.1.2: Classification by timber properties and uses
  - Sub Part 3.1.3: Classification by ecological zone in Nigeria
- **Part 3.2: Morphology of Important Nigerian Forest Trees**
  - Sub Part 3.2.1: Vegetative morphology: roots, stems, and leaves
  - Sub Part 3.2.2: Reproductive morphology: flowers, fruits, and seeds
  - Sub Part 3.2.3: Diagnostic features of selected Nigerian timber species
- **Part 3.3: Distribution of Important Nigerian Forest Trees**
  - Sub Part 3.3.1: Distribution of rainforest timber species
  - Sub Part 3.3.2: Distribution of savanna tree species
  - Sub Part 3.3.3: Endemic and threatened forest tree species in Nigeria
- **Part 3.4: Wildlife in Nigerian Forests**
  - Sub Part 3.4.1: Important wildlife species of Nigerian forests
  - Sub Part 3.4.2: Forest-wildlife interactions
  - Sub Part 3.4.3: Wildlife conservation in Nigeria

Introduction

Nigeria's forests contain an exceptional diversity of tree species. The lowland tropical rainforest alone harbours several hundred tree species per hectare, many of commercial, ecological, or medicinal importance. The Guinea savanna woodlands add a further suite of species adapted to seasonal drought, fire, and the demands of pastoralism. Understanding the classification, morphology, and distribution of these species is foundational to forest management: a forest manager who cannot identify the trees in a stand cannot inventory its resources, plan its management, or monitor its condition.

This Series covers the botanical classification and nomenclature of Nigerian forest trees, their vegetative and reproductive morphology, their distribution across the country's ecological zones, and the wildlife that inhabits Nigerian forests. It also addresses the conservation challenges facing both forest trees and wildlife, with emphasis on threatened and endemic species.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 3.1** explain botanical classification and binomial nomenclature as applied to Nigerian forest trees (Linked to Part 3.1),
- **SLO 3.2** classify Nigerian forest trees by timber properties, uses, and ecological zone (Linked to Part 3.1),
- **SLO 3.3** describe the vegetative and reproductive morphological features of selected important Nigerian forest trees (Linked to Part 3.2),
- **SLO 3.4** describe the distribution of key timber and savanna tree species across Nigeria's ecological zones (Linked to Part 3.3), and
- **SLO 3.5** identify important wildlife species of Nigerian forests and describe the principles of wildlife conservation in Nigeria (Linked to Part 3.4).

3.1 Classification of Important Forest Trees

3.1.1 Botanical classification and nomenclature of forest trees

Forest trees, like all living organisms, are classified using the Linnaean hierarchical system: Kingdom, Phylum (Division), Class, Order, Family, Genus, Species. The binomial nomenclature system, developed by Carl Linnaeus (1753), gives every species a unique two-part Latin name: Genus species (italicised, or underlined in handwriting). The genus name is capitalised; the species epithet is in lower case. Example: Milicia excelsa (Welw.) C.C. Berg; the authority in parentheses (Welw.) indicates the botanist who first described the species, and C.C. Berg is the botanist who made the combination currently used. Common names vary by language and region (iroko in Yoruba; odum in Ghana; moreira in Portuguese) and cannot be used reliably in scientific or management contexts.

The major plant families containing important Nigerian timber trees: Meliaceae (the mahogany family; Khaya, Entandrophragma, Guarea, Trichilia; characterised by pinnately compound leaves and capsular fruits); Moraceae (fig family; Milicia excelsa/iroko, Antiaris toxicaria; latex-producing; alternate simple leaves); Combretaceae (Terminalia superba/afara, Anogeissus; alternate leaves, dry fruits); Sterculiaceae (Triplochiton scleroxylon/obeche; star-shaped flowers; stellate hairs); Rubiaceae (Nauclea diderrichii/opepe, Mitragyna ciliata/abura; opposite leaves; stipules); and Caesalpiniaceae (Afzelia africana, Daniellia oliveri; pinnate leaves; pod fruits).

Fill in the blank: In binomial nomenclature, every species is given a unique two-part Latin name consisting of the _____ name (capitalised) followed by the species epithet (lower case); both are italicised in print and underlined in handwriting.

3.1.2 Classification by timber properties and uses

Nigerian timber species are classified by their wood properties into several commercial categories. Heavy hardwoods (high density above 800 kg/m3; very hard; highly durable; Class 1 to 2 durability): Milicia excelsa (iroko), Nauclea diderrichii (opepe), Afzelia africana (apa/doussie); used in heavy construction, bridge decking, railway sleepers, marine piling.

Medium hardwoods (density 500 to 800 kg/m3; Class 2 to 3 durability): Khaya species (African mahogany), Entandrophragma species (sapele, utile, sipo); used in furniture, joinery, veneer, boat-building. Light hardwoods (density below 500 kg/m3; perishable without treatment): Triplochiton scleroxylon (obeche/wawa), Terminalia superba (afara/limba); used in plywood, interior joinery, packing cases.

Timber is also classified by end use: structural timber (sawn into beams, posts, and planks for construction); veneer timber (peeled or sliced into thin sheets for plywood and decorative surfaces; requires straight grain and large diameter: sapele, utile, obeche); pulpwood (species with suitable fibre length for paper making); fuelwood and charcoal (dense species with high calorific value: Anogeissus, Combretum, Acacia, Prosopis juliflora in northern Nigeria). The durability class of a timber (Class 1 = very durable; Class 5 = perishable) is determined by standard field tests (EN 350; BSI) and determines which end uses are appropriate without preservative treatment.

Fill in the blank: Milicia excelsa (iroko) is classified as a _____ hardwood with density above 800 kg/m3 and Class 1 to 2 durability; it is used in heavy construction, bridge decking, and marine piling without preservative treatment.

3.1.3 Classification by ecological zone in Nigeria

Nigerian forest trees are grouped by the ecological zone in which they naturally occur. Rainforest species (humid south; above 1,500 mm rainfall): Khaya ivorensis, Entandrophragma cylindricum, Milicia excelsa, Triplochiton scleroxylon, Terminalia superba, Nauclea diderrichii, Guarea cedrata, Lovoa trichilioides (Nigerian walnut). Freshwater swamp forest species: Mitragyna ciliata (abura), Anthocleista vogelii, Uapaca heudelotii. Mangrove species: Rhizophora racemosa, R. harrisonii, Avicennia germinans, Laguncularia racemosa, Nypa fruticans (nipa palm). Guinea savanna species (1,000 to 1,500 mm rainfall): Vitellaria paradoxa (shea butter), Isoberlinia doka, Daniellia oliveri (balsam tree), Burkea africana, Lophira lanceolata, Afzelia africana. Sudan and Sahel savanna species (below 1,000 mm): Acacia

senegal, A. nilotica, Balanites aegyptiaca, Baobab (Adansonia digitata), Ziziphus mauritiana, Prosopis juliflora.

Species at the forest-savanna boundary include Parkia biglobosa (locust bean tree; shea savanna), Pterocarpus erinaceus (African rosewood; threatened by overexploitation for export; listed CITES Appendix II), and Anogeissus leiocarpus (iron wood; common in Guinea savanna). Many species are restricted to a single ecological zone; others are widespread. Species range maps produced by FRIN and herbarium records at the National Herbarium of Nigeria (Oshodi, Lagos) document the distribution of Nigerian forest tree species.

Fill in the blank: Pterocarpus erinaceus, commonly known as African rosewood, is a Guinea savanna species listed on CITES Appendix _____ due to overexploitation for export; it is one of the most threatened timber species in West Africa.

Pilot questions 3.1

6. Write the binomial name of iroko and explain what the genus name, species epithet, and authority each represent.
7. Name the plant family to which Khaya and Entandrophragma belong and state two morphological characteristics of that family.
8. Distinguish between heavy hardwoods and light hardwoods in terms of density, durability, and end use, with one Nigerian example of each.
9. Name four rainforest timber species and four Guinea savanna tree species found in Nigeria.
10. What is a durability class and why is it important in timber utilisation?

3.2 Morphology of Important Nigerian Forest Trees

3.2.1 Vegetative morphology: roots, stems, and leaves

Roots: tropical rainforest trees commonly develop buttress roots (plank-like flanges extending from the base of the trunk and spreading along the soil surface; provide mechanical support and increase surface area for nutrient absorption in shallow soils; pronounced in Triplochiton scleroxylon, Ceiba pentandra, Terminalia superba, and Milicia excelsa). Stilt roots (aerial prop

roots extending from the lower trunk to the soil; found in Rhizophora species in mangroves) and pneumatophores (erect respiratory roots projecting above waterlogged soil; in Avicennia germinans and Mitragyna ciliata) are adaptations to waterlogged or anaerobic conditions.

Stems: tropical forest trees have tall, straight, unbranched boles that extend high into the canopy before branching (a response to competition for light). Bark characters are important in field identification: smooth and grey (Triplochiton); fibrous and brown (Terminalia superba); scaly and reddish-brown (Khaya ivorensis); blistered and exfoliating (Entandrophragma cylindricum); bright orange inner bark (Nauclea diderrichii). Leaves: most Nigerian forest trees are evergreen or briefly deciduous. Leaf arrangement (alternate, opposite, or whorled), leaf type (simple or compound), leaf shape, margin (entire, serrate, lobed), texture, and venation are key diagnostic characters. Khaya: pinnately compound; Terminalia: simple, alternate, clustered at branch tips; Milicia: simple, alternate, rough texture.

Fill in the blank: Buttress roots are plank-like flanges that extend from the base of the trunk along the soil surface; they are prominent in Nigerian rainforest species such as Triplochiton scleroxylon and _____, providing mechanical support and enhancing nutrient absorption in shallow soils.

3.2.2 Reproductive morphology: flowers, fruits, and seeds

Flowers: Khaya species produce small, white, 4- to 5-petalled flowers in large panicles; they are insect-pollinated and have a characteristic staminal tube (fused filaments forming a tube around the ovary, diagnostic of the family Meliaceae). Milicia excelsa produces catkin-like male and female inflorescences on separate trees (dioecious); female trees bear a fleshy syncarp (multiple fruit). Triplochiton scleroxylon has star-shaped (stellate) white flowers; a capsule splitting into winged samaras. Terminalia superba has small, white, petal-less flowers in elongated spikes; the fruit is a woody 2-winged samara dispersed by wind.

Fruits and seeds are important for identification and regeneration management. Dispersal mechanisms: wind (samaras of Terminalia, Triplochiton; tufted seeds of Ceiba pentandra/kapok);

water (seeds of Rhizophora propagules germinate on the tree and fall into water; vivipary); animals (fleshy fruits of Milicia, Antiaris, Irvingia dispersed by birds and mammals; the completeness of animal dispersal depends on the survival of disperser populations). Seed size varies enormously: Irvingia gabonensis (very large, heavy seeds, gravity-dispersed); Khaya (winged seeds, wind-dispersed over short distances). Seed viability periods are short for most tropical rainforest species (recalcitrant seeds: Milicia, Khaya, most Meliaceae cannot be dried and stored; must be planted fresh).

Fill in the blank: Most tropical rainforest timber tree seeds are _____ (cannot be dried and stored); they must be collected and planted fresh, which makes seed supply for plantation establishment a logistical challenge in Nigerian forestry.

3.2.3 Diagnostic features of selected Nigerian timber species

Khaya ivorensis (Lagos mahogany): large tree to 45 m; buttressed; bark scaly, reddish-brown, peeling in irregular scales; leaves pinnately compound, 3 to 5 pairs of leaflets, entire margins; flowers white, in large terminal panicles; fruit a woody globose capsule 5 to 7 cm diameter splitting into 4 to 5 valves; seeds winged. Diagnostic: scaly bark + pinnate leaves + globose capsule. Milicia excelsa (iroko): large tree to 50 m; strongly buttressed; bark rough, grey-brown; leaves simple, alternate, elliptic to obovate, rough (sandpaper texture) due to cystolith crystals; dioecious; fruit a fleshy orange-yellow multiple fruit (syncarp). Diagnostic: rough sandpaper leaves + orange syncarp.

Triplochiton scleroxylon (obeche/wawa): large tree to 55 m; prominent buttresses; bark smooth to slightly fibrous, pale grey; leaves simple, alternate, 3- to 7-lobed (palmate), large (15 to 25 cm across), with stellate hairs; flowers white, star-shaped; fruit a 5-valved woody capsule with winged seeds. Diagnostic: large palmate leaves + stellate hairs + winged capsule. Nauclea diderrichii (opepe): large tree to 40 m; bark grey, deeply furrowed longitudinally, inner bark bright orange; leaves simple, opposite, large, glossy; stipules large and persistent; flowers in dense spherical heads (capitula); fruit a hard globose syncarp. Diagnostic: orange inner bark + opposite glossy leaves + spherical flower heads.

Fill in the blank: Milicia excelsa (iroko) is identified in the field by its simple alternate leaves with a _____ (sandpaper) texture caused by cystolith crystals, and by its orange-yellow fleshy syncarp fruit borne on female trees.

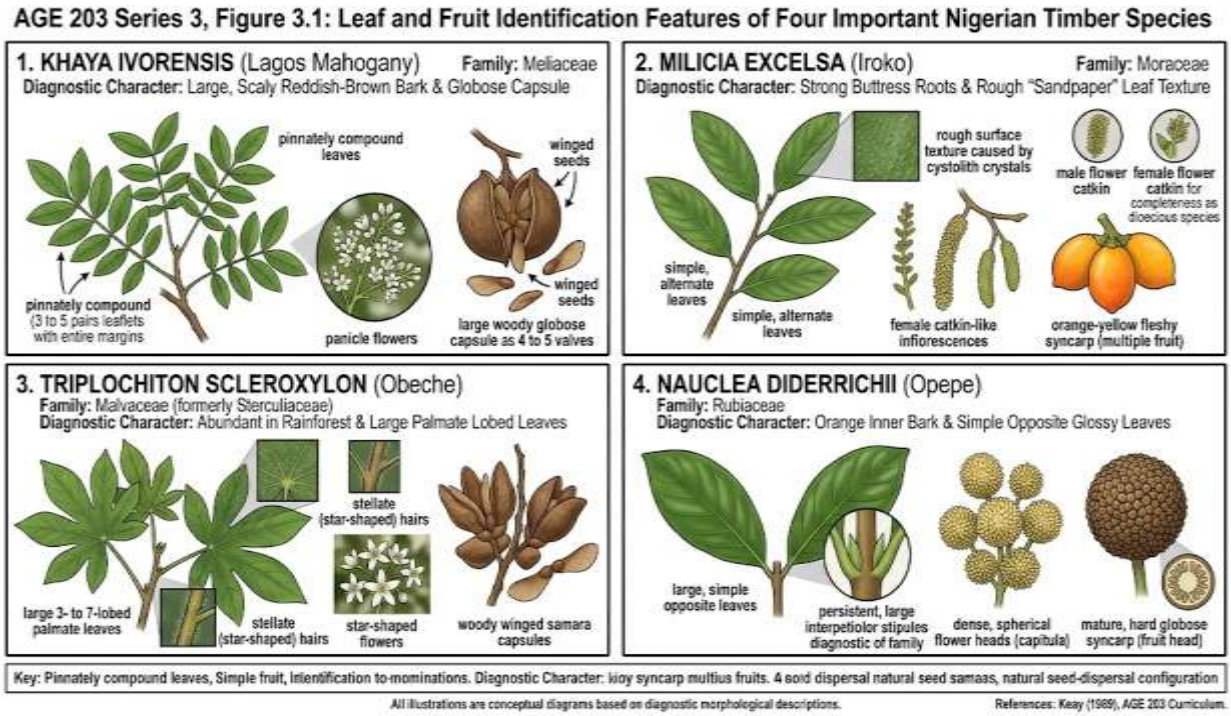

Figure 3.1: Leaf and fruit identification features of four important Nigerian timber species

Pilot questions 3.2

6. Explain the function of buttress roots in tropical rainforest trees and name three Nigerian species that develop them.
7. Describe three bark characters useful for field identification of Nigerian timber trees and state the species associated with each.
8. Distinguish between the leaf types of Khaya ivorensis and Triplochiton scleroxylon and explain how leaf type aids field identification.
9. Describe the fruit type and seed dispersal mechanism of (a) Terminalia superba and (b) Milicia excelsa.
10. State three diagnostic field characters of Nauclea diderrichii (opepe) that distinguish it from other Nigerian timber species.

3.3 Distribution of Important Nigerian Forest Trees

3.3.1 Distribution of rainforest timber species

The lowland tropical rainforest timber species of Nigeria are distributed across the humid south in a band running roughly from the western border (Ogun, Lagos) to the eastern border (Cross River) between the coast and approximately latitude 7 degrees N (the forest-savanna boundary). Key distribution patterns: Khaya ivorensis (Lagos mahogany): found throughout the lowland rainforest from Lagos to Cross River; most abundant in Ondo and Cross River forest reserves; heavily exploited and now rare in accessible areas. Khaya senegalensis (dry-zone mahogany): extends from the forest-savanna boundary into the Guinea savanna, occurring as far north as Sokoto; more drought-tolerant than K. ivorensis. Entandrophragma cylindricum (sapele): widespread in the rainforest from Edo to Cross River; prefers well-drained soils; very heavily logged.

Milicia excelsa (iroko): once widespread throughout the rainforest zone; now rare in exploited areas; regenerates poorly in logged-over forest due to damage by the gall insect Phytolyma lata; more common in sacred groves and unlogged reserves (Cross River NP; Okomu NP). Triplochiton scleroxylon (obeche): the most abundant and widespread commercial timber species in the Nigerian rainforest; occurs throughout the moist semi-deciduous and evergreen forest zones; regenerates prolifically after logging; the basis of the plywood industry. Nauclea diderrichii (opepe): widespread in rainforest but reaches its best development in moist gallery forests and forest-savanna transition areas; commonly found along stream banks.

Fill in the blank: Triplochiton scleroxylon (obeche) is the most _____ and widespread commercial timber species in the Nigerian rainforest; it regenerates prolifically after logging and forms the basis of the Nigerian plywood industry.

3.3.2 Distribution of savanna tree species

Guinea savanna (central Nigeria; approximately 7 to 11 degrees N; Kwara, Kogi, Niger, Benue, Nasarawa, FCT, Plateau, Oyo, Osun, Ekiti, Kaduna, Bauchi states): Vitellaria paradoxa (shea butter) and Parkia biglobosa (locust bean) are the most economically important species; both are

protected by farmers in cultivated fields and constitute a parkland agroforestry system. Isoberlinia doka and I. tomentosa form characteristic woodland associations on well-drained soils; Daniellia oliveri occurs on seasonally waterlogged soils. Lophira lanceolata (red iron wood) and Burkea africana are common on leached, nutrient-poor soils. Afzelia africana (apa) is a commercially valuable timber species occurring throughout the Guinea savanna; heavily exploited and increasingly scarce.

Sudan savanna (approximately 11 to 13 degrees N; Sokoto, Kebbi, Zamfara, Katsina, Kano, Jigawa, Yobe, Borno, Adamawa states): Acacia senegal (gum arabic), A. nilotica, A. albida (winter thorn; leafy in dry season, leafless in rains; important fodder tree), Balanites aegyptiaca (desert date; edible fruits; medicinal bark), Combretum species. Sahel savanna (above 13 degrees N; Sokoto, Katsina, Jigawa, Yobe, Borno states): Acacia species, Adansonia digitata (baobab; multi-purpose: fruit, leaves, bark, wood), Ziziphus mauritiana (jujube), Hyphaene thebaica (doum palm), Boscia senegalensis (aizen; drought refuge food for humans and livestock during famine).

Fill in the blank: Vitellaria paradoxa (shea butter) and Parkia biglobosa (locust bean) are the most economically important tree species of Nigeria's Guinea savanna; farmers actively protect them in cultivated fields, creating a _____ agroforestry parkland system.

3.3.3 Endemic and threatened forest tree species in Nigeria

Endemism in Nigerian forest trees: while Nigeria does not have many strict endemic tree species (species found nowhere else), the Cross River and Edo rainforests are part of the Guineo-Congolian flora, which harbours several near-endemic and threatened species. Examples: Cola gigantea var. glabrescens (a large-seeded Cola species of limited distribution in Cross River State); Daniellia ogea (copal; limited to coastal swamp forests); Khaya grandifoliola (large-leaved mahogany; limited to riparian gallery forests in the Guinea savanna). IUCN Red List assessments for Nigerian forest trees: Pterocarpus erinaceus (Vulnerable; heavily exploited for export timber); Milicia excelsa (listed as Vulnerable globally; protected under Nigerian law);

Lovoa trichilioides (Nigerian walnut; Near Threatened); Pericopsis elata (afrormosia/satinwood; Endangered globally; rare in Nigeria).

The threats to Nigerian forest tree species include: selective logging targeting the highest-value species (Khaya, Entandrophragma, Milicia, Pterocarpus); charcoal production depleting savanna woodlands (Vitellaria, Isoberlinia, Anogeissus); agricultural expansion clearing forest patches; and invasive species (Chromolaena odorata/siam weed; Imperata cylindrica/spear grass) suppressing natural regeneration in logged-over areas. Conservation responses include: legal protection (several species protected under the Endangered Species Act Cap E9 LFN 2004); CITES listing (Pterocarpus erinaceus Appendix II); in situ conservation in national parks (Cross River NP is the most important in situ refuge for Nigerian rainforest tree diversity); and ex situ conservation of seed and genetic material at FRIN.

Fill in the blank: Pterocarpus erinaceus is listed as _____ on the IUCN Red List and on CITES Appendix II; it is threatened primarily by unsustainable logging for export, particularly to Asian markets.

Pilot questions 3.3

6. Describe the natural distribution of Milicia excelsa (iroko) in Nigeria and explain why it is now rare in most accessible forest areas.
7. Distinguish between the distribution and ecology of Khaya ivorensis and Khaya senegalensis in Nigeria.
8. Name three economically important Guinea savanna tree species and state the main product and economic use of each.
9. Define endemism and give two examples of threatened or near-endemic forest tree species in Nigeria.
10. Name three threats to the survival of Nigerian forest tree species and state one conservation measure for each.

3.4 Wildlife in Nigerian Forests

3.4.1 Important wildlife species of Nigerian forests

Nigeria's forests support a rich but severely depleted fauna. Mammals: African forest elephant (Loxodonta cyclotis; occurs in Cross River NP and Omo Forest Reserve; critically threatened by poaching and habitat loss); Nigeria-Cameroon chimpanzee (Pan troglodytes ellioti; the most endangered chimpanzee subspecies; fewer than 3,500 individuals remain; restricted to Cross River and Taraba states; IUCN Endangered); African buffalo (Syncerus caffer nanus; forest subspecies; Cross River NP); African lion (Panthera leo; Kainji Lake NP; Yankari NP; IUCN Vulnerable); leopard (Panthera pardus; widespread but secretive; persists in Gashaka-Gumti, Cross River, and Yankari NPs); hippopotamus (Hippopotamus amphibius; major rivers; Yankari NP); African manatee (Trichechus senegalensis; Cross River, lower Niger Delta; aquatic); red river hog (Potamochoerus porcus; forest; common bushmeat species); giant pangolin (Manis gigantea; heavily hunted for scales and meat).

Primates: chimpanzee (as above); drill (Mandrillus leucophaeus; Cross River and Taraba states; IUCN Endangered; one of Africa's most threatened primates); Preuss's monkey (Allochrocebus preussi; Cross River; Endangered); red-capped mangabey (Cercocebus torquatus; south-eastern Nigeria; Vulnerable); putty-nosed monkey (Cercopithecus nictitans; widespread in southern rainforest). Birds: African grey parrot (Psittacus erithacus; heavily traded; IUCN Endangered in Nigeria; Cross River, Delta, Edo states); yellow-casqued hornbill (Ceratogymna elata; rainforest; seed disperser); crowned eagle (Stephanoaetus coronatus; apex predator; disperses seeds of large-seeded trees). Reptiles: African rock python (Python sebae; widespread), Nile crocodile (Crocodylus niloticus; major rivers and Yankari NP; hunted). The biodiversity of Cross River State forests is internationally recognised; this area is part of the Cameroon Highlands biodiversity hotspot.

Fill in the blank: The Nigeria-Cameroon chimpanzee (Pan troglodytes ellioti) is the most _____ chimpanzee subspecies; fewer than 3,500 individuals remain, restricted to forests in Cross River and Taraba states in Nigeria.

3.4.2 Forest-wildlife interactions

Wildlife plays critical ecological roles in forest ecosystems. Seed dispersal: large mammals and birds disperse the seeds of many forest trees; African forest elephants disperse large-seeded species (Irvingia gabonensis, Cola species) that no other animal can swallow; hornbills, turacos, and pigeons disperse smaller-seeded species (Milicia, Ficus); the loss of large mammal dispersers from hunted forests causes recruitment failure of large-seeded tree species (defaunation syndrome). Pollination: many forest trees are pollinated by insects (bees, beetles, moths), bats (Khaya species are bat-pollinated at night), or birds; decline of pollinators reduces fruit set and genetic diversity. Herbivory and browsing: elephants push over trees, creating canopy gaps that allow light-demanding pioneers to establish; their dung contains viable seeds; they are therefore keystone species in forest dynamics.

Predator-prey relationships: large predators (leopards, eagles, pythons) regulate herbivore populations; removal of top predators causes herbivore population explosions (trophic cascade) that can lead to overgrazing of forest undergrowth. Bushmeat hunting directly depletes herbivore and primate populations and indirectly disrupts forest dynamics by removing seed dispersers and pollinators. This creates empty forest syndrome: forests that still look structurally intact but have lost most of their large fauna and the ecological processes they drive. The Cross River and Gashaka-Gumti national parks are among the last Nigerian forests where intact predator-prey-disperser food webs partially function.

Fill in the blank: The loss of large mammal seed dispersers from hunted forests is called _____ syndrome; forests lose the ecological processes driven by large fauna (seed dispersal, browsing, gap creation) even though the canopy structure remains visually intact.

3.4.3 Wildlife conservation in Nigeria

Wildlife conservation in Nigeria is governed by the Endangered Species (Control of International Trade and Traffic) Act Cap E9 LFN 2004, which prohibits the capture, trade, and killing of listed species; and the National Park Service Act 1991, which establishes national parks as protected areas for wildlife. State wildlife laws and regulations govern game reserves and hunting licences. The National Park Service manages the seven national parks (Yankari, Cross River, Gashaka-

Gumti, Kainji Lake, Old Oyo, Chad Basin, Okomu) with a combined area of approximately 2.4 million ha; these are the most important refugia for Nigeria's threatened wildlife.

Key conservation programmes: Wildlife Conservation Society (WCS) Nigeria programme (Cross River NP; chimpanzee and elephant monitoring; anti-poaching patrols); Pandrillus Foundation (drill and chimpanzee sanctuary in Cross River State; captive breeding and rehabilitation); NCF (Nigerian Conservation Foundation; awareness, policy advocacy, and community conservation); Lekki Conservation Centre (Lagos; urban wildlife conservation and ecotourism). Challenges: inadequate funding for national park management; widespread bushmeat hunting (wire snares, firearms); illegal wildlife trade (African grey parrots, pangolins, elephants); human encroachment into national parks; and corruption undermining enforcement. Community-based wildlife management (CBWM): giving communities adjacent to reserves a stake in wildlife conservation through revenue-sharing from ecotourism and regulated NTFP harvesting.

Fill in the blank: The _____ Species (Control of International Trade and Traffic) Act Cap E9 LFN 2004 is the primary federal law governing wildlife conservation in Nigeria; it prohibits the capture, trade, and killing of listed threatened species.

Short description: A summary table of important wildlife species in Nigerian forests: four columns (Species; Common name; Conservation status; Nigerian location). Rows: Pan troglodytes ellioti (Nigeria-Cameroon chimpanzee; Endangered; Cross River and Taraba states); Mandrillus leucophaeus (drill; Endangered; Cross River State); Loxodonta cyclotis (African forest elephant; Critically threatened; Cross River NP and Omo Forest Reserve); Psittacus erithacus (African grey parrot; Endangered; Cross River, Delta, Edo); Manis gigantea (giant pangolin; Vulnerable; southern forests); Panthera pardus (leopard; Vulnerable; Gashaka-Gumti, Cross River, Yankari NPs).

Scientific Name	Common Name	IUCN Status	Nigerian Location

Pan troglodytes	Chimpanzee	Endangered	Cross River State, Gashaka-Gumti National Park
Mandrillus leucophaeus	Drill	Endangered	Cross River forests, Afi Mountain Wildlife Sanctuary
Loxodonta cyclotis	Forest Elephant	Endangered	Omo Forest Reserve, Cross River National Park
Psittacus erithacus	African Grey Parrot	Endangered	Niger Delta mangroves, Cross River rainforest
Smutsia gigantea	Giant Pangolin	Endangered	Rainforests of southern Nigeria, Okomu National Park
Panthera pardus	Leopard	Vulnerable	Yankari National Park, Cross River National Park

Box 3.1: Important threatened wildlife species of Nigerian forests

Pilot questions 3.4

6. Name four mammal species found in Nigerian forests and state the IUCN conservation status and main threat facing each.
7. Explain the ecological role of the African forest elephant in Nigerian forest ecosystems.
8. Explain what is meant by empty forest syndrome and state two causes in Nigerian forests.
9. Describe the role of the National Park Service in wildlife conservation in Nigeria and name three national parks under its management.
10. Explain one conservation programme operating in Cross River State and describe its main activities.

Series Summary

This Series examined the classification and identification of important forest trees using the Linnaean system and binomial nomenclature. Major tree families include Meliaceae, Moraceae, Sterculiaceae, and Rubiaceae, each recognised by distinctive features such as leaf arrangement, fruit type, bark, latex, and floral structure. Timber species are also grouped by wood density into heavy, medium, and light hardwoods, which determines their suitability for construction, furniture, veneer, plywood, and other uses. Important rainforest species include Khaya ivorensis, Entandrophragma species, Milicia excelsa, Triplochiton scleroxylon, and Nauclea diderrichii, while savanna species include Vitellaria paradoxa, Isoberlinia, Daniellia, Parkia, Acacia, baobab, and Balanites. Some valuable species, including Pterocarpus erinaceus, Milicia excelsa, and Pericopsis elata, are threatened by overexploitation and habitat loss.

The Series also covered major forest wildlife and their ecological roles. Species such as the Nigeria-Cameroon chimpanzee, drill, forest elephant, African grey parrot, and leopard depend on protected forest habitats. Wildlife contributes to seed dispersal, pollination, vegetation control, and forest regeneration, but intensive hunting can cause empty forest syndrome, where the vegetation remains but animal populations and ecological processes are greatly reduced. Conservation measures include wildlife laws, national parks, anti-poaching programmes, species recovery projects, and community-based management. However, poaching, illegal trade, habitat encroachment, and inadequate funding continue to threaten forest wildlife in Nigeria.

Glossary of Terms

- **Binomial nomenclature:** the system developed by Linnaeus giving each species a unique two-part Latin name (Genus species); the genus is capitalised and the species epithet is in lower case; both are italicised.
- **Buttress roots:** plank-like flanges extending from the base of tropical rainforest tree trunks along the soil surface; provide mechanical support and increase nutrient absorption surface area; prominent in Triplochiton, Ceiba, and Milicia.

- **Defaunation syndrome (empty forest syndrome):** the loss of large animal populations from forests through hunting, leaving a structurally intact forest that has lost the ecological processes driven by large fauna including seed dispersal, pollination, and gap creation.
- **Drill (Mandrillus leucophaeus):** a large primate found only in Cross River State and parts of Cameroon and Bioko Island; IUCN Endangered; one of Africa's most threatened primates; threatened by habitat loss and bushmeat hunting.
- **Durability class:** a classification of timber resistance to biological degradation (fungi, insects, marine borers); Class 1 (very durable: iroko, opepe) to Class 5 (perishable); determines appropriate end uses without preservative treatment.
- **Heavy hardwood:** timber with wood density above 800 kg/m3 and Class 1 to 2 durability; examples from Nigeria include Milicia excelsa (iroko) and Nauclea diderrichii (opepe); used in heavy construction and marine applications.
- **Meliaceae:** the mahogany plant family; contains important Nigerian timber genera Khaya and Entandrophragma; characterised by pinnately compound leaves, a staminal tube in the flower, and a woody capsular fruit with winged seeds.
- **Nigeria-Cameroon chimpanzee (Pan troglodytes ellioti):** the most endangered chimpanzee subspecies; fewer than 3,500 individuals remain; restricted to Cross River and Taraba states in Nigeria; threatened by habitat loss and bushmeat hunting.
- **Parkland agroforestry:** a land-use system in which economically valuable trees (Vitellaria paradoxa, Parkia biglobosa) are retained and protected by farmers in cultivated fields; widespread in the Guinea savanna of Nigeria.
- **Pterocarpus erinaceus:** African rosewood; a Guinea savanna timber species listed as Vulnerable on the IUCN Red List and on CITES Appendix II; heavily exploited for export, particularly to Asian markets.
- **Recalcitrant seeds:** seeds that cannot be dried and stored without losing viability; must be planted fresh; characteristic of most tropical rainforest timber species (Milicia, Khaya, most Meliaceae); a logistical challenge in plantation establishment.
- **Seed dispersal syndrome:** the suite of fruit and seed characteristics (size, colour, fleshy reward, hardness) associated with a particular dispersal mechanism (wind, water, animal); understanding dispersal syndromes is important for forest regeneration management.

- **Triplochiton scleroxylon:** obeche or wawa; the most abundant commercial timber species in the Nigerian rainforest; light hardwood; palmate leaves with stellate hairs; widely used in plywood production; regenerates prolifically after logging.
- **Wildlife Conservation Society (WCS) Nigeria:** an international conservation organisation operating in Cross River National Park; conducts chimpanzee and elephant monitoring, anti-poaching patrols, and community conservation programmes.

Concept Check Questions [Series 3]

Objective Questions

6. In binomial nomenclature, the _____ name is capitalised and the species epithet is written in lower case; both are italicised. (Linked to SLO 3.1)
7. Khaya and Entandrophragma belong to the plant family _____, characterised by pinnate leaves, a staminal tube, and woody capsular fruits. (Linked to SLO 3.1)
8. Milicia excelsa (iroko) is identified in the field by its rough _____ texture leaves and orange-yellow fleshy syncarp fruit. (Linked to SLO 3.3)
9. The Nigeria-Cameroon chimpanzee (Pan troglodytes ellioti) is classified as _____ by the IUCN and is restricted to Cross River and Taraba states. (Linked to SLO 3.5)
10. The loss of large mammal dispersers from hunted forests, leaving a structurally intact but ecologically depleted forest, is called _____ forest syndrome. (Linked to SLO 3.5)

Short-Answer Questions

11. Define binomial nomenclature and write the binomial name of iroko, sapele, and obeche. (Linked to SLO 3.1)
12. Distinguish between heavy and light hardwoods with one Nigerian example of each, stating density, durability class, and end use. (Linked to SLO 3.2)
13. State three diagnostic field characters of Khaya ivorensis and three of Nauclea diderrichii. (Linked to SLO 3.3)
14. Name three threatened wildlife species of Nigerian forests and state the main conservation threat facing each. (Linked to SLO 3.5)
15. Explain the ecological role of the African forest elephant in Nigerian forest ecosystems. (Linked to SLO 3.5)

Long-Answer Questions

13. Describe the botanical classification, timber property classification, and ecological zone classification of important Nigerian forest trees. Give morphological diagnostic features of four key species. (Linked to SLOs 3.1, 3.2, 3.3)
14. Describe the distribution of rainforest and savanna tree species in Nigeria. Identify endemic and threatened tree species and explain the importance of wildlife in forest ecosystems and the measures taken for wildlife conservation in Nigeria. (Linked to SLOs 3.3, 3.4, 3.5)

Answers to Concept Check Questions [Series 3]

Objective Questions

1. Genus.
2. Meliaceae.
3. Sandpaper.
4. Endangered.
5. Empty.

Short-Answer Questions

6. Binomial nomenclature gives each species a unique two-part Latin name (Genus species, italicised). Iroko: Milicia excelsa. Sapele: Entandrophragma cylindricum. Obeche: Triplochiton scleroxylon.
7. Heavy hardwood: density above 800 kg/m3; Class 1 to 2 durability; used in heavy construction; example: Milicia excelsa (iroko). Light hardwood: density below 500 kg/m3; perishable; used in plywood and interior joinery; example: Triplochiton scleroxylon (obeche).
8. Khaya ivorensis: scaly reddish-brown bark; pinnately compound leaves (3 to 5 pairs); globose woody capsule splitting into 4 to 5 valves. Nauclea diderrichii: deeply furrowed grey bark with bright orange inner bark; simple opposite glossy leaves; spherical flower heads (capitula).
9. Nigeria-Cameroon chimpanzee (Endangered; habitat loss and bushmeat hunting). Drill (Endangered; deforestation in Cross River). African grey parrot (Endangered; illegal capture for pet trade).
10. Forest elephants disperse large-seeded species (Irvingia, Cola) that no other animal can carry; their dung deposits viable seeds; they push over trees creating canopy gaps that promote pioneer regeneration; they are keystone species in forest dynamics.

Long-Answer Questions

10. Botanical classification: Linnaean hierarchy (Kingdom to Species); binomial nomenclature (Genus species, italicised). Key families: Meliaceae (Khaya, Entandrophragma; pinnate leaves; staminal tube; capsule); Moraceae (Milicia; simple rough leaves; latex; syncarp); Sterculiaceae (Triplochiton; palmate leaves; stellate hairs; winged capsule); Rubiaceae (Nauclea; opposite leaves; stipules; spherical heads; orange bark). Timber property classification: heavy hardwoods above 800 kg/m3, Class 1 to 2 (iroko, opepe; heavy construction, marine use); medium 500 to 800 kg/m3 (Khaya, Entandrophragma; furniture, veneer); light below 500 kg/m3 (obeche, afara; plywood). Ecological zone classification: rainforest (Khaya ivorensis, Milicia, Entandrophragma,

Triplochiton); Guinea savanna (Vitellaria, Isoberlinia, Daniellia, Afzelia); Sudan/Sahel (Acacia, Baobab). Diagnostic features: Khaya ivorensis (scaly bark; pinnate leaves; globose capsule). Milicia excelsa (sandpaper leaves; orange syncarp). Triplochiton (palmate leaves; stellate hairs; winged capsule). Nauclea diderrichii (orange inner bark; opposite glossy leaves; spherical capitula).

11. Rainforest species distribution: concentrated in southern states (Cross River, Edo, Ondo); Khaya ivorensis and Entandrophragma widespread but heavily logged; Milicia excelsa now rare except in unlogged reserves and sacred groves; Triplochiton most abundant, regenerates well after logging. Savanna distribution: Guinea savanna (Vitellaria, Parkia, Isoberlinia, Daniellia; central Nigeria); Sudan/Sahel (Acacia, Baobab, Balanites; northern Nigeria). Threatened species: Pterocarpus erinaceus (Vulnerable; CITES II; export logging); Milicia excelsa (Vulnerable; over-logging); Pericopsis elata (Endangered). Wildlife in ecosystems: seed dispersal (elephants for large seeds; hornbills for small seeds); pollination (bats, bees); canopy gap creation (elephants); trophic regulation (predators control herbivores). Empty forest syndrome: structurally intact forest depleted of fauna by hunting; recruitment failure of large-seeded trees. Conservation: Endangered Species Act Cap E9 LFN 2004; National Park Service (7 parks; 2.4 million ha); WCS Nigeria (Cross River NP; anti-poaching; monitoring); Pandrillus Foundation (drill sanctuary). Challenges: funding, poaching, illegal trade, encroachment.

Answers to Pilot Questions [Series 3]

Part 3.1

6. Milicia excelsa (Welw.) C.C. Berg. Milicia = genus (capitalised); excelsa = species epithet (lower case); Welw. = botanist who first described the species; C.C. Berg = botanist who made the current name combination.
7. Family Meliaceae. Two characteristics: (1) leaves pinnately compound with entire leaflet margins; (2) flowers with a staminal tube (fused filaments enclosing the ovary).
8. Heavy hardwood: density above 800 kg/m3; Class 1 to 2 durability; heavy construction; example: Milicia excelsa (iroko). Light hardwood: density below 500 kg/m3; perishable; plywood and interior joinery; example: Triplochiton scleroxylon (obeche).
9. Rainforest: Khaya ivorensis, Milicia excelsa, Entandrophragma cylindricum, Triplochiton scleroxylon. Guinea savanna: Vitellaria paradoxa, Isoberlinia doka, Daniellia oliveri, Parkia biglobosa.
10. Durability class rates timber resistance to decay and insect attack (Class 1 = very durable; Class 5 = perishable). It determines suitability for outdoor use, heavy construction, or marine applications without preservative treatment.

Part 3.2

6. Buttress roots provide mechanical support to the tall trunk in shallow tropical soils and increase root surface area for nutrient uptake. Three species: Triplochiton scleroxylon, Ceiba pentandra, Milicia excelsa.
7. Scaly reddish-brown bark peeling in irregular plates: Khaya ivorensis. Deeply furrowed grey bark with bright orange inner bark: Nauclea diderrichii. Smooth pale grey bark: Triplochiton scleroxylon.
8. Khaya ivorensis: pinnately compound leaves with 3 to 5 pairs of entire leaflets. Triplochiton scleroxylon: large simple palmate (3 to 7 lobed) leaves with stellate hairs. The different leaf forms immediately separate the two species in the field.
9. (a) Terminalia superba: 2-winged woody samara; dispersed by wind. (b) Milicia excelsa: fleshy orange syncarp; dispersed by birds and mammals attracted to the fleshy reward.
10. Deeply furrowed grey bark with bright orange inner bark; simple opposite glossy leaves with large persistent stipules; dense spherical flower heads (capitula).

Part 3.3

6. Milicia excelsa was once widespread throughout the Nigerian lowland rainforest. It is now rare in accessible areas because it was heavily targeted by selective loggers for its high-value durable timber, and because the gall insect Phytolyma lata attacks its seedlings, preventing regeneration in logged-over forest.
7. Khaya ivorensis: lowland rainforest of southern Nigeria (Lagos to Cross River); prefers humid conditions above 1,500 mm rainfall. Khaya senegalensis: extends from the forest-savanna boundary into the Guinea savanna; more drought-tolerant; found as far north as Sokoto.
8. Vitellaria paradoxa (shea butter; kernel fat for food and cosmetics). Parkia biglobosa (locust bean; seeds fermented to make dawadawa condiment). Isoberlinia doka (heavy durable fuelwood and charcoal).
9. Endemism refers to a species being naturally restricted to a defined geographical area. Examples: Pterocarpus erinaceus (Vulnerable; CITES II; threatened by export logging); Milicia excelsa (Vulnerable globally; protected under Nigerian law; heavily exploited).
10. Selective logging: protected under Endangered Species Act and CITES listing. Bushmeat hunting: community-based wildlife management and anti-poaching patrols by NPS. Agricultural expansion: in situ conservation through national parks and forest reserves.

Part 3.4

6. Nigeria-Cameroon chimpanzee (Endangered; bushmeat hunting and deforestation). Forest elephant (critically threatened; poaching for ivory). African grey parrot (Endangered; illegal capture for pet trade). Drill (Endangered; habitat loss in Cross River forests).
7. Forest elephants are keystone species: they disperse large-seeded trees (Irvingia, Cola) whose seeds are too large for other dispersers; they create canopy gaps by pushing over trees, promoting regeneration; their dung deposits viable seeds across the forest.
8. Empty forest syndrome describes a forest that is structurally intact but ecologically depleted because large animals have been removed by hunting. Two causes in Nigeria: widespread bushmeat hunting using wire snares and firearms; illegal wildlife trade removing parrots, pangolins, and primates.
9. The National Park Service manages seven national parks for biodiversity conservation, research, and ecotourism; it employs rangers for anti-poaching patrols and manages park boundaries against encroachment. Three parks: Yankari, Cross River, Gashaka-Gumti.
10. WCS Nigeria (Wildlife Conservation Society) operates in Cross River National Park; it conducts chimpanzee and forest elephant population monitoring using camera traps and transect surveys,

trains and equips anti-poaching rangers, and works with border communities on alternative livelihoods to reduce bushmeat hunting.

References and Attributions [Series 3]

Textual References (Books and External Sources)

- Keay, R. W. J. (1989). Trees of Nigeria. Clarendon Press, Oxford.
- Lowe, R. G. (1978). Nigerian forestry information bulletin (new series) No. 1: The timber trees of Nigeria. Federal Department of Forestry, Lagos.
- Happold, D. C. D. (1987). The mammals of Nigeria. Clarendon Press, Oxford.
- WCS Nigeria. (2018). Status of chimpanzees and drills in Cross River State. Wildlife Conservation Society, New York.
- IUCN. (2023). The IUCN Red List of threatened species. Version 2023-1. https://www.iucnredlist.org

Figures, Plates, Tables, and Boxes

- Figure 3.1: Leaf and fruit identification features of four important Nigerian timber species. Attribution: AI generated. Suggested OER search string: “Nigerian timber species leaf fruit identification Khaya Milicia Triplochiton Nauclea botanical plate OER”.
- Box 3.1: Important threatened wildlife species of Nigerian forests. Attribution: AI generated. Suggested OER search string: “threatened wildlife species Nigeria forest conservation status chimpanzee elephant parrot pangolin table OER”.

Course code: AGE 203

Course title: Forest Management Education

Course credit load: 2 Units

Series 4: Silviculture and Afforestation Practices

- **Part 4.1: Introduction to Silviculture**
  - Sub Part 4.1.1: Definition and scope of silviculture
  - Sub Part 4.1.2: Silvicultural systems: even-aged and uneven-aged management
  - Sub Part 4.1.3: The selection and shelterwood systems
- **Part 4.2: Natural Regeneration of Nigerian Forests**
  - Sub Part 4.2.1: Mechanisms of natural regeneration
  - Sub Part 4.2.2: The tropical shelterwood system in Nigeria
  - Sub Part 4.2.3: Enrichment planting
- **Part 4.3: Afforestation and Plantation Forestry**
  - Sub Part 4.3.1: Definition and rationale for afforestation in Nigeria
  - Sub Part 4.3.2: Species selection for plantations in Nigeria
  - Sub Part 4.3.3: Plantation establishment: site preparation, planting, and tending
- **Part 4.4: Characteristics of Major Nigerian Timber Species**
  - Sub Part 4.4.1: Wood anatomy and properties of selected species
  - Sub Part 4.4.2: Utilisation properties and grading of Nigerian timbers
  - Sub Part 4.4.3: Timber seasoning, preservation, and defects

Introduction

Silviculture is the science and art of controlling the establishment, composition, structure, and growth of forests to achieve specified management objectives. It is the operational core of forest management: the set of practical interventions that shape the forest. In Nigeria, silviculture encompasses both the management of natural forests for timber production and the establishment and tending of plantations on degraded land. Afforestation programmes address the twin challenges of restoring degraded forest land and supplying timber to reduce pressure on natural forests.

This Series covers the major silvicultural systems applicable to Nigerian conditions, the mechanisms and techniques for natural forest regeneration, the principles and practice of plantation forestry in Nigeria, and the wood properties and utilisation characteristics of the country's major timber species. These topics are directly applied in forest management planning, plantation design, and timber marketing.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 4.1** define silviculture and distinguish between even-aged and uneven-aged silvicultural systems (Linked to Part 4.1),
- **SLO 4.2** describe the mechanisms of natural regeneration in tropical forests and explain the tropical shelterwood system as applied in Nigeria (Linked to Part 4.2),
- **SLO 4.3** explain the rationale for afforestation in Nigeria, describe species selection criteria, and outline the steps in plantation establishment (Linked to Part 4.3),
- **SLO 4.4** describe the wood anatomy and physical properties of selected major Nigerian timber species (Linked to Part 4.4), and
- **SLO 4.5** explain timber seasoning and preservation methods and identify common timber defects (Linked to Part 4.4).

4.1 Introduction to Silviculture

4.1.1 Definition and scope of silviculture

Silviculture is defined as the theory and practice of controlling the establishment, composition, structure, and growth of forests. The word derives from the Latin silva (forest) and cultura (cultivation). Silviculture encompasses all deliberate interventions in the forest aimed at shaping its development: site preparation, planting, tending (weeding, thinning, pruning), harvesting, and post-harvest treatment to initiate regeneration. The silviculturist's decisions determine which tree species grow in a stand, how densely they grow, how quickly they grow, and when and how they are harvested. Silviculture is therefore the bridge between ecology (understanding how forests develop) and forest management (directing that development toward human and ecological goals).

The scope of silviculture includes: (1) regeneration silviculture (how new trees are established, whether naturally or artificially); (2) tending operations (intermediate treatments applied between establishment and final harvest: weeding, cleaning, thinning, pruning); (3) harvesting systems (how and when trees are removed, which determines the structure of the residual stand and the conditions for regeneration); and (4) site improvement (drainage, soil preparation, prescribed burning for savanna management). In tropical countries such as Nigeria, silviculture must also address the complexity of species-rich natural forests in which hundreds of species grow in mixtures, compared with the simplified monocultures more typical of temperate plantation forestry.

Fill in the blank: Silviculture is derived from the Latin words silva (forest) and cultura (cultivation); its scope includes regeneration, _____ operations (weeding, thinning, pruning), harvesting systems, and site improvement.

4.1.2 Silvicultural systems: even-aged and uneven-aged management

A silvicultural system is a planned programme of treatments applied throughout the life of a stand to achieve specified objectives. Even-aged systems produce stands in which all trees are approximately the same age: the entire stand (or a defined cutting area called a coupe or compartment) is harvested at one time (clear-cutting) or in two or three successive cuts (shelterwood system), after which new trees establish from seed, coppice, or planting and grow as a new even-aged cohort. Even-aged systems are simple to manage, facilitate mechanised harvesting, and maximise volume production of preferred species; they are best suited to light-demanding pioneer species and plantation monocultures.

Uneven-aged (all-aged or selection) systems maintain a continuous range of tree ages and sizes in the same stand at all times; individual mature trees or small groups are removed at each harvesting entry while younger trees continue to develop. The stand always has a continuous canopy and never experiences the drastic disruption of clear-cutting. Uneven-aged systems are more complex to manage, require skilled foresters to select harvest trees, and are appropriate for shade-tolerant climax species and for forests where continuous canopy cover is needed for biodiversity or watershed protection. Most natural Nigerian rainforests, if managed at all, are managed under modified selection or tropical shelterwood systems.

Fill in the blank: Even-aged silvicultural systems produce stands in which all trees are approximately the same _____; uneven-aged systems maintain a continuous range of tree ages and sizes, with individual trees removed at each harvesting entry.

4.1.3 The selection and shelterwood systems

The selection system removes individual trees or small groups of trees scattered across the stand at regular intervals (the felling cycle; typically 25 to 40 years in tropical forests). Single-tree selection removes isolated mature trees; group selection removes small groups (0.1 to 1 ha gaps) and is better for semi-light-demanding species. The selection system maintains an uneven-aged structure, continuous canopy cover, and biodiversity; it is the most appropriate system for shade-tolerant climax species (many Nigerian rainforest timber species) and for protected forests where soil disturbance and aesthetic disruption must be minimised.

The shelterwood system removes the overstorey in two to three cuts over a regeneration period of 10 to 20 years. The first cut (preparatory cut) opens the canopy slightly and stimulates seed production and seedling establishment; the second cut (seed cut) removes most of the overstorey, leaving sufficient shelter trees to protect seedlings and provide seed; the final cut (removal cut) removes the remaining shelter trees once the new cohort is well established. The shelterwood system is used for species that require moderate light for establishment but cannot tolerate full exposure; it was adapted for tropical forests as the Tropical Shelterwood System (TSS) used in West African forests including Nigeria.

Fill in the blank: In the shelterwood system, the _____ cut removes most of the overstorey while leaving shelter trees to provide shade and seed for the establishing new cohort; the removal cut follows once the new generation is well established.

Pilot questions 4.1

11. Define silviculture and state three operations that fall within its scope.
12. Distinguish between even-aged and uneven-aged silvicultural systems in terms of stand structure, harvesting method, and best application.
13. Describe the three cuts in the shelterwood system and state the purpose of each.
14. State two advantages and two disadvantages of even-aged management compared with uneven-aged management.
15. For what type of species and forest conditions is the selection system most appropriate and why?

4.2 Natural Regeneration of Nigerian Forests

4.2.1 Mechanisms of natural regeneration

Natural regeneration is the re-establishment of forest through natural processes without artificial planting. Mechanisms include: (1) Seed regeneration: seeds from parent trees in or adjacent to the stand germinate and grow into new seedlings; the most important mechanism in species-rich tropical forests; depends on seed source (adequate parent trees), seed viability (most tropical timber species have recalcitrant seeds that must germinate quickly), and safe site availability (suitable microsites with adequate light, moisture, and mineral soil for germination). (2) Coppice

regeneration: new shoots arise from cut stumps; effective in many hardwood species; Triplochiton scleroxylon and Terminalia species coppice vigorously; produces rapid early growth because the stump root system is already established. (3) Root sucker regeneration: new shoots arise from lateral roots; less common but occurs in some species (Antiaris toxicaria).

The seed bank (seeds stored in the soil) plays a role in some forest types (pioneer species with hard-coated long-lived seeds: Musanga cecropioides; Anthocleista species) but is of limited importance for climax timber species whose seeds have short viability. The seedling bank (advance regeneration; established seedlings and saplings growing slowly under the closed canopy) is critical for management: many shade-tolerant species (Khaya, Entandrophragma) maintain a pool of suppressed seedlings that respond to canopy opening by accelerating growth. Successful natural regeneration requires: seed source trees, appropriate light levels for germination and early growth, control of competing vegetation (climbers, grasses), and protection from fire and livestock.

Fill in the blank: The pool of suppressed seedlings and saplings growing slowly under a closed forest canopy is called _____ regeneration; these plants respond rapidly to canopy opening caused by logging or natural tree death, making them critical for natural forest recovery.

4.2.2 The tropical shelterwood system in Nigeria

The Tropical Shelterwood System (TSS) was developed by foresters working in West African forests (notably by A.J. Swaine and F.W. Thompson in Ghana; later adapted for Nigeria) in the 1940s and 1950s as a method for managing natural mixed tropical rainforest for sustained timber production. The TSS involves: (1) Pre-treatment: climber cutting and poison-girdling of non-commercial trees (weed trees) that compete with commercial seedlings and saplings; this is carried out 3 to 5 years before the main harvest to reduce competition and allow the seedling bank to build up. (2) Harvesting: all commercial-sized trees above the minimum girth limit (MGL; typically 120 to 150 cm girth at breast height) are felled and extracted; seed trees of commercial species below MGL are retained. (3) Post-harvest treatment: cutting of climbers that

smother regenerating seedlings; cleaning of undesirable vegetation around commercial seedlings; enrichment planting in gaps where natural regeneration is inadequate.

The TSS was applied in Omo Forest Reserve (Ogun and Oyo states), Sapoba Forest Reserve (Edo State), and Omo-Shasha-Oluwa complex (Ondo State). Its success was limited by: inadequate pre-treatment (climber cutting often omitted for cost reasons); damage to regeneration during log extraction; re-invasion of logged areas by climbers and Chromolaena odorata (siam weed); and insufficient post-harvest tending. The MGL system (simply setting a minimum harvesting girth without the full TSS treatment package) became the de facto management system in many Nigerian forest reserves, often with poor regeneration outcomes. Modern reduced-impact logging (RIL) incorporates many TSS principles with better planning and monitoring.

Fill in the blank: In the Tropical Shelterwood System, the minimum _____ limit (MGL) specifies the minimum stem girth at breast height below which trees must not be felled; trees above this limit are harvested while smaller trees are retained as future crop trees.

4.2.3 Enrichment planting

Enrichment planting is the introduction of seedlings or transplants of commercially valuable species into gaps or under an existing forest canopy to supplement inadequate natural regeneration. It is used when: natural regeneration of desired species is absent or insufficient after logging; the species composition of regeneration is dominated by undesirable pioneers; or specific high-value species (Milicia excelsa, Khaya species) need to be re-introduced into degraded forest. Methods: line planting (strips of vegetation cleared at regular intervals, typically 3 to 5 m wide and 10 to 20 m apart; seedlings planted in the cleared strips); gap planting (seedlings planted in existing natural canopy gaps); and taungya (trees planted in combination with food crops grown by farmers who tend both trees and crops for 2 to 3 years before crops are shaded out).

Species used for enrichment planting in Nigerian forests: Milicia excelsa (iroko; planted in gaps 10 to 15 m diameter for adequate light); Khaya ivorensis (Lagos mahogany; tolerates partial shade; line planting); Terminalia ivorensis (black afara; line planting in Ondo and Edo reserves); Nauclea diderrichii (opepe; riparian gaps); Triplochiton scleroxylon (obeche; vigorous; planted in open areas). Seedling production: seeds collected from good parent trees; germinated in nursery beds or polythene bags; transplanted to the field after 3 to 6 months. Major challenges: high mortality in the first year (drought, weed competition, browsing by livestock and wildlife); maintenance costs (repeated weeding for 3 to 5 years); and the long time before enrichment planting produces a visible impact on stand composition.

Fill in the blank: _____ planting introduces seedlings of commercially valuable species into gaps or cleared strips in a logged-over or degraded forest to supplement inadequate natural regeneration; it is used to re-establish species such as iroko and mahogany that fail to regenerate naturally after heavy logging.

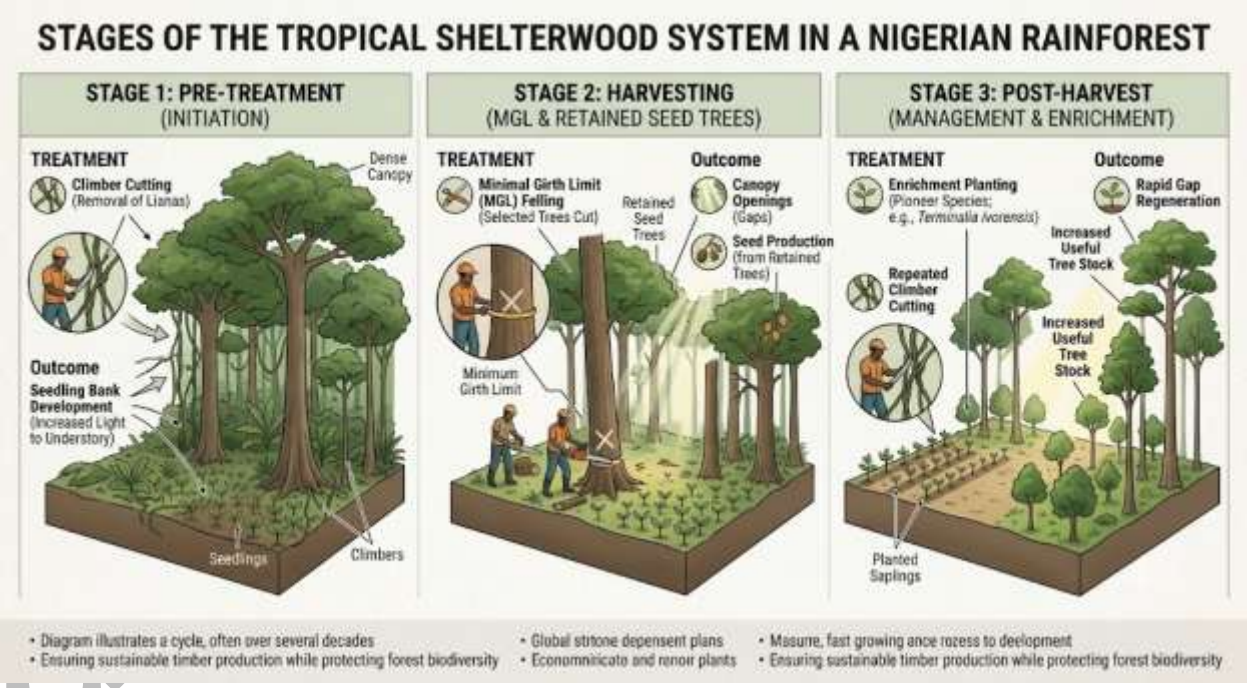

Figure 4.1: Three stages of the Tropical Shelterwood System in a Nigerian rainforest

Pilot questions 4.2

11. Distinguish between seed regeneration, coppice regeneration, and root sucker regeneration as mechanisms of natural forest recovery.
12. Explain what advance regeneration (seedling bank) is and why it is important for post-harvest forest recovery in Nigeria.
13. Describe the three main stages of the Tropical Shelterwood System (TSS) as applied in Nigeria.
14. State two reasons why the TSS was not fully successful in many Nigerian forest reserves.
15. Define enrichment planting and state two species used for enrichment planting in Nigerian forests with the planting method for each.

4.3 Afforestation and Plantation Forestry

4.3.1 Definition and rationale for afforestation in Nigeria

Afforestation is the establishment of a forest or stand of trees in an area where there was no previous forest cover. It is distinguished from reforestation (re-establishing forest on recently deforested land) and enrichment planting (introducing trees into an existing degraded forest). The rationale for afforestation in Nigeria is compelling: rapid population growth (Nigeria's population of approximately 220 million is projected to reach 400 million by 2050) drives increasing demand for timber, fuelwood, and other forest products; natural forests are insufficient and declining; and large areas of degraded land (an estimated 50 million ha of degraded savanna and forest fringe land) are available for plantation establishment.

Afforestation in Nigeria addresses several objectives simultaneously: (1) timber supply (reducing pressure on natural forests by producing construction and industrial timber from plantations); (2) fuelwood and charcoal supply (fast-growing plantation species produce fuel in 5 to 10 years); (3) land rehabilitation (trees stabilise eroded soils, improve water infiltration, and restore soil organic matter on degraded sites); (4) carbon sequestration (new plantations absorb CO2; relevant to Nigeria's REDD+ and NDC climate commitments); (5) employment (nursery work, planting, tending, and harvesting create rural employment); and (6) raw material for wood-based industries (plywood, particle board, pulp; Triplochiton plantations in south-west Nigeria).

Fill in the blank: Afforestation is the establishment of forest on land that previously had no forest cover; it is distinguished from _____, which is re-establishing forest on recently deforested land where forest previously existed.

4.3.2 Species selection for plantations in Nigeria

Species selection is the most critical decision in plantation forestry; the wrong choice leads to plantation failure or production of unsuitable timber. Selection criteria: (1) site suitability (the species must be adapted to the rainfall, temperature, soil type, and drainage of the planting site); (2) growth rate (fast-growing species produce economic returns sooner; important for fuelwood and pulpwood); (3) timber quality (the species must produce timber with the properties required for the intended end use); (4) seed availability (seeds must be obtainable in adequate quantities from reliable sources); (5) silvicultural manageability (the species must respond well to nursery production, transplanting, and tending); (6) market demand (the timber must have an established or developable market).

Key plantation species in Nigeria by ecological zone: Humid south (above 1,200 mm rainfall): Triplochiton scleroxylon (obeche; fast-growing; plywood; planted extensively in south-west Nigeria); Gmelina arborea (introduced from South/South-east Asia; very fast-growing; up to 15 m3/ha/year MAI; pulpwood, fuelwood, furniture; most widely planted exotic species in Nigeria; tolerates a range of soils); Tectona grandis (teak; from South-east Asia; valuable furniture and construction timber; durable; planted in Ondo, Ogun, Edo states); Terminalia ivorensis (black afara; indigenous; good form; joinery). Guinea savanna (800 to 1,200 mm): Eucalyptus species (E. camaldulensis; fuelwood and poles; fast-growing; drought-tolerant; widely planted in central and northern Nigeria); Azadirachta indica (neem; from India; widely planted throughout Nigeria for shade, windbreaks, and medicinal use; drought-tolerant). Sudan/Sahel (below 800 mm): Acacia senegal (gum arabic); Prosopis juliflora (mesquite; invasive in some areas but used for fuelwood and pods); Casuarina equisetifolia (coastal and dry areas; windbreaks).

Fill in the blank: Gmelina arborea, introduced from South and South-east Asia, is the most widely planted _____ tree species in Nigeria; it grows very fast (up to 15 m3/ha/year mean annual increment) and is used for pulpwood, fuelwood, and furniture.

4.3.3 Plantation establishment: site preparation, planting, and tending

Site preparation: removing existing vegetation to reduce competition with planted seedlings. Methods vary by intensity: (1) Manual clearing (cutlass and axe; most common in Nigerian smallholder plantations); (2) Mechanical clearing (bulldozers and tree pushers; used on large commercial estates; disturbs soil structure and is unsuitable on steep slopes or erosion-prone sites); (3) Chemical clearing (herbicide application; glyphosate or paraquat; more selective than mechanical; avoids soil disturbance). Line clearing (cutting strips 1 to 2 m wide at planting intervals while leaving uncleared strips to protect soil) is preferred in erodible sites. After clearing, the site is marked out at the desired spacing (typically 2 m x 2 m to 3 m x 3 m for timber species; 1 m x 1 m for fuelwood); planting holes (30 cm x 30 cm x 30 cm) are dug along the lines.

Planting: seedlings raised in the nursery (polythene bag or bare-root) are transplanted at the start of the rainy season (April to June in southern Nigeria; June to July in central Nigeria) to maximise rainfall availability during establishment. The polythene bag is removed before planting; the seedling is set at the same depth it grew in the nursery; soil is firmed around the roots. Tending operations: (1) Weeding (the most critical and expensive tending operation; clearing competing vegetation around seedlings 2 to 4 times per year for the first 2 to 3 years); (2) Thinning (removing suppressed and malformed trees to concentrate growth on the best stems; typically carried out at 3 to 5 years and again at 7 to 10 years; thinnings from Gmelina and Eucalyptus plantations are sold as fuelwood or poles); (3) Pruning (removing lower branches to improve log quality, reduce knot defects, and allow light into the understorey); (4) Fire protection (firebreak maintenance in savanna plantations; particularly important for Eucalyptus and Tectona plantations).

Fill in the blank: In plantation establishment, _____ is the most critical and expensive tending operation during the first 2 to 3 years; competing vegetation must be cleared 2 to 4 times per year to prevent seedlings from being overwhelmed and dying.

Pilot questions 4.3

11. Define afforestation and distinguish it from reforestation and enrichment planting.
12. State four criteria used in selecting species for plantation establishment in Nigeria.
13. Name two plantation species suited to the humid south and two suited to the Guinea savanna of Nigeria, stating the main product from each.
14. Describe the steps in plantation establishment from site preparation to planting.
15. Name three tending operations applied in Nigerian plantations and state the purpose of each.

4.4 Characteristics of Major Nigerian Timber Species

4.4.1 Wood anatomy and properties of selected species

Wood (secondary xylem) consists of cells that transport water and nutrients and provide mechanical support to the tree. Key anatomical features visible under a hand lens or microscope: vessel elements (pores; large diameter cells conducting water; hardwoods have vessels; softwoods do not); fibres (thick-walled cells providing mechanical strength; fibre length and wall thickness determine pulp quality); rays (radial strands of parenchyma cells transporting materials laterally; produce the ray figure visible on quartersawn timber); axial parenchyma (vertically aligned storage cells; patterns of parenchyma visible on cross-section are important in species identification). Grain direction: straight grain (fibres parallel to stem axis; easy to work; Triplochiton); interlocked grain (fibres alternately inclined left and right; produces ribbon figure on quartersawn surfaces; Khaya, Entandrophragma); wavy grain (undulating; produces fiddle-back figure; Lovoa).

Key physical properties of Nigerian timbers: density (mass per unit volume at 12 percent moisture content; the most important single property; determines strength, hardness, and ease of working): Milicia excelsa 660 kg/m3; Khaya ivorensis 530 kg/m3; Entandrophragma cylindricum 620 kg/m3; Triplochiton scleroxylon 370 kg/m3; Nauclea diderrichii 740 kg/m3.

Colour: sapwood (outer, younger, lighter-coloured wood, not durable) and heartwood (inner, darker, often containing extractives that resist decay; the commercial timber). Texture: fine (small pores, smooth feel: Guarea, Lovoa); medium (Khaya); coarse (large pores, rough feel: Triplochiton). Shrinkage: the tendency to change dimensions on drying; high shrinkage causes warping and checking; Triplochiton has low shrinkage (good dimensional stability).

Fill in the blank: Interlocked grain, in which wood fibres are alternately inclined in opposite directions, produces a _____ figure on quartersawn timber surfaces; it is characteristic of Khaya and Entandrophragma species and is highly valued for furniture veneers.

4.4.2 Utilisation properties and grading of Nigerian timbers

Utilisation properties determine the end uses for which a timber is suited. Workability: ease of sawing, planing, turning, and finishing. Triplochiton scleroxylon works easily with both hand and machine tools; Milicia excelsa requires sharp tools due to silica deposits in the wood that blunt saw teeth rapidly. Gluing: most Nigerian timbers glue satisfactorily with PVA and urea-formaldehyde adhesives. Nailing and screwing: dense timbers (Milicia, Nauclea) require pre-drilling; lighter timbers (Triplochiton, Terminalia) take nails and screws without splitting. Finishing: Khaya and Entandrophragma respond excellently to staining, polishing, and varnishing due to their fine to medium texture and attractive grain pattern.

Timber grading in Nigeria follows standards based on visual inspection for defects (knots, splits, wane, resin pockets, insect damage). The Nigerian Hardwood Export Grading Rules (Federal Department of Forestry) classify sawn hardwood into: Prime (best quality; no significant defects); No. 1 Common; No. 2 Common; and Below grade. Log grading assesses girth, length, straightness, and freedom from defects. The Forestry Research Institute of Nigeria (FRIN) publishes technical data sheets for individual Nigerian timber species listing density, strength, shrinkage, durability, workability, and recommended end uses; these are the primary reference documents for timber utilisation in Nigeria.

Fill in the blank: The Forestry Research Institute of Nigeria (FRIN) publishes technical _____ sheets for individual Nigerian timber species listing density, strength, shrinkage, durability, workability, and recommended end uses.

4.4.3 Timber seasoning, preservation, and defects

Seasoning is the controlled reduction of moisture content (MC) in freshly sawn timber to a level appropriate for its end use. Green (freshly felled) timber has MC of 80 to 150 percent (above fibre saturation point, FSP, which is approximately 30 percent); timber must be dried to the equilibrium moisture content (EMC) of its service environment (12 to 15 percent for indoor furniture in southern Nigeria; 8 to 10 percent for joinery). Air drying (stacking sawn timber on raised stickers in the open air with good airflow; slow; 6 to 24 months depending on species and thickness; no energy cost; risk of stain and degrade). Kiln drying (forced hot air in a drying kiln; faster, 2 to 8 weeks; more uniform; higher cost; required for export quality timber and precision joinery).

Timber preservation: applying chemical preservatives to increase resistance to fungi and wood-boring insects. Methods: brushing or dipping (superficial penetration; adequate for low-hazard uses); hot-and-cold bath (open tank; moderate penetration; used for poles and sleepers); pressure impregnation (full-cell Bethell process or empty-cell Lowry/Rueping process; deepest penetration; required for ground-contact and marine applications). Common preservatives used in Nigeria: CCA (chromated copper arsenate; green colour; widely used for poles, fencing, marine piling); creosote (coal tar derivate; dark brown; railway sleepers, telegraph poles; toxic; use declining). Timber defects: knots (branch bases enclosed in the wood; weaken timber; reduce grade); splits and checks (cracks along the grain caused by drying stresses); wane (presence of bark or absence of wood at the corner of a sawn piece); blue stain (fungal discolouration; does not weaken but reduces grade); insect damage (pinhole borers, powder-post beetles).

Fill in the blank: Pressure _____ forces preservative chemicals deep into the timber using a sealed cylinder; it gives the greatest depth of penetration and is required for timber used in ground contact, marine piling, or other high-hazard applications.

- [Insert Box here]

Short description: A summary table of wood properties and uses of major Nigerian timber species: five columns (Species; Common name; Density kg/m3; Durability class; Principal uses). Rows: Milicia excelsa (iroko; 660; Class 2; outdoor construction, bridge decking, heavy joinery); Khaya ivorensis (Lagos mahogany; 530; Class 3; furniture, panelling, veneer, boat-building); Entandrophragma cylindricum (sapele; 620; Class 3; furniture, veneer, flooring); Triplochiton scleroxylon (obeche; 370; Class 5; plywood, interior joinery, packing cases); Nauclea diderrichii (opepe; 740; Class 2; heavy construction, marine piling, railway sleepers); Gmelina arborea (gmelina; 400; Class 4; pulpwood, fuelwood, light furniture).

Species Name	Common Name	Density (kg/m³)	Durability Class	Principal Uses
Milicia excelsa	Iroko	~660	Very durable	Furniture, flooring, boat building, joinery
Khaya ivorensis	Lagos Mahogany	~560	Moderately durable	High-quality furniture, veneer, interior joinery
Entandrophragma cylindricum	Sapele	~640	Durable	Flooring, doors, paneling, musical instruments
Triplochiton scleroxylon	Obeche	~370	Non-durable	Plywood, carving, light furniture, packaging
Nauclea diderrichii	Opepe	~720	Highly durable	Heavy construction, bridges, railway sleepers
Gmelina arborea	Gmelina	~480	Moderately durable	Paper pulp, furniture, general utility timber

Box 4.1: Wood properties and principal uses of major Nigerian timber species

Pilot questions 4.4

11. Define density and durability class of timber and explain how each influences the choice of end use.
12. Distinguish between sapwood and heartwood and explain why heartwood is the commercially preferred part of a timber log.
13. Describe the difference between air drying and kiln drying of timber in terms of speed, cost, and quality of the dried product.

14. State three common timber defects found in Nigerian hardwoods and explain how each affects the grade and value of the timber.
15. Explain the purpose of timber preservation and describe two methods used in Nigeria.

Series Summary

This Series examined silviculture as the management of forest establishment, composition, structure, and growth. Even-aged systems such as clear-cutting and shelterwood produce stands of similar age, while uneven-aged selection systems maintain trees of different ages. The shelterwood system uses preparatory, seed, and removal cuts, while the Tropical Shelterwood System was adapted for Nigerian forests through climber cutting, removal of undesirable trees, controlled harvesting, and post-harvest tending. Natural regeneration may occur through seed, coppice shoots, or root suckers, while enrichment planting introduces valuable species such as iroko, mahogany, afara, opepe, and obeche through line, gap, or taungya planting.

Afforestation is important for timber and fuelwood supply, land rehabilitation, carbon storage, and employment. Species are selected according to site conditions, growth rate, timber quality, seed availability, ease of management, and market demand. Plantation establishment involves site preparation, planting at the beginning of the rains, weeding, thinning, pruning, and fire protection. The Series also covered wood properties such as density, durability, and grain, as well as seasoning by air or kiln drying, preservation by brushing, hot-and-cold treatment, or pressure impregnation, and common defects including knots, checks, wane, stains, and insect damage.

Glossary of Terms

- **Afforestation:** the establishment of a forest on land that previously had no forest cover; distinguished from reforestation (restoring recently deforested land) and enrichment planting (introducing trees into degraded forest).
- **Air drying:** seasoning sawn timber by stacking it outdoors on stickers with good airflow; slow (6 to 24 months) but free of energy cost; suitable for most Nigerian construction timber.
- **CCA (chromated copper arsenate):** a chemical wood preservative imparting a green colour; applied by pressure impregnation; widely used in Nigeria for poles, fencing, and marine piling.

- **Coppice regeneration:** new shoots arising from cut stumps after tree felling; vigorous in Triplochiton scleroxylon and Terminalia species; produces rapid early growth using the established root system.
- **Enrichment planting:** the introduction of seedlings of commercially valuable species into gaps or cleared strips in a degraded or logged-over forest to supplement inadequate natural regeneration.
- **Even-aged system:** a silvicultural system producing stands in which all trees are approximately the same age; examples include clear-cutting and shelterwood; suited to light-demanding pioneer species and plantation monocultures.
- **Gmelina arborea:** a fast-growing exotic tree introduced from South and South-east Asia; the most widely planted exotic species in Nigeria; used for pulpwood, fuelwood, and light furniture; achieves mean annual increments of up to 15 m3/ha/year.
- **Heartwood:** the inner, darker core of a tree stem containing extractives that resist fungal and insect attack; the commercially preferred part of a log; more durable than the outer sapwood.
- **Interlocked grain:** a wood grain pattern in which fibres are alternately inclined in opposite directions in successive growth layers; produces a ribbon figure on quartersawn timber; characteristic of Khaya and Entandrophragma.
- **Kiln drying:** seasoning timber in a heated chamber with controlled temperature, humidity, and airflow; much faster than air drying (2 to 8 weeks); required for export quality timber and precision joinery.
- **Minimum girth limit (MGL):** the minimum stem girth at breast height below which trees must not be harvested; a key tool of sustained yield management in Nigerian forest reserves; typically 120 to 150 cm.
- **Pressure impregnation:** a timber preservation method using a sealed cylinder to force preservative chemicals deep into the wood under pressure; gives the greatest penetration depth; required for high-hazard applications.
- **Seedling bank (advance regeneration):** established seedlings and suppressed saplings growing slowly under a closed forest canopy; critical for post-logging recovery because these plants respond rapidly to canopy opening.
- **Silviculture:** the science and art of controlling the establishment, composition, structure, and growth of forests; from Latin silva (forest) and cultura (cultivation).

- **Taungya:** a plantation establishment system in which food crops are grown between tree seedlings by farmers for 2 to 3 years until the canopy closes; reduces tending costs and provides short-term food security for participating communities.
- **Tectona grandis:** teak; a large deciduous tree introduced from South-east Asia; produces very durable, valuable timber for furniture and construction; planted in Ondo, Ogun, and Edo states of Nigeria.
- **Tropical Shelterwood System (TSS):** a silvicultural system developed for West African natural mixed tropical rainforests; involves pre-treatment (climber cutting; poison-girdling), MGL harvesting, and post-harvest tending to promote natural regeneration.
- **Uneven-aged system:** a silvicultural system maintaining a continuous range of tree ages and sizes in the same stand; individual or small groups of mature trees are removed at each harvesting entry; suited to shade-tolerant climax species.

Concept Check Questions [Series 4]

Objective Questions

11. Silviculture is derived from the Latin words silva (forest) and _____ (cultivation); it controls the establishment, composition, structure, and growth of forests. (Linked to SLO 4.1)
12. In the shelterwood system, the _____ cut removes most of the overstorey while leaving shelter trees to protect and seed the new cohort. (Linked to SLO 4.1)
13. Gmelina arborea is the most widely planted _____ tree species in Nigeria, used for pulpwood, fuelwood, and light furniture. (Linked to SLO 4.3)
14. The density of Triplochiton scleroxylon (obeche) is approximately _____ kg/m3, making it a light hardwood suited to plywood and interior joinery. (Linked to SLO 4.4)
15. Pressure _____ forces preservative chemicals deep into timber under pressure and is required for high-hazard applications such as ground contact and marine piling. (Linked to SLO 4.5)

Short-Answer Questions

16. Distinguish between even-aged and uneven-aged silvicultural systems with one example of each. (Linked to SLO 4.1)
17. Explain what advance regeneration (seedling bank) is and why it matters for post-logging forest recovery. (Linked to SLO 4.2)
18. State four criteria for species selection in plantation forestry and give one example for each. (Linked to SLO 4.3)
19. Compare air drying and kiln drying of timber under the headings of speed, cost, and suitability. (Linked to SLO 4.5)
20. Name three timber defects found in Nigerian hardwoods and state how each affects timber grade. (Linked to SLO 4.5)

Long-Answer Questions

15. Describe the major silvicultural systems used in Nigerian forests (even-aged, shelterwood, selection, TSS), the mechanisms of natural regeneration, and the principles and practice of enrichment planting. (Linked to SLOs 4.1, 4.2)
16. Explain the rationale for afforestation in Nigeria, describe the criteria for species selection and the steps in plantation establishment, and outline the wood properties, seasoning, preservation, and defects of major Nigerian timber species. (Linked to SLOs 4.3, 4.4, 4.5)

Answers to Concept Check Questions [Series 4]

Objective Questions

1. Cultura.
2. Seed.
3. Exotic.
4. 370.
5. Impregnation.

Short-Answer Questions

6. Even-aged: all trees approximately the same age; harvested together; example: clear-cutting Gmelina plantation. Uneven-aged: continuous range of ages; individual trees removed at each entry; example: selection system in Cross River rainforest.
7. Advance regeneration is the pool of suppressed seedlings and saplings growing slowly under a closed canopy. When logging opens the canopy, these plants respond rapidly by accelerating growth, making them the primary source of new crop trees after harvesting.
8. Site suitability (Gmelina tolerates varied soils in the humid south). Growth rate (Eucalyptus fast-growing for fuelwood). Timber quality (Tectona grandis produces durable furniture timber). Seed availability (Triplochiton seed widely available from natural forest).
9. Air drying: slow (6 to 24 months); no energy cost; risk of staining and degrade; suitable for construction timber. Kiln drying: fast (2 to 8 weeks); higher cost; uniform moisture content; required for export quality and precision joinery.
10. Knots (enclosed branch bases; weaken timber; reduce to lower grade). Checks (drying cracks along grain; structural weakness; downgrade). Blue stain (fungal discolouration; no strength loss but reduces grade and marketability).

Long-Answer Questions

11. Even-aged systems (clear-cut, shelterwood): all trees same age; harvested together; suited to light-demanding species and plantations. Shelterwood cuts: preparatory (opens canopy slightly), seed (removes most overstorey; shelter trees retained), removal (shelter trees felled once regeneration established). Uneven-aged systems (selection): continuous age range; individual or small groups removed; shade-tolerant climax species; continuous canopy cover. Tropical Shelterwood System (TSS): adapted for Nigerian mixed rainforest; pre-treatment (climber cutting; poison-girdling weed trees 3 to 5 years before harvest); MGL harvesting (trees above 120 to 150 cm girth felled); post-harvest tending (climber cutting; cleaning; enrichment planting in

large gaps); applied in Omo, Sapoba, Omo-Shasha-Oluwa reserves; limited by cost-cutting on pre-treatment and climber re-invasion. Natural regeneration: seed (seedling bank most important for climax species); coppice (Triplochiton, Terminalia vigorous resprouters); root suckers (Antiaris). Advance regeneration critical: suppressed seedlings respond rapidly to canopy opening. Enrichment planting: seedlings introduced into gaps or cleared lines; species: iroko (gap planting), mahogany (line planting), obeche (open areas); methods: line planting, gap planting, taungya; challenges: weeding costs, browsing, long time to impact.

12. Afforestation rationale: rising timber and fuelwood demand; land rehabilitation; carbon sequestration (REDD+, NDC); employment. Species selection criteria: site suitability; growth rate; timber quality; seed availability; silvicultural manageability; market demand. Species: humid south (Gmelina arborea; Tectona grandis teak; Triplochiton; Terminalia ivorensis); Guinea savanna (Eucalyptus camaldulensis; Azadirachta indica neem); Sudan/Sahel (Acacia senegal; Casuarina). Plantation establishment: site preparation (manual clearing most common; mechanical on large estates; chemical where appropriate; line clearing on erodible sites); marking spacing (2 x 2 m to 3 x 3 m); planting (start of rains; polythene bag seedlings; correct depth). Tending: weeding (most critical; 2 to 4 times/year for first 2 to 3 years); thinning (3 to 5 years; 7 to 10 years; removes suppressed trees); pruning (log quality; knot reduction); fire protection (firebreaks; especially Eucalyptus and Tectona). Wood properties: density (opepe 740; iroko 660; sapele 620; Khaya 530; Gmelina 400; obeche 370 kg/m3); durability (Class 1 to 2: iroko, opepe; Class 5: obeche). Grain: interlocked ribbon figure (Khaya, Entandrophragma); straight (Triplochiton). Seasoning: air drying (slow; free; 6 to 24 months); kiln drying (fast; costly; 2 to 8 weeks). Preservation: brushing (superficial); hot-and-cold bath (moderate penetration); pressure impregnation (deepest; CCA or creosote; ground contact and marine). Defects: knots (weaken; downgrade); checks (drying cracks); wane (bark or missing corner); blue stain (fungal; no strength loss); insect damage.

Answers to Pilot Questions [Series 4]

Part 4.1

11. Silviculture is the science and art of controlling forest establishment, composition, structure, and growth. Three operations: regeneration (planting or promoting natural seedling establishment);

thinning (removing suppressed trees to concentrate growth); harvesting (felling mature trees to initiate regeneration).

12. Even-aged: all trees approximately the same age; whole stand harvested at once or in a few cuts; suited to light-demanding species and plantations. Uneven-aged: continuous range of ages; individual or small groups removed at each entry; continuous canopy maintained; suited to shade-tolerant climax species.
13. Preparatory cut: opens canopy slightly to stimulate seed production and seedling establishment. Seed cut: removes most overstorey; shelter trees retained to provide shade and seed. Removal cut: remaining shelter trees felled once the new generation is well established.
14. Advantages of even-aged: simple to plan and manage; allows mechanised harvesting; maximises volume of preferred species. Disadvantages: drastic canopy removal increases erosion risk; reduces biodiversity; even-aged stands are more vulnerable to wind-throw and pest outbreaks.
15. The selection system suits shade-tolerant climax species because their seedlings establish and grow under partial shade; continuous canopy cover is maintained, protecting soil and biodiversity; it is also appropriate where visual amenity or watershed protection requires unbroken forest cover.

Part 4.2

11. Seed regeneration: new trees from germinating seeds; depends on seed source, viability, and safe sites. Coppice: new shoots from cut stumps; rapid growth using existing root system; common in Triplochiton and Terminalia. Root suckers: new shoots from lateral roots; less common; occurs in Antiaris toxicaria.
12. Advance regeneration is the pool of suppressed seedlings under the closed canopy. It is important because these plants have established root systems and respond rapidly to canopy opening, providing immediate new crop trees without waiting for new seed germination.
13. Pre-treatment: climber cutting and poison-girdling of weed trees 3 to 5 years before harvesting to reduce competition. Harvesting: all commercial stems above the MGL (120 to 150 cm girth) are felled; seed trees retained. Post-harvest tending: climber cutting, cleaning around commercial seedlings, and enrichment planting in large gaps.
14. Inadequate pre-treatment (climber cutting often omitted to save cost). Rapid re-invasion of logged areas by Chromolaena odorata (siam weed) and climbers that smother natural regeneration before it establishes.

15. Enrichment planting introduces seedlings of valuable species into gaps or cleared strips to supplement poor natural regeneration. Milicia excelsa: gap planting in openings 10 to 15 m diameter. Khaya ivorensis: line planting in cleared strips.

Part 4.3

11. Afforestation: establishing forest on previously unforested land. Reforestation: re-establishing forest on recently deforested land where forest previously existed. Enrichment planting: introducing tree seedlings into an existing degraded or logged-over forest.
12. Site suitability (species must match local rainfall, soil, and drainage). Growth rate (fast-growers give quicker returns). Timber quality (wood must meet end-use requirements). Seed availability (adequate seed supply from reliable sources).
13. Humid south: Gmelina arborea (pulpwood and fuelwood); Tectona grandis/teak (furniture and construction timber). Guinea savanna: Eucalyptus camaldulensis (fuelwood and poles); Azadirachta indica/neem (shade, windbreaks, and medicinal use).
14. Clear existing vegetation (manual, mechanical, or chemical clearing; line clearing on erodible sites). Mark planting lines and holes at desired spacing (2 x 2 m to 3 x 3 m). Dig planting holes (30 x 30 x 30 cm). Plant nursery-raised seedlings at the start of the rainy season; firm soil around roots; remove polythene bag before planting.
15. Weeding: clearing competing vegetation 2 to 4 times per year for the first 2 to 3 years to prevent seedling mortality. Thinning: removing suppressed and malformed trees to concentrate growth on the best stems. Pruning: removing lower branches to improve log quality and reduce knot defects.

Part 4.4

11. Density (mass per unit volume at 12% MC) determines strength and hardness; high density (opepe 740 kg/m3) = heavy construction; low density (obeche 370 kg/m3) = plywood. Durability class (1 = very durable; 5 = perishable) determines suitability for outdoor use; Class 1 to 2 timbers (iroko, opepe) can be used in ground contact without preservative.
12. Sapwood is the outer, lighter-coloured, younger wood; it is permeable and non-durable. Heartwood is the inner, darker core containing extractives that resist decay; it is durable, less permeable, and the commercially preferred part of the log.
13. Air drying: slow (6 to 24 months); no energy cost; risk of staining; suitable for construction timber. Kiln drying: fast (2 to 8 weeks); higher cost; uniform MC; required for export quality and precision joinery.

14. Knots (enclosed branch bases; reduce strength and bending resistance; downgrade). Checks (drying cracks along grain; structural weakness; reduce grade). Wane (bark or absence of wood at log corner; reduces usable cross-section; downgrade).
15. Preservation increases resistance to fungi and wood-boring insects, extending service life. Brushing: simple surface application; superficial penetration; low hazard uses. Pressure impregnation (CCA or creosote): deepest penetration; required for ground contact, poles, marine piling, and railway sleepers.

References and Attributions [Series 4]

Textual References (Books and External Sources)

- Dawkins, H. C. (1958). The management of natural tropical high forest with special reference to Uganda. Imperial Forestry Institute, Oxford.
- Lowe, R. G. (1978). Nigerian forestry information bulletin No. 26: The natural regeneration of tropical high forest in Nigeria. Federal Department of Forestry, Lagos.
- Lamb, A. F. A. (1968). Gmelina arborea. Fast growing timber trees of the lowland tropics No. 1. Commonwealth Forestry Institute, Oxford.
- Desch, H. E., & Dinwoodie, J. M. (1996). Timber: Structure, properties, conversion and use (7th ed.). Macmillan Press, London.
- FRIN. (2005). Technical data sheets for Nigerian timber species. Forestry Research Institute of Nigeria, Ibadan.

Figures, Plates, Tables, and Boxes

- Figure 4.1: Three stages of the Tropical Shelterwood System in a Nigerian rainforest. Attribution: AI generated. Suggested OER search string: “Tropical Shelterwood System Nigeria natural regeneration silviculture stages diagram OER”.
- Box 4.1: Wood properties and principal uses of major Nigerian timber species. Attribution: AI generated. Suggested OER search string: “Nigerian timber species wood properties density durability uses table iroko mahogany sapele obeche OER”.

Course code: AGE 203

Course title: Forest Management Education

Series 5: Timber Utilization and Transportation

- **Part 5.1: Timber Harvesting Operations**
  - Sub Part 5.1.1: Pre-harvest planning and forest roads
  - Sub Part 5.1.2: Tree felling methods and equipment
  - Sub Part 5.1.3: Log extraction (skidding and forwarding)
- **Part 5.2: Log Transportation**
  - Sub Part 5.2.1: Road transportation of logs in Nigeria
  - Sub Part 5.2.2: River and waterway transportation
  - Sub Part 5.2.3: Safety and environmental impacts of log transportation
- **Part 5.3: Primary Wood Processing**
  - Sub Part 5.3.1: Sawmilling: layout and operations
  - Sub Part 5.3.2: Veneer and plywood production
  - Sub Part 5.3.3: Other primary wood products in Nigeria
- **Part 5.4: Timber Marketing, Trade, and Forest Industry in Nigeria**
  - Sub Part 5.4.1: The Nigerian timber market and value chain
  - Sub Part 5.4.2: Timber export, regulation, and certification
  - Sub Part 5.4.3: Challenges and future prospects of the Nigerian forest industry

Introduction

The forest industry in Nigeria spans the entire chain from felling trees in the forest to delivering finished wood products to the consumer. Each link in this chain, from pre-harvest planning and road construction through felling, extraction, transportation, sawmilling, and marketing, has direct consequences for the economic value of the timber, the safety of workers, and the environmental condition of the forest. Understanding these operations is essential for the forest manager responsible for both the productivity and the sustainability of the forest estate.

This Series covers the practical operations of timber harvesting (felling, extraction, and transportation), primary processing (sawmilling, veneer, and plywood), and the marketing and regulatory framework of the Nigerian timber trade. It also examines the environmental and social impacts of logging operations and the prospects for a more sustainable Nigerian forest industry.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 5.1** describe the pre-harvest planning process and explain the role of forest roads in timber harvesting operations (Linked to Part 5.1),
- **SLO 5.2** describe tree felling methods and equipment and explain log extraction (skidding and forwarding) techniques (Linked to Part 5.1),
- **SLO 5.3** describe the methods and equipment used for road and river transportation of logs in Nigeria (Linked to Part 5.2),
- **SLO 5.4** describe the layout and operations of a Nigerian sawmill and explain veneer and plywood production (Linked to Part 5.3), and
- **SLO 5.5** describe the Nigerian timber value chain, export regulations, and the challenges facing the Nigerian forest industry (Linked to Part 5.4).

5.1 Timber Harvesting Operations

5.1.1 Pre-Harvest Planning and Forest Roads

Pre-harvest planning involves preparing a detailed operational plan before tree felling begins. It includes forest inventory and tree marking, selection of trees to be harvested or retained, planning the direction of felling, designing skid trails, and identifying protected areas. Directional felling reduces damage to surrounding trees and makes log extraction easier, while planned skid trails help avoid steep slopes, streams, and environmentally sensitive zones. These measures are central to reduced-impact logging and improve safety, efficiency, and forest protection.

Forest roads provide access to timber stands and allow logs to be transported to processing centres. However, poorly designed roads can compact soil, increase erosion, disturb drainage, fragment habitats, and encourage encroachment. Main haulage roads are usually wider and more permanent, while secondary roads and skid trails are narrower and may be temporary. Good road design should minimise road density, avoid unnecessary stream crossings, provide culverts or bridges where required, and include drainage structures such as water bars and mitre drains to reduce erosion.

Fill in the blank: Pre-harvest _____ is the most critical step in responsible logging; it includes stand inventory, tree marking, felling direction planning, skid trail layout, and identification of stream buffers and protected areas before any felling begins.

5.1.2 Tree felling methods and equipment

Tree felling is the cutting of standing trees. Manual felling uses the axe (traditional; very slow; still used by small-scale operators in Nigeria) or the two-man crosscut saw. Mechanised felling uses the chainsaw (the dominant felling tool in Nigerian commercial logging since the 1970s): a portable petrol-powered saw with a bar length of 40 to 90 cm; the felling cut is made at the base of the tree in two steps: (1) the undercut (a notch cut on the intended felling side, comprising a

top cut angled downward and a bottom cut; the notch controls the direction of fall); (2) the back cut (a horizontal cut on the opposite side, slightly above the bottom of the notch, leaving a hinge of uncut wood that guides the tree in the intended direction).

Felling safety: the chainsaw operator must clear an escape route before felling; operators and support workers must stand clear of the danger zone (360 degrees around the felling tree); the tree must never be felled into an existing gap where it will fall on retained seedlings or saplings; the hinge must be of correct width (approximately 10 percent of tree diameter) to maintain directional control. Felling damage: large trees inevitably damage surrounding vegetation when they fall; canopy gaps created by felling allow light to reach the forest floor (beneficial for regeneration) but also allow climbers and weeds to establish (potentially detrimental). Controlled directional felling reduces the crown landing zone and minimises damage to retained trees and advance regeneration.

Fill in the blank: In chainsaw felling, the _____ cut creates a notch on the intended felling side that controls the direction of fall; the back cut on the opposite side leaves a hinge of uncut wood that guides the tree as it falls.

5.1.3 Log extraction (skidding and forwarding)

Log extraction is the movement of felled logs from the felling site to the log landing (a cleared area at the roadside where logs are sorted, measured, and loaded onto trucks). Methods of extraction in Nigeria: (1) Manual extraction: logs are manhandled over short distances using levers, rollers, and ropes; limited to small logs in inaccessible terrain. (2) Animal traction: cattle or draught animals pull logs along skid trails; low ground disturbance; used in some community logging operations. (3) Tractor skidding: a wheeled or crawler tractor equipped with a winch and arch (grapple skidder or cable skidder) drags logs along the ground to the landing; the most common extraction method in Nigerian commercial logging; causes significant soil compaction and ground disturbance along skid trails. (4) Forwarding: logs are lifted completely off the ground and carried on a forwarder vehicle; much lower soil disturbance than skidding; used on sensitive soils.

Log landing operations: at the landing, logs are bucked (cross-cut to standardised lengths, typically 3.6 m, 4.8 m, or 6.0 m); bark is removed from one end for species identification and quality assessment; logs are measured for girth (circumference at mid-length using a girth tape) and length; volume is calculated using Hoppus's formula (V = G2/16 x L, where G = quarter girth in feet, L = length in feet; traditional British system still widely used in Nigeria) or metric formulae. Logs are sorted by species, size, and quality; royalties (stumpage fees) are assessed by the state forestry department at the landing before removal.

Fill in the blank: Tractor _____ drags logs along the ground from the felling site to the log landing; it is the most common extraction method in Nigerian commercial logging but causes soil compaction and surface disturbance along skid trails.

Pilot questions 5.1

16. State four components that must be included in a pre-harvest logging plan.
17. Explain why forest road construction is considered one of the most environmentally damaging operations in logging.
18. Describe the two cuts used in chainsaw felling and explain the function of the hinge.
19. Distinguish between log skidding and log forwarding in terms of method, equipment, and ground disturbance.
20. Describe three operations carried out at the log landing before logs are loaded onto trucks.

5.2 Log Transportation

5.2.1 Road transportation of logs in Nigeria

Road transportation is the dominant mode of log movement in Nigeria. Logs are loaded onto timber lorries (log trucks) at the forest landing using a mechanical loader (hydraulic crane mounted on the truck or a separate wheeled loader). Standard Nigerian log trucks carry 15 to 25 tonnes of logs per trip; articulated timber lorries (tractor-trailers) carry up to 40 tonnes. Load configurations: long logs transported as a single piece on a bolster (a rotating cradle on the rear

trailer); short logs (pulpwood, firewood bolts) transported in the truck body. In dense forest terrain, lighter trucks or tractors with trailers are used on secondary roads that cannot bear heavy lorry loads.

Nigeria's road infrastructure significantly affects logging economics and forest management. In the southern rainforest states, the rainy season (April to October) renders many secondary and feeder roads impassable, restricting the logging season to 5 to 7 months per year. Poor road maintenance leads to high vehicle operating costs and vehicle breakdowns that delay timber reaching the mill. Overloading of log trucks is a widespread problem that causes accelerated road deterioration, high accident rates, and legal violations. The Federal Road Safety Corps (FRSC) and state governments regulate truck loads and road use, but enforcement on forest access roads is inconsistent.

Fill in the blank: Standard Nigerian log trucks carry 15 to 25 tonnes per trip; _____ timber lorries (tractor-trailers) can carry up to 40 tonnes and are used on main haulage roads between forest reserves and major sawmill centres.

5.2.2 River and waterway transportation

Before the development of road networks, rivers were the primary means of transporting logs in Nigeria. Log driving (floating individual logs downstream with river current) was widely practised on the Niger, Cross River, Ogun, and Ondo river systems in the colonial period; logs were driven to riverside sawmills or to coastal ports for export. River transportation requires: logs with sufficient natural buoyancy (density below 1,000 kg/m3; most Nigerian timbers float, exceptions include Nauclea diderrichii/opepe which sinks due to high density and silica content); clear river channels free of rapids and sandbars; and boom arrangements to collect and sort logs at the sawmill landing.

Today, river log transportation has largely been replaced by road transport except in areas inaccessible by road (Niger Delta creeks and the Cross River basin). In the Niger Delta, logs from coastal mangrove and swamp forest areas are transported by canoe and motorised barge

along creek systems to coastal sawmills (Warri, Sapele, Port Harcourt). Rafts (bundles of logs lashed together and towed by a motorised boat) are used on the lower Niger and Cross River. The advantages of river transport (low operating cost; no road building required; low fuel consumption per tonne-km) are offset by its dependence on river conditions, long transit times, and log losses from sinking or stranding.

Fill in the blank: River transportation of logs by _____ (individual logs floating downstream) was the primary transport method in Nigeria before road networks were developed; it is still used in the Niger Delta creek system where roads are absent.

5.2.3 Safety and environmental impacts of log transportation

Safety hazards in log transportation: log trucks are among the most dangerous vehicles on Nigerian roads; common accidents include brake failure on steep descents, load shifting causing rollover, and collisions caused by overloaded, overwide or overlong vehicles on narrow roads. Workers at landings and loading sites face crush injuries from rolling logs and being struck by crane booms. Federal Road Safety Corps (FRSC) regulations require load securing, visible marking of oversized loads, and road-worthy vehicles; these are frequently violated. The Workmen's Compensation Act provides for injured workers, but enforcement in the informal logging sector is weak.

Environmental impacts of log transportation: road construction opens previously inaccessible forest to encroachment, illegal farming, and hunting; the disturbance of road verges facilitates invasion by Chromolaena odorata (siam weed) and other weeds; sediment from unpaved log roads washes into streams during rain, increasing turbidity and damaging aquatic habitat; oil and fuel spills from vehicles contaminate soil and water near forest roads and landings; and noise from heavy trucks disturbs wildlife. Reduced-impact logging (RIL) addresses these impacts by minimising road density, controlling skid trail layout, installing drainage structures, and closing and rehabilitating roads after use.

Fill in the blank: The opening of forest roads for log transportation facilitates the invasion of forest edges by _____ (siam weed), an aggressive exotic plant that suppresses natural tree regeneration and is one of the most damaging secondary effects of logging in Nigerian forests.

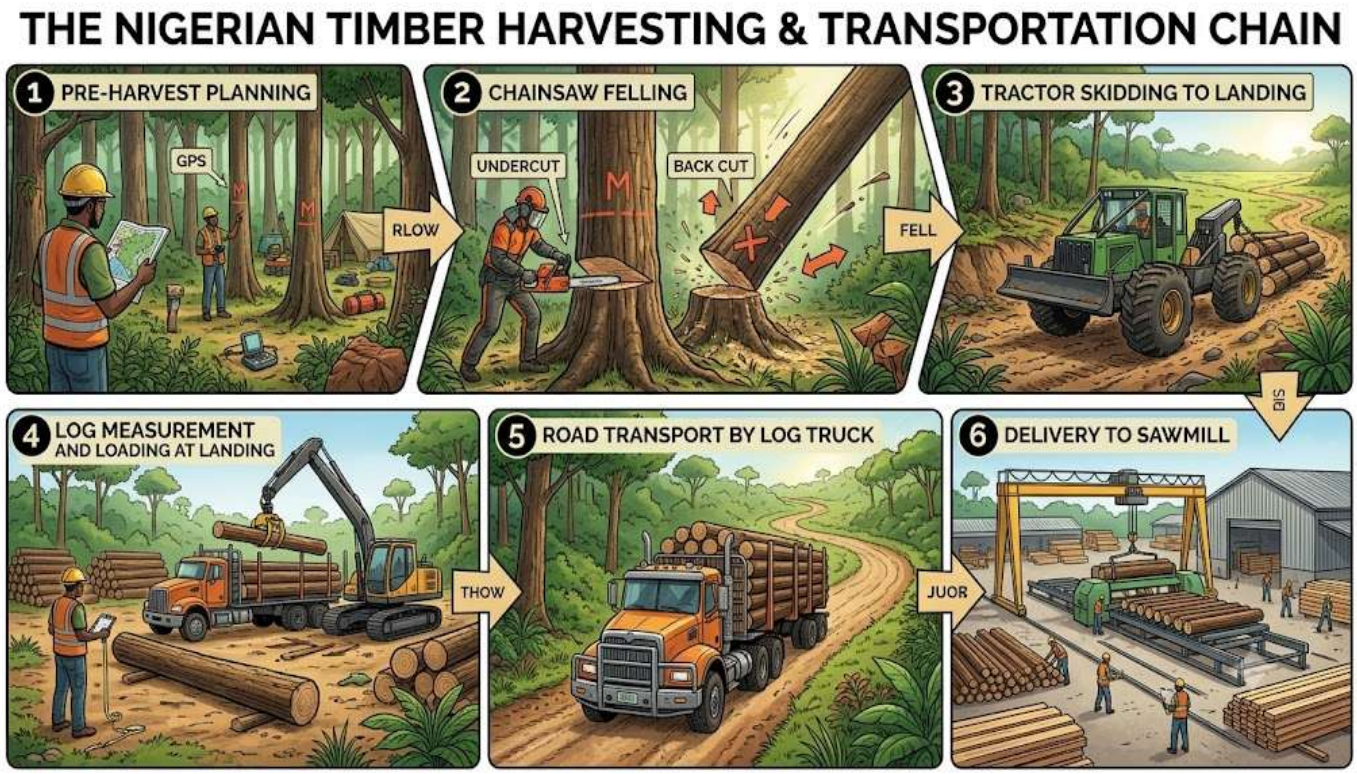

Figure 5.1: The Nigerian timber harvesting and road transportation chain from forest to sawmill

Pilot questions 5.2

16. Describe how logs are loaded onto log trucks at the forest landing and state the typical load capacity of a Nigerian log truck.
17. Explain why river log transportation has largely been replaced by road transport in Nigeria, and state one area where river transport is still practised.
18. State three safety hazards associated with log truck transportation on Nigerian roads.
19. Describe two environmental impacts of forest road construction and log transportation on Nigerian forest ecosystems.
20. Explain what reduced-impact logging (RIL) does to reduce the environmental damage caused by log extraction and transportation.

5.3 Primary Wood Processing

5.3.1 Sawmilling: layout and operations

A sawmill converts round logs into sawn timber (planks, boards, beams, and scantlings). Layout of a typical Nigerian sawmill: (1) Log pond or log yard (logs stored in water or on land at the mill; water storage reduces checking and blue stain; keeps logs fresh). (2) Log debarker (removes bark from logs before sawing; bark blunts saw teeth and contains grit and stones). (3) Head rig (the primary saw that makes the first cuts along the log, converting it from a round log into a cant or flitch; types: bandsaw headrig, frame saw, or circular saw headrig; the bandsaw headrig is most efficient for large logs and gives a thin kerf, reducing wood waste). (4) Re-saw or breakdown saw (makes secondary cuts on the cant to produce planks and boards of the required thickness). (5) Edger (trims the rough sawn edges of boards to produce straight parallel edges). (6) Trimmer (cross-cuts boards to standard lengths and removes defective ends). (7) Sorting and grading table. (8) Drying shed or kiln.

Sawmill efficiency is measured by the recovery percentage: the proportion of the log volume converted into useful sawn timber. Typical recovery in Nigerian sawmills is 40 to 55 percent; the remainder (45 to 60 percent) is waste (slabs, edgings, sawdust, and offcuts). Improving recovery is a major challenge: wider saw blades (larger kerf) waste more wood; blunt saws increase kerf; poor log alignment wastes the outermost boards. Small and medium Nigerian sawmills (of which there are an estimated 3,000 to 4,000) are often equipped with old, poorly maintained machinery that gives low recovery and poor quality output. Modern computerised optimising systems can increase recovery to 65 to 70 percent by analysing log shape before cutting.

Fill in the blank: Sawmill recovery percentage is the proportion of the log volume converted to useful sawn timber; typical recovery in Nigerian sawmills is _____ to 55 percent, with the remainder lost as slabs, edgings, and sawdust.

5.3.2 Veneer and plywood production

Veneer is a thin sheet of wood (typically 0.5 to 6 mm thick) produced by rotary peeling (a log is mounted on a lathe and rotated against a stationary knife, peeling a continuous sheet of veneer) or slicing (a flitch is moved against a stationary knife, producing flat-cut or quartered slices for decorative veneers). Rotary-peeled veneer is the basis of plywood production; sliced veneer is used for decorative face veneers on furniture and panelling.

Plywood production: (1) logs are peeled on a veneer lathe; (2) wet veneer sheets are dried in a continuous roller dryer or compartment dryer to 6 to 10 percent MC; (3) odd-numbered layers (3-ply, 5-ply, 7-ply) are assembled with grain of adjacent layers at right angles (cross-banding); (4) adhesive (urea-formaldehyde for interior use; phenol-formaldehyde for exterior/marine use) is applied to alternate sheets; (5) the assembly is pressed in a heated hydraulic press (hot press) at 130 to 160 degrees C; (6) panels are trimmed to standard sizes (1,220 x 2,440 mm; 4 x 8 feet) and sanded. Nigerian plywood is produced primarily from Triplochiton scleroxylon (obeche/wawa; the preferred species due to its large diameter, light colour, and good peeling properties). Major plywood mills in Nigeria include Plywoods Nigeria Limited (Sapele, Edo State) and WEMPCO (Ogun State).

Fill in the blank: Plywood panels are produced by assembling an odd number of veneer layers with the grain of adjacent layers at _____ angles to each other; this cross-banding arrangement gives plywood its dimensional stability and resistance to splitting along the grain.

5.3.3 Other primary wood products in Nigeria

Particle board (chipboard): wood chips and shavings are mixed with synthetic resin (urea-formaldehyde) and pressed into flat panels; used for furniture, floor underlayment, and interior partitioning; raw material can be mill waste (sawdust, offcuts), reducing dependence on round logs. Fibreboard (MDF, hardboard): wood fibres are separated by steam pressure (defibration), mixed with resin, and formed into panels by pressing; denser and stronger than particle board; used for furniture, door skins, and flooring. Poles and posts: round or roughly squared timber

used for utility transmission line poles (Eucalyptus camaldulensis widely used; treated with CCA preservative by the Electricity Distribution Companies), fencing, and building frames. Fuelwood and charcoal: an estimated 50 to 70 million tonnes of wood and charcoal are consumed annually in Nigeria for domestic cooking; the largest wood product by volume; the primary cause of savanna woodland depletion.

Pulp and paper: Nigeria has very limited commercial paper production; the Nigerian Newsprint Manufacturing Company (Oku Iboku, Akwa Ibom State) and the Nigerian Paper Mill (Jebba, Kwara State) were established in the 1970s but have been largely non-operational due to poor management and irregular log supply. The raw material for pulp production in Nigeria includes Gmelina arborea plantations (specifically established for pulpwood in the 1970s and 1980s) and agricultural residues (bagasse from sugar cane; bamboo). Nigeria currently imports most of its paper and paperboard requirements, representing a large opportunity for domestic forest industry development if plantations and processing capacity are developed.

Fill in the blank: The Nigerian Newsprint Manufacturing Company at Oku Iboku (Akwa Ibom State) and the Nigerian Paper Mill at Jebba (Kwara State) were established in the 1970s using _____ arborea plantation pulpwood as the primary raw material.

Pilot questions 5.3

16. Describe the sequence of operations in a Nigerian sawmill from log intake to finished sawn timber.
17. Define sawmill recovery percentage and explain two ways in which it can be improved.
18. Distinguish between rotary-peeled veneer and sliced veneer in terms of production method and end use.
19. Describe the steps in plywood production from log to finished panel, naming the adhesive used for exterior-grade plywood.
20. Name three wood products other than sawn timber and plywood produced in Nigeria and state the raw material or process for each.

5.4 Timber Marketing, Trade, and Forest Industry in Nigeria

5.4.1 The Nigerian timber market and value chain

The Nigerian timber value chain runs from the forest owner (state government holding the forest reserve) through the logger (who holds a logging concession or permit), the log transporter, the sawmill owner, the timber merchant (who buys sawn timber from the mill and sells to retailers and contractors), the timber retailer (market stalls at timber markets), and finally the end user (builder, furniture maker, carver, or household). At each stage, value is added and costs are incurred. The major timber markets in Nigeria are: Oke-Odo Timber Market (Lagos; the largest in West Africa; trades sawn timber, plywood, and wood products from across Nigeria); Timber Market Ibadan (Oyo State; Oja Igi); Sapele Timber Market (Edo State; linked to the plywood industry); and timber markets in Benin City, Enugu, and Port Harcourt.

Pricing in the Nigerian timber market is determined by species (Khaya and Entandrophragma command the highest prices; Triplochiton the lowest among commercial species), dimensions (longer and wider boards command premium prices), quality (clear, defect-free timber is priced above knotty or stained timber), and market location (prices are higher in Lagos and Abuja than at origin mills). Forest royalties (stumpage fees) paid to state forestry departments are typically set far below the true market value of the timber, a form of implicit subsidy to the logging industry that discourages sustainable management. The informal sector dominates: most small sawmills and timber merchants operate outside formal registration and tax systems, making the true scale of the industry difficult to quantify.

Fill in the blank: The largest timber market in West Africa is the _____ Timber Market in Lagos; it trades sawn timber, plywood, and wood products from across Nigeria and serves as the primary price-setting hub for the Nigerian timber trade.

5.4.2 Timber export, regulation, and certification

Nigeria has maintained a ban on the export of unprocessed logs since 1976, intended to encourage domestic processing and increase the value added retained in Nigeria. The ban has

been imperfectly enforced: some log smuggling occurs across the Cross River border with Cameroon and through ports. Sawn timber, veneer, and plywood can be exported; timber export is regulated by the Federal Ministry of Environment (FMEnv) and the Nigerian Export Promotion Council (NEPC). Export markets for Nigerian timber: European Union (sawn Khaya and Entandrophragma; strict phytosanitary and sustainability requirements); China and Asian markets (active buyers of African hardwoods including Triplochiton and Terminalia; less stringent sustainability requirements); and regional African markets (Benin Republic, Togo, Ghana).

Timber certification: the Forest Stewardship Council (FSC) certifies forests and timber products managed and traded according to defined sustainability standards; FSC chain of custody certification tracks timber from the certified forest through all processing and trading steps to the final product. FSC-certified Nigerian timber commands a premium price in European markets. However, the area of FSC-certified forest in Nigeria remains very small (a few privately managed forest areas in Cross River State); most Nigerian timber is uncertified and faces increasing trade barriers in European and North American markets that require legal and sustainable sourcing documentation (the EU Timber Regulation, EUTR; the US Lacey Act). The EUTR (now superseded by the EU Deforestation Regulation, EUDR, from 2024) requires importers to demonstrate due diligence that timber was legally harvested.

Fill in the blank: The Forest Stewardship Council (FSC) certifies forests and timber products against sustainability standards; FSC _____ of custody certification tracks timber from the certified forest through every stage of processing and trade to the final product.

5.4.3 Challenges and future prospects of the Nigerian forest industry

The Nigerian forest industry faces severe structural challenges: (1) Raw material shortage: decades of overexploitation have depleted natural forest timber stocks; most accessible forest reserves are heavily high-graded; sustainable annual supply from natural forests is far below current mill capacity. (2) Outdated processing equipment: most Nigerian sawmills use old, poorly maintained machinery that wastes 45 to 60 percent of log volume; capital investment is

constrained by high interest rates and lack of long-term financing. (3) Inadequate infrastructure: poor roads increase transport costs and restrict the logging season; unreliable electricity increases mill operating costs (most mills use diesel generators); ports are congested and inefficient. (4) Weak governance and enforcement: forest law enforcement is inadequate; illegal logging, encroachment into reserves, and smuggling of logs undermine both natural forest management and legitimate industry. (5) Lack of certification: most Nigerian timber cannot access premium sustainability-certified markets.

Future prospects and opportunities: (1) Plantation development: Gmelina arborea, Tectona grandis, and Triplochiton plantations can provide a renewable raw material supply within 20 to 30 years if established at sufficient scale; the 2006 National Forest Policy set targets for plantation expansion. (2) Value-added processing: developing furniture, joinery, and panel products instead of exporting raw sawn timber would increase value added retained in Nigeria. (3) Non-timber forest products: formalising and developing the NTFP trade (shea butter, gum arabic, honey, medicinal plants) would diversify forest industry income and reduce dependence on timber. (4) Ecotourism: Nigeria's national parks and scenic forests have underdeveloped ecotourism potential; investment in facilities and marketing could generate significant revenue. (5) REDD+ and carbon markets: sustainable forest management and plantation carbon sequestration could generate carbon credit revenue if governance and monitoring systems are strengthened.

Fill in the blank: The EU _____ Regulation (EUDR), which replaced the EU Timber Regulation (EUTR) from 2024, requires importers of timber and other forest commodities to demonstrate that products were not produced on deforested land; this creates a significant trade barrier for uncertified Nigerian timber exports to European markets.

Short description: A summary table of the Nigerian timber value chain: two columns (Stage; Key actor and activity). Rows: Forest (State government; holds forest reserve; grants concessions); Logging (Logger/concessionaire; pre-harvest planning; felling; extraction; log royalty payment); Transport (Transporter; log truck road haulage to sawmill); Primary processing (Sawmill owner; conversion of logs to sawn timber, veneer, or plywood); Wholesale (Timber merchant; buys from mill; sells to retailers); Retail (Market trader; Oke-Odo and other

timber markets; sells to builders and furniture makers); End use (Builder, furniture maker, household).

Stage	Key Actor & Main Activity
Forest Production	State Forestry Departments / Local Communities — Tree growing, forest reservation, and harvesting permits
Harvesting & Logging	Licensed Loggers / Contractors — Felling trees, cutting logs, and transporting to depots
Primary Processing	Sawmill Operators — Conversion of logs into sawn timber, planks, and boards
Secondary Processing	Furniture Makers / Carpenters / Industrial Firms — Production of furniture, doors, panels, paper pulp, and other wood products
Distribution & Marketing	Timber Merchants / Wholesalers / Retailers — Sale of processed timber and wood products in local and export markets
End Use	Consumers / Construction Companies / Export Buyers — Utilisation of timber for housing, furniture, industrial products, and international trade

Box 5.1: The Nigerian timber value chain from forest to end user

Pilot questions 5.4

16. Describe the Nigerian timber value chain from the forest to the end user, naming the key actor at each stage.
17. State why forest royalties (stumpage fees) set below market value are a problem for sustainable forest management in Nigeria.
18. Explain Nigeria's log export ban and describe its objectives and limitations.
19. Explain what FSC certification is and state two reasons why most Nigerian timber is not FSC certified.
20. State three challenges facing the Nigerian forest industry and suggest one solution for each.

Series Summary

This Series examined timber harvesting operations, beginning with pre-harvest planning, tree marking, directional felling, skid-trail design, stream protection, and forest-road construction. Chainsaw felling requires a properly made undercut, back cut, hinge, and escape route. Logs may be extracted manually, by animal traction, skidding, or forwarding, then bucked, measured, assessed for royalties, and transported by road or water. Poor harvesting can cause soil compaction, erosion, sedimentation, invasive plant spread, fuel pollution, and forest encroachment, while reduced-impact logging helps minimise these effects.

The Series also covered sawmilling and wood processing, including debarking, head-rig sawing, re-sawing, edging, trimming, grading, and drying. Other products include veneer, plywood, particle board, fibreboard, poles, charcoal, fuelwood, and pulp. The timber value chain links forest operators, transporters, processors, merchants, retailers, and consumers. Major challenges include raw-material shortages, outdated machinery, poor infrastructure, weak regulation, low recovery, and limited certification. Future opportunities include plantation development, improved processing efficiency, value-added products, sustainable NTFP use, ecotourism, and REDD+ initiatives.

Glossary of Terms

- **Back cut:** the horizontal chainsaw cut made on the opposite side of the tree from the undercut; leaves a hinge of uncut wood that controls the direction of the tree's fall.
- **Cross-banding:** the arrangement of veneer layers in plywood with the grain of adjacent layers at right angles to each other; gives plywood dimensional stability and resistance to splitting.
- **EU Deforestation Regulation (EUDR):** an EU regulation (replacing the EU Timber Regulation from 2024) requiring importers of commodities including timber to demonstrate that products were not produced on deforested land; creates a significant market barrier for uncertified Nigerian timber.

- **FSC (Forest Stewardship Council):** an international non-governmental organisation that certifies forests and timber products against defined sustainability standards; FSC chain of custody certification tracks timber from the certified forest to the final product.
- **Head rig:** the primary saw in a sawmill that makes the first cuts along a log, converting it from a round log into a cant or flitch; types include bandsaw, frame saw, and circular saw.
- **Hoppus formula:** a traditional British log volume formula (V = G2/16 x L; G = quarter girth in feet; L = length in feet) still widely used in Nigerian log measurement; it underestimates true volume by approximately 21 percent due to the assumption of a square cross-section.
- **Hot press:** a heated hydraulic press used in plywood manufacturing to cure the adhesive between veneer layers; operating temperature 130 to 160 degrees C.
- **Log driving:** floating individual logs downstream on river current; the primary colonial-era log transportation method in Nigeria on the Niger, Cross River, Ogun, and Ondo river systems.
- **Log landing:** a cleared area at the roadside in a logging concession where felled logs are collected, bucked to length, measured, sorted by species and quality, and loaded onto trucks for transport to the sawmill.
- **Oke-Odo Timber Market:** the largest timber market in West Africa, located in Lagos, Nigeria; trades sawn timber, plywood, and wood products from across the country.
- **Plywood:** a sheet panel made from an odd number of rotary-peeled veneer layers bonded with synthetic adhesive and hot-pressed; cross-banded layers give strength and stability; produced primarily from Triplochiton scleroxylon in Nigeria.
- **Recovery percentage:** the proportion of log volume converted to useful sawn timber in a sawmill; typically 40 to 55 percent in Nigerian mills; the remainder is waste (slabs, edgings, sawdust).
- **Reduced-impact logging (RIL):** a set of logging practices (pre-harvest planning, directional felling, planned skid trails, drainage structures, road rehabilitation) that minimise the environmental damage caused by timber harvesting operations.

- **Skidding:** a log extraction method in which a tractor equipped with a winch drags logs along the ground to the landing; the most common extraction method in Nigerian commercial logging; causes soil compaction and surface disturbance.
- **Undercut:** a notch cut on the intended felling side of a tree, comprising a top angled cut and a bottom horizontal cut; controls the direction of fall in chainsaw felling.
- **Veneer:** a thin sheet of wood (0.5 to 6 mm) produced by rotary peeling or slicing; rotary-peeled veneer is used for plywood production; sliced veneer is used as decorative face material for furniture and panelling.

Concept Check Questions [Series 5]

Objective Questions

1. Pre-harvest _____ is the most critical step in responsible logging; it includes stand inventory, tree marking, felling direction planning, and skid trail layout. (Linked to SLO 5.1)
2. In chainsaw felling, the _____ cut creates a notch on the intended felling side that controls the direction of the tree's fall. (Linked to SLO 5.2)
3. Typical sawmill recovery in Nigerian mills is _____ to 55 percent; the remainder is waste consisting of slabs, edgings, and sawdust. (Linked to SLO 5.4)
4. The largest timber market in West Africa is the _____ Timber Market in Lagos. (Linked to SLO 5.5)
5. Nigeria has banned the export of unprocessed _____ since 1976 in order to encourage domestic processing and increase value added retained in the country. (Linked to SLO 5.5)

Short-Answer Questions

1. State four components of a pre-harvest logging plan and explain the purpose of each. (Linked to SLO 5.1)
2. Distinguish between log skidding and log forwarding in terms of ground disturbance and equipment. (Linked to SLO 5.2)
3. Describe the layout of a Nigerian sawmill from log intake to finished sawn timber. (Linked to SLO 5.4)
4. Explain what FSC certification is and state two reasons why it is important for Nigerian timber exports. (Linked to SLO 5.5)
5. State three challenges facing the Nigerian forest industry and suggest one practical solution for each. (Linked to SLO 5.5)

Long-Answer Questions

1. Describe the timber harvesting chain in Nigeria from pre-harvest planning through felling, extraction, and road and river transportation to the sawmill, including the environmental and safety impacts of each stage. (Linked to SLOs 5.1, 5.2, 5.3)

2. Describe the primary wood processing operations in Nigeria (sawmilling, veneer and plywood production, and other products), the Nigerian timber value chain and market, export regulation and certification, and the challenges and future prospects of the Nigerian forest industry. (Linked to SLOs 5.4, 5.5)

Answers to Concept Check Questions [Series 5]

Objective Questions

1. Planning.
2. Undercut.
3. 40.
4. Oke-Odo.
5. Logs.

Short-Answer Questions

1. Stand inventory (locates and maps all harvestable trees). Tree marking (identifies trees to fell and trees to retain as seed or future crop trees). Felling direction planning (minimises damage to retained trees and advance regeneration). Skid trail layout (plans extraction routes to minimise length, avoid steep slopes and stream crossings, and reduce soil disturbance).
2. Skidding: tractor drags logs along the ground; compact soil and disturb surface vegetation along skid trails; most common in Nigeria. Forwarding: vehicle lifts logs completely off the ground and carries them; much lower soil disturbance; used on sensitive sites.
3. Log pond or yard (log storage). Debarker (removes bark). Head rig (primary saw; first cuts along the log). Re-saw (secondary cuts to produce planks). Edger (trims board edges straight). Trimmer (cross-cuts to standard lengths). Grading table (sorts by quality). Drying shed or kiln.
4. FSC certification verifies that a forest and its timber products are managed and traded according to defined environmental, social, and economic sustainability standards. It is important because: (1) FSC-certified timber commands premium prices in European and North American markets; (2) the EU Deforestation Regulation (EUDR) increasingly requires sustainability documentation that FSC provides, preventing uncertified timber from accessing EU markets.
5. Raw material shortage (solution: invest in plantation development of Gmelina, teak, Triplochiton). Outdated processing equipment (solution: capital investment in modern sawmill machinery with higher recovery). Weak governance and illegal logging (solution:

strengthen forest law enforcement and establish transparent royalty and concession management systems).

Long-Answer Questions

1. Pre-harvest planning: stand inventory; tree and felling direction marking; skid trail layout; stream buffer delineation; ensures RIL principles are applied before any felling. Forest roads: main haulage (all-weather; 7 to 10 m); secondary (seasonal; 4 to 6 m); skid trails (temporary; 2 to 3 m; close after use); road density below 50 m/ha; drainage structures required; road construction fragments forest and enables encroachment. Chainsaw felling: undercut (notch on felling side; controls direction) + back cut (leaves hinge); escape route essential; directional felling minimises damage to retained trees and advance regeneration. Extraction: manual (small logs; no machines); animal traction (low disturbance); tractor skidding (most common; compacts soil along trails); forwarding (low disturbance; lifts logs off ground). Log landing: bucking to standard lengths; girth and length measurement (Hoppus formula); royalty assessment by forestry department; loading onto trucks. Road transport: 15 to 25 tonne standard trucks; articulated up to 40 tonnes; rainy season restricts access on secondary roads. River transport: log driving and rafts; Niger Delta creeks and Cross River basin; replaced elsewhere by roads. Safety: brake failure; load shift rollover; crush injuries at landing. Environmental impacts: Chromolaena invasion on road verges; sedimentation of streams; fuel spills; wildlife disturbance; RIL reduces road density, installs drainage, rehabilitates roads after use.
2. Sawmilling: log pond; debarker; head rig (bandsaw preferred; thin kerf); re-saw; edger; trimmer; grading; drying. Recovery 40 to 55 percent; computerised optimisers raise this to 65 to 70 percent. Veneer: rotary peeling (continuous sheet; plywood raw material); slicing (decorative face veneer for furniture). Plywood: logs peeled; veneer dried to 6 to 10 percent MC; odd-number layers cross-banded; glued (UF interior; PF exterior); hot-pressed at 130 to 160 degrees C; trimmed to 1,220 x 2,440 mm; Triplochiton main species; Plywoods Nigeria Ltd (Sapele); WEMPCO (Ogun). Other products: particle board (wood chips + resin; furniture); poles (Eucalyptus; CCA treated); fuelwood/charcoal (50 to 70 million tonnes/year; largest by volume); pulp (Oku Iboku; Jebba; largely inactive). Value chain: forest (state government) to logger to transporter to sawmill to merchant to retailer (Oke-Odo; largest in West Africa) to end user. Pricing by

species, dimension, quality, and location; royalties set below market value (implicit subsidy; discourages SFM). Log export ban since 1976; sawn timber/veneer/plywood exportable; regulated by FMEnv and NEPC; markets: EU, Asia, regional Africa. FSC certification rare; EUDR requires deforestation-free sourcing; trade barrier for uncertified Nigerian timber. Challenges: raw material shortage; old equipment (40 to 60 percent waste); poor infrastructure; illegal logging; no certification. Prospects: plantation development (Gmelina, teak); value-added processing; NTFP trade formalisation; ecotourism (national parks); REDD+ carbon markets.

Answers to Pilot Questions [Series 5]

Part 5.1

1. Stand inventory and tree marking; felling direction planning; skid trail layout; identification of stream buffers and protected areas.
2. Road construction compacts and erodes soil, increases surface runoff, fragments forest creating edges for encroachment and hunting, and opens previously inaccessible areas to illegal farming and wildlife poaching.
3. Undercut: a notch cut on the intended felling side (top angled + bottom horizontal cuts); controls the direction of fall. Back cut: horizontal cut on the opposite side, leaving a hinge of uncut wood that guides the falling tree. The hinge maintains directional control and prevents the tree from falling backwards onto the operator.
4. Skidding: tractor drags logs along the ground to the landing; most common in Nigeria; causes soil compaction and surface disturbance on skid trails. Forwarding: vehicle lifts logs completely off the ground and carries them; causes much less soil disturbance; suitable for sensitive or waterlogged sites.
5. Bucking: cross-cutting logs to standard lengths. Girth and volume measurement (Hoppus formula). Royalty (stumpage fee) assessment by the state forestry department before logs are removed.

Part 5.2

1. Logs are loaded using a hydraulic crane mounted on the truck or a separate wheeled loader that lifts logs onto the truck bolsters. Standard Nigerian log trucks carry 15 to 25 tonnes; articulated tractor-trailer lorries carry up to 40 tonnes.
2. River transport has been replaced because road networks now reach most forest areas; river transport is slow, season-dependent, and causes log losses from sinking. It is still practised in the Niger Delta creek system where roads are absent or impassable.
3. Brake failure on steep descents; load shifting causing vehicle rollover; crush injuries to workers at loading sites from rolling logs or crane booms.
4. Road construction opens forest to encroachment and hunting. Chromolaena odorata invades road verges and logged areas, suppressing natural regeneration. Sediment from unpaved roads washes into streams, damaging aquatic habitat and reducing water quality.

5. RIL minimises road and skid trail density through pre-harvest planning; installs drainage structures (mitre drains, culverts) to prevent road erosion; closes and rehabilitates skid trails after use; uses directional felling to reduce canopy damage.

Part 5.3

1. Log pond (storage); debarker (bark removal); head rig (first cuts along log); re-saw (secondary cuts to plank thickness); edger (straight parallel edges); trimmer (cross-cut to length; remove defective ends); grading table (quality sorting); drying shed or kiln.
2. Recovery percentage is the proportion of log volume converted to useful sawn timber. It can be improved by: (1) using thin-kerf bandsaws instead of thick-kerf circular saws to reduce wood lost as sawdust; (2) installing computerised optimising systems that analyse log shape and plan cuts to maximise usable timber from each log.
3. Rotary peeling: a log is rotated against a stationary knife, producing a continuous sheet of veneer; used for plywood core and face layers. Slicing: a flitch is moved against a knife, producing individual flat-cut or quartered sheets; used for decorative face veneers on furniture and panelling.
4. Logs peeled on veneer lathe; wet veneer dried to 6 to 10 percent MC; odd-number layers (3, 5, or 7) assembled with adjacent grains at right angles (cross-banding); phenol-formaldehyde adhesive applied (exterior/marine grade); panels hot-pressed at 130 to 160 degrees C; trimmed to 1,220 x 2,440 mm and sanded.
5. Particle board (wood chips + urea-formaldehyde resin; pressed into flat panels; furniture). CCA-treated Eucalyptus poles (round timber; pressure impregnated; utility transmission lines). Fuelwood and charcoal (harvested woody biomass; domestic cooking; largest wood product by volume in Nigeria).

Part 5.4

1. Forest (state government holds reserve; grants logging concession) to logger (pre-harvest planning; felling; extraction; pays royalty) to transporter (road haulage by log truck to sawmill) to sawmill owner (converts logs to sawn timber or plywood) to timber merchant (buys from mill; sells to retailers) to retailer (Oke-Odo market; sells to builders and furniture makers) to end user (builder; furniture maker; household).

2. When royalties are set below market value, loggers pay less than the true economic cost of the timber they remove. This implicit subsidy encourages over-harvesting and removes the financial incentive to log sustainably; there is little reason to invest in good management if timber can be obtained cheaply regardless of how it is managed.
3. Nigeria banned log exports in 1976 to encourage domestic processing and retain value added in-country. Objective: develop sawmilling, veneer, and plywood industries rather than exporting raw material. Limitations: the ban has been imperfectly enforced; log smuggling across the Cross River border into Cameroon occurs; domestic processing capacity has not expanded sufficiently to absorb all harvestable timber at sustainable yields.
4. FSC certification verifies that forests and timber products meet international sustainability standards. Two reasons it is rare in Nigeria: (1) the pre-conditions for certification (documented management plans, forest inventories, environmental impact assessments, community consultation) require investment that most small Nigerian operators cannot afford; (2) weak governance makes it difficult to demonstrate legal compliance, which is a prerequisite for FSC certification.
5. Raw material shortage (solution: accelerate plantation establishment of Gmelina, teak, and Triplochiton to provide a renewable supply within 20 to 30 years). Outdated equipment with low recovery (solution: targeted investment in modern sawmill machinery with computerised optimising systems). Weak forest governance and illegal logging (solution: strengthen forest law enforcement, increase forest department budgets, and implement transparent royalty collection and concession management).

References and Attributions [Series 5]

Textual References (Books and External Sources)

- FAO. (2004). Reduced impact logging in tropical forests: Literature synthesis, analysis and prototype statistical framework. FAO Forestry Paper 139. Food and Agriculture Organization of the United Nations, Rome.
- Desch, H. E., & Dinwoodie, J. M. (1996). Timber: Structure, properties, conversion and use (7th ed.). Macmillan Press, London.
- Lowe, R. G. (1997). Nigerian forest industry: Challenges and opportunities. Federal Department of Forestry, Abuja.
- Enters, T., Durst, P. B., & Brown, C. (2003). What does it take? The role of incentives in forest plantation development in Asia and the Pacific. FAO, Bangkok.
- FSC. (2023). Forest Stewardship Council: Global FSC certificates. https://www.fsc.org

Figures, Plates, Tables, and Boxes

- Figure 5.1: The Nigerian timber harvesting and road transportation chain from forest to sawmill. Attribution: AI generated. Suggested OER search string: “timber harvesting transportation chain felling extraction skidding log truck sawmill Nigeria diagram OER”.
- Box 5.1: The Nigerian timber value chain from forest to end user. Attribution: AI generated. Suggested OER search string: “Nigerian timber value chain forest logging sawmill market end user stages table OER”.