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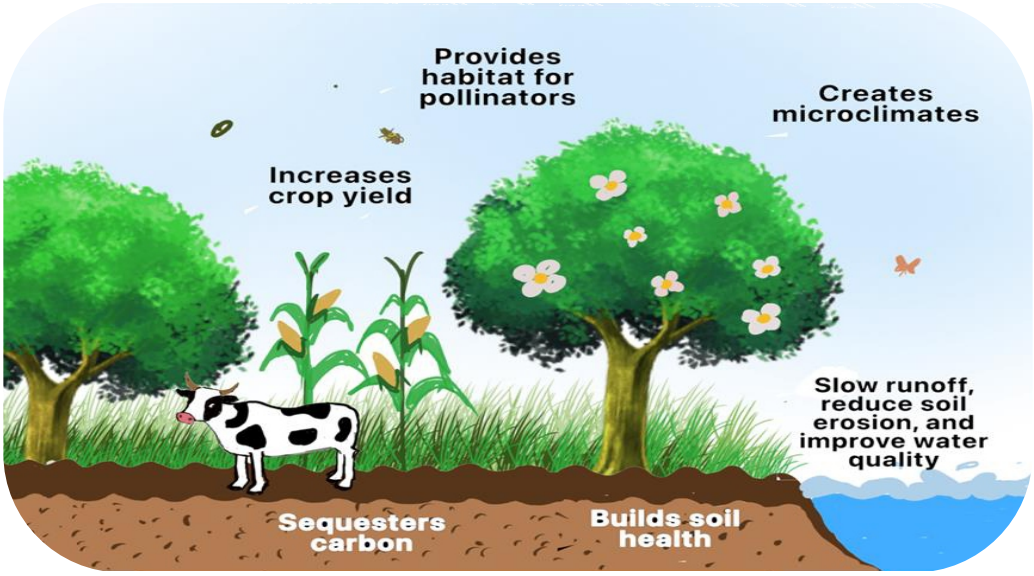
Agroforestry Training Manual



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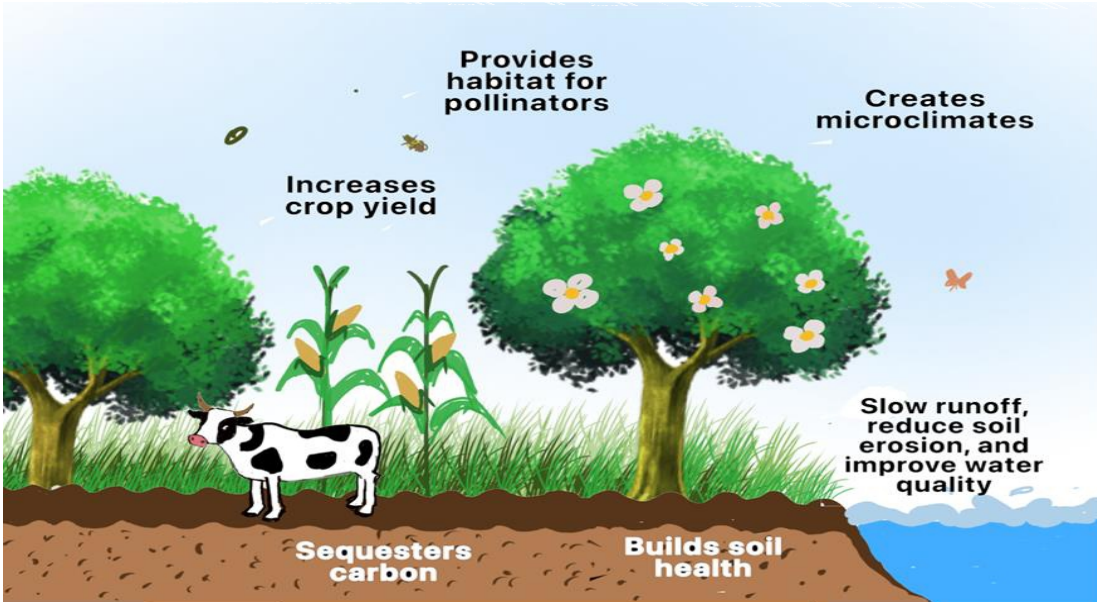

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The Plaza, 23 Ibrahim Tahir Street, Utako 900108, FCT Abuja

T+234 704 994 5395

E giz-nigeria@giz.de

I www.giz.de

Responsible

Ozman Altamirano, Project Manager. GIAE NG InACC EU-BMZ

Developed by

Prof. Ibrahim Muhammad Haruna, Department of Agronomy, Nasarawa State University, Keffi

Prof. Mamman Mango Adua, Department of Animal Science, Nasarawa State University, Keffi

Dr. Emmanuel Tertsea Ikyaagba, Department of Social and Environmental Forestry, Joseph Sarwuan Tarka University, Makurdi

Dr. Victor Akwu Otene, Department of Agricultural Extension and Communication Joseph Sarwuan Tarka University, Makurdi

Dr. Ver Terlumun Abraham, Department of Agribusiness and Extension, Akperan Orshi Polytechnic, Yandev, Benue State.

Dr. Daladi Zaknayiba Bebwa, Department of Agricultural Extension and Management, Nasarawa State College of Agriculture, Science and Technology, Lafia

Content contributors

Moses Anzenge, Larai Abdulkadir, Fumu Bello

Sketches, Animations and Graphic Design

Kayode Ogunwole

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FOREWORD

In recent years, the levels of deforestation and carbon emissions linked to rice production, livestock production and land clearing have significantly increased.

Agroforestry takes into account these global challenges in a holistic way, looking at the interactions between different living beings that inhabit a common land space. The presence of trees on farms can help farmers adapt to climate change while absorbing carbon dioxide from the atmosphere, providing a habitat for biodiversity, and regenerating soil and water resources. This practice not only diversifies income sources and creates economic value, but it also improves farmers' climate resilience.

The forest cover that is chosen for each type of agroforestry system should be identified by the people who cultivate the production plots. Preference should be given to tree species that are adapted to local conditions before considering the introduction of new species. Most trees have deep root systems, and high canopies and can complement the crops around them, thus making farming systems more resilient to the effects of climate change, such as the increasingly frequent and severe floods and droughts in Nigeria.

The experience of the GIAE InACC Project with selected universities in Benue and Nasarawa States, as well as the experience of institutions such as IITA and Be The Help Foundation inspired the publication of this Agroforestry Manual.

This manual explains in a sequential and detailed way the concepts and different types of systems relevant to developing Agroforestry systems. The manual will serve as a reference guide to strengthen the capacities of technicians, extensionists, officials and other professionals working in rural development in Nigeria. We are convinced that they will come to the same conclusion that we have drawn: Agroforestry, when well applied, is one of the most effective long-term strategies to adapt to the negative effects of climate change.

We would also like to thank all the people who have been involved in the development of this important manual, we hope that you enjoy reading the manual and applying the knowledge it contains, and it will positively impact livelihoods and communities around Nigeria.

Dr Andrea Ruediger
Cluster Coordinator for
Rural Development & Agriculture

Ozman Altamirano
Project Manager
GIAE InACC EU-BMZ

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ABOUT THE MANUAL

Objectives of the manual

This training manual provides basic guidance for trainers to design and deliver training that will help individuals or organizations increase their knowledge, skills and experience in agroforestry development. In addition, the exercises contained in this manual are designed to help participants foster the understanding and basic skills necessary to support farmers in developing effective and efficient agroforestry practices. This training manual delivers in two main ways:

- Providing basic materials to help people learn about agroforestry design and practice for environmental sustainability.
- Equipping participants in the training courses with the necessary knowledge, skills and attitudes with regard to agroforestry development, particularly within the context of community forestry, forest landscape restoration and climate change adaptation.

The manual covers key aspects of agroforestry development, theoretical and practical, as well as explaining tools for planning, designing, establishing and evaluating agroforestry interventions towards environmental sustainability. It is an important tool for effectively promoting agroforestry in Nigeria.

LIST OF ABBREVIATIONS

S/No.	Abbreviation	Meaning
1.	**ADP**	Agriculture Development Programme
2.	**EA**	Extension Agent
3.	**EU**	European Union
4.	**FC**	Fixed Costs
5.	**GIZ**	German International Cooperation
6.	**GM**	Gross Margin
7.	**Ha**	Hectare
8.	**InACC**	Integrated Approach to Climate Change
9.	**IPCC**	Intergovernmental Panel on Climate Change
10.	**M**	Meter
11.	**RECOFTC**	Regional Community Forestry Training Centre for Asia and the Pacific
12.	**TR**	Total Revenue
13.	**VR**	Variable Costs

MODULE 1: INTRODUCTION TO AGROFORESTRY.

1.1 Objectives of the module

At the end of this module, the trainees will learn the following:

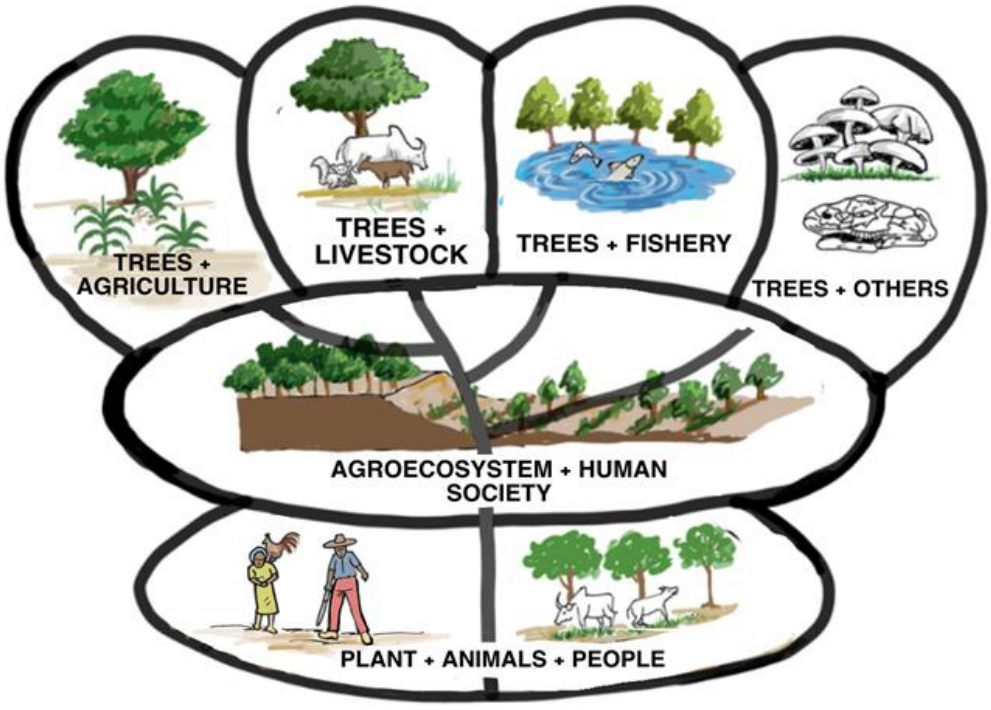
i. Definition of agroforestry.
ii. The different benefits of agroforestry ranging from economic, social, health and environmental benefits).
iii. Types of agroforestry systems.
iv. Measures that will facilitate the adoption of agroforestry.

1.2 What is Agroforestry?

Agroforestry is the inclusion of trees in farming systems and their management in rural landscapes to enhance productivity, profitability, diversity and ecosystem sustainability [(1)].

It describes practices developed and employed by farmers over many centuries to cultivate trees on farmland in different combinations with crops and livestock.

Agroforestry is about recognizing and promoting trees on a farm.



Agroforestry is where trees interact with agriculture

1.3 What are the Components of Agroforestry?

The major components of agroforestry are:

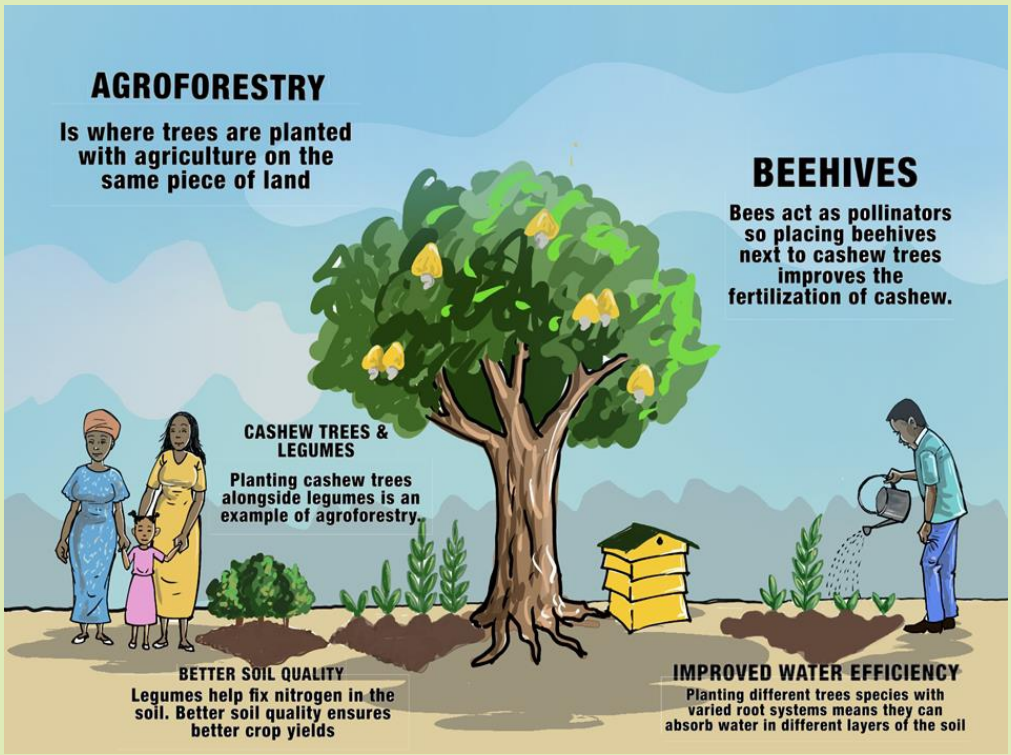
1. **Land:** Agroforestry is neither a system of pots on the balcony nor for the greenhouse. Any farmer intending to go into agroforestry must own land. Farmers that rent land may not have the right to establish permanent trees on the land because the owner may think he/she wants to take possession of the land. Where the owner gives the right, he/she may have little interest in the long-term benefits of agroforestry considering the lease period.
2. **Trees:** In agroforestry, particular attention is placed on multipurpose trees or perennial shrubs. The most important of these trees are the legumes because of their ability to fix nitrogen and thus make it available to other plants. The tree species or shrubs to be used should be that which is compatible with the crop it will be combined with. Any tree can be used in agroforestry systems, including all trees with edible products. In actual practice, very large trees are usually not used in agroforestry except casually, not by design
3. **Non-tree crops:** Any crop plant can be used in agroforestry systems. The choice of crop plants in designing such systems should be based on those crops already produced in a particular region either for marketing, feeding animals, or for home consumption, or that have great promise for production in a particular area. Examples are cowpea, maize, rice, yam, sorghum, elephant grass, *mucuna*, etc.
4. **Livestock:** Livestock also interact synergistically with crops, trees and soils. Agroforestry systems could be sustained by the contribution of livestock to household income and the maintenance of soil health. It will also help to reduce farmer herders' crises.

1.4 What are the benefits of agroforestry?

Trees provide multiple functions and services not only for farmers but also for the environment in which they live. Agroforestry improves rural livelihoods by producing more products of higher value from trees, crops and livestock while conserving biodiversity and soil fertility. Below are some of the benefits of incorporating trees into the farm systems:

- Help reduce temperatures
- Improve infiltration of water into the soil
- Reduce soil erosion
- Store more carbon
- Diversify farm production, which lowers both climate and market risks.
- Adds up to greater adaptability and resilience not only for individual farmers and communities but also for their environments.
- Growing trees, which produce food (fruits, nuts, leaves, etc.), provide an easily accessible nutritious food for households.

- Leaves, and other parts of trees, can serve as forage for livestock.
- Trees and plants grown on farms are important sources of medicines and natural remedies, which help improve people's health.
- Improve the biodiversity of the land
- The pruned part of the trees and the fallen leaves when decomposed add nutrients to the soil. They are sometimes used for mulching and composting.
- Improve and diversify the income along the time for farmers
- Short-term food production offsetting the cost of establishment of trees in taungya system.
- Above all, agroforestry contributes to food security



Benefits of Agroforestry

1.5 Role of Agroforestry in Risk Management

Agroforestry plays a significant role in risk management for farming systems. Below are the contributions of agroforestry to risk management.

1. **Diversification of Income:** Agroforestry systems diversify sources of income by combining crops, livestock, and trees. This diversification reduces financial risk as farmers are less dependent on a single commodity. If one component fails (e.g., due to pest infestation, drought, flood or market fluctuations), others can compensate [(2)].

DIVERSIFICATION OF INCOME

2. **Climate Resilience:** Trees and shrubs in agroforestry systems help to mitigate the impacts of climate change. They provide shade, reduce soil temperature, and help retain soil moisture, which is crucial during drought periods. Trees can also serve as windbreaks, reducing the damage from storms and heavy winds [(3)].

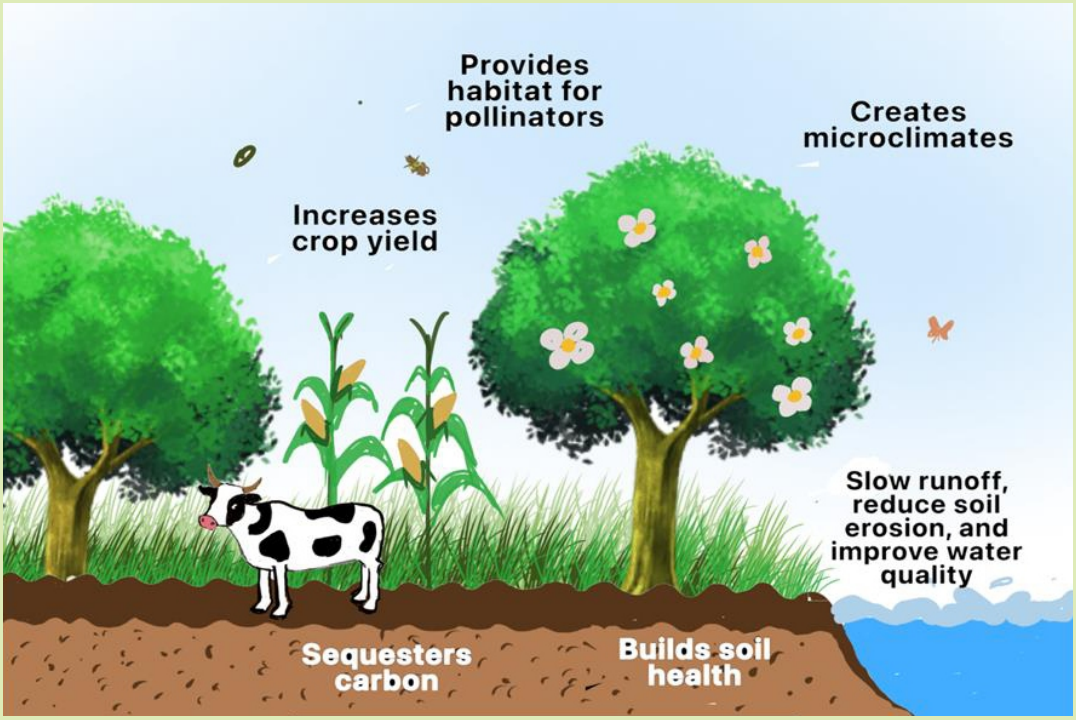
3. **Soil Health Improvement:** Agroforestry improves soil structure and fertility through leaf litter and root systems, reducing the risk of soil degradation and erosion. Improved soil health enhances water retention and nutrient cycling, supporting crop and pasture productivity [(4).]
4. **Biodiversity Enhancement:** By creating more diverse habitats, agroforestry promotes biodiversity, which can improve ecosystem stability and resilience.

Biodiversity can enhance pest control and pollination services, reducing the risk of crop failures [5].

5. **Pest and Disease Management:** Agroforestry systems can reduce the prevalence of pests and diseases through habitat diversification. The presence of various plant species disrupts the life cycles of pests and diseases, reducing their impact on crops and livestock.
6. **Water Management/flood and Erosion Control:** Trees and shrubs play a critical role in water management by reducing runoff and increasing groundwater recharge. This helps in managing risks associated with water scarcity and flooding. Agroforestry has emerged as a sustainable strategy to mitigate the impact of floods and river erosion. Floods and river erosion are common occurrences in areas with low-lying topography and monsoon climate and they can cause significant damage to agricultural land, infrastructure, and livelihoods. Agroforestry can help to mitigate the impact of floods and river erosion by promoting soil stability, reducing erosion, and slowing down floodwaters. Agroforestry systems have been reported to effectively reduce soil erosion and sedimentation, as well as reduce the velocity of floodwaters, thereby minimizing damage to crops and improving the resilience of farming communities [6].

AGROFORESTRY REDUCES FLOODING AND WATER EROSION

7. **Carbon Sequestration:** Trees in agroforestry systems sequester carbon, contributing to climate change mitigation (i.e. trees in agroforestry capture and store atmospheric carbon dioxide thereby reducing the amount of carbon dioxide in the atmosphere with the goal of reducing global climate change). This can also provide farmers with additional income through carbon credits, adding another layer of financial security [7].



IMPORTANCE OF AGROFORESTRY

8. **Social and Community Benefits:** Agroforestry can enhance social resilience by promoting community cooperation and knowledge sharing. Farmers who adopt agroforestry often work together to manage resources and share best practices, strengthening community ties and collective capacity to manage risks.

9. **Policy and Market Opportunities:** Agroforestry can open up new policy and market opportunities, such as certification for sustainable practices or access to specific markets that value biodiversity and environmental stewardship. These opportunities can provide financial incentives and reduce market risks.

Types of Agroforestry Systems

Three of the main components of agroforestry - trees, crops and animals - can be combined in numerous spatial and temporal arrangements for different functions, creating the different types of Agroforestry systems [8].

The basic types of Agroforestry systems are:

1. **Agrisilviculture (Crops + trees):** This is a system of agroforestry in which tree species are grown and managed in the farmland along with crops. For example, oil palm and rice, citrus and rice, Parkia and maize, etc. under this system we have the following agroforestry practices:

a. **Shelterbelts and windbreaks:** This is the planting of trees along agricultural fields against the direction of the wind to protect soil from wind erosion and crops from windstorms. These are found in Kano, Plateau, Katsina, etc.

SHELTER BELT

b. Alley Cropping: This is defined as the planting of trees and/or shrubs in rows to create alleys within which arable or horticultural crops are produced. The trees may include leguminous species or shrubs with high coppicing ability. The rows of trees are widely spaced to allow for mechanization.

ALLEY CROPPING

c. Taungya System: This is **an** agroforestry system in which short-term crops are grown in the early years of the plantation of a woody perennials species to utilize the land, control weeds, reduce establishment costs, generate early income, and stimulate the development of the woody perennials species.

TAUNGYA SYSTEM

1. **Silvopastoral (Pasture/animal + trees);** It is a genre of agroforestry system where fodder plants are grown in pastures for livestock along with the production of trees and shrubs in the same piece of land. This is a unique practice where fodder plants like leguminous herbs and grasses are grown. These types of plants grow very fast.

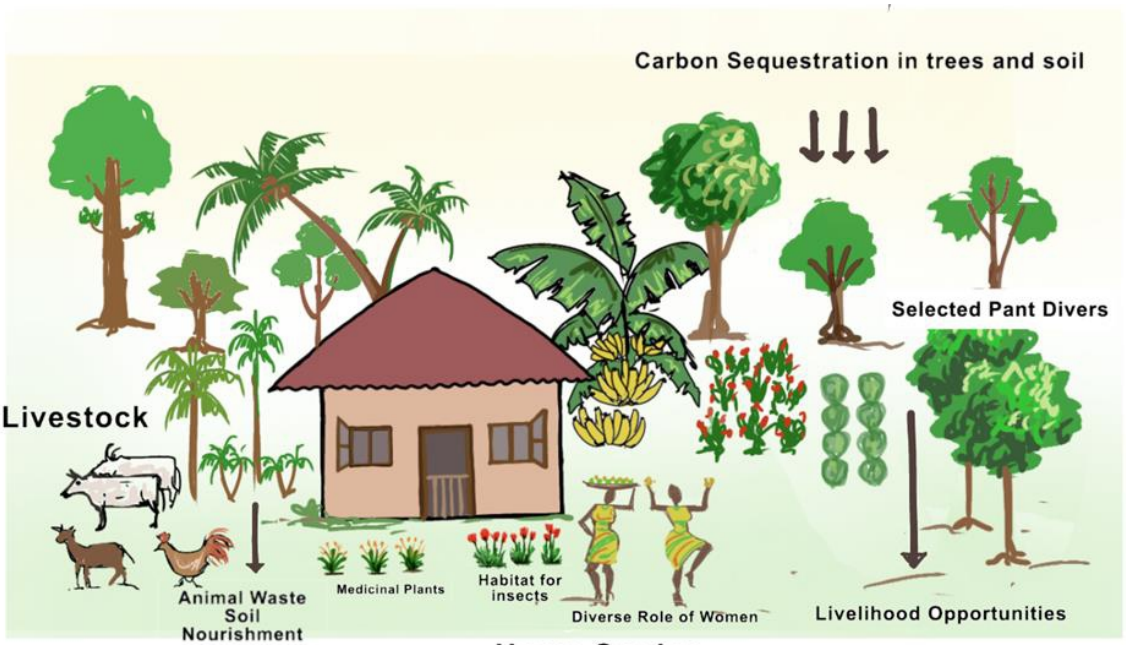
SILVOPASTORAL SYSTEM

2. **Agrosilvopastoral (crops + trees + livestocks):** Is a system where trees, animals and crops, can be integrated or managed on the same unit of land. The animals are either left loose for free grazing or confined, forming an integrated system of livestock and human food, manure and vegetable compost, building material and medicines to get agricultural and forest crops where farmers can also rear animals.

AGROSILVOPASTORAL (CROP + TREES + LIVESTOCK)

5. Home gardens

A home garden is an agroforestry practice in which mixed crops of annual crops and perennial crops (trees) are grown in combination with animals close to the homestead to supplement the staple food supplied by the field crops. It is an agrosilvopastoral system. It is often only a tiny part of the complete farm but plays a special role in that it provides daily produce. Tree home gardens are especially well known in the humid tropics. They are small, and the carefully selected species of different sizes, types and growth cycles, together with many domesticated animals aim to supply the household with a continuous flow of products such as banana, papaya, orange, vegetables, root crops, legumes and grasses which can be used for human consumption or fodder.



Home Garden

6. Others

i. **Trees with insects (Apisilviculture):** This is more commonly known as bee keeping or apiculture. It is the practice of raising and managing bees for honey. The multipurpose tropical trees and shrubs used for apisilviculture are: *Acacia confusa* (formosa koa), *Acacia holosericea* (holosericea), *Albizia adianthifolia*, *Cajanus cajan* (pigeon pea), *Citrus species* (citrus trees), *Cocos nucifera* (coconut), *Eucalyptus species* (eucalyptus), *Dalbergia sissoo* (sissoo rosewood), *Gliricidia sepium* (madre de cacao), *Gmelina arborea* (white beech) etc.

To foster wild bees in agroforestry systems, the following should be done:

- Leave hedgerows or unmanaged areas in crop areas as nesting sites.
- Utilize more diverse crop plantings (to feed diverse pollinators).
- Utilize no-till systems (to preserve ground nesting sites).
- Plant alternative forage adjacent to agricultural areas.
- Reduce pesticide use, or at least shift the timing of sprays to minimize impact on feral bees.

APISILVICULTURE

ii. **Aqua forestry (trees with fish):** This is the combination of trees and aquaculture. The trees are usually planted around the ponds. Trees surrounding fish ponds can enhance the nutrients in the ponds through leaf litter. The trees equally help to reduce the impact of the direct heat of the sun on the ponds thereby reducing evaporation of the water and reducing the temperature in the ponds. The water from the ponds is used to irrigate the trees and sometimes as a source of fertilizer for the tree crops.

FISH POND SURROUNDED BY BANANA

FISH POND SURROUNDED BY SHRUBS AND TREES

iii. **Sericulture:** This involves rearing of silkworms for the production of raw silk, which is the yarn obtained out of cocoons spun by certain species of insects. The major activities of sericulture comprises of food-plant cultivation to feed the silkworms which spin silk cocoons and reeling the cocoons for unwinding the silk filament for value added benefits such as processing and weaving. Traditionally, sericulture has been carried out as a monoculture system, with mulberry (Morus spp.) being the primary host plant for the domesticated silkworm, Bombyx mori [10]. However, in recent years, there has been growing interest in integrating sericulture into agroforestry systems to promote sustainable silk production while delivering multiple economic and ecological benefits [11].

SERICULTURE

1.6 What are the Challenges of Agroforestry Systems?

Despite the many benefits, agroforestry systems are not without its own disadvantages, hence, care must be taken when integrating trees with rice. Some of the challenges facing agroforestry system include but not limited to the following:

1. Competition for light, nutrients, and water: Agroforestry systems need to be carefully designed so that use of light, nutrients and water is not at the expense of crop growth owing to competition.
2. Diseases and pests: Diseases and pests are more of a concern in simultaneous agroforestry systems than in sequential system because crops and trees in the same fields provide alternating hosts (of diseases and pests) and non-host plants because different trees host different diseases and pests. Providing short sequences of rotation reduces the likelihood of severe, chronic infestations.
3. Mechanization of crop production: Mechanization reduces the practicability of scattered planting of trees through crop fields because they interfere with the efficiencies of the machinery. Farmers therefore might better plant trees alongside the bunds or the boundaries of the farm.
4. High cost of agroforestry inputs: High cost of inputs for agroforestry, including seeds, seedlings, black polyethene sleeves, and labour for digging of holes for planting tree

seedlings and maintaining tree nurseries is one of the greatest challenge among the agroforestry farmers.

5. Capacity and Knowledge: Inadequate managerial knowledge of silvicultural practices like pruning, pollarding, and thinning among others is a challenge to the practice of agroforestry.

6. Land Tenure System: Land tenure is an important factor in agricultural development. The Nigerian system of land ownership is mainly patriarchal favouring men while women and youth mainly work on the land. In addition, in the communities, land ownership is often by inheritance, which is biased against women. This absence of clearly defined land tenure weakens incentives for long-term agroforestry investments in land to increase its productivity. In addition, inheritance of land is the reason for the increased land defragmentation resulting in farmers owning smaller parcels of land that limit the scale of production.

1.7 Measures to Support Agroforestry Practices

There is no single way in which agroforestry is promoted. Agroforestry policies and programs are shaped by a variety of factors, including the social-ecological contexts in which they are implemented; the specific objectives, knowledge, and interests of the external organization and farmers involved; and the financial, technical and material, including tree and shrub germplasm, resources available. There are at least six different types of measures through which agroforestry can be designed [9].

i. Building farmer's capacity

- Through the provision of training, extension, other advisory services, technical information, demonstration sites, participatory trials, and other modes of action learning.

ii. Enhancing access to tree seedlings/germplasm

This can be achieved through:

- Direct provision of tree seedlings or other germplasm,
- Linking farmers to tree germplasm suppliers,
- And building farmer capacity to propagate their own seedlings.

iii. Community-level campaigning and advocacy

- By encouraging community members to plant trees on their farms and/or pursue specific agroforestry practices.
- Through radio, newspapers, social media, focus groups, farmer group meetings, community meetings, and theatrical performances.
- Sometimes the targeted action is mass tree planting, such as on a specific day of the year.

iv. **Providing incentives**

- Through direct payments or rewards to farmers for planting and taking care of trees on their farms and the receipt of premiums for particular agricultural commodities produced under certain conditions, for example, certification schemes for organic oil palm.

v. **Facilitating market links**

- By a greater and/or more favourable integration of smallholders into tree-product value chains.
- Linking producers to buyers, improving contractual arrangements with buyers, and collective marketing of agroforestry products.

vi. **Policy and institutional change**

- By creating new policies that will enhance the enabling environment that promotes and strengthens the adoption of agroforestry practices to yield desired social-ecological outcomes. For example, the issue of the land tenure system.

vii. Appropriate land tenure reforms to help many people own land so that they can practice agroforestry.

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MODULE 2: PLANNING AND DESIGNING AGROFORESTRY SYSTEMS

2.1 Objectives of the Module

At the end of this module, Trainees should be able to know:

1. Necessary things to consider or put in place before establishing an Agroforestry system
2. Site selection and assessment for Agroforestry
3. The criteria for Selection of tree species for agroforestry
4. Farm record keeping and its importance
5. The definition of a nursery, its types, establishment, importance and management.

2.2 Planning the Key to Success

What are the necessary things to consider or put in place before establishing an Agroforestry system?

Before establishing agroforestry, it is necessary to have the following:

1. Must own a land/secured land tenure system
2. Know the size of the land because some agroforestry designs are not practical or feasible economically below a certain size
3. Identify the tree species that can perform better or has a comparative advantage on the land or locality in question taking into account the climatic, soil and other environmental factors.
4. Identify markets/buyers of the tree products
5. Join a cooperative society that is into agroforestry
6. Attend training on agroforestry.

2.2.1 Site selection and assessment for Agroforestry

The site to be selected for agroforestry is the land on which the farmer is growing or cultivating his/her annual crop. Depending on the type of annual crop, the soil should be fertile, flat with good drainage and no shade. It should be free from soil salinity, iron toxicity and heavy metals such as lead, mercury, arsenic, etc. Degraded land can also be used as site for establishing agroforestry.

SITE SELECTION

2.2.2 How do we select tree species for Agroforestry?

The main criterion for selecting trees is that they are liked by farmers. A well-known tree is better than an unknown tree but when a new species is introduced it is, of course, necessary to work with an unknown tree. A tree that is disliked by the farmers, for whatever reason, is always best avoided. Below are the general characteristics of trees to be selected for agroforestry:

- The best trees to grow together with crops are those with deep roots so that they do not compete with crops for water and nutrients.
- They should allow light through their leaves to allow crops to grow.
- They should survive regular pruning and cutting back.
- They should add nutrients to the soil.
- Their leaves should provide either animal fodder or soil mulch.
- They should have uses that help the farm family.
- If one of the objectives of establishing agroforestry is to increase food production, then trees with fruit, nuts or leaves for farmers' consumption (as well as for livestock feed to produce food from the livestock) and/ or sale can be used.

2.2.3 Input Procurement

Where can I buy inputs for the agroforestry system?

Inputs for agroforestry systems should be procured from a certified source or authorized agro-allied dealer.

2.2.4 What are the inputs for agroforestry systems?

The inputs for agroforestry systems depend on the type of agroforestry system the farmer intends to practice. For example, if the farmer intends to grow annual crops with trees, the inputs are:

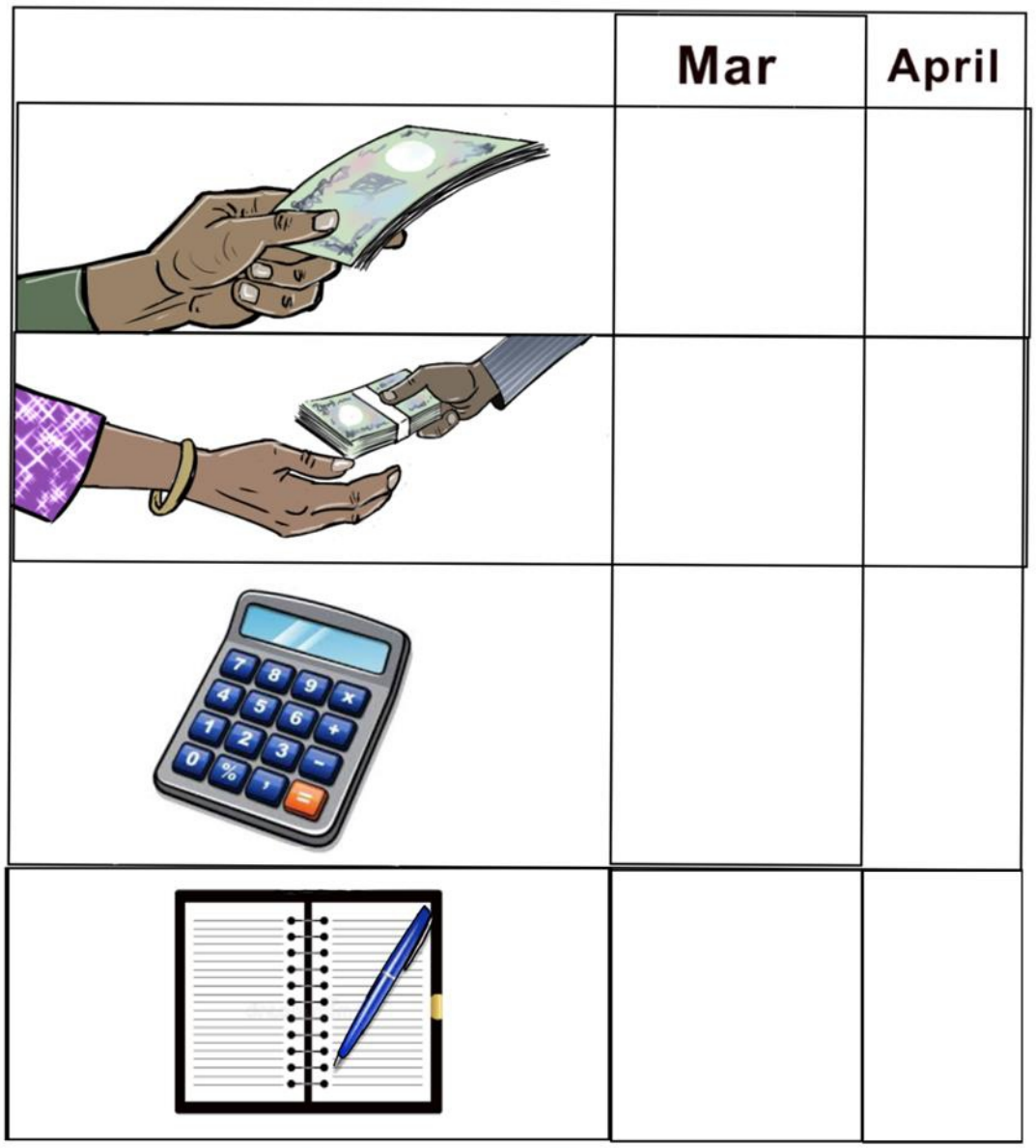
- Tree seed/seedlings.
- Seeds of annual crops.
- Fertilizers/organic manure the quantity of which depends on the size of the farm and annual crop in question.
- Herbicides the quantity of which depends on the size of the farm.

INPUT DEALER SHOP

2.3 Farm Record Keeping

2.3.1 What is a farm record?

- A farm record is a document (in most cases a book) that is used to keep account of different activities, events, materials etc. regarding the farm and operations.
- In simple terms, it refers to writing down money spent in the purchase of farm inputs (such as seeds, seedlings, fertilizers, pesticides, etc.); the cost of farm operations (such as sowing/planting, weeding, fertilizer applications, pesticide applications and the total revenue gotten from the sales of farm produce after harvest (such as quantity of paddy harvested, sales price of paddy and quantity of tree products harvested and sold.



Farm Record Template

2.3.2 Why do I have to keep farm records?

You need to keep farm records because:

i. It helps the farmer to know whether the farm operation is profitable or not.
ii. They help farmers know the progress and contributions of each aspect of the farm to its overall success.
iii. They are important for proper farm management.
iv. They can be very helpful when a farmer needs to access financial aid from banks or other financial institutions.
v. Help a farmer to keep stock and manage each aspect of the farm properly.
vi. They are important for planning and budgeting.

2.4 Nursery Establishment and Management

2.4.1 What is a nursery?

- A nursery is the place where young plants are raised under intensive management and later transplanted to the permanent site or field.

NURSERY

2.4.2 What are the purposes of having a tree nursery when establishing agroforestry?

The purpose of having a tree nursery are:

- To provide a protected site for young seedlings so that they are strong and healthy when transferred to the field.
- Young trees in nurseries can be carefully monitored and managed during their most vulnerable growth stages.
- Protect seedlings from theft, and from damage by animals, people, wind, rain and too much sun.
- Producing seedlings in a nursery can be more cost-effective than purchasing them from external sources. Nurseries can produce large quantities of seedlings at a lower cost, providing a more economical option for large-scale agroforestry projects.
- With a nursery, seedlings can be grown and maintained until the optimal planting season, ensuring that trees are transplanted at the best time for their survival and growth.
- Nurseries can produce seedlings that are specifically adapted to local climatic and soil conditions. This local adaptation increases the chances of successful tree establishment and growth when the seedlings are transplanted to the field [(1)].
- Nurseries provide a wide range of tree species, including those that may not be readily available in the wild.

2.4.3 What are the advantages of having a tree nursery?

The advantages of having a tree nursery are:

i. Fewer seeds are required for raising seedlings in the nursery than for sowing directly into the field.
ii. Enables the germination and raising of seeds and cuttings which cannot ordinarily survive in normal field conditions.
iii. Provides young plants with a better growth medium than when seeds are sown directly in the field.
iv. Seedlings receive more intensive care such as protection from animals, diseases and pests, regular maintenance, watering, irrigation and application of green manure, compost or artificial fertilizers;
v. Opportunity for selecting well-grown, vigorous and disease-free seedlings for transplanting.

2.4.4 Types of Tree Nurseries

There are three types of nurseries: peasant, temporary/intermediate and standard/permanent nurseries [(2)].

1. **Peasant nursery**
   These are nurseries where peasant or subsistence farmers raise their seedlings for planting in their backyard, compound or farm. It is usually located near the

house preferably behind the bathroom shed, along streams or riverbanks, along swamps, or by any other permanent source of water.

2. **Temporary (Intermediate) nursery**
   These are improved types of peasant nurseries and are comparatively larger than peasant nurseries. They are used to raise seedlings very close to the planting site to avoid the cost and problems associated with long-distance transportation of seedlings. There are no permanent structures in intermediate nurseries. The site is cleared, fenced with wire netting and provided with a temporary shade using materials such as palm fronds, and could serve for one season or more.

3. **Permanent nursery**
   These are established at centralized locations within the areas they serve and produce large numbers of seedlings continuously for a variety of needs such as the establishment of plantations, shade trees, woodlots, fodder banks, arboreta, shelterbelts, ornamental plants for landscape management, etc. They are usually large and intensively managed, and contain permanent and durable structures.

2.4.5 What are the Criteria for selecting a Nursery Site?

The following are the factors that must be taken into consideration when selecting a site for nursery establishment:

i. Nearness to the planting site.
ii. Nearness to the water supply.
iii. Nearness to good motorable road.
iv. Land must be fairly level with a gentle slope to avoid flooding.
v. Soil must be fertile with good drainage system.
vi. Availability of labour.
vii. Nearness to the market.
viii. Feasibility of establishing windbreaks.

2.4.6 How to establish and manage a tree Nursery

- Good quality seedlings depend on the quality of seeds used. The seeds for planting should therefore be sourced from a certified source.
- Clearing of the nursery site, stumping, burning of the trash and removal of debris.
- Levelling of the nursery site.
- A slight slope will help to drain off excess surface water.
- Laying out of the nursery site according to plan.
- Fencing of the nursery.
- Erecting of the shed (shading materials).

- Most agroforestry species in nurseries are established as either bare roots in raised beds or as potted seedlings in containers.
- In bare roots, seeds are sown on beds of soil raised to 30cm high. The width is usually 1.0 – 1.2m and the length usually depends upon the number of seedlings required and the available space.

CONSTRUCTION OF RAISED BED

- Potting of fertile soil into polybags requires a mixture of three-fifths of good quality topsoil, one-fifth of compost and one-fifth of sand (3:1:1).
- Pot filling is one of the most time-consuming activities in a nursery establishment. However, with experience, one person can fill up to 500 sleeves per day. Usually, women and youth learn this practice quickly.

FILLING THE PLASTIC SLEEVES WITH SOIL

- A large tree in one or two corners of the nursery is useful to provide shade for worker and to protect young seedlings from extreme weather.
- Nursery size depends on scale of operation.
- In general, a bed area of $5m^2$ is needed for 1000 seedlings regardless of whether seedlings are raised in pots or as bare-rooted stock; double this area to allow space for walkways, sheds and poles [(2)].

A TYPICAL NURSERY SETTING

- Make individual beds 80 – 100 cm wide to allow easy access to all seedlings. Make walkways between beds at least 60 cm wide.
- Thus, for 5,000 seedlings, the area needed is 10 m^2 x 5 = 50 m^2. Increase this to 20 m^2 x 5 = 100 m^2 if large pots are used, or if bare-rooted plants are widely spaced in seedbeds.
- Arrange beds in blocks of 500 or 1000 to make stock-taking easy.
- Do this by making beds 10 or 20 pots wide by 50 or 100 pots long. If possible, orient the long dimension of the beds east-west to give seedlings more uniform exposure to the sun by reducing edge effects [3].
- The nursery should be clean always.

SEEDLINGS DIRECTLY SOWN INTO A PREPARED SEEDBED

SEEDLINGS PLATED INTO PLASTIC SLEEVES

- Nursery tools and equipment must be cleaned after use and properly stored.
- Nursery worker(s) should be provided with protective materials such as gloves, aprons, coats, and rain boots.
- The nursery must be laid out to show the arrangement and classes of trees available for ease of taking records like planting dates, quantities planted, names, quantities and names of seedlings sold, price of seedlings, etc. [4].

2.5 Agroforestry Development Plan

2.5.1 Why agroforestry development plan?

The purpose of having an agroforestry development plan is to create a schedule of the work that needs to be done in the years ahead in order to fully develop the agroforestry area(s). Agroforestry Development plan will include specific tasks, timelines, and labor projections for each agroforestry practice on a year-by-year basis.

You will need a Development Plan for each agroforestry development area. You will no doubt change and adapt your work projections in the years ahead, but a good Development Plan will form a clear starting point and help focus your management efforts. The Development Plan includes two distinct parts:

1. A five-year plan outlining specific tasks for each agroforestry practice.
2. A yearly activity plan, broken down into specific tasks for each month.

2.5.2 Five-Year Management Projection

A five-year management projection is a schedule of the work you plan to undertake in the next five years to develop your agroforestry practices. The specific tasks and timelines you prepare will form the basis for your yearly activity schedule. Don't worry too much about getting absolutely everything right on the first pass. Your plans will change over time and you can go back and adjust your projections accordingly. For now, you are mainly interested in conceptualizing the overall operation on paper. The five-year management projection plan has four sections:

i. Area: size of the area to be managed.
ii. Practice: agroforestry practice and its associated products.
iii. Year: year that you want the management activity to take place.

Management Objective: specific objective you hope to accomplish.

Template of a 5 year Agroforestry Development Plan

Activity	Year 1	Year 2	Year 3	Year 4	Year 5
Farm size					
Choice of crop and trees as well as type of agroforestry to practice					
Project commencement time					
Management objectives					

2.5.3 Yearly Activity Schedule

The yearly activity schedule describes specific tasks that need to be done, when and by whom. This is the document you will use to plan your work schedule on a month-by-month basis. A good yearly activity schedule will allow you to identify potential time and business conflicts, and ensure you avoid overlapping seasonal activities that could create shortages of labor and resources. A yearly activity schedule—one for each agroforestry practice—has five sections:

i. Crop Plant: the plants that you have decided you can grow and market.
ii. Management Objectives: a record of objectives, transferred from your five-year projection.
iii. Task and Time of Year: a list of specific tasks that must be accomplished to achieve each objective, including timelines associated with each task. • Materials: estimates of seed, seedlings, fertilizer, fencing, animals, feed and other items necessary for corresponding tasks.
iv. Labor and Equipment: a record of labor and equipment needs (if any) for each of the specific tasks.

Template for a one-year Agroforestry Development Plan

Activity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Choice of crop and tree to grow												
Management objectives												
Task and time of year e.g. • Site selection and measurement												
• Purchase of seeds and seedlings												
• Land clearing and preparation, etc.												
Farm record keeping of all expenditure												

Like the five-year management projection, the yearly activity schedule will likely change as one learn more. Remember to leave yourself plenty of time to complete all the work. As landowners well know, most tasks take longer than expected. The yearly activity schedule will also be helpful in costing the materials, labor and equipment that are necessary for the cash flow projection of your business plan. For details on business planning, refer to Building a Sustainable Business: A Guide to Developing a Business Plan for Farms and Rural Businesses. The information in the Workbook will provide a good basis for a business plan that includes a comprehensive cash flow projection.

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MODULE 3: CLIMATE CHANGE AND AGROFORESTRY; ESTABLISHMENT AND MAINTENANCE OF AGROFORESTRY FIELDS

3.1 Objectives of the module

At the end of this module, the trainees will have a full understanding of:

i. Climate change and its causes.
ii. The effect of climate change on agricultural and fisheries production.
iii. The role of agroforestry in the adaptation and mitigating of climate change.
iv. Establishing an agroforestry plot.
v. Maintaining an agroforestry plot.
vi. Harvesting and value addition to agroforestry products.

3.2 Climate Change and the Role of Agroforestry in its Adaptation and Mitigation

3.2.1 What is Climate Change?

Climate change refers to long-term shifts in temperatures and weather patterns [1]. Such shifts can be natural, due to changes in the sun's activity or large volcanic eruptions. But since the 1800s, human activities have been the main driver of climate change, primarily due to the burning of fossil fuels like coal, oil and gas.

3.2.2 What are the causes of climate change?

The causes of climate change are:

i. Burning of fossils fuel (like coal, oil and gas) which produces heat-trapping gases known as greenhouse gases.

ii. Agriculture (land clearing)/Deforestation releases carbon dioxide into the atmosphere while some agricultural operations such as continuous flooding of rice field and livestock production releases methane gas into the atmosphere.

iii. Land degradation Land degradation: Soil store carbon. When land is degraded, soil carbon is released into the atmosphere, along with nitrous oxide, making it one of the biggest contributors to climate change. An estimated two-thirds of all terrestrial carbon stores from soils and vegetation have been lost since the 19th century through land degradation.

3.2.3 What are the effects of Climate change on Agricultural production?

Agriculture and fisheries are highly dependent on the climate.

- High temperature above the optimum required by crops and fodders causes heat stress that results in low yield and sometimes crop failure
- Extreme heat in livestock can eventually lead to heat stroke which can be fatal, reduced meat and milk production and quality.
- Erratic rainfall means both an increase and decrease in the amount of rainfall. Decreased rainfall and drought can cause low yields and crop/fodder failure,

depletion of surface and groundwater irrigation supplies, depletion of domestic water supplies, and an increase in wildfire potential. Extreme or excessive rainfall leads to flooding which results in crop loss and soil erosion.

Maize field affected by heat stress | Maize field affected by drought | Maize affected by flood

- High incidences of pests and diseases
- Livestock and poultry may be at risk, both directly from heat stress and indirectly from reduced quality of their food supply.
- Fisheries will be affected by changes in water temperature that make waters more hospitable to invasive species and shift the ranges or lifecycle timing of certain fish species.
- The rising sea level results in salinization of the farm land in coastal areas thereby leading to stunted growth of the crops and low yield.

From the foregoing, climate change is making it more difficult to grow crops, raise animals, and catch fish in the same ways and same places as we have done in the past. This situation poses serious challenges to the farmer's livelihood and a threat to food security.

3.2.4 What are the Roles of Agroforestry in the Mitigation of Climate Change?

Agroforestry contributes to climate change mitigation in the following ways:

- Trees and shrubs play a critical role in water management by reducing runoff and increasing groundwater recharge. This helps in managing risks associated with water scarcity and flooding.
- Agroforestry has emerged as a sustainable strategy to mitigate the impact of floods and river erosion. Floods and river erosion are common occurrences in areas with low-lying topography and monsoon climate and they can cause significant damage to agricultural land, infrastructure, and livelihoods. Agroforestry can help to mitigate the impact of floods and river erosion by promoting soil stability, reducing erosion, and slowing down floodwaters. Agroforestry systems have been reported to effectively reduce soil erosion and sedimentation, as well as reduce the velocity of

floodwaters, thereby minimizing damage to crops and improving the resilience of farming communities [2].

- Trees in agroforestry systems sequester carbon, contributing to climate change mitigation (i.e. trees in agroforestry capture and store atmospheric carbon dioxide thereby reducing the amount of carbon dioxide in the atmosphere with the goal of reducing global climate change). This can also provide farmers with additional income through carbon credits, adding another layer of financial security [3].
- They provide shade, reduce soil temperature, and help retain soil moisture, which is crucial during drought periods.
- Trees can also serve as windbreaks, reducing the damage from storms and heavy winds.
- Agroforestry improves soil structure and fertility through leaf litter and root systems, reducing the risk of soil degradation and erosion.
- Improved soil health enhances water retention and nutrient cycling, supporting crop and pasture productivity.
- Agroforestry systems can reduce the prevalence of pests and diseases through habitat diversification. The presence of various plant species disrupts the life cycles of pests and diseases, reducing their impact on crops and livestock [4].

3.3 Establishment and Maintenance of an Agroforestry Plot

3.3.1 How are tree seedlings planted in the Agroforestry Plot?

Below are the ways to plant tree seedlings in an agroforestry plot.

i. **Land Clearing**: The field should be cleared manually, according to the agroforestry system that has been chosen.

ii. **Pegging:** This is to show the place where the holes will be dug. Such places can be pointed out with stakes or by making a small hole. Spaces between the trees depend on the species of the tree to be planted.

iii. **Making holes:** This operation consists of digging the hole where the tree will be planted. Ideally, at an early stage of the rainy season, a hole - 70 cm deep and 70 cm wide will be dug, depending on the species one month before planting the tree. Sunlight and rain will then have time to soften the bottom of the hole.

iv. **Selecting and transporting tree seedlings:** Before planting, it is important to select trees by burning those that are weak or affected by diseases. For transportation, it is important to respect the following:
• Water the young trees one day before movement.
• Transport young trees early in the morning or late in the day to avoid transplanting shock.
• Make sure you have prepared an appropriate place to receive the tree seedlings.

v. **Planting the tree seedlings**
   - Handle gently, ensuring you keep the clump of earth surrounding the roots.
   - Cut the bottom of the pot (polybag) and place it straight in the hole.
   - Fill the hole with soil without packing it too densely.
   - Pull the polybag to remove it.

- Pack the soil around the young tree.
- Water the young tree.
- If there is no substantial rain within two days of planting, the tree must be carefully watered.

vi. Protecting the young trees

Young trees should be protected by all possible means from animals, particularly cows and goats. It is sometimes possible to combine the following practices:

- Constructing an individual protection using bamboo, palm leaves or wood.
- Surrounding young trees with spiny branches.
- Wrapping the trunk with textile fabric so that animals not feed on the bark.
- Putting a topless and bottomless barrel on the young tree.

3.3.2 How do we maintain or manage an Agroforestry plot/field?

Agroforestry systems differ, but broad management goals are similar. Below are the ways of managing an agroforestry field to maximize the productivity and profitability of the system.

- After planting, it is important to monitor young trees well, including protecting and caring for them (watering, weeding around, etc.).

a. Protection

Seedlings and saplings in the field need to be protected from livestock with a fence of some kind either around individual trees or the planted area. A fence can consist of bamboo sticks placed in the ground and bent over the seedling or sapling or, in the case of an agroforestry adjacent to a rice field, be a living fence of *Gliricidia* or other fast-growing species or made of rocks or even wire and poles, depending on what is easily and cheaply available [5].

FENCING OF YOUNG SEEDLINGS AND SAPLINGS

b. Weed control

Seedlings and Saplings in fields need to be regularly weeded to reduce competition for nutrients, light and moisture. For the older trees, it is important to remove weeds around a tree at least twice yearly in the rainy season during the first 3 years. Dead trees should be replaced during the next rainy season.

WEEDED SAPLING FIELD OF CITRUS

c. **Diseases and Pest Control**

Trees planted in agroforestry with arable crops will likely benefit from any pesticides applied to the crop though this should not be assumed and testing might be required. In semi-arid areas, termites can cause serious damage to seedlings and mature trees, so mitigation measures like selecting termite-resistant species and employing protection strategies are very important. Strategies include removing dead and damaged wood from trees quickly after damage, mulching to provide alternative food sources, and careful management of the tree (especially when it is young) to keep it healthy and able to resist termites. Pesticides can be used, but they tend to kill natural enemies, and are most effective when used to kill termite colonies rather than to protect individual trees, which is undesirable. Several botanical extracts can be used to control termites [6].

d. **Fertilizer Application**

Trees planted in arable crop fields will benefit from any fertilizer applied to the arable crop. Trees planted outside crop fields can have organic fertilizer, such as compost, added to their planting holes. Different trees will likely require additional fertilization at different times, especially fruit trees to ensure productivity.

Agroforestry systems can be critical in improving soil fertility. Leguminous trees planted as fallows or interspersed with crops can accumulate significant amounts of nitrogen in their leaves and roots, which is then made available to crops [4]. Incorporating leaves into the soil can increase crop yields several-fold.

APPLICATION OF FERTILIZER TO TREE SEEDLINGS

e. Watering

Trees planted in areas that are not irrigated should be planted to coincide with the wet season but, in areas with long dry seasons, bucket or drip irrigation might be beneficial during the early stages of growth to ensure survival. For those planted in rice field, watering should coincide with the time of flooding.

WATERING OF SEEDLINGS

f. Thinning and Pruning

Trees that are planted densely should be thinned at a later age after the establishment by removing the slower–growing and poorer quality trees to allow the better quality trees to grow to maturity. The trees that have been removed can be used for other purposes, such as fencing, building or fuel wood. The particular needs of each tree in relation to planting distance should be discussed at the design stage with both specialists and farmers. For example, some species coppice after cutting. The coppice will need to be cut again but can be used as fuel wood, animal fodder or other purposes depending on the species [6].

THINNING

Pruning is key in agroforestry management but should be done carefully without affecting the growth of the trees. Each tree has special requirements for pruning, for example, for timber trees, it is the branches that diverge from the main trunk and threaten to create a V shape or branches that grow horizontally will encourage the tree to grow straight, which increases the value of the timber at harvest. For fruit trees, horizontal, fruit-bearing branches are usually preferred. Pruning is best done in stages.

i. First, when the sapling reaches a human height, regardless of its age. Using hand pruners (for smaller branches) or a saw (for larger ones) rather than a machete reduces the risk of damage to the tree by keeping the scar small; larger scar attract diseases and pests more easily. Cut the branch close to the trunk and at an angle so that rain will not easily enter the scar [7]. Covering the scar with paint or even a marker pen can lessen the risk of water, disease or insect damage.

ii. Second, particularly for timber trees, when the tree is well above human height, pruning can be done with a pole saw and pruner (a combined set is often available in agricultural supply shops) attached to a long pole.

iii. Third, small, unwanted branches can be removed at any time in a tree's life.

PRUNING

Lopping

Sometimes, lopping which is a process of cutting down entire branches, or even whole trees, for a variety of reasons (this can include the removal of dead or diseased branches to reduce the risk of further damage to the tree, as well as the removal of branches blocking roads, sightlines, etc.) may be done to the intended purpose.

LOPPING

g. Coppicing

Coppicing is done in agroforestry systems where the tree crop is meant for timber or wood production. It is a method of cutting trees to ground level, leading to a strong vegetative response and the regeneration of new shoots from the base. Coppiced trees have a fully developed root system so that regrowth is rapid and the wood from the new stems may be harvested in short intervals of 2–10 years. In the tropics, *Acacia* spp., *Gmelina arborea* and *Tectona grandis* are grown for this purpose [8].

COPPICED TREE

h. Fire Tracing

Fire must be strictly avoided around planted trees, which should be protected and their surroundings cleared regularly. It is particularly important to protect local African (native) tree species like the *Cola*, *Irvingia* or *Allanblackia* trees since they are often threatened.

i. Harvesting

Timber trees can usually be harvested at 5 to 30 years of age, depending on the species, stocking and the farmer's needs. Teak, for example, will be most valuable when mature at 30 or more years old but most farmers will harvest when the tree is much younger to meet cash needs. *Albizia chinensis* can be harvested at around 5–10 years, making it a popular crop for farmers. Harvesting is often carried out by traders themselves, which reduces time and labour costs for farmers but also reduces price premiums. An option would be that farmers cooperate to harvest and market their timber. Fruit and nut trees vary in harvest times but most fruit annually. Growing a mix of timber and fruit trees in an agroforestry landscape helps farmers maintain cash flow throughout the year and over decades [(9)].

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MODULE 4: POST-HARVEST MANAGEMENT AND MARKETING OF AGROFORESTRY PRODUCTS

4.1 Objectives of the module

At the end of this module, the trainees will have a full understanding of:

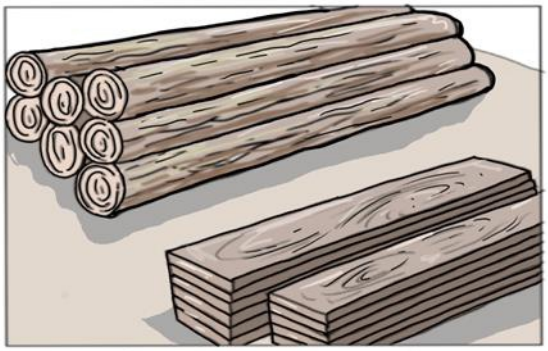
i. Post-harvest management of trees and harvested agroforestry products.
ii. Value addition to agroforestry products.
iii. The nature of agroforestry value chain.
iv. Agroforestry marketing.
v. Gross Margin analysis in Agroforestry.
vi. Investment opportunities in agroforestry.

4.2 Post-harvest Management of trees and harvested Agroforestry Products

For fruit and nut trees, post-harvest work can include the application of fertilizer, pruning and processing of the fruit either for fresh-fruit sale or the creation of other products, such as dried fruit, teas, alcoholic drinks, pastes or preserves. Collaboration among farmers will help reduce costs, strengthen bargaining power and add value to their products that will increase their incomes. Post-harvest processing of timber trees that increases income includes processing logs into planks to suit market demand, something that is best done cooperatively or in collaboration with a local sawmill. Again, collaboration among farmers is usually beneficial.

Please note that with timber trees, harvesting an entire area can create environmental problems, such as erosion and sedimentation. In the design stage, these risks at the post-harvest stage can be reduced. For example, a mix of trees planted at different times and in different areas, which can be harvested at different times and intensities, will help reduce damage to soil. Such design will also help with post-harvest replanting, reducing the number of seedlings to be sourced and planted at any one time. Care should be taken to ensure that the complexity of management does not become too great.

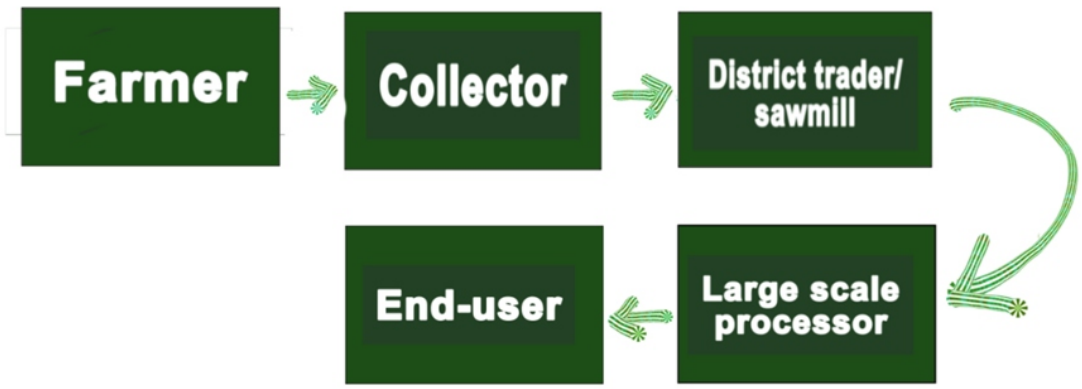
Value addition to Sheer Butter



Value addition to timber

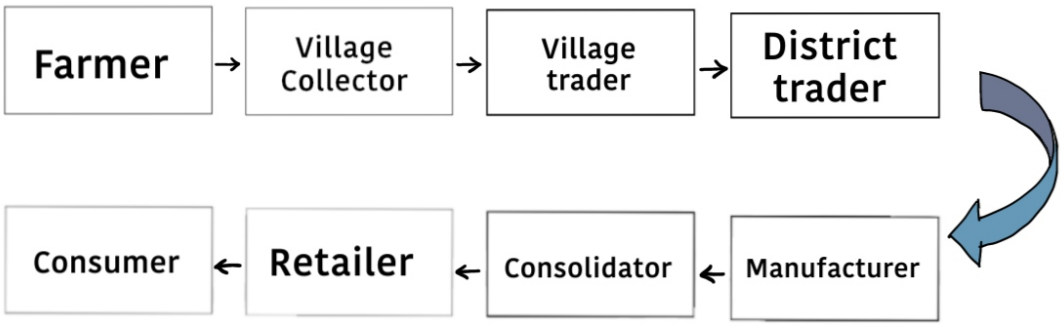
4.3 Value chains

Traders are the link between farmers, sawmills and manufacturers (Fig. 1). Each has an important role to play in transforming trees. A farmer is a producer. Their involvement ends after selling tree products to traders, who often also do the harvesting. The timber value chain is relatively simple [1, 2].



Example of Timber value chain
source: Xu et al., 2013

For non-timber products, the value chain might not be as straightforward as for timber [3]. It could include more levels of traders because the product might be processed several times (Fig. 2). The spice value chain, for example, often involves sorting, drying, peeling, deshelling, washing, drying again, crushing or other types of processing and then packaging and sale. Rules, costs, marketing margins, and profits are embedded in each of these stages as value is added to the product.



Example of value chain for non-timber product

Non-timber products often make substantial contributions to both local and national economies [1]. This can be a powerful incentive to maintain both agroforestry and natural forests. Rural advisors can help farmers by categorizing together the things considered to be non-timber products, for example, leaves, bark, branches, flowers, fruits, seeds, saps and resins. Most non-timber products are seasonal, so a seasonal calendar could be created that shows planting and harvest times. Including other factors, such as weather and busy farming periods, helps farmers to prepare equipment, labour and capital. A simple map showing locations of non-timber products helps farmers visualize the environment and estimate transport costs. Advisors can also assist with finding markets.

4.4 What are the Barriers to Agroforestry Market system?

The barriers are:

- Under-developed markets are the main challenges for agroforestry value chains and market systems to be sustainable and successful.
- Most agroforestry products lack connections to markets due to poorly developed policies that tend to focus on conventional agricultural methods such as monocropping systems [4].

4.4.1 How can agroforestry value chains and market systems become more efficient and profitable?

Agroforestry value chains and market systems can be made more efficient and profitable in order to provide sufficient income to farmers by:

i. Supporting smallholder farmers to organize themselves in cooperatives.
ii. Supporting smallholder farmers especially women access to finance and advisory services, as agroforestry farming systems require investments in technical skills, and skills for marketing of products.
iii. Linking smallholder farmers to markets: An inclusive market systems approach focuses on connecting farmers to local and regional markets. Once the producers/cooperatives can ensure a steady stream of a certain volume of products for example supermarkets or farmers markets, it can increase the price.
iv. Adopting a flexible market systems approach can be applied to connect, build value-added services and enhance market access among smallholder producers and agribusinesses while minimizing direct actions that risk further distorting the market system [5].
v. Developing a marketing plan which includes what products to offer, the price of the products, where to sell the products, and how to promote the products through advertisement, promotions and other marketing activities.

SALES ADVERTISMENT

vi. Conducting market research to identify potential markets where agroforestry products can be sold at local, regional and international levels.

vii. Knowing the preferences and trends in the demand of consumers, the seasonal demands of the products, identifying competitors for the agroforestry products, and analyze their strengths and weaknesses [6].

viii. Carefully considering the distribution channel – direct sales could be done in the markets, fairs, or through farm stands; retail outlets by partnering with local stores, supermarkets, or specialized shops.

ix. Ensuring that quality control measures are put in place throughout the production process and relevant certificates are obtained to enhance product credibility, access to premium markets, and higher price increase customer trust and demand.

4.5 Income Generation Opportunities in Agroforestry

4.5.1 Wind breaks

- Multiple row windbreaks are places to produce marketable products like hybrid poplar, wood, nuts, apples, cherries, blackberries and woody floral products.
- Evergreens can be sold as Christmas trees, bought for seasonal floral products or as landscaping plants while adding colour to farms and providing protection for birds and other wildlife.

4.5.2 Woodlots

- Well-managed woodlots can potentially produce high-quality lumber, firewood and valuable specialty forest products like maple syrup, ginseng and other medicinal plants, which are grown under shade.
- Teak is an income-generating tree because it is used for electrical poles, beams, trusses, columns, roofs, doors, window frames, flooring, planking, paneling, and staircases, and other constructional work. It is one of the best timbers for furniture and cabinet-making.

WOODLOT

4.5.3 Alley cropping

- Blueberries, chokecherries, elderberries, chestnuts, hazelnuts, palm oil, palm kernel oil, and many others have great potential when marketed as locally grown products while still protecting the land.
- Some forest product companies may offer advanced purchase or lease agreements that provide annual payments before the trees are harvested. Because these plantings also attract wildlife, hunting leases are a possible income source.
- Possible inter-crops include vegetables, horticultural plants, forages, rice, cowpea, banana/plantain, and traditional row crops which will be sold for income aside from the tree products. This system will produce valuable products while protecting the land.

4.5.4 Silvopasture

- Tree canopies provide livestock with shade and wind protection and may yield additional income when the trees or tree products are harvested.
- The branches and leaves of some trees can be pruned from the trees and fed directly to livestock.
- Pine stands and nut and fruit orchards may be grazed to produce income before and while trees are bearing and growing.

4.5.5 Apiary

- The bees apart from pollinating the arable crops and the trees which leads to increased yield of both trees and crops also produce honey which are all sources of income.
- The trees still protect the land for sustainable agricultural production.

4.5.6 Aqua forestry (trees with fish)

- The fish and the tree products are marketed for income generation
- The wastewater from the fishpond is a source of fertilizer for the tree crops.

The tree crops provide shade for the fishpond thereby reducing the impact of heat from the sun and also reducing the evaporation of the water from the pond.

4.6 Net Farm Income for Agroforestry System

Net farm income refers to the return (both monetary and non-monetary) to farm operators for their labour, management and capita. To compute the net farm income, you need the following:

1. Identify Revenue Sources

In agroforestry, revenue can come from various sources including:

Crops: Annual crops like vegetables, rice, cowpea, grains, or perennial crops like fruit and nut trees.
Livestock: Revenue from animals that graze in the agroforestry system.
Timber and Non-timber Products: Revenue from timber, firewood, medicinal plants, etc.

2. Calculate Total Revenue

Total Revenue (TR) = Sum of all revenue sources over a specified period.

3. Identify Costs of production

Costs in agroforestry can be categorized into:

Variable Costs: Costs that vary with production levels, such as seeds, fertilizers, pesticides, labor, feed, and veterinary costs.
Fixed assets Costs: Costs that do not vary with production levels, such as machinery, equipment, land rent, insurance, and taxes.

4. Calculate Total Costs

Total Costs (TC) = Variable Costs (VC) + Fixed Costs (FC)

5. Calculate Net Farm Income

Net Farm Income (NFI) = Total Revenue (TR) - Variable Costs (VC)

Example Analysis

Suppose we have the following data from a hectare of farmland:

Revenue from Crops: ₦2,000,000.00
Revenue from Livestock: ₦1,000,000.00
Revenue from Timber: ₦500,000.00
Total Revenue (TR): ₦3,500,000.00
Variable Costs:
- Seeds and Fertilizers: **₦200**,000.00
- Labor: ₦80,000.00
- Feed: ₦200,000.00
- Veterinary Costs: ₦10,000.00
- Total Variable Costs (VC): ₦490,000.00

Fixed Costs:
- Equipment: ₦400,000.00
- Land Rent: ₦100,000.00

- Total Fixed Costs (FC): ₦500,000.00

Calculation:
Total Costs (TC) = Variable Costs (VC) + Fixed Costs (FC) = ₦490,000 + ₦500,000 = ₦990,000.00

Net Farm Income (NFI) = Total Revenue (TR) - Variable Costs (VC) = ₦3,500,000 - ₦990,000 = ₦2,510,000.00

This analysis helps in understanding the profitability of agroforestry by showing how much revenue is left after covering the variable costs.

4.7 The Role of Gender in Agroforestry

"The failure to recognize the roles, differences and inequities between men and women (gender blind) poses a serious threat to the effectiveness of the agricultural development agenda" [7].

THE ROLES OF GENDER IN AGROFORESTRY

4.7.1 What are the Roles of Gender in Agroforestry?

In agroforestry, men and women often have distinct roles and responsibilities, shaped by cultural norms, socioeconomic factors, and access to resources [7]. Recognizing these roles is essential for designing effective and equitable agroforestry interventions. Every gender should however complement the other to ensure efficient and profitable agroforestry.

4.7.2 Roles of Men in Agroforestry

Below are the roles of men in agroforestry:

- Men are commonly involved in land clearing, digging holes, and planting trees. These tasks often require physical strength and access to tools and machinery and frequently make decisions about which trees to plant, where to plant them, and how to manage land resources.
- Maintenance and Management roles like pruning, thinning, and managing tree growth to ensure optimal health and productivity.
- Pest and disease control. These tasks require technical knowledge about tree species and management practices.
- Harvesting of timber and non-timber forest products, such as fruits, nuts, and wood. They also play a significant role in marketing and selling these products.

- Control the income generated from the sale of agroforestry products. This can lead to uneven distribution of economic benefits of agroforestry, with men controlling the major income-generating activities.
- Building of infrastructure such as fences, storage facilities, and irrigation systems.

4.7.3 Roles of Women in Agroforestry

Below are the roles of women in agroforestry:

- Management of nurseries, including seed collection, germination, and caring for seedlings until they are ready for planting.
- Women are frequently involved in intercropping, where they plant crops between rows of trees.
- Management of soil fertility through practices like mulching and composting. These practices contribute to soil health and overall farm productivity.
- Processing of agroforestry products, such as drying of fruits, extracting oils, and preparing medicinal plants.
- They often engage in value addition activities to increase the market value of products. These activities provide essential income for households and can improve women's financial independence.
- They are primarily responsible for utilizing agroforestry products to enhance household nutrition.
- They manage home gardens and small livestock integrated within the agroforestry system. This role ensures food diversity and nutrition security for the family.

4.7.4 What are the constraints faced by women in adopting agroforestry?

Below are the constraints faced by women in the adoption of agroforestry.

- They are largely excluded from obtaining permanent and secure land rights particularly in Africa. Securing land tenure rights is a crucial factor in agroforestry investment.
- Restricted access to knowledge through farmer groups, controlled by socially higher-ranked males, and Inadequate extension services further impede women's farming practices, as programmes often fail to address their specific training needs [8].
- Imbalance in the power that women and men have in decision-making processes within the household and the community based on traditional social norms have long considered agriculture, including agroforestry, as a domain of men.
- Limited access to labour is a major challenge for female farmers. Women allocate more time to family and childrearing tasks compared to men, which reduces the amount of time they can dedicate to farm work.
- Women have limited access to credit, loans or investment capital because they lack secured land rights and collateral assets which are frequently required as prerequisites for securing loans or credit from financial institutions.

4.7.5 How can the above problems be solved to ensure Gender Equity in Agroforestry

Here are several strategies to promote gender equality in agroforestry:

- Provisions of enabling policies and initiatives by government and organizations that provide equal access to land, financial resources (credit, loans), agricultural inputs, tools and extension services for women and men can help level the playing field and enable both genders to fully participate in agroforestry activities.
- Provisions of Gender-sensitive training programmes and educational initiatives developed and implemented by governments and organizations can challenge traditional perceptions and stereotypes. This can be achieved by-
  i. Ensuring that training schedules and locations are convenient for women, considering their household responsibilities.
  ii. Strengthening of extension services to be more inclusive and responsive to women's needs.
  iii. Recruitment and training of female extension agents to work with women farmers.
- Advocacy by organizations and individuals for the incorporation of gender-responsive policies at all levels of government includes enforcing regulations that ensure a minimum representation of women in decision-making bodies, such as the introduction of a quota for women in farmers' groups.
- Foster women's leadership and participation in agroforestry and rural development initiatives.
- Encouragement and Implementation of programs that empower women economically, socially, and politically. This includes entrepreneurship training, leadership development, and confidence-building activities. Promotion of successful female role models in agroforestry to inspire and encourage other women to participate and take on leadership roles.


GENDER
EQUITY

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MODULE 5: RICE AGROFORESTRY AND OTHER SUCCEFULL AGROFORESTRY MODELS

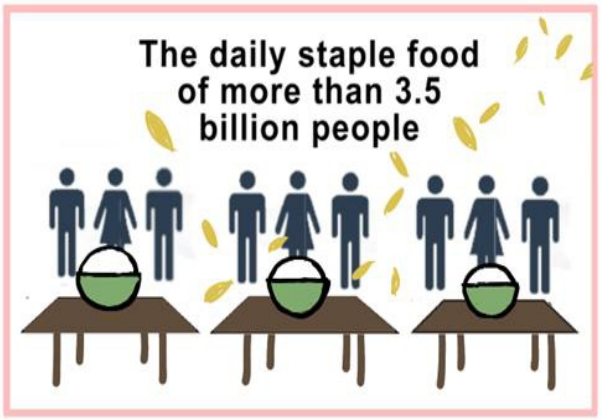
5.1 Objectives of the Module

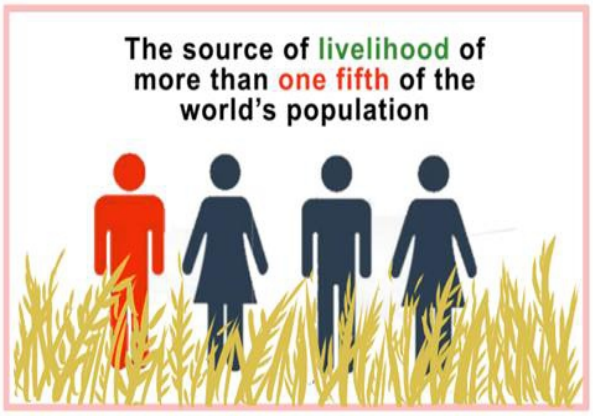
At the end of this module the Trainees will learn the following:

i. The contribution of rice to food security and livelihood.
ii. Effects of climate change on rice production.
iii. Existing rice agroforestry systems.
iv. The challenges of rice agroforestry system.
v. Some successful Agroforestry models.

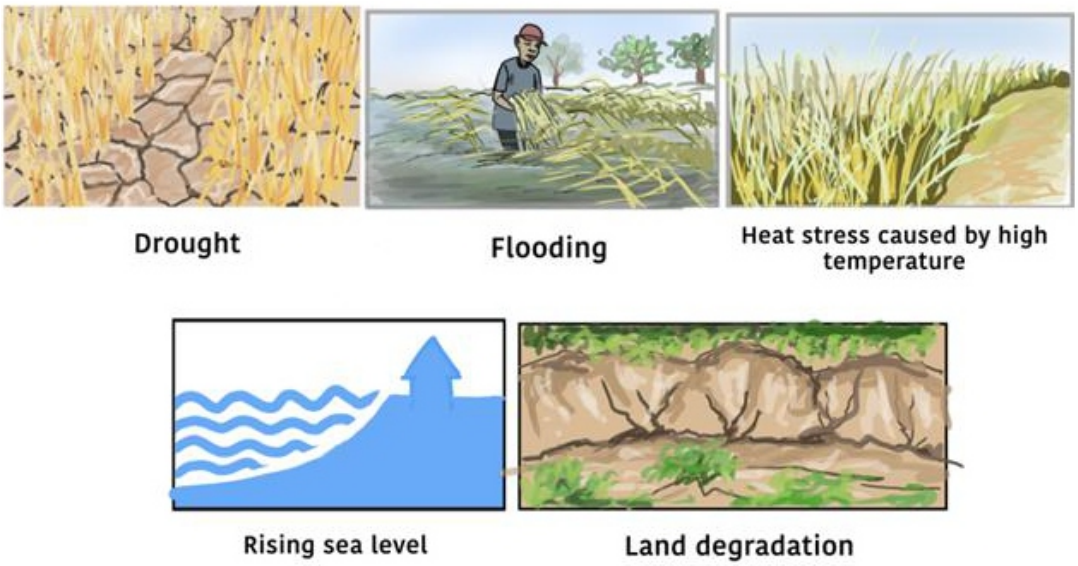
5.2 RICE AGROFORESTRY SYSTEM

Rice is a staple food for over 3.5 billion people across the globe and a source of livelihood for one fifth of the population of the world (farmer, processor, input seller, marketer, transporter, mechanization service provider, farm worker, etc). The demand for rice will continue to increase owing to increase in population.





Unfortunately, rice production is threatened by climate change (rising temperature, flooding, drought, rising sea level, land degradation, water scarcity, and over exploitation of natural resources thereby leading to food insecurity and putting farmers livelihood at risk [1]. Rice farmers are among the World's most vulnerable to the impact of climate change.



Supporting farmers to learn new skills and techniques is critically important in helping them adapt to climate change. Integrating trees into rice-production landscapes has been shown to help reduce temperatures and improve infiltration of water into the soil, store more carbon and diversify farm production, which lowers both climate and market risks. This adds up to greater adaptability and resilience not only for individual farmers and communities but also their environments.

5.3 What are the Rice Agroforestry Systems in Practice?

Existing rice-agroforestry systems include woodlot; boundary planting; windbreaks or hedgerows; dispersed trees on fields or pasture (e.g. park lands); improved fallow (as part of rotation between years of crops); alley cropping and Taungya system [2,3].

5.4 SUCCESSFUL AGROFORESTRY MODELS

The two other major successful agroforestry system practiced include:

- The Brazilian system which they referred to as Modern Brazilian System (MBS).
- The Indian system which they also referred to as the Vetri system (named after the partner from India that helped established it).

5.4.1 Modern Brazilian System (MBS).

Here, Alley cropping is the only type of agroforestry that is practiced. It is called Brazilian system because Brazilians are the ones famously known for alley cropping type of agroforestry. The MBS aimed to get the rural or smallholder farmers practice the system of agroforestry without disrupting their traditional ways of farming. The trees are planted in rows at 1.2 x 4.8 meters intra and inter row spacing. The crops (maize, groundnut and sorghum which are the major crops grown in the area) are grown in the alleys (4.8 m space). In the MBS model, crops that do not require much water are usually planted alongside trees with similar characteristics in a definite pattern, this means that irrigation

is not practiced under this system. In each hectare, 2,500 trees are planted and many tree seedlings were raised.

In a bid to reduce farmer-herder crises occasioned partly by climate change, some varieties of nutritious grasses like Napier grass, Ruzi grass, Gamba grasses, etc. were planted for livestock instead of growing arable crops within the alleys. The grasses help to improve the livelihood and sources of income for the farmers all year round because the grasses are drought tolerant and remain green throughout the dry season. On one hectare, the trees were planted at 1.2m intra row spacing by 4.8m inter row spacing thereby giving 16 alleys where the different grasses were sown. The same principle is applied when arable crops are planted in the alleys.

GROWING PASTURE WITHIN THE ALLEY

5.4.2 Indian System (also referred to as Vetri System).

This system is named after the Indian man that help them establish it. The Indian system is irrigated and it bears crops that are mostly vegetables, spices and herbs being grown along with trees all year round. Fast growing food crops—bananas, pawpaw, chilli peppers, turmeric, castor plants, rice, beans, hibiscus and trees (Eucalyptus, moringa, bamboo, etc), among many others — were deliberately planted because they wanted a situation whereby once a farmer sets up a farm, after 60 days the farmer would be harvesting food crops for the rest of their lives. In this system, for 12 months for sure, the farmers will have one or two crops that are produced every month. It is not like the traditional system of farming where you grow crops for four to five months, after harvesting, the farmers will now sit at home for another six months, while they keep selling

what they have harvested instead of having multiple streams of income if this type of system is adopted. Both the trees and the crops are planted at optimum population densities.

IMAGE OF INDIA AGROFORESTRY MODEL

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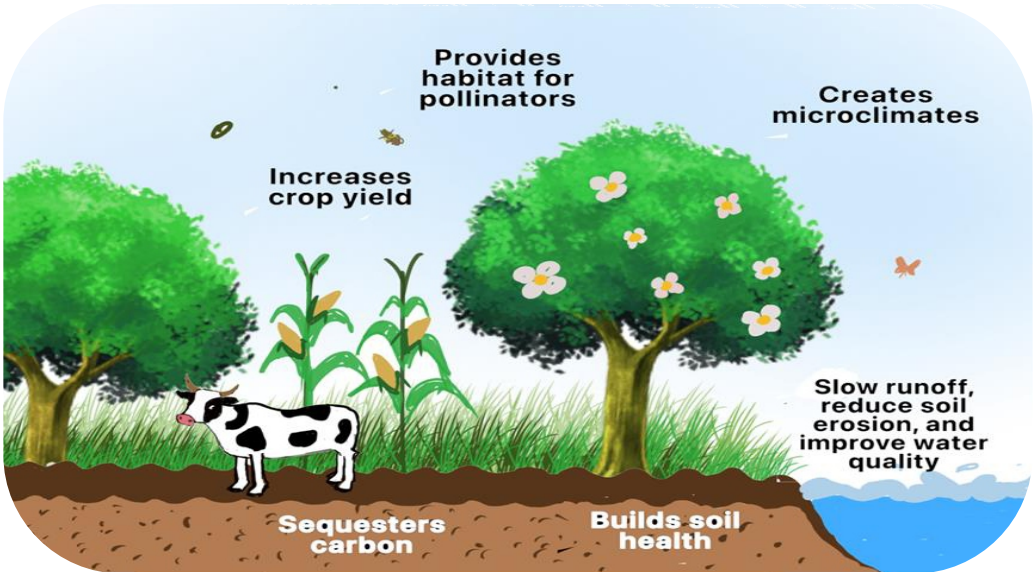
Provides habitat for pollinators
Creates microclimates
Increases crop yield
Slow runoff, reduce soil erosion, and improve water quality
Sequesters carbon
Builds soil health