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Training Manual on Vegetable and Rice Cultivation Through Climate-Smart Agriculture Practices

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Abstract

Climate-smart agriculture (CSA) provides an important framework for improving agricultural productivity, strengthening resilience to climate variability and change, and promoting sustainable management of natural resources. This training manual was developed as a practical educational resource for trainers, extension agents, and farmers in Sierra Leone, with particular emphasis on vegetable and rice production. The manual comprises interconnected modules covering climate and climate change, climate-smart agriculture, policy, financing, soil and water management, ecosystem and community resilience, agro-farming systems, agrochemical management, nursery management, carbon and nitrogen management, natural-resource management, disaster management, and crop-specific value chains for onion, hot pepper, and rice. The development process incorporated literature and policy sources, stakeholder input, expert review, field-testing, participant feedback, and adult-learning and agricultural-extension principles. The manual uses simple language, visual materials, modular learning, and pre- and post-session assessments to support users with different levels of literacy and agricultural experience. Preliminary field-testing reported in the manuscript involved a cohort of 45 farmers in Bombali and Moyamba districts and indicated higher post-session than pre-session knowledge scores, together with preliminary observations relating to skills acquisition, adoption of selected climate-smart practices, agricultural productivity, income, and food security. These findings should be interpreted as preliminary because the current manuscript does not provide sufficient methodological detail or statistical analysis to establish causal effects. The manual therefore provides a structured practical resource for CSA training while also establishing a framework for future formal evaluation of knowledge, skills, adoption, productivity, livelihood outcomes, and climate resilience.

Preface

This training manual on the cultivation of vegetables and rice through Climate-Smart Agriculture (CSA) practices is specifically developed for the largely illiterate farmers in Sierra Leone. However, it is equally very useful for literate farmers and farm resource and service providers. It is organized in modules, and each module is a stand-alone guide in a specific area of CSA. Even so, the modules throughout the manual are reinforcingly inter-connected. This builds the needed flexibility into the manual for use both as a personal reading material and as a training tool.

The general layout is structured such that each module is complete with background information fitted to the concept and process of climate change. Here, the main causes of climate change are discussed. This is followed by a discussion on climate change reduction measures. All of this is put into crop-specific context to guide the farmers to see very clearly the underlying causes and mitigation measures of climate change. In this case, specific vegetables such as onion, hot pepper, and Irish potato are emphasized. Also, rice cultivation and specifically Inland Valley Swamp (IVS) rice is prioritized.

A broad mode of presenting the content was the preferred choice because of its appeal to various calibers of readers. This was covered as infographics, pictorial presentations, bullet points, and short notes. This mix of context-building is the singular strength of this training manual. Each module also has a pre-session evaluation designed to know who the trainees are in terms of background knowledge in climate change and CSA. This is deliberately put into the model to help the trainer know what the trainees know about the specific issues covered under that module. There is also a post-session evaluation that tells the trainer exactly what the trainees have learned in a completed training session. This informs the trainer on the decision to redo some parts of the module, all of the module, or to move on to the next module.

It is hoped that the picking apart and joining together done in this manual can yield the desired effect where the trainers, the trainees, and the general readership find the knowledge sought about the causes of and solutions to climate change in relation to rice and vegetable crop cultivation.

Introduction

0.1. Purpose and Scope of the Manual

This document is a comprehensive Training Manual developed to serve as a practical educational resource for trainers, extension agents, and farmers, specifically within the context of Sierra Leone. Its primary purpose is to guide the delivery of hands-on training on climate-smart agriculture (CSA) for vegetable and rice production. The manual is designed to be a direct, user-friendly tool for capacity building, and its structure, complete with pre- and post-session tests, is built for immediate application in a training setting.

The manual is organized into eighteen modules that cover foundational concepts, thematic areas, and specific crop value chains. Each module is self-contained and yet interconnected with others, allowing for flexible training delivery. The manual is specifically designed for use in Sierra Leone, but contains principles and practices that are applicable to other tropical and sub-tropical agricultural systems.

0.2. Manual development and educational framework

The development of this manual was guided by a multi-stage, participatory process to ensure its relevance, practicality, and effectiveness for the target audience.

0.2.1.Information Sources and Literature: The content was synthesized from a wide range of high-quality sources, including

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recent peer-reviewed literature, policy documents from the Food and Agriculture Organization (FAO), World Bank, International Fund for Agricultural Development (IFAD), and other international bodies. Key references include the Intergovernmental Panel on Climate Change (IPCC) reports, the Sierra Leone National Adaptation Programme of Action (NAPA, 2007), national communications to the United Nations Framework Convention on Climate Change (UNFCCC), and the works cited in the reference list. The manual builds on established scientific knowledge on CSA, agronomy, extension methodologies, and adult learning principles.

0.2.2. Stakeholder and Expert Input: The foundation of the manual was shaped by extensive field experience and consultations with key stakeholders in the Sierra Leone agricultural sector, including:

i. Target Community Engagement: Initial needs assessments and pilot training sessions were conducted with smallholder farmer groups in target regions to identify the specific challenges, existing knowledge, and learning preferences. These engagements were facilitated through the Agriculture Value Chain Development Project (AVDP) and partner organizations.

ii. Expert Review: An iterative review process was undertaken with a panel of subject matter experts, including agronomists, climate change specialists, experienced extension officers, and representatives from the Sierra Leone Ministry of Agriculture, Forestry, and Food Security (MAFS). These experts reviewed the draft modules for scientific accuracy, practical applicability, and pedagogical effectiveness. The expert feedback led to significant refinements in the technical content and instructional flow.

0.2.3. Validation and Field-Testing: To validate the content and usability of the manual, field-testing activities were conducted with a cohort of volunteer farmers and extension personnel in selected districts. Observations during training sessions, participant feedback, and pre/post-session test results were systematically recorded. This feedback was critical in identifying areas where language was unclear, technical content needed simplification, or practical aspects were insufficiently detailed. Based on the feedback of the farmers, sections on nursery management were expanded to include more detailed guidance on different types of nurseries and the use of locally available materials. This iterative process of 'train, evaluate, and revise' ensures that the final version of the manual is not only scientifically sound, but also practically effective and user-focused.

0.2.4. Educational and Extension Framework: The design of the manual is rooted in established adult learning and extension principles:

i) Visual and Simple Language: It prioritizes infographics, illustrations, bullet points, and short notes, making it accessible to audiences with low literacy levels.

ii) Modular Structure: The content is divided into interconnected stand-alone modules, allowing for flexible and targeted training delivery.

iii) Action-Oriented Assessment: Each module includes pre- and post-session tests. This serves a dual purpose: gauging baseline knowledge of participants and providing immediate feedback to the trainer on session effectiveness, thereby enabling adaptive teaching.

iv) Practical Focus: The modules on specific value chains are based on comprehensive, step-by-step agronomic practices, ensuring the training is directly applicable to farmers' fields.

0.3. Crop Selection Justification

The manual focuses on onion, hot pepper, Irish potato, and rice (specifically Inland Valley Swamp rice) for several strategic reasons that align with agricultural development priorities in Sierra Leone.

i) Agricultural and Economic Significance

These crops are of critical importance to the agricultural economy and food security of Sierra Leone:

- Rice: This is the primary staple food, accounting for the largest share of agricultural GDP and 42% of average energy intake (SLCAR, 2016). Rice cultivation supports the livelihoods of millions of smallholder farmers across Sierra Leone, particularly in inland valley swamps which offer significant production potential.

- Onion and Hot Pepper: These are high-value vegetables that offer significant income-generating opportunities for smallholder farmers, particularly women. These crops have growing domestic and regional market demand and contribute to dietary diversity.

- Irish Potato: This crop serves as an important alternative food source and cash crop, particularly in the cooler highland areas of Sierra Leone.

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ii) Climate Vulnerability and Adaptation Opportunities

The selection is also based on differential vulnerability of the crops to the impacts of climate change and their suitability for climate-smart interventions:

- Rice: Rice yields are highly sensitive to variations in rainfall and temperature (McSweeney et al., 2010). Inland Valley Swamp rice cultivation is particularly vulnerable to changes in water availability and extreme weather events, making it a priority for adaptation efforts.

- Onion and Pepper: These vegetables are susceptible to heat stress, water-related diseases, and pest outbreaks that are exacerbated by climate change. Their cultivation offers clear opportunities for improved water management, integrated pest management, and soil health interventions.

iii) Practical Applicability for Climate-Smart Agriculture

These crops are practical entry points for promoting climate-smart agriculture in the region:

- Onion: Offers opportunities for improved water management through efficient irrigation, integrated pest management, and improved post-harvest handling.

- Pepper: Allows for implementation of integrated pest management, soil conservation, and agroecological practices.

- Rice: Provides clear pathways for water management (alternate wetting and drying), improved nutrient management, and sustainable intensification.

The detailed management practices for these crops provide concrete and scalable entry points for farmers to adopt more climate-resilient agricultural systems while addressing the specific challenges posed by climate change in Sierra Leone.

Module One

Climate and climate change

1.1 Module Outline

Weather; Climate; Climate variability; Climate change; Global warming and climate change.

1.2 Learning Objectives

To know the basic terms used in climate change. To know the link between global warming and climate change

1.3 Pre-session Test

Table 1.1: Assessing knowledge base of trainees on climate.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)				
No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	What is weather?			
2.	What is climate?			
3.	What is climate variability?			
4.	What is climate change?			
5.	What is the link between global warming and climate change?			
6.	Average			

1.4 Module Content

1.4.1 Weather: Weather is the short-term state of the air around us. It can be hot, cold, wet, dry, still, windy, clear, cloudy, rainy, sunny, or dusty. Weather is affected by latitude, vegetation, altitude, and water bodies. The variables used to measure weather are temperature, humidity, wind speed, precipitation, air pressure, sunshine, etc.

1.4.2 Climate: Climate is the weather condition of a place over a long period of time. Weather variables averaged for some given periods (often 30 years) are said to be the climate of a place.

1.4.3 Climate Variability: Climate variability is the natural ups and downs in climate over short time periods (for example, days, seasons or years), but with almost no change in the long-term average. Climate variability affects weather conditions, including temperature and rainfall (Figure 1.1).

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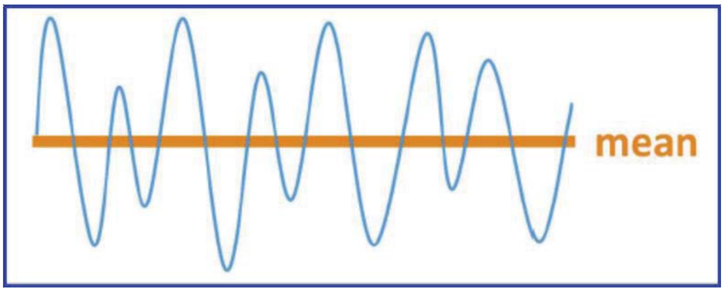


Figure 1.1: A show of climate variability in a diagram.

1.4.4 Climate Change: Climate change is the steady shift in climatic conditions, with a notable change in the long-term average. Climate change is driven by both natural and human factors, and it happens when the long-term variability and the mean show a significant difference. For example, an overall warmer, cooler, wetter, or drier climate over a decade is climate change (Figure 1.2 and 1.3).

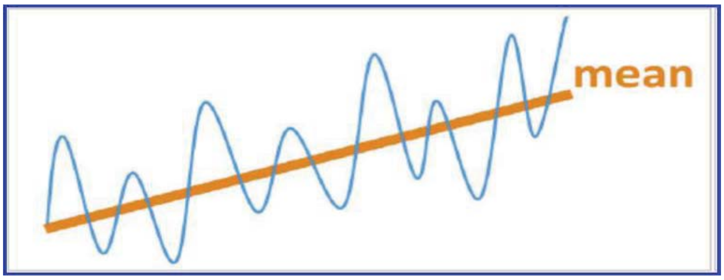


Figure 1.2: A show of climate change in a diagram.

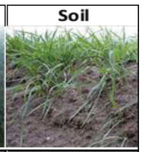
	Drought	Temperature	Rain	Wind	Forest	River	Soil
State							
20 years ago							
Now							

Figure 1.3: Classwork on climate change in an area.

1.5 Post-session Test

Table 1.2: Assessing knowledge learned by trainees on climate

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)

No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	What is weather?			
2.	What is climate?			
3.	What is climate variability?			
4.	What is climate change?			
5.	What is the link between global warming and climate change?			
6.	Average			

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Module Two

Climate change and agriculture

2.1 Module Outline

Causes of climate change; Risk of agriculture to climate change; Risk of climate change to agriculture; Climate change and agriculture in Sierra Leone.

2.2 Learning Objectives

To know the causes of climate change. To know how agriculture affects climate change. To know how climate change affects agriculture.

2.3 Pre-session Test

Table 2.1: Assessing knowledge base of trainees on causes of climate change and risks to agriculture.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)

No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	What is risk?			
2.	What is agriculture?			
3.	What are the causes of climate change?			
4.	How does agriculture affect climate change?			
5.	How does climate change affect agriculture?			
6.	Average			

2.4 Module Content

2.4.1 Risk: Risk is the likelihood of a negative outcome of a decision or action. It is a state that could result in loss, disaster, or an unknown bad outcome. For instance, if all the trees around a village are cut for timber (from which money is earned), there is the risk of a windstorm damaging houses that are no longer protected by the trees.

2.4.2 Agriculture: Agriculture is the science and practice of farming that includes the cultivation of soil for growing crops and the rearing of animals to provide food, shelter and other needs. Agriculture is among the things humans do to sustain life. This is because not only is food from agriculture, but also clothing, medicine, shelter, and so on.

2.4.3 Climate Change: The energy from the sun reaches the Earth as short-wave radiation, and it is the source of energy for both weather and climate. This energy heats up the surface of the land and water bodies (including the oceans, seas, lakes and rivers), and in turn heats the atmosphere as long-wave radiation. Although most of this energy is sent back into the atmosphere, some is trapped in the ground, oceans, seas, lakes, rivers and in the atmosphere. In the atmosphere, the main elements are nitrogen (N), oxygen (O), and argon (A), elements with no.

Effect on climate. However, other gases (which are mostly in small amounts; so-called greenhouse gases) such as water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) can form a blanket in the upper layer of the atmosphere and trap long-wave radiation reflected from the surface of the Earth to give rise to the greenhouse effect. The trapped radiation heats up the air and warms up the atmosphere further, resulting in a rise in temperature. The rise in temperature in turn causes changes in the patterns of weather and climate that, in the end, result in climate change.

2.4.4 Risk of Agriculture to Climate Change: Although man needs agriculture to produce food needed to support life, it has its own effect on climate. The atmosphere has many different Greenhouse Gases (GHG) in different amounts. Water vapor is the water that evaporates in the atmosphere from the oceans, seas, lakes and rivers, soil surfaces and plants; and mainly determines air humidity. Agriculture accounts for only a small part of the water vapor (especially as clouds) in the atmosphere. Carbon dioxide (CO_2) occurs in nature, and it can come from volcanic and geyser activities. Carbon dioxide can also come from human activities (such as engine combustion that uses fossil fuels such as coal, mineral oil, and gas). Animals and plants also give out carbon dioxide through respiration. Carbon dioxide can also occur in the atmosphere through organic matter decay, deforestation, burning, and industrial processes. Methane from livestock production and microbial activities in the soil and water also enters the atmosphere. Nitrous oxide (N_2O) is produced in farming by the use of organic and synthetic fertilizers, during industrial production, and also in burning fossil fuels. Fluorinated gases (CFCs) used in refrigerators, air-conditioners, foams, cosmetics, and fire extinguishers are also greenhouse gases.

Global warming potential (GWP) is the heat absorbed by any greenhouse gas in the atmosphere, as a multiple of the heat that would be absorbed by the same mass of carbon dioxide. GWP is 1 for carbon dioxide. For other gases, it depends on the gas and the

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time frame. Carbon dioxide equivalent (CO_2e or CO_2eq or CO_2-e) is calculated from GWP. It can be measured in weight or concentration. For any amount of any gas, it is the amount of carbon dioxide that would warm the Earth as much as that amount of that gas. Thus, it provides a common scale for measuring the effects of different gases on climate. It is calculated as GWP times the amount of the other gas. For example, if a gas has a GWP of 100, two tons of the gas have a carbon dioxide equivalent of 200 tons, and 1 part per million of the gas in the atmosphere has a carbon dioxide equivalent of 100 parts per million. In carbon equivalent, the GWP of methane is 25, nitrous oxide 298, and fluorinated gases 628 (https://en.wikipedia.org/wiki/Global_warming_potential).

However, although carbon dioxide is the least potent greenhouse gas, it cannot break down into other gases. Sunlight can break down methane to carbon dioxide in 12 years, nitrous oxide in 121 years, and fluorinated gases in thousands of years (IPCC, 2014). As most greenhouse gases are produced during agricultural activities, the risk of agriculture to climate change will increase with intensifying agricultural activities. This is even more true when, in the practice of agriculture, climate change mitigation measures are not taken into account.

2.4.5 Risk of Climate Change to Agriculture: Climate change can be a risk to agriculture in so many ways. For example, flooding due to climate change can damage crops. Drought can also kill crops, including cereal and grain crops. Both flooding and drought can also kill farm animals. Therefore, the most important risk of climate change to agriculture is the damage it can cause to farm crops and animals. This can be via floods, droughts, wildfires, storms (wind, rain, and dust), pests and diseases, etc. When crops are damaged, especially in the field, both the quantity and quality of harvest drop. Without food, life is not sustainable.

Water life (e.g., fish) is also affected by climate change. Global warming increases water temperature. This condition makes water weeds grow fast and use more oxygen in the water, leaving little for water animals to breathe. Sediment transport and deposition increase with more rain, which can also destroy fish breeding sites in water bodies.

In cold regions, climate change, such as global warming, makes it possible to grow some crops. However, in tropical regions, global warming releases more carbon dioxide into the atmosphere and makes crops grow fast, thereby changing the phenological cycle of crops.

Climate change can also affect the ecosystem through ocean acidification, a rise in sea surface temperature, and changes in upwellings. There will be a 21% decline in annual landed value of fish by 2050, resulting in nearly a 50% decline in fisheries-related jobs and a total annual loss of millions to the national economies (IPCC, 2014).

2.4.6 Climate Change and Agriculture in Sierra Leone: Sierra Leone has a predominantly hot and humid tropical climate with two distinct seasons, dry and wet. The dry season is from November to April and the wet season from May to October. More recently, the variations in the start time and duration of the seasons are widening. The average temperature range is 25–27 °C, with slightly lower temperatures (22–25 °C) in the wet season. The average annual temperature has increased by 0.8 °C since 1960, with a significant increase in the frequency of hot nights. The average annual temperature is projected to increase by 1.0-2.6 °C by the 2060s.

Although variable, average annual rainfall has dropped since 1960. Invariably, flooding has increased over the same period (SLNAPA, 2007). Regional studies suggest that although the number of extreme rainfall days is increasing, rainfall generally decreases from January to March and increases through the latter half of the year (McSweeney et al., 2010).

As an agrarian nation, the growing population means more people in agriculture for livelihood. The slash-and-burn bush fallow system that is the predominant agricultural practice releases huge volumes of greenhouse gases into the atmosphere. In terms of carbon dioxide equivalent ($MtCO_2e$), greenhouse gas emissions in Sierra Leone were 11.69 million metric tons in 2013. This is 51.3% of the total emissions in the country and 0.02% of the global carbon dioxide emissions. Some 51.3% of this was from agriculture through changes in land use and forestry (SLCAR, 2016). Agriculture was the second highest source of emissions (25.7%), with rice cultivation and livestock accounting for 58% of agricultural emissions.

These are some of the ways agriculture influences climate in Sierra Leone. Thus, Sierra Leone plans to maintain its emission levels in 2035 close to the world's average of 7.58 $MtCO_2e$. It is estimated that by 2050, the carbon footprint will balance out with green growth pathways in all its economic sectors.

Two primary food sources in Sierra Leone (rice and fish) are highly vulnerable to climate change. With all the rich soils, good rainfall and abundant water resources, Sierra Leone is still a net food importer. Only 12% of the arable land is cultivated, often using crude farming techniques. Rice, which accounts for the largest share of the gross domestic product (GDP) in the agriculture sector and 42% of average energy intake, is highly sensitive to humidity, rainfall and pests/diseases that thrive in high temperatures. Fish accounts for more than 75% of animal protein intake, and it is also vulnerable to rising water temperatures. Temperature alters food-chain dynamics and water quality in inland fish farms and the Oceans. These are all ways climate influences agriculture in Sierra Leone.

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2.5 Post-session Test

Table 2.2: Assessing knowledge learned by trainees on risk of climate change to agriculture.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)

No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	What is risk?			
2.	What is agriculture?			
3.	What are the causes of climate change?			
4.	How does agriculture affect climate change?			
5.	How does climate change affect agriculture?			
6.	Average			

Module Three

Climate-smart agriculture concept

3.1 Module Outline

Climate-smart agriculture; Concept of climate-smart agriculture; Options of climate-smart agriculture; Pillars of climate-smart agriculture; Practices of climate-smart agriculture; Gender in climate-smart agriculture.

3.2 Learning Objectives

To know the meaning and concept of climate-smart agriculture. To know the key pillars and need for climate-smart agriculture. To know the role of gender in climate-smart agriculture practices.

3.3 Pre-session Test

Table 3.1: Assessing knowledge base of trainees on the concept of climate-smart agriculture.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)

No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	What is climate-smart agriculture?			
2.	Why is climate-smart agriculture useful?			
3.	What are the pillars of climate-smart agriculture?			
4.	State gender roles in climate-smart agriculture.			
5.	Average			

3.4 Module Content

3.4.1 Climate-smart Agriculture: Climate-smart agriculture is the practice of agriculture that ensures sustainable production under changing climatic conditions (FAO, 2013). This is the form of agriculture that ensures more food production through adaptation to changing weather patterns and protection of the environment. It also ensures that the same opportunities exist for men and women, especially in agriculture. To address these challenges, food production systems should be more efficient and resilient to changes and shocks in climate. Climate-smart agriculture should make efficient use of natural resources and produce more with fewer resources such as land, water, energy, etc.

3.4.2 Climate-smart Agriculture Concept: The concept of climate-smart agriculture stands on the development of technical, policy, and investment conditions to support sustainable agricultural production and food security under changing climatic conditions (FAO, 2013). It is the integration of the economy, society, and the environment for sustainable development. By this means, it addresses both food security and climatic challenges. The goal is a sustainable increase in agricultural productivity and income, adaptation or resilience to climate change, and reduction or elimination of greenhouse gas emissions.

Because climate-smart agriculture is site-specific and evidence-based, it is a knowledge and dialogue-building process that uses technologies and practices in line with national and local needs. It is an agricultural practice that is based on local evidence. For effectiveness and sustainability, climate-smart interventions take into account social and cultural differences, but ensure equal benefits across gender and social status (Figure 3.1).

3.4.3 Climate-smart Agriculture Options: The drive behind the global call for climate-smart agriculture is to slow down, stop, and reverse climate change. Climate change has a lot of uncertainties not only in agriculture, but in every aspect of life. It starts with emissions of greenhouse gases (CO_2, CH_4, N_2O, F-gases, etc.) during human activities such as agriculture, especially the practice of slash-and-burn agriculture that slashes and burns vegetation. The release of greenhouse gases can trigger a temperature rise that, in turn, makes the air lighter. Lighter air takes up more water vapor (H_2O), causing more rain. Also, high temperatures cause drought.

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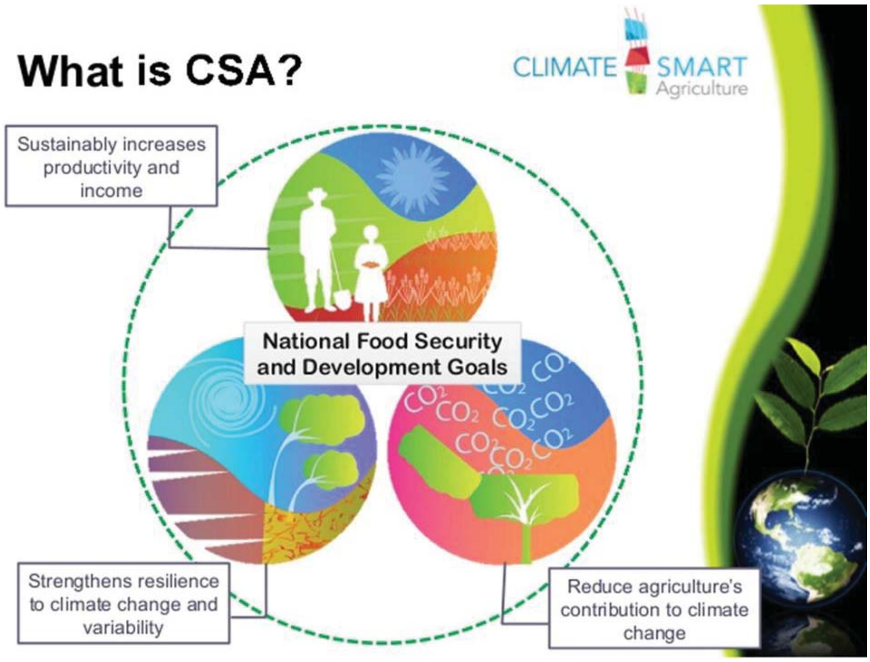

Figure 3.1: Infographic depiction of the concept of climate-smart agriculture.

Both floods and droughts can damage the soil and trigger the release of stored gases into the air, inducing climate change. Of course, poor soils, heavy rains, and severe droughts can lead to poor crop performance and food shortages. Climate-smart agriculture can restore the ecosystem to its natural state and thereby reduce or prevent the effects of climate change.

3.4.4 Climate-smart Agriculture Elements: The elements of climate-smart agriculture are adaptation, mitigation, reversal, and productivity. The aim is to build an agricultural system that ensures sufficient food production and healthy ecological systems.

Adaptation ensures that farmers are little or not at all exposed to the risks of climate change. This requires strengthening resilience by capacitating farmers to overcome climate-related shocks and stresses. The key element here is to protect and enhance ecosystem services for sustainable productivity.

Mitigation is the reduction in emissions of greenhouse gases to reduce the rate of climate change. This can be achieved by reforestation and effective soil and water management to take back greenhouse gases from the air.

Mitigation is not enough until it is done on such a scale that it not only stops but also reverses the trend of climate change. It is never wrong to reverse climatic conditions to pre-industrial conditions, and it is the hope that this state is reached despite the growing population and advancing industrialization.

Productivity focuses on sustainable increase in agricultural production and income without significant negative impact on the environment. A key productivity element is agricultural intensification, especially in a resource-limited world like ours.

3.4.5 Climate-smart Agriculture Practices: Climate-smart agriculture is farming in ways that drive greenhouse gases from the atmosphere into plants, soil, and water bodies. The factors that influence the adoption of climate-smart agriculture technologies, principles and practices include perceived threats to production; ease, cost and benefits of use of technologies; agriculture policy environment (e.g., land ownership policies); available incentives, experiences, etc.

Climate-smart agriculture forges synergies and trade-offs among adaptation, mitigation and productivity. Enforcing these trade-off synergies requires not only climate-smart agriculture practices, but also sufficiently innovative climate-smart technologies.

3.4.6 Gender in Climate-smart Agriculture: Gender is critical for equity and success of climate-smart agriculture. Gender analyses can respond to what, how, and why issues that are related to agricultural practices. The results of gender analyses can be used to integrate traditional with climate-smart agriculture practices. This can lay the basis for innovative climate-smart solutions that fit the local context.

Traditionally, gender gaps affect agricultural practices and productivity. In Sierra Leone, women have fewer privileges, entitlements, and endowments than men. More than men, women face more challenges in accessing, using, and controlling productive resources and services. These include access to land, water, credit, input, technology, information, knowledge, education,

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and services (World Bank, 2015; FAO, 2015; IFAD, 2015). Closing gender gaps is one step closer to solving agricultural production challenges. This can reduce the population of hungry people by 18%, from 820 million to 150 million (FAO, 2011). Thus, climate-smart agriculture includes approaches that address the needs of men and women with the view of promoting gender equity.

3.5 Post-session Test

Table 3.2: Assessing knowledge learned by trainees on the concept of climate-smart agriculture.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)				
No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	What is climate-smart agriculture?			
2.	Why is climate-smart agriculture needed?			
3.	What are the pillars of climate-smart agriculture?			
4.	State gender roles in climate-smart agriculture.			
5.	Average			

Module Four

Climate-smart agriculture policies

4.1 Module Outline

Definition of policy; Technology adoption; Policy levels and linkages; Agriculture promoting policies; Agriculture limiting policies.

4.2 Learning Objectives

To know what a policy and adoption. To know the linkages among different levels of policy. To know the policies that promote or limit climate-smart agriculture.

4.3 Pre-session Test

Table 4.1: Assessing knowledge base of trainees on policies on adoption of climate-smart agriculture.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)				
No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	What is policy?			
2.	Why is climate-smart agriculture needed?			
3.	What are the pillars of climate-smart agriculture?			
4.	State the roles in climate-smart agriculture.			
5.	Average			

4.4 Module Content

4.4.1 Policy Definition: Policies are set principles, rules, regulations, by-laws, and laws that guide behaviors in societies. Policies are passed at different points of interaction, ranging from personal to public or from local to global. Although generally not necessarily legally binding, policies can carry punishable actions when violated. Unlike other policies, laws ensure justice and generally have legal implications. Depending on the circumstance, policies are passed to either restrain or enhance behaviors or actions in societies.

4.4.2 Technology Adoption: Adoption is the decision to accept, integrate, and use something. Technology adoption is a phasic process. Based on users, technology can be put into five groups — innovators, early adopters, early majority, late majority, and laggards. Adoption is about buying in and committing to the use of a technology. Disruptions of daily routines by the introduction of new technologies can cause frustration and resistance. Thus, policies should create the enabling environment to reduce such frustrations and resistance (Figure 4.1).

4.4.3 Policy Levels and Linkages: Policies exist at different levels. For example, individual policies can be based on values and interests that guide behaviors in specific circumstances. Other policy levels include family, organizational, and governmental policies. While the reverse is possible, global policies generally drive and shape international policies, in turn driving and shaping national and then local policies. For developing countries generally, policy flow is from global to local.

A good example of policy levels and linkages is the Sustainable Development Goals (SDGs) of the United Nations. The roll-out of the SDG policy by the United Nations and the huge sum of money invested in it led national governments to realign their policies to the global SDG policy. Another example is the green revolution in the 1970s that brought huge funds to developing countries. This is similar to what exists today for climate-smart agriculture practices. Irrespective, however, there are instances where local policy conditions lead to the creation of more robust national policies.

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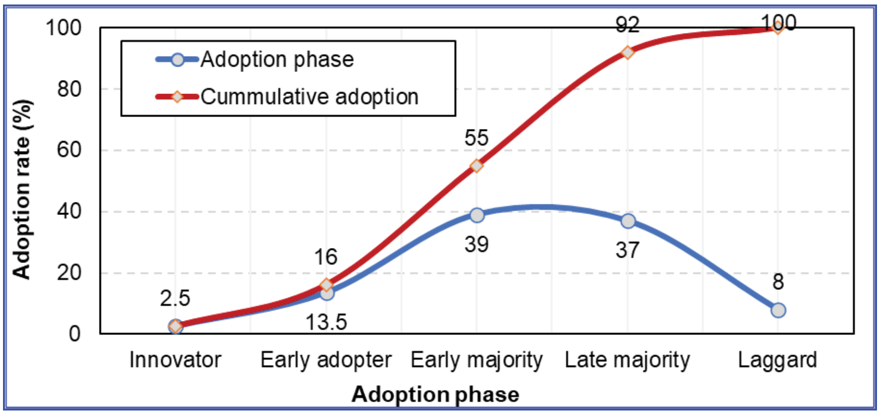

Figure 4.1: A plot showing the phases in the process of technology adoption (blue line) and cumulative adoption (brown line).

Major global policies with national and local effects include the 2030 Agenda for Sustainable Development and the related Sustainable Development Goals (SDGs) adopted in September 2015; the Paris Agreement on Climate Change in December 2015 and ratified in November 2016; the Sendai Framework for Disaster Risk Reduction (SFDRR) adopted at the Third World Conference on Disaster Risk Reduction in Japan in March 2015.

There are other international agreements with no explicit climate focus, but influence national and local climate policy objectives. Policies should capture synergies across adoption, mitigation, reversal and productivity in relation to climate change. Because of these interdependences, the 2030 Agenda recognizes that it is not possible to address the challenges associated with food security, rural livelihoods and sustainable management of natural resources in isolation. An integrated cross-sectoral approach is required, which will involve a range of activities, including greater integration in collecting and harmonizing data.

4.4.4 Policies Promoting Climate-smart Agriculture: Since 2000, Sierra Leone has passed three national strategies on climate change and adopted its first special program on climate change in 2009. In 2007, Sierra Leone published its National Adaptation Programme of Action (NAPA). In addition, Sierra Leone presented two national communications one greenhouse gas inventories, to the United Nations Framework Convention on Climate Change (UNFCCC).

The Sierra Leone Environmental Protection Agency (SLEPA) was also established in 2008 to lead environment and climate change policy implementation. The SLEPA committee has the mandate and potential to build institutional links between various agencies on cross-cutting climate change adaptation issues, including disaster management, agricultural development, and infrastructure design and planning. The government plans to strengthen the institutional and policy framework to enhance coordination and implementation of climate change adaptation and mitigation. Also, global and international policies attract huge capital investments in climate-smart agriculture activities. Most of these investments are implemented by non-governmental organizations such as AVDP, the agency behind the development of this training manual.

4.4.5 Policies Limiting Climate-smart Agriculture: Some of the factors that limit the adoption of climate-smart agriculture practices and the related policy measures are summarized in Table 4.2 below.

Table 4.2: A summary of policies that limit the adoption of climate-smart agriculture practices.

Barrier Type	Description	Suggested Policy Role
Farm Level		
Structural	None or unclear land tenure	Limited policy priority
	Poor infrastructure & matching markets	Area of investment
	Farm succession, age & structure	Not a policy priority
Economic	Perceived or real negative effects on production	Communicate & educate; Improve access to funding; Pay for environmental services.
	High cost of adoption	Some measures supported, but outcomes mixed
	Hidden & transaction costs	Make regulation simple
	Limited access to credit	Strengthen capacity of public or private finance.
Socio-cultural	Appropriateness of practices from socio-cultural standpoint	Communicate & participate
Behavioral & cognitive	Beliefs about climate change	Communicate & engage
	Perceived long-term horizon, uncertainty & risk management	Communicate & engage; Assure where possible (e.g., regulation)
	Competing pressures due to increased regulations	Not a policy priority
National Level		

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National level	Perceived negative effects on competitive position in international markets	Targeted policies & demonstration
	General level of information & education awareness	Certainty in policy regulatory
	Limited climate policy	Global governance
	Possible leakage	Include environmental & climate issues in national regulations.
	Pre-decided farm management for industry cooperation	International level inventory reform
	Sectoral report on greenhouse gas & administrative costs	Remove policy distortions
Policy related	Non-climate-related agricultural policies (e.g., subsidies for input, production & insurance)	Targeted engagement policies & demonstrations

4.5 Post-session Test

Table 4.3: Assessing knowledge learned by trainees on policies on adoption of climate-smart agriculture

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)				
No.	Question	Response (%)s		
		Right	Wrong	Class Rating
1.	What is policy?			
2.	Why is climate-smart agriculture needed?			
3.	What are the pillars of climate-smart agriculture?			
4.	State gender roles in climate-smart agriculture.			
5.	Average			

Module Five

Barriers to climate-smart agriculture

5.1 Module Outline

Policy barriers; Socio-cultural barriers; Technological barriers; Financial barriers; Infrastructural barriers.

5.2 Learning Objectives

To know how policy, culture, technology, finance, and infrastructure can be barriers to the adoption of climate-smart agriculture practices.

5.3 Pre-session Test

Table 5.1: Assessing knowledge base of trainees on barriers to climate-smart agriculture adoption.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)				
No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	What policy barriers do you know?			
2.	What socio-cultural barriers do you know?			
3.	What technological barriers do you know?			
4.	What financial barriers do you know?			
5.	What infrastructural barriers do you know?			
6.	Average			

5.4 Module Content

5.4.1 Policy Barriers: Policy is the regulating environment that defines what is or is not acceptable under a given condition. Until recently, climate change was a very contentious issue. This was the reason why some governments ranked climate change issues as a low-priority policy area. In many countries, economic growth is driven by industrialization at the expense of the environment. There is a lack of comprehensive or enforceable policies to ensure environmental protection. Also, very limited policies exist to reward farmers for practicing climate-smart agriculture. Even worse, there are no policies to punish farmers who continue with the old (environmentally unfriendly) ways of agriculture. Thus, incentives for practicing climate-smart agriculture largely remain limited to the efforts of NGOs.

Climate-smart agriculture is organic agriculture that is good not only for climate change, but also for human health. In this regard, it needs policies that encourage farmers to abandon old (climate-damaging) practices and adopt new (climate-resilient) agricultural practices.

5.4.2 Socio-cultural Barriers: Culture is the totality of the value systems of a society, including social behaviors and norms evident in the knowledge, beliefs, arts, laws, customs, capabilities and habits of the people. In some societies, women and men

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take different roles. Some practices (including positions held, work done, meetings attended, crops cultivated, etc.) are implicitly associated with gender. This can cause unequal gender growth in society.

In most societies, local leaders command a great deal of influence. Thus, enlisting the support of such leaders is critical for the success of climate-smart agriculture technologies. A communal land tenure system is not sufficient incentive for the huge investment required by some technologies for climate-smart agriculture. There are also cultural norms (gender or otherwise) that work against the use of some technologies. Furthermore, switching from age-old activities to new ones is challenging, except if the benefits can be readily felt.

5.4.3 Technological Barriers: Technology can be a barrier to climate-smart agriculture in so many different ways. It can be that a required technology does not exist, or it exists but is expensive, complex, labor-intensive, time-consuming, and/or inappropriate. It can even be that the technology is socio-culturally unacceptable. This is more the reason why no climate-smart agriculture practice is considered a "one-solution-fits-all". It is a practice that is heavily based on the local context.

5.4.4 Financial Barriers: The roll-out of a technology has financial implications, large or small. More often than not, poor farmers expect incentives (also a cost implication) to drive the adoption of new agricultural technologies. This is true even if the new practice is solely for the good of the farmers. The only exception is when it is perceived that the failure to change (adopt) is a survival threat. Even when a solution is developed (of course with financial implications), putting together resources (human and/or logistics) to deliver the solution always requires financial cost. Finance is so very critical to the success of technology adoption (as climate-smart agriculture) that it cuts across the entire phases of innovation — from conceiving the concept to developing, transferring and adopting it.

5.4.5 Infrastructural Barriers: The delivery systems are part of the infrastructure for the development, transfer and adoption of technology. Institutional infrastructure (for production or implementation of technology) can pose challenges to successful adoption of climate-smart agriculture. This can be road and communication networks or banking systems for transfer of services. Storage and marketing infrastructures are also key for successful adoption of climate-smart agriculture practices.

5.6 Post-session Test

Table 5.2: Assessing knowledge learned by trainees on barriers to climate-smart-agriculture adoption.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)

No.	Question	Response (%)		
		% Right	% Wrong	Class Rating
1.	What policy barriers do you know?			
2.	What cultural barriers do you know?			
3.	What technological barriers do you know?			
4.	What financial barriers do you know?			
5.	What in Do you know any infrastructural barriers?			
6.	Average			

Module Six

Climate-smart agriculture financing

6.1 Module Outline

Domestic financing; Foreign financing; Financial delivery.

6.2 Learning Objectives

To know what domestic and foreign financial opportunities and financial aid delivery bodies exist.

6.3 Pre-session Test

Table 6.1: Assessing knowledge base of trainees on financing climate-smart agriculture.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)

No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	Which finance delivery bodies do you know?			
2.	State some domestic financial opportunities.			
3.	State some foreign financial opportunities.			
4.	Average			

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6.4 Module Content

6.4.1 Domestic Financing: Finance is the backbone of innovation; then innovation is the engine of development; and yet development is the striving of civilization. Without finance, no innovation (technology) can move beyond the conceptual phase. Financial opportunities for climate-smart agriculture can be put into two broad groups: domestic and foreign.

Domestic financial opportunities can come from the private sector (local individuals and businesses), national governments (local and federal), and non-governmental organizations run on domestic funds. Among these are financial opportunities in the form of grants, aids, credits, etc. This can come with or without pre-conditions.

6.4.2 Foreign Financing: This includes finance for the promotion of climate-smart agriculture that is from outside countries. Also, this financial opportunity can be the private sector (outside individuals and businesses), outside governments (local and federal), non-governmental organizations with outside funding, international organizations and bodies.

There is sometimes overlap in some of these areas, but the bottom line is that the financing is from an outside source. Like domestic financial opportunities, foreign financial opportunities can come in the form of grants, aids, credits, etc., with or without pre-conditions.

6.4.3 Finance Delivery: The focus of distinction between domestic and foreign financial opportunities is on the sources of funding. The finance delivery body is the conduit through which funds pass to reach beneficiaries. These can be farmers engaged in climate-smart agriculture. In some instances, the funders (private sector, businesses, organizations, and governments) use their own internal structures to deliver funds directly to farmers.

Most cases, however, funds (domestic and foreign) are passed (aids, grants, and loans) through formal organizations (e.g., aid organizations — local or international) for delivery to beneficiaries. These are the finance delivery bodies in the support chain in climate-smart agriculture.

6.5 Post-session Test

Table 6.2: Assessing knowledge learned by trainees on financing of climate-smart agriculture.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)

No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	What financial aid delivery bodies do you know?			
2.	State some domestic financial opportunities.			
3.	State some international financial opportunities.			
4.	Average			

Module Seven

Soil and water management

7.1 Module Outline

Soil management principles; Water management principles; Soil/water management technologies; Enhanced soil health and ecosystem functions.

7.2 Learning Objectives

To understand soil and water management practices. To know soil and water management principles and technologies. To understand soil health and ecosystem functions.

7.3 Pre-session Test

Table 7.1: Assessing knowledge base of trainees on soil/water management principles and practices.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)

No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	What is soil management?			
2.	What are the principles of soil management?			
3.	What is water management?			
4.	What are the principles of water management?			
5.	State some soil & water management technologies.			
6.	What is soil health enhancement?			
7.	State some ecosystem functions.			
8.	Average			

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7.4 Module Content

7.4.1 Soil Management Principles: Soil is a medium where plants grow. It is that part of the earth's surface that supports plant growth. Soil management is the things done to either maintain or improve its performance. It includes soil conservation, soil amendment, and soil health. Soil management is key to the success of farming. It is about adjusting tillage and inputs to the specific needs of crops in relation to existing soil conditions.

Soil management aims to maintain soil in a fertile and productive state. The basic principle of soil management is to ensure that crops firmly establish in the soil and have adequate nutrients (including water) throughout the period of growth. The emerging paradigm of soil management principles is to prevent damage to the soil and the ecosystem. This is critical because food is the support of life and it is grown in the soil.

Although soil-specific, soil management can make production sustainable on agricultural lands. In particular, climate-smart agriculture emphasizes optimal soil management driven largely by organic farming. Although soil fertility is the basis for healthy soil, soil management practices such as fertilizer use, irrigation, and tillage can release greenhouse gases such as nitrous oxide (N_2O) into the air. Livestock production and composting can also release large amounts of methane (NH_4) into the air. Inorganic fertilizers release greenhouse gases, but also cause imbalance in soil nutrients. Both nitrous oxide and methane can break down into carbon dioxide (CO_2), a greenhouse gas that lasts far longer in the air.

It is therefore important that soil management practices are screened to retain only those with the potential to reduce greenhouse gas emissions. Carbon dioxide is taken from the air through plant photosynthesis and stored in the soil as organic or inorganic carbon. Biochar can retain 54% of nitrous oxide in the soil. Organic farming practices such as no-tillage, mulching, cover cropping and crop rotation enhance soil carbon sequestration. Putting arable lands under grass, crop residues, and cover crops also enhances carbon sequestration. It is critical that in developing climate-smart agricultural practices, the issues of climate change are fully addressed (Figure 7.1).

Figure 7.1: Plots showing different soil colors and cover due to different soil management practices.

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7.4.2 Water Management Principles: Water is a natural liquid that falls from the sky as rain, runs on the surface of the earth as rivers, enters and is stored in the soil as groundwater, and returns into the sky as vapor. It is the most basic of life after air and also a key requirement for agricultural production. Water is renewable, but its amount in nature is fixed and must therefore be managed to avoid depletion. The basic principle of water management is to ensure availability at the time of need, in the quantity needed and of the quality needed. This optimizes agricultural production. The length of time water stays in the soil depends on several factors, including soil type, land form, vegetation cover, climatic conditions and land use. Also, with good soil management practices such as minimal tillage, mulching, plowing straw into the soil, water can stay long enough in the soil to support crop growth (Figure 7.2).

Figure 7.2: A plate showing water management for irrigation as diversion through canal.

7.4.3 Soil-Water Management Technologies: The soil and water management technologies of high relevance to climate-smart agriculture practices include zero burning, zero/minimal vegetation clearing, zero/minimal tillage, water harvesting (rainwater, surface water and groundwater) for irrigation of various types, use of organic manure, integrated farming for nutrient recycling, crop residue recycling as in mulching and straw plow-in. In all these technologies, sustainability is key and can be achieved through efficient use of both soil and water.

7.4.4 Soil Health and Ecosystem Functions: Soil health is the level to which the soil can support the functions of the ecosystem on a sustainable basis. The health of a soil is a function of the interactions of its constituent parts, including biotic and abiotic components of the soil. Soil health depends on soil biodiversity (or robust soil biota) that is improved through soil management, especially by maintaining vegetative cover on the soil and natural (carbon-containing) soil amendment methods. Even inorganic fertilizers, if appropriately used (time and dose), can improve plant growth and sequester more carbon-based residues into the soil.

Thus, soil health is used to describe the state of the soil in terms of: 1) sustaining plant and animal productivity — agronomic focus; 2) enhancing biodiversity — soil biodiversity that is ecological focus; 3) enhancing water and air quality that is climatic focus; and 4) supporting human health and habitation that is sustainability focus (Figure 7.3).

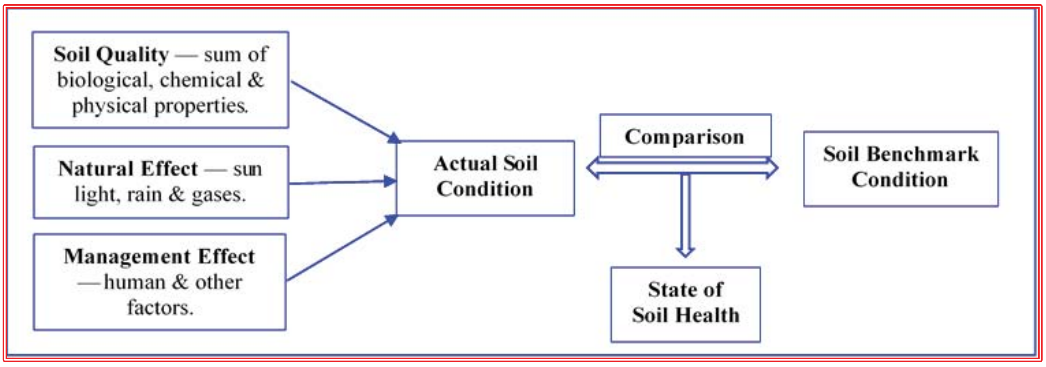

Figure 7.3: A flowchart of carbon storage in the soil to reduce, stop or reverse climate change.

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7.5 Post-session Test

Table 7.2: Assessing knowledge learned by trainees on the principles of soil and water management.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)				
No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	What is soil management?			
2.	What are the principles of soil management?			
3.	What is water management?			
4.	What are the principles of water management?			
5.	State some soil & water management technologies.			
6.	What is soil health enhancement?			
7.	State some ecosystem functions.			
8.	Average			

Module Eight

Ecosystem and community resilience

8.1 Module Outline

Ecosystem; Community resilience; Climate-smart agriculture and ecosystem building; Ecosystem building and community resilience; Synergies across climate-smart agriculture, ecosystem building and climate change.

8.2 Learning Objectives

To know the meaning of ecosystem and community resilience. To know how climate-smart agriculture leads to ecosystem building. To know how ecosystem building leads to community resilience. To know the synergies across climate-smart agriculture, ecosystem building and climate change.

8.3 Pre-session Test

Table 8.1: Assessing knowledge base of trainees on ecosystem building and community resilience.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)				
No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	What is an ecosystem?			
2.	What is community resilience?			
3.	How does CSA lead ecosystem building (ESB)?			
4.	How does ESB lead community resilience?			
5.	What is the relationship between CSA, ESB & climate change?			
6.	Average			

8.4 Module Content

8.4.1 Ecosystem Resilience: An ecosystem is the space where living things interact, especially along the nutrient cycle and energy flow. Energy enters the system from the sun and is harnessed by plants through photosynthesis. Through the food chain (where plants feed on soil nutrients and animals in turn feed on plants), matter and energy are moved through the system. The amount of energy that passes through the system influences the quantity of plant and microbial biomass in the system. Decomposers break down dead organic matter and release carbon into the air and nutrients into the soil. The ecosystem is influenced by external (such as climate and parent material, which form the soil, and topography) and internal (such as decomposition, root competition, shading, disturbance, succession, and species type) factors.

In Sierra Leone, there are generally the lowland and highland ecosystems. The lowland ecosystem is further subdivided into inland lowlands (such as bolilands and inland valley swamps) and coastal lowlands (such as estuaries of mangrove swamps). The highland ecosystem includes the undulating and mountainous lands. Almost all of these ecosystems have agricultural value in terms of providing support to crops. Humans disturb the ecosystem through agriculture. The time it takes for the ecosystem to recover from a disturbance depends on the farming system and agronomic practices used. It is therefore important that climate-smart agricultural practices ensure the fastest recovery with the least effect on climate change.

8.4.2 Community Resilience: With increasing intensity of droughts, floods, storms and even heat/cold waves, climate change is having a disaster on our known modes of life. Community resilience is the capacity of a community exposed to hazards to resist or change the usual ways of doing things so that it can continue to function.

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Ecosystems offer different services, including regulating services (e.g., climate and disease regulation, pollination), cultural services (e.g., spiritual, recreational and aesthetic value, inspiration), support services (e.g., food, freshwater, fuel wood, iochemical, soil formation, nutrient cycling, primary production). Under climate-smart agriculture, the goal is to stand by communities to find new climate-smart ways of doing agriculture. It could be using more resilient crop varieties, intensifying soil and water management in our farmlands, etc.

There is a need for environmental literacy in order to understand threats and implement solutions that build community resilience to extreme weather conditions, climate change, and other environmental hazards. Environmental literacy includes knowledge, skills, and confidence to: 1) reason through the ways humans and nature interact locally and globally, including knowledge of the disproportionate distribution of vulnerabilities; 2) participate in civic processes; and 3) incorporate scientific knowledge and cultural values into anticipated hazards and prepare response and recovery measures, including mitigating and adapting to climate change.

8.4.3 Climate-smart Ecosystem Building: Climate change has increased the risk of the ecosystem (including communities) falling victim to disasters. What climate-smart agriculture does is replace old agricultural practices with new ones that have the potential to build the ecosystem and not only undo but also outdo the effects of climate change. With climate-smart agriculture practices, the recovery time of degraded ecosystems is shortened, or the degradation rate is slowed down. By so doing, climate-smart agriculture can support ecosystem building. Climate-smart agriculture practices are the adaptation measures that help communities maintain or increase production levels and reduce or reverse the trend in climate change.

8.4.4 Climate-smart Community BuildingL: Climate-smart Agriculture supports ecosystem building in much the same way as it supports community resilience. The success of rural agriculture depends on the state of the ecosystem. With healthy ecosystems, communities can produce enough for sustenance. There is a ripple-effect connection across climate-smart agriculture, ecosystem building, and community resilience.

It is important to note that production activities cause climate change, not so understood until recently. As a trending solution to climate change, climate-smart agriculture can only be achieved through ecosystem building. Since communities are the drivers of climate change, the solution tool should come from the communities. The successful application of all such solution measures is called community resilience. This suggests that resilient communities are those which successfully apply climate-smart agriculture practices in ecosystem building as a way of reducing or driving back climate change.

8.5 Post-session Test

Table 8.2: Assessing knowledge learned by trainees on building ecosystem and community resilience.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)				
No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	What is an ecosystem?			
2.	What is community resilience?			
3.	How does CSA lead ecosystem building (ESB)?			
4.	How does ESB lead community resilience?			
5.	What is the relationship between CSA, ESB & climate change?			
6.	Average			

Module Nine

Agro-farming Systems

9.1 Module Outline

Agro-farming system; Hunting and gathering; Shifting cultivation; Bush-fallow system; Pastural/livestock farming; Conservation farming.

9.2 Learning Objectives

To know the chain of change in agro-farming systems. To know the principles of conservation agriculture.

9.3 Pre-session Test

Table 9.1: Assessing knowledge base of trainees on agro-farming systems.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)				
No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	What is an agro-farming system?			
2.	Give examples of agro-farming systems.			

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3.	What is conservation agriculture?			
4.	Gives examples of conservation agriculture.			
5.	List reasons for shifts in agro-farming systems.			
6.	Average			

9.4 Module Content

9.4.1 Agro-farming Systems: Agro-farming systems are the many different ways farming is practiced now and before in response to prevailing conditions (such as changes in ecological, climatic, social, cultural and economic conditions), including changing human needs. Agro-farming systems can be classified based on tools used (traditional or modern), settlement mode (nomadic and sedentary), farming purpose (subsistence and commercial farming), farming mode (mono-farming and mixed farming) or even farming type (livestock and crop farming).

9.4.2 Hunting and Gathering: Hunting-gathering or foraging is one of the oldest traditional forms of subsistence agriculture that involves hunting of wild animals and gathering of wild foods. It is also largely a nomadic form of agriculture where people roam from place to place on a daily basis in search of animals and fruits. Until 12,000 to 11,000 years ago, when agriculture and animal domestication started in Southwest Asia and in Mesoamerica, hunting and gathering was the main mode of agriculture.

9.4.3 Shifting Cultivation: Shifting cultivation is a traditional subsistence farming system where a piece of land is cultivated and then left to fallow to allow vegetation regrowth. The period for which the land is cultivated depends on when the soil shows signs of exhaustion, e.g., when the field is overrun by weeds. In typical land-sufficient communities, farmers do not return to the same land after cultivation.

9.4.4 Bush Fallow System: The bush-fallow system is a traditional subsistence farming system similar to shifting cultivation but where farmers return to cultivated land after the soil fertility shows signs of adequate recovery. During the fallow period, farmers cultivate other parcels of land. This is possible in societies where land is not very sufficient.

9.4.5 Pastoral Farming: Pastoral farming or livestock farming is the rearing of animals. Pastoral farming can be sedentary, where herders stay at one settlement and move animals from one location to another. There is also nomadic pastoral farming where herders move together with the animals from place to place.

9.4.6 Conservation Farming: Conservation farming is a form of farming that promotes minimum soil disturbance, permanent soil cover and diversified cropping. It enhances biodiversity and natural bioprocesses and thereby increases water and nutrient efficiency and production sustainability. Conservation farming can be in the form of agroforestry, alley farming, mixed-cropping, mixed-farming, mono-cropping, animal rearing, rotation cropping or even climate-smart agriculture.

9.5 Post-session Test

Table 9.2: Assessing knowledge learned by trainees on agro-farming systems.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)

No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	What is an agro-farming system?			
2.	Give examples of agro-farming systems.			
3.	What is conservation agriculture?			
4.	Give examples of conservation agriculture.			
5.	List reasons for shifts in agro-farming system.			
6.	Average			

Module Ten

Effects of agrochemicals on environment

10.1 Module Outline

Agrochemicals; Uses of agrochemicals; Effects of agrochemicals.

10.2 Learning Objectives

To know the meaning and types of agrochemicals. To know the uses and effects of agrochemicals on crops, humans and the environment.

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10.3 Pre-session Test

Table 10.1: Assessing knowledge base of trainees on effects of agrochemicals on environment.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)				
No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	What is agrochemical?			
2.	State the types of agrochemicals.			
3.	List the uses of agrochemicals.			
4.	State the environmental effects of agrochemicals.			
5.	Average			

10.4 Module Content

10.4.1 Agrochemicals: An agrochemical is a product which enhances crop and animal production. Agrochemicals can be chemical or biological products that either kill or enhance the growth of plants and animals, improve soil fertility, or are concentrated stores of plant and animal manure. Pesticides, herbicides, synthetic fertilizers, hormones, and soil conditioners all belong to agrochemicals. Agro-chemicals of inorganic sources are called synthetic chemicals, and those of organic sources are called bio-chemicals. While biochemicals are preferred over synthetic chemicals in agriculture, the efficient use of any can enhance farm productivity.

10.4.2 Uses of Agrochemicals: There are approved procedures for the importation, manufacture, distribution, sales and uses of agro-chemicals in all countries. As the name implies, agro-chemicals are used mainly in agriculture to deal with issues of pests and diseases in both farm animals and crops. Examples of agro-chemicals include pesticides, herbicides, insecticides, fertilizers, etc.

The choice of agro-chemicals can depend on availability, cost, efficacy, etc. The misuse of agro-chemicals in farmlands can occur by: i) absence of clear instructions; ii) illiteracy of farmers; iii) knowledge gap on risks of bad uses; iv) improper doses, etc. The supply routes of agro-chemicals can be formal or informal, including: i) authorized retail outlets; ii) government extension services; iii) small-scale informal vendors; and iv) bulk suppliers.

10.4.3 Effects of Agrochemicals: The real-life effects of the use of agro-chemicals can vary (positive or negative), but the intended effect is to enhance production and food security. Sometimes, even when used within prescribed limits, the unintended effects can have far-reaching consequences. There are risks of such negative effects of the use of agro-chemicals as air, soil, and water pollution. Some component ingredients of agro-chemicals are found in ozone layer destruction; some may distort the natural food chain in the ecosystem and thereby destroy biodiversity. Against these odds, however, the proper use of agro-chemicals has proven crucial in driving high productivity and long shelf-life of agricultural produce.

10.5 Post-session Test

Table 10.2: Assessing knowledge learned by trainees on effects of agro-chemicals on the environment.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)				
No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	What is an agro-chemical?			
2.	State the types of agro-chemicals.			
3.	What are the uses of agro-chemicals?			
4.	State the environmental effects of agro-chemicals.			
5.	Average			

Module Eleven

Nursery management

11.1 Module Outline

Seed and seedling management; Soil and water management; Pest, disease and weed management; Shade and fertilizer management.

11.2 Learning Objectives

To know how to manage a nursery in terms of seeds, seedlings, pests, diseases, weeds, fertilizers, shade, soil and water.

11.3 Pre-session Test

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Table 11.1: Assessing knowledge base of trainees on nursery management.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)				
No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	How do you manage seeds/seedlings in the nursery?			
2.	How do you manage soil/water in the nursery?			
3.	How do you manage pest/disease/weed in the nursery?			
4.	How do you manage shade/fertilizers in the nursery?			
5.	Average			

11.4 Module Content

11.4.1 What is a Nursery: A nursery is the place where plants are propagated and maintained for the period required for field planting. It is a place where plant materials like seedlings, saplings of trees, shrubs, and plants are grown, developed, and maintained before permanent placement or use as stock plants for a propagation program. Most crops are raised in nurseries before transplanting in the field. The nursery ensures better germination and establishment because efficient time, land, and labor management makes maintenance of nursery crops easy. The establishment of a nursery requires knowledge of propagation methods and resources such as land, propagation structures, and growing media. Nursery sites are generally flat with no waterlogging. Too much water can make seeds/seedlings rot, and erosion can also wash away seeds/seedlings on lands with high slopes.

11.4.2 Seed and Seedling Management: A seed is the reduced form of a plant that has all that is needed to grow into a full plant under favorable conditions. Seeds can wake up and burst into seedlings under required soil moisture and temperature conditions. As there are as many different seeds as there are different plants, so do each seed type's requirements for germination differ. However, all seeds require temperature, moisture, air, and light to sprout, although in different degrees. Thus, before putting any seed into the nursery, it is important to know its requirements regarding the general conditions. Some seeds are pre-germinated before being put into nursery beds.

Dry seeds in contact with moist soils or growing media take up water via the seed coat. The seeds expand, and the seed coats crack open. Then the embryos in seeds have small shoots and roots that emerge into seedlings, starting with roots and then shoots. Roots fix seedlings into the ground and absorb water and nutrients to support shoot growth.

In summary, the recommended processes for a healthy nursery.

Good seed selection: Seeds that are fully developed, clean of any disease or pest attack, and of high quality.

Provision of right environment: Seeds need correct temperature, moisture, air and light conditions to germinate.

Conducting germination test: Seeds not stored under appropriate conditions may fail to germinate. Thus, germination tests are needed to show whether or not seeds are viable. Seeds may be rejected for nursing if the germination rate is less than 85%.

Uniform germination: It is good that all seeds germinate nearly at the same time and grow at the same rate. This makes seedlings easy to manage and grow into good crops. One way of ensuring rapid uniform germination is by use of germination mats. Good ventilation during germination and early seedling growth can prevent disease conditions in the nursery. Fine-textured seedbed soils provide good growing conditions.

Seedling development: Seedlings need ample light to grow. If light levels are low or seedlings are too crowded, stems stretch for more light, resulting in weak, leggy transplants.

Seedling maturation and hardening off: The length of time seedlings grow before transplanting varies by crop. All transplants should be hardened off before being sent in the field to prevent damage by harsher conditions. In hardening off, gradually expose seedlings to expected conditions in the field. Plants hardened off are better able to tolerate transplanting conditions and grow in the field uninterrupted (Figure 11.1).

Figure 11.1: Plots showing examples of seeds and a sprouting seedling in nursery.

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11.4.3 Soil and Water Management: Growing media are where seeds and cuttings are nursed, with soil and substrate as the two main types. Substrate can be sand, leaf mold, sphagnum moss, vermiculite, sawdust, water, perlite, compost, soil mixture, cocopeat, rockwool, polystyrene foam, rice hulls, calcined clays, bagasse peat, coir pith, wood fibers and bark. Soil is by far the most commonly used growing medium in nurseries. In most nurseries, it is only for seeds with delicate nursery conditions that substrates are used.

Finally, nursery media should be prepared and preserved in ways that allow raising and harvesting healthy field stock. Nursery conditions should be correctly managed so that seeds, seedlings and cuttings can do well and support good stock production. For healthy plant growth in nurseries, growing media should ensure: i) optimum rooting environment; ii) sufficient storage of air; iii) sufficient water absorption and retention; and iv) sufficient supply of nutrients. Proper soil and water conservation measures can ensure the availability of these growth elements in sufficient quantity.

The characteristics of a good nursery medium therefore include: i) loose, friable texture that crumbles well; ii) no clods and underlying hardpans below plow depth; iii) rich in slow-release nutrients and high cation exchange capacity; iv) always moist; v) supports beneficial fungi, bacteria, and earthworms.

Water seed beds to Field capacity, especially in the first three days before and after germination. This ensures adequate moisture in the soil for the seeds and seedlings to grow. Fertilizer application is a soil management issue and is done to seedlings to boost growth. However, water and fertilizer must be applied in required amounts to prevent destroying seeds and seedlings in the nursery.

Soil conservation measures should be simple to reduce the dire environmental impacts. Some soil conservation measures include: agricultural soil conservation; low-to-zero tillage farming; contour plowing; contour planting; organic gardening/farming; terrace farming; rain garden cultivation; hard surface reduction; resource planning; vegetation cover cultivation; forest restoration; waste management/disposal; wetland restoration; maintaining trees/vegetation along waterways; etc (Figure 11.2).

Figure 11.2: Plots of typical seed/seedling growing media and water management in nurseries.

11.4.4 Pest, Disease and Weed Management: In native plant nurseries, a disease can be caused by biological stress called a pest or environmental stress. Nurseries have many potential pests, including fungi, insects, nematodes, snails and even larger animals such as mice. Other plant species such as weeds and cryptogams (moss, algae, or liverworts) can become pests when in competition with crop plants for growing space and light. Plant diseases can also be caused by abiotic (environmental) stress, including heat and chemicals. Sometimes, people are pests when they apply too much fertilizers that cause chemical injury known as fertilizer burn. Pests and diseases often affect healthy gardens. It is important to regularly check plants for spreading diseases or signs of pest damage.

A useful concept to explain nursery pest challenges is the “disease triangle,” which illustrates the interrelationships among pest, host, and environment (Figure 11.3). The wrong conditions of all three factors can cause biotic diseases. For example, a fungus or insect can survive inside a warm environment of a greenhouse and attack a host plant. Although diseases may appear to involve only host plants and biological pests, environmental factors are always involved. Environmental stress may weaken plants and predispose them to pest attack, or a particular environment may favor pest populations and increase harmful levels. Abiotic diseases can be

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visualized as two-way relationships between host plants and adverse environmental stresses. Abiotic diseases may develop suddenly as a result of injurious climatic incidents such as a freeze or more gradually as difficult-to-detect growth loss due to low optimum environmental factors such as mineral nutrient deficiency (Figure 11.3).

Pest management starts with keeping nurseries very clean and early detection of any pest damage. Once this is done, the pests concerned can be identified, and control measures sought. In much the same way, disease management can start with keeping nurseries clean and early detection and identification of any disease damage to crops. Also, making sure that crops are in optimal growth conditions can prevent both pest and disease attacks (Figure 11.4).

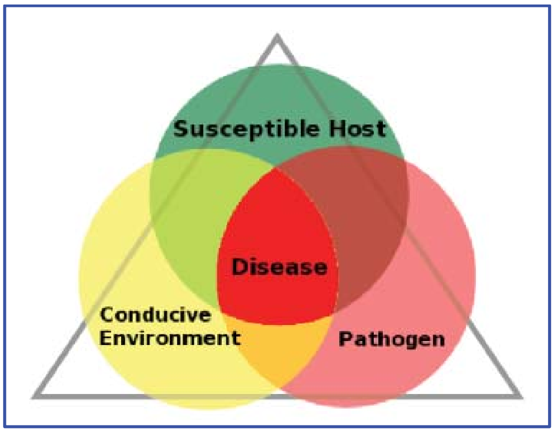

Figure 11.3: A plate showing the disease triangle for horticultural nurseries.

Figure 11.4: A plate showing some typical pests and disease control measures in nurseries.

11.4.5 Shade and Fertilizer Management: Sunlight is vital as a source of heat for the germination of seeds and the growth of seedlings in nurseries; too much of it in the tender state can damage nursery crops. It is therefore important to keep minimum shade in nurseries as required by different seeds and seedlings. Fertilizers are growth boosters and are added to the soil only for nutrients that are not in adequate supply. While fertilizers can be applied in solid or liquid state, it is advisable that the liquid state is used in nurseries to prevent damage to nursery crops.

11.5 Post-session Test

Table 11.2: Assessing knowledge learned by trainees on nursery management.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)				
No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	How do you manage seeds/seedlings in the nursery?			

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2.	How do you manage soil/water in the nursery?			
3.	How do you manage pest/disease/weed in the nursery?			
4.	How do you manage shade/fertilizers in the nursery?			
5.	Average			

Module Twelve

Carbon and nitrogen management

12.1 Module Outline

Carbon cycle infographic; Nitrogen cycle infographic; Soil carbon and nitrogen management.

12.2 Learning Objectives

To know the flow of carbon in soil, crops/animals, and atmosphere. To know the flow of nitrogen in soil, crops/animals, and atmosphere. To know the carbon and nitrogen management in soil.

12.3 Pre-session Test

Table 12.1: Assessinwg knowledge base of trainees on carbon and nitrogen management.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)

No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	Explain the carbon cycle.			
2.	Explain the nitrogen cycle.			
3.	Explain soil carbon and nitrogen management.			
4.	Average			

12.4 Module Content

12.4.1 Carbon Cycle: Carbon (C) exists in two forms in the soil — organic and inorganic. Organic carbon can be obtained from decaying plant matter, soil organisms and microbes and can be increased through soil management practices. Inorganic carbon is mineral-based and is relatively stable. Except for liming, inorganic carbon is not strongly influenced by land management practices.

Atmospheric concentrations of carbon dioxide (CO_2) can be lowered either by reducing emissions or by taking CO_2 out of the atmosphere and storing it in the soil, ocean, or freshwater ecosystems (carbon sink). Agriculture, by converting forestlands to croplands, causes loss of soil carbon. There is also the potential to increase soil carbon through restoration of degraded soils and soil conservation practices.

The focus here is the effect of agriculture on climate change, the effect of climate change on agriculture, and then the role agriculture can play in mitigating climate change. Agriculture is an important source of greenhouse gases (GHGs). However, improved agricultural practices can help mitigate climate change by reducing emissions from agriculture and other sources and by storing carbon in plant biomass and soil. What is needed is the identification, development, and promotion of those practices that reduce agricultural emissions and harness carbon and, at the same time, help to improve the livelihoods of farmers, especially in developing countries.

Such practices must reverse land degradation due to deforestation and inadequate land management by promoting improved land use and management practices. These are win-win practices in terms of economic gains and environmental benefits, including biodiversity, soil/water conservation, environmental management, and carbon harnessing. There are also the benefits of quality crops and the environment, controlled erosion and desertification, and enhanced biodiversity (Figure 12.1).

12.4.2 Nitrogen Cycle: Although nitrogen (N) is the most abundant element in the atmosphere, it is also the most crop-limiting nutrient. Nitrogen moves through the soil in various processes and in various forms. Conversion is needed from N into forms that plants can use. Some processes such as leaching or volatilization can lead to N loss. Nitrogen is added to the soil naturally from N fixation by soil bacteria and legumes and by atmospheric deposition through rainfall. Additional N is typically supplied to crops by fertilizers, manure, or other organic materials. Soil nitrate-N is an excellent indicator of N flow in the soil, whether carryover nitrogen is used by previous crops or additional nitrogen is needed.

Apart from nitrogen (N2) gas in soil pore spaces, N is found in both organic and inorganic forms in the soil. Organic forms occur in soil organic matter, which has three primary parts — including small (fresh) plant residues and small living soil organisms; decomposing (active) organic matter; and stable organic matter. Predominantly, inorganic forms of N in soils occur as ammonium (NH4) and nitrate (NO3), which are both usable by plants. The N cycle (Figure 2) illustrates the reactions that various inorganic and organic N compounds undergo in the soil. The N cycle typically begins with nitrogen in its simplest stable form, dinitrogen

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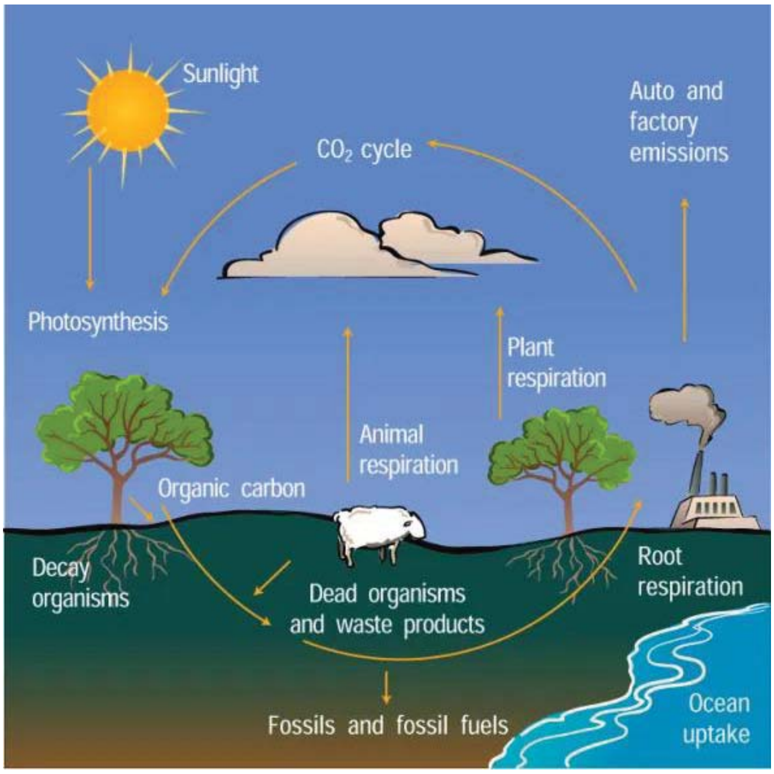

Figure 12.1: A carbon cycle infographic showing the flow of carbon across various media.

(N2) in air, followed by the processes of fixation, mineralization, nitrification, leaching, plant assimilation, ammonia volatilization, denitrification, and immobilization (Figure 12.2).

12.4.3 Soil Carbon-Nitrogen Management: Good carbon and nitrogen management practices not only ensure good crop productivity and soil sustainability, but also reduce greenhouse gas emissions and environmental pollution. The challenge, however, is joint optimal management of these elements. Soil carbon is enhanced by manure application. However, this can cause excess phosphorus input, and poor application time can also lead to nitrate leaching. Also, no-till soil management increases soil carbon at the soil surface and reduces carbon in subsoils. Surface applications can further lead to phosphorus stratification and increased risk of loss of soluble P through runoff.

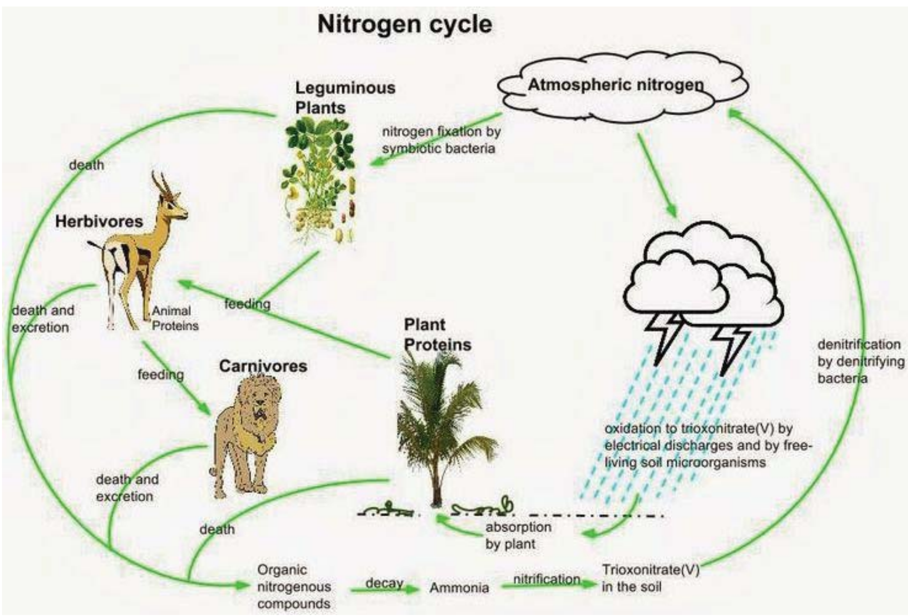

Figure 12.2: A nitrogen cycle infographic showing the flow of nitrogen across various media.

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Some two-thirds of the carbon in the terrestrial biosphere is stored in the soil, mainly as decayed organic material. Carbon cycles rapidly between the atmosphere and soil as CO_2, and soils, depending on how they are managed, represent an important source (from where CO_2 is released) or sink (to where CO_2 is stored) of CO_2 to the atmosphere. There is concern that soils are increasingly becoming a CO_2 source as the climate warms and as land-use change results in increased soil disturbance. Nitrogen is a macronutrient that is often limiting to plant growth in temperate ecosystems, although it may be a pollutant in aquatic ecosystems and in drinking water. It is rapidly cycled in soil as organic matter is broken down by decomposer microorganisms. Nitrogen is also artificially added to the soil by the application of synthetic fertilizers or by atmospheric pollution. High levels of nitrogen addition can affect forest growth and reduce water quality. Thus, soil management practices that support the storage and supply of carbon and nitrogen to plants in nurseries and in the field should be emphasized in climate-smart agriculture (Figure 12.3).

Figure 12.3: Monitoring soil management for optimal carbon and nitrogen storage in farmlands.

12.5 Post-session Test

Table 12.2: Assessing knowledge learned by trainees on carbon and nitrogen management.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)

No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	Explain the carbon cycle.			
2.	Explain the nitrogen cycle.			
3.	Explain soil carbon and nitrogen management.			
4.	Average			

Module Thirteen

Natural resources management

13.1 Module Outline

Natural resource; Natural resource types; Natural resource protection; Natural resource enhancement.

13.2 Learning Objectives

To know the meaning of natural resource. To know the types of natural resources. To know how to protect and exploit natural resources.

13.3 Pre-session Test

Table 13.1: Assessing knowledge base of trainees on natural resources management.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)

No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	What is a natural resource?			

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2.	What are the types of natural resources?			
3.	In what ways can natural resources be protected?			
4.	In what ways can natural resources be exploited?			
	Average			

13.4 Module Content

13.4.1 Natural Resources: A natural resource is almost anything that occurs freely in the environment and is exploitable for the use of man. Natural resources are the key to life on Earth. These include land, rock, vegetation, water, fossil fuel, animals, minerals, sunlight, air, etc. While a few natural resources are critical for life (e.g., water and air), most (e.g., coal, gas, and oil) only satisfy daily needs. Almost all things are made from natural resources. Natural resources can be used in their natural state or after conversion into other forms (Figure 13.1).

Figure 13.1: Plots showing examples of natural resources, especially those related to global warming.

13.4.2 Types of Natural Resources: Natural resources are classified into different types on the basis of origin, development stage, and recovery rate.

Origin: On the basis of origin, natural resources are classified into biotic and abiotic resources.

Biotic resources are from the biosphere — living and organic materials. Examples include forests, animals, and materials from these. Fossil fuels such as coal and petroleum that are from decayed organic matter are also in this category.

Abiotic resources come from non-living, non-organic material. Examples include land, water, air, minerals, and metals, including ores such as gold, iron, copper, silver, etc.

Development stage: On the basis of development stage, natural resources are classified into potential, actual, reserve and stock resources.

Potential resources are marked for future use for various reasons. Examples are petroleum in sedimentary rocks until technology is developed to drill economically.

Actual resources are those that are surveyed, quantified and qualified and are in use. Examples include wood processing that depends on technology and cost.

Reserve resources are actual resources for which technology or economics is available but are still protected for future use.

Stock resources are resources surveyed but not put to use due to lack of technology. An example is hydrogen.

Recovery Rate: On the basis of recovery rate, natural resources are classified into renewable and non-renewable resources.

Renewable resources are resources that are naturally replenishable. In terms of use, resources are said to be renewable so long as the rate of recovery exceeds that of use. Wind, sunlight, air, water, etc. are some examples of renewable resources.

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Non-renewable resources are resources that either do not naturally form in the environment or form so slowly that use exceeds recovery. Minerals are the most common form of non-renewable resources. These resources take millions of years to replenish once fully used.

13.4.3 Natural Resource Protection: The United Nations developed the World Charter for Nature in 1982, which recognized the need to protect nature from further depletion due to human activity. Measures were to be taken at all levels to protect nature. It outlined the need for sustainable use of natural resources and suggested incorporation of resource protection into local, national and international systems of law. The World Ethic of Sustainability also laid out eight values for sustainability, including the need to protect natural resources from depletion. Many measures have been set up to protect natural resources since, including the establishment of scientific fields and the practice of conservation biology and habitat conservation.

Conservation biology is the scientific study of the nature and status of biodiversity. The aim is to protect species, habitats and ecosystems from excessive rates of extinction. Habitat conservation is a land management activity that seeks to conserve, protect and restore habitats to prevent extinction, fragmentation or reduction of wild plants and animals.

As the human population keeps increasing, pressure keeps building on the use of almost all natural resources, resulting in over-exploitation. Exhaustible natural resources such as arable land, coral reefs, freshwater, fossil fuels and forests drop sharply due to over-exploitation to sustain the increasing population. This creates competitive demands on vital life-sustaining resources and contributes to an incredible decline in the quality of life. Overpopulation means more demand for natural resources such as food, timber, fish, clothes, leather, natural gas, electrical equipment, etc. The main modes of depletion include intensive agriculture, causing hard landings such as global warming and climate change.

Table 13.2: Some key natural resources and their conservation/protection measures.

No.	Resource	Use and Status
1.	Water	Only 2.5% of global water is freshwater, and even less is potable. Global warming and climate change worsen water availability. Educate and regulate the use of water and explore technology.
2.	Air	Clean air is needed for life in plants, animals, and wildlife. Reduce or stop air pollution.
3.	Coal	Coal could last only for the next 200 years. Coal, the cheapest source of fuel, also pollutes the air.
4.	Oil	Oil, the main source of fuel, could last only for the next 30-40 more years and is a major land and air pollutant.
5.	Natural gas	Natural gas reserves could last only for the next 60 60 years and are a cleaner fuel source than oil.
6.	Phosphorus	Phosphate rock, used to make phosphorus fertilizers for growing crops, could last only for the next 100 years. Invest in research to develop fertilizers to replace phosphorus.
7.	Bauxite	Bauxite forms as rock in soil with very little soluble materials and is used to make aluminum metal and in oil and gas drilling. Can run out.
8.	Copper	Copper, the first metal ever used by man, has been in use for thousands of years. It occurs naturally and is mostly used in electric wires, industrial machinery, roofing, and plumbing. Copper is also used in nutritional supplements and as fungicides in agriculture. Can run out.
9.	Helium	Helium is used in balloons; cooling; MRI scanners; NMR spectrometers; satellites; fiber optics; semiconductors; air-conditioners; air-bags. Though second most abundant, it still can run out.
10.	Iron	Iron was the driver of industrialization, and both iron and steel are still useful today. It can run out.
11.	Other Minerals	Other minerals like gypsum, phosphate, bentonite, mica, titanium, and zirconium are found in sea beds along the coastal plains. Rare earth elements like scandium and terbium are two of the earth's powerful minerals that are used in wind turbines and electronic circuits in smartphones. Coastal plains contain deposits of potassium carbonate and rare elements like cerium and neodymium. All can run out.
12.	Soil	Soil has many different particles and nutrients that make plants grow. Apart from this, soil can also be used to make shelter. Garbage and soil as compost even make plants grow healthier. Does not run out if managed.
13	Salt	Salt is good for humans and animals, and it can come from rocks, soil, seawater, and. Inland saltwater.
14	Forests and Timber	Used in housing and construction, to preserve ecology of natural resources and life, provide habitat, cleans air. Does not run out if managed.

13.4.4 Resource Management: Management of natural resources involves identifying who has the right to use the resources and who does not. This is used to define the boundaries of the resource. The goal of natural resource management is enhancement for continued use to serve both the present and future generations. The resources may be managed by the users according to the rules governing when and how the resource is used, depending on local conditions, or the resources may be managed by a governmental organization or other central authority.

Natural resource management is a complex and contentious issue. First, ecological and hydrological cycles, issues of climate, animals, plants, geography, etc., are all dynamic, interrelated, and therefore complex issues. Second, the issues of stakeholders, interests, policies, politics, geographical boundaries, and economic implications make it contentious. It is impossible to satisfy all aspects at the same time. Thus, between the scientific complexity and interest diversity lies the continuity of natural resource management.

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Natural resources can be managed via: 1) top-down management; 2) community-based management; 3) adaptive management; 4) precautionary management; 5) integrated management; and 6) ecosystem management. Here, only community-based resource management and integrated resource management will be discussed because they are most critical to adaptation and resilience to climate change.

Community-based Resource Management (CBNRM) combines conservation objectives with economic benefits for rural communities. The three key assumptions are that: i) locals are better placed to conserve natural resources; ii) people will conserve a resource only if benefits exceed the costs of conservation; and iii) people will conserve a resource that is linked directly to their life. When a local quality of life is enhanced, the efforts and commitment of the people to ensure the future well-being of the resource are also enhanced.

The problem with this type of management is that it is difficult to reconcile and harmonize the objectives of socioeconomic development, biodiversity protection, and sustainable resource utilization. The concept and conflicting interests of -CBNRM show how the motives behind participation are differentiated as either people-centered or planner-centered. Understanding power relations is crucial to the success of CBNRM. Locals can be reluctant to challenge government recommendations for fear of losing promised benefits.

On the one hand, CBNRM is based particularly on advocacy by non-governmental organizations that work with local groups and communities, and on the other, national and transnational organizations. The goal is to build and extend new versions of environmental and social advocacy that link social justice and environmental management agendas with both direct and indirect benefits, including shares of revenues, diversification of livelihoods, employment, and increased pride and identity. Ecological and societal successes and failures could also occur. It has new challenges, as concepts of community, territory, conservation, and indigenous are worked into politically varied plans and programs in disparate sites. There are also conflict and governance issues.

This approach includes recognition that adaptation occurs through a process of 'plan-do-review-act'. It also recognizes seven key components to consider for quality natural resource management practice: determination of scale; collection and use of knowledge; information management; monitoring and evaluation; risk management; community engagement; opportunities for collaboration.

Integrated natural resource management (INRM) is a process of managing natural resources for multiple uses (biophysical, socio-political and economic) to meet production (e.g., food security, profitability, risk aversion) and community (e.g., poverty alleviation, future generation welfare, environmental conservation) goals. While it focuses on sustainability, it also incorporates all possible stakeholders to reduce possible future conflicts. The conceptual basis of INRM has evolved in recent years through the convergence of research in diverse areas such as sustainable land use, participatory planning, integrated watershed management and adaptive management. INRM is used extensively and successfully in regional and community-based natural resource management (Figure 13.2).

Figure 13.2: Plot showing developed national and provincial capacities for integrated catchment management and integrated urban ecosystem-based adaptation for climate risk reduction.

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13.5 Post-session Test

Table 13.3: Assessing knowledge learned by trainees on natural resources management.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)

No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	What is a natural resource?			
2.	What are the types of natural resources?			
3.	How can you protect natural resources?			
4.	How can you enhance natural resources?			
5.	Average			

Module Fourteen

Disaster management

14.1 Module Outline

Definition of disaster; Disaster classification; Disaster management; Disaster response; Disaster and climate change.

14.2 Learning Objectives

To know the meaning of disaster. To know the types of disaster and how to respond. To know the link between disaster and climate change. To know how to prevent and control disasters.

14.3 Pre-session Test

Table 14.1: Assessing knowledge base of trainees on disaster management.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)

No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	What is a disaster?			
2.	What are the things to do in times of disaster?			
3.	How are disaster and climate change linked?			
4.	How can disaster be prevented or controlled?			
	Average			

14.4 Module Content

14.4.1 Disaster: Disaster is a human, material, economic, or environmental loss in excess of what the community or society can cope with using its resources. Disaster losses are 20 times greater (in terms of GDP) in developing countries than in industrialized countries, and over 95% of disaster deaths are in developing countries. Disasters can prompt changes in governments and social life. Disasters can even change the course of history and expose mismanagement or corruption in society (Figure 14.1).

Figure 14.1: Plot of disaster scenes with the potential to destroy lives and properties.

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14.4.2 Disaster Classification: Disasters can be classified as natural or human-made, primary or secondary, and then predictable or unpredictable.

Natural disasters are caused by natural events such as earthquakes, landslides, volcanoes, floods, hurricanes, tornadoes, blizzards, tsunamis, cyclones, and pandemics. Man-made disasters are triggered by human activities such as airplane crashes, terrorist attacks, pollution, stampedes, fires, transport accidents, industrial accidents, oil spills, nuclear explosions/radiations, wars, etc.

While primary disasters are triggered by single root causes such as earthquakes, secondary disasters such as tsunamis are first triggered by primary disasters. Predictable disasters are recurrent disasters such as yearly floods in floodplains. Unpredictable disasters are those that occur at random, such as volcanoes.

14.4.3 Disaster Management: Disaster management is a process implemented before, during, or after a disaster. This process can be initiated when things threaten to disrupt normal operations or put people at risk. Governments at all levels and businesses should develop disaster plans to make it possible to overcome disasters and return speedily to normal life.

There are four essential parts to disaster management — prevention, preparation, relief and recovery. Although many are avoidable, not all disasters are preventable, and the effects of others are mitigatable. Preparation can include long-term plans for readiness and quick response to imminent disasters such as hurricanes that are about to make landfall. Relief involves actions during and after disasters. Recovery includes repairing, rebuilding, restoring and/or replacing damaged, injured or lost things in disasters (Figure 14.2).

14.4.4 Disaster Response: Disasters hurt the poor and vulnerable the most. Although low- and middle-income countries experienced only 32% of the storms in 1998-2018, 91% of the deaths were in these countries. Since 1980, over two million people and 3 trillion dollars have been lost to natural disasters. The total damage increased by over 600% from 23 billion dollars a year in the 1980s to 150 billion dollars a year in the last decade. Almost 75% of the losses are due to extreme weather events. Based on the current trend of events, climate change alone could put 100 million more people into destitution by 2030.

Population growth and urbanization increase disaster risk. Some two-thirds of the world's population will live in cities by 2050, putting 1.3 billion people more and 158 trillion dollars in assets at risk of river and coastal floods. Without significant investments in city resilience, natural disasters could cost cities worldwide some 314 billion dollars each year after 2030. But investing in more resilient infrastructure will give a net benefit of 4.2 trillion dollars (with 4 dollars in benefit for each one-dollar investment) in low- and middle-income countries.

Mainstreaming disaster risk management into development plans can reverse current trends in disaster impacts. Furthermore, when countries rebuild stronger, faster and more inclusively after disasters, they can reduce the impact on livelihoods and well-being of people by as much as 31%, cutting down on global average losses.

Figure 14.2: Plot of examples of disaster management activities that limit impacts on lives and properties.

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Table 14.2: Categories of disaster and first response initiatives.

Example	Profile	Response
Natural Disaster		
Avalanche	Sudden drastic flow of snow down slopes triggered by new snow/rain loadings, explosives, backcountry skiers, snowpack overload	Turn off utilities; evacuate buildings; determine impact on equipment and facilities & any disruptions
Blizzard	Intense snowstorm in very strong winds & low temperatures	Turn off equipment; listen to blizzard advisories; evacuate area; assess damage
Earthquake	Shaking of the Earth's crust, caused by underground volcanic forces which break & shift rocks beneath the earth	Turn off utilities; evacuate buildings; determine impact on equipment & facilities & any disruptions.
Fire	Fires starting in bushes could spread to settlements and risk lives & properties.	Put out fires in early stages; evacuate people on alarm; notify fire departments; turn off utilities; monitor weather advisories.
Flood	Flash floods in small creeks, gullies, dry streambeds, ravines, culverts or even lowlands	Monitor flood advisories; determine flood potential to facilities; pre-stage emergency power generating equipment; assess damage
Freezing rain	Rainfall when outside surface temperature is below the freezing point	Monitor weather advisories; arrange for snow and ice removal
Head wave	Prolonged period of very hot weather relative to usual weather pattern in an area & relative to normal temperatures for the season	Follow weather advisories; turn off servers in imminent power failure; shut down main electric circuit in buildings.
Hurricane	Heavy rains and high winds	Turn off equipment; follow hurricane advisories; evacuate area, check gas, water & electrical lines; do not use telephones in events of severe lightning; assess damage
Landslide	Geological events include ground movements such as rock falls, deep failures of slopes & shallow debris flows.	Shut down utilities; evacuate buildings; determine impact on equipment & facilities & any disruptions
Lightning	Electrical discharge caused by lightning, especially during thunderstorms	Power off all equipment; follow hurricane advisories; evacuate area; check gas, water & electrical lines for damage; do not use telephones in severe lightning; assess damage
Limnic eruption	Sudden eruption of carbon dioxide from deep lake waters	Shut off utilities; evacuate buildings; determine impact on equipment & facilities & any disruptions
Tornado	Violent rotating columns of air from severe thunderstorm cloud systems	Monitor tornado advisories; power off equipment; shut off utilities (power & gas); assess damage after storm
Tsunami	Series of waves hitting shores strongly, mainly caused by displacements of large volumes of water bodies, typically oceans or lakes, usually due to earthquakes, volcanic eruptions, underwater explosions, landslides, glacier calving, meteorite impacts & other disturbances above or below water	Power off all equipment; follow tsunami advice; evacuate area; check gas, water & electrical lines for damage; assess damage
Volcano	Release of hot magma, volcanic ashes and/or gases from volcanoes	Shut off utilities; evacuate buildings; determine impact on the equipment & facilities & any disruption
Man-made Disaster		
Bioterrorism	International release of biological agents as a means of coercion	Get information immediately from public health officials via news media on the right course of action; quickly remove clothing and wash off skin; put on HEPA to prevent inhalation of agent
Civil unrest	Disturbance by people including sit-ins & other forms of obstructions, riots, sabotage & other forms of crime that escalate to chaos	Contact police or law enforcement; suppress fire in early stages; evacuate people on alarm; notify fire department; shut off utilities; monitor weather advisories.
Fire (urban)	Even with strict fire codes, people still perish in fires	Put out fires in early stages; evacuate people on alarm; notify fire departments; turn off utilities; monitor weather advisories
Hazardous spills	Escape of solids, liquids or gases that can harm people, organisms, property or environment	Leave area and call fire department for help; If spill, call local emergency medical services line
Nuclear & radiation accidents	Events of significant release of radioactivity to the environment or reactor core meltdown causing major consequences to people, environment or facility	Know that CBRN incident can occur; gather, assess and spread information to responders; establish overview of affected area; provide & obtain regular updates from responders
Power failure	Caused by summer or winter storms, lightning, or construction equipment in wrong places	Wait 5–10 minutes; power off all servers after shutdown; do not use telephones; shut down main electric circuit to buildings.

14.4.5 Disaster and Climate Change: It is all very clear now that climate change can lead to disaster with huge impacts on life and property. As climate change continues, more frequent and severe disasters occur and with greater impacts. Limited natural resources such as drinking water will become even scarcer in many parts of the world. Crops and livestock will struggle to survive in climate change hotspots where conditions get too hot and dry or too cold and wet, threatening livelihoods and worsening food insecurity. Climate change causes poverty and food shortages and forces even higher numbers of men, women and children to flee their homes.

In 2018, more than 17.2 million people fled disasters in 125 countries and territories. Natural disasters displace 3-10 times more people than conflicts and wars worldwide. Some 26 million people are displaced on average by disasters such as floods and storms every year since 2016. This suggests that one person is forced to flee every second. New patterns of displacement and competition over depleted natural resources can spark conflicts between communities or compound pre-existing risks.

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14.5 Post-session Test

Table 14.3: Assessing knowledge learned by trainees on disaster management.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)				
No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	What is disaster?			
2.	What are the things to do in times of disaster?			
3.	How are disaster and climate change linked?			
4.	How can disaster be prevented or controlled?			
5.	Average			

Module Fifteen

Onion value chain

15.1 Module Outline

Introduction; Nursery cultivation; Field cultivation; On-field postharvest handling; Off-field postharvest handling; Marketing.

15.2 Learning Objectives

To know what onion is. To know nursery cultivation of onion. To know field cultivation of onion. To know on-field postharvest handling of onion. To know off-field postharvest handling of onion. To know marketing of onion.

15.3 Pre-session Test

Table 15.1: Assessing knowledge base of trainees on onion value chain.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)				
No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	Describe onion plant.			
2.	Explain onion cultivation in the nursery.			
3.	Explain onion cultivation in the field.			
4.	Describe on-field onion chain.			
5.	Describe the off-field onion chain.			
6.	Describe onion marketing chain.			
	Average			

15.4 Module Content

15.4.1 Introduction: Onion (Allium cepa L., with the Latin word cepa meaning onion) is the most widely cultivated species of the genus Allium. Onion belongs to the class of crops called vegetable, and its close relatives include garlic, scallion, shallot, leek, chive, and Chinese onion, Japanese bunching onion, tree onion, Canada onion, etc. Contrary to dry onion (grown for bulbs), green onion is pulled while tops are still green and before large bulbs are formed.

Onion has no known wild ancestor, but it is reported to originate from Afghanistan and the environs. Onion is among the most widely adaptable vegetable crops, and it can grow from tropical to subarctic regions. Unlike most other species, day length influences bulb formation in onion, as opposed to flower formation. Onion cultivars (varieties) are classified based on bulb formation as long-day (14-16 hours), medium-day (12-14 hours), or short-day (10-12 hours) type. Bulbs also vary in color (red, yellow, and white), shape (round or flat), and flavor (sweet or pungent).

Dry onion is good for small-scale and part-time farming. Either biennial or perennial, onion is usually treated as annual and harvested in the first growing season. Onion has rings of hollow, bluish-green leaves, a basal bulb that is a compressed underground stem, and a central bud at the tip. Onion is harvested and dried before it is ready for use or storage. It has many pests and diseases, including onion fly, eelworm, and fungi that can cause rot. Some varieties of onion, such as shallot and potato onion, produce multiple bulbs. Onions are cultivated and used around the world. As a food, onion can be served cooked, as a vegetable or part of savory dishes, but can also be eaten raw or used to make pickles or chutneys. Onion is pungent when cut and contains chemical substances that irritate the eyes.

15.4.2 Nursery cultivation: Onion planting materials: Onion, like most other vegetable crops, can be planted using seed or seedling (bulb). For especially short-day onion, either seed or bulb is used. But for most other onions, the bulb is the preferred planting material.

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Onion seed production: There are two ways to produce onion seeds — seed-to-seed and bulb-to-seed production. However, bulb-to-seed production is by far the most common method. This method has plenty of good sides, including options for selection of bulbs of good size, type, color, disease, and damage state. It produces several stalks per bulb and therefore gives high seed yield. Although this method is good for maintaining variety identity, it takes 10-12 months to produce seeds (some 4-5 months for bulb production and 6-7 months for seed setting and maturity). The good side of seed-to-seed production is not as high as that for bulb-to-seed production. Seed-to-seed production produces fewer flower stalks per bulb. However, it takes only 7-8 months to produce seeds. The nursery practices for both seed-to-seed and bulb-to-seed production are given below.

Nursery site: The nursery site should be selected near a source of water and with deep, smooth, and fertile soils. Onions grow best on light sandy loam soils that have not been planted with crops like onion, garlic, tomato, etc. in at least two seasons.

Isolation: Onion is a cross-pollinated crop, and therefore seed fields are isolated from other flowering types of onion by 500-1000 meters to avoid cross-pollination by insects. Timing of isolation is also crucial, and bulb production requires 5-10 meters of space from other plants.

Land preparation: Nursery land is ploughed at least three times to ensure that the field soil is adequately loose and aerated.

Seed bed: Nursery seed bed soil should be well prepared and leveled. It can be smaller or bigger, but a bed size of 1 meter wide and 5 meters long (1 m x 5 m) is most recommended. The seed bed can be raised ridges or flats or even sunken flats, depending on soil type and site/moisture conditions and season. Raised beds are most commonly used because of risk of excess moisture (Figure 15.1).

Figure 15.1: Plots of raised (top plates) and sunken (bottom plates) seed/crop beds for different land conditions and seasons.

Seed selection and treatment: Nursery seeds must be viable and treated (coated) with fungicide and insecticide mixtures (e.g., Apron Star) to avoid fungal diseases such as damping. They are kept in dry, cool conditions to maintain high viability.

Seeding rate: Broadcast 80-100 grams of seed per 1 m x 5 m seed bed (for seeds with over 90% germination rate) and 3-4 kilograms of seeds per hectare of well-prepared land.

Seed/bulb spacing: Holes are drilled in rows opened 10 cm apart (both for row and seed/bulb spacing) and seeds buried 0.5-1.0 cm in the seed bed and slightly covered with soil. Bulbs need deeper holes but only deep enough to bury the bulbs at the same 10 cm x 10 cm spacing.

Fertilizer: During sowing, about 100 grams of urea fertilizer can be applied per 1 m x 5 m seed bed. Manure can also be applied during sowing.

Mulching: Planted seed beds are covered with fine dry grass to a thickness of 3-5 cm. It is not good practice to use green (non-dry grass) or broad-leaved materials.

Mulch removal: Mulch is removed after seedlings emerge, and the best time for this is morning or late afternoon.

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Irrigation: The seedbed is irrigated in the morning or late afternoon from the time of sowing until two weeks after seedling emergence. It can continue till transplanting, if possible. Watering can, drip, or furrow irrigation can be used, but care should be taken in all events.

Pest control: Apply registered fungicides like Ridomil Gold within 3-4 days after grass cover removal. Then other applications will depend on disease or insect incidents.

Disease control: Botrytis leaf blight (blast) is caused by Botrytis squamosa. It is very destructive and found everywhere. Symptoms appear as oval whitish or yellowish spots some 1-3 mm long, slightly depressed and bordered with a diffuse silver halo. At severe infection, it reduces yield considerably, and the disease may continue in storage and cause neck and bulb rot. Other diseases include Purple Blotch (caused by Alternaria porri) and Downy Mildew (caused by Peronospora destructor) (Figure 15.2).

Figure 15.2: Appearance of onion under attack by common diseases like pink rot, basal rot, neck rot and open bulb rot.

Weeding: Weeding frequency for seed production is similar to that for bulb production. However, care is needed during flowering to avoid damage to flower stalks. Otherwise, fields should be free of weeds before flowering.

Pollination: Onion is pollinated by insects like honeybees. Do not apply insecticides during noon time when beneficial insect activity is high, but can do so when there is no movement of insects (e.g., early night hours).

Harvesting: Not all umbels per plant mature at the same time due to differences in stalk growth; hence, harvesting can be done 3-4 times. Although harvest can start when over 10% of the black seeds are exposed on an umbel, it is best to harvest mature umbels (when about 50% of the black seeds are exposed on an umbel). If overstayed, heads can readily shatter seeds in the field. Harvesting is done by hand. Heads cut are supported in the palm and held between the fingers to avoid seed shattering.

Drying umbels: The harvested umbels are dried by spreading on canvas in the sun in the morning or late afternoon, or under shade (for hot-sun days) for a few days.

Seed extraction: The seeds are properly separated from the umbels so that no damage is done to the seeds during the extraction. Seeds can be threshed by mowing or rubbing dried umbels by hand, cleaned by winnowing, and separated seeds from chaff by flotation.

Seed drying: Pure seeds that settled in the container are collected and dried under morning and late afternoon sun or under shade for 3-4 days. Seeds should not be dried in hot noon sun for fear of damage.

Seed storage: Dried seeds are stored in porous materials such as cloth, paper bags, or similar materials in dry and aerated conditions at 7-9% moisture. Do not store in plastic bags for a long time. Seed moisture significantly affects seed quality, as high or low seed moisture makes seeds rapidly lose viability (Figure 15.3 and 4).

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Figure 15.3: Sequence of processing onion seeds — flowering, umbel harvest, drying, mowing, winnowing, water rubbing, seed-chaff separation, seed drying and seed storage.

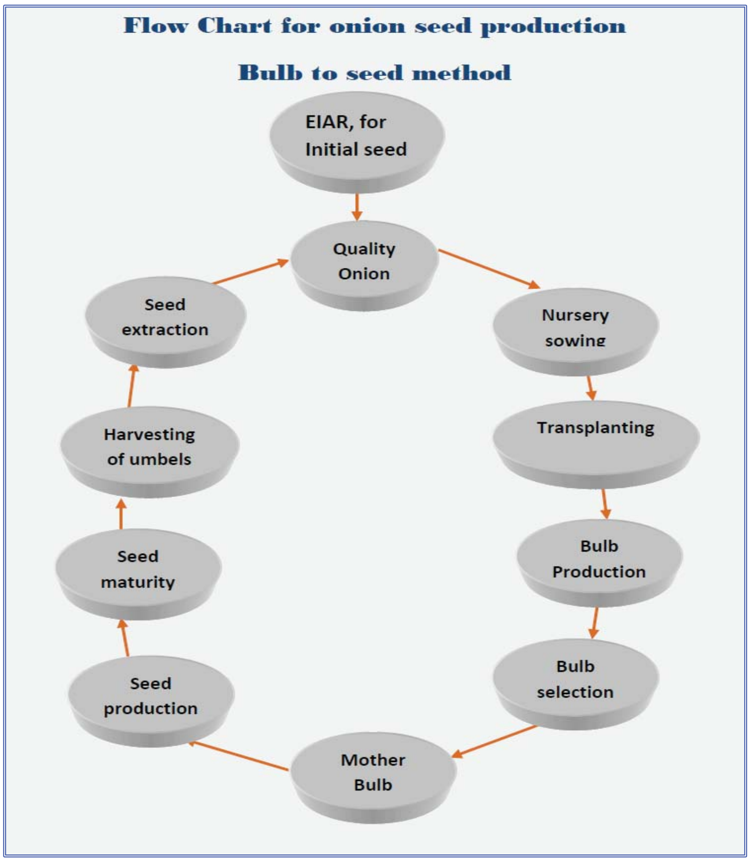

Figure 15.4: Summary of onion seed production by bulb-to-seed method.

Table 15.2: Standard for onion seed production (courtesy of FAO seed quality standard).

Factor	Standard
Pure seed (varietal purity)	89%
Analytical purity	97%
Other crop seeds (maximum)	2
Weed seed	Reasonably free from weeds
Germination (minimum)	60%
Moisture (maximum)	8%

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15.4.3 Field cultivation: Land preparation: Different management practices are done in the field for the production of high-quality bulbs and yield. Ridges, flat beds, sunken beds, and furrow beds can be constructed for onion production (Figure 15.5).

Transplanting: Field production of onion starts by transplanting mature and healthy seedlings. Transplants are field set on slightly raised beds that are four feet wide with one foot spacing. The beds or panels can have 4 rows of onions spaced about 12 inches apart and 6 inches within row (Figure 15.5). The spacing is determined by a pegger used to place 1-2 inches deep holes in the beds and hand-set.

Irrigation: The amount and frequency of irrigation varies with soil type, climatic conditions, and stage of crop. Some light irrigation is needed soon after field transplanting. Then the field is irrigated every 4-5 days for the first month for good establishment. This is continued every 5-7 days until maturity. Both over- and under-irrigation can reduce bulb yield.

Weeding/cultivation: Onion is susceptible to weeds and should be free from weeds during the first 60 days (especially between 21-60 days) after transplanting. Hence, 2-3 cultivations are needed — the first 21-30 days after transplanting; the second 45-55 days; and the third weeding as necessary.

Pests/diseases: The pests and diseases of onion are the same as discussed under onion seed production.

Harvest and Storage: Onions are harvested when 35-50% of the top has fallen over. Bulbs are generally pulled from the soil after being loosened with a disk.

15.4.4 On-field postharvest handling: Handling: Handling involves sorting, assembling, and transporting. Harvested onions are topped about one inch above the bulb. To prevent rot, onion bulbs are adequately cured (drying of cut top or neck) in the field, in open shade, or by other artificial means before being transported into storage. Curing takes 2-4 weeks, depending on weather conditions. In high humidity and wet regions, onions are removed from the field for curing. Curing also helps remove dirt from onion bulbs.

15.4.5 Off-field postharvest handling: Processing: This includes cleaning, sorting, treating, packaging, and storing. If onion bulbs are not cured and dried in the field, then that can be done while in storage. It is important that some light cleaning of the bulbs is done in the field before curing and drying. This is followed by sorting. Sorting is done on the basis of size, quality, etc. Proper sorting increases the market value of produce.

15.4.6 Marketing: End of nursery marketing: End-of-nursery marketing is mainly about sales of seeds or bulbs ready for transplanting. In the case of seeds, standard procedures are followed in treatment, packaging, and sales. This increases the length of time seeds are on the shelf without losing viability.

Figure 15.5: Sample beds for onion production in the field.

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Produce marketing: To ensure marketing of high-quality produce, grade onions by size and color and check for insect damage. Onions that are maintained at 32 °F (0 °C) and 65-70% relative humidity can be stored for up to 1-8 months, depending on variety.

15.5 Post-session Test

Table 15.3: Assessing knowledge learned by trainees on onion value chain.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)

No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	Describe an onion plant.			
2.	Explain onion cultivation in the nursery.			
3.	Explain onion cultivation in the field.			
4.	Describe on-field onion chain.			
5.	Describe the off-field onion chain.			
	Average			

Module Sixteen

Pepper value chain

16.1 Module Outline

Nursery cultivation; Field cultivation; On-field postharvest handling; Off-field postharvest handling; Marketing.

16.2 Learning Objectives

To know about nursery cultivation of hot pepper. To know about field cultivation of hot pepper. To know about on-field postharvest handling of hot pepper. To know about off-field postharvest handling of hot pepper. To know about marketing of hot pepper.

16.3 Pre-session Test

Table 16.1: Assessing knowledge base of trainees on pepper value chain.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)

No.	Questionv	Response (%)		
		Right	Wrong	Class Rating
1.	Describe hot pepper cultivation in the nursery.			
2.	Describe hot pepper cultivation in the field.			
3.	Describe hot pepper on-field postharvest handling.			
4.	Describe hot pepper off-field postharvest handling.			
5.	Describe the hot pepper marketing chain.			
	Average			

16.4 Module Content

16.4.1 Nursery cultivation: Seed selection: The selection of what pepper seed to plant starts with what variety to cultivate. This is again driven by whether it is cultivated for market or household consumption. Quality drives this decision more for home consumption than for market purposes. In terms of productivity and marketability, the reverse is the case.

When available on the farm, pepper seeds can come from the best ripe fruits. It can also be purchased from the market. The choice of growing landrace pepper variety is dependent on the purpose of production, consumer preference, productivity, environmental adaptability, pest/disease tolerance, and quality seed/seedling availability. Irrespective, always ensure that seeds are of the highest quality possible and are no less than 90% viable.

Seed treatment: Good fruits picked for seeds are split open and seeds carefully removed, put in water and left to settle for 5-10 minutes. Seeds that float on water are discarded as not fully developed, and those that sink are put in cloth or similar suitable material for drying at room temperature for 3-5 hours. It is then commonly dusted with fungicides before storage at a moisture content not above 10%.

Setting up nursery seedlings: Pepper can be directly planted or transplanted, but transplanting is preferred when germination is limited by seed dormancy, as it ensures quality planting materials. It is good to use certified seeds in raising pepper seedlings. In cases where farmers use their own seeds, they should be extracted from mature pods picked from high-yielding, disease-free plants. Gloves are used in extracting seeds to protect the eyes, and also care is needed to prevent irritation of the eyes and nose. About 200-250 grams of seeds are sown per hectare. Seeds are soaked in clean water for two hours and sown to improve germination.

Nursery beds for sowing pepper should have free-draining soils that are free from pathogens. Soils known for pathogens and

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pests are sterilized using pesticides or heat, although heating is preferred in organic farming. This involves covering already prepared propagation media with polythene paper in an open place exposed to sunlight. The media is left for three weeks before being used to raise seeds. As this is not effective against all pathogens, retesting for soil PGAQ sterilization is needed.

Steam sterilization can be done in enclosed nurseries. However, initial costs of equipment such as drums, pipes, labor, and clean water can be high. Soils are prepared to fine tilth in beds measuring 1.5 by 6 m. Beds are raised to 15 cm in areas with excess rainfall. Add 60 kg of well-decomposed manure to the top 10 cm of soil.

In poor soil structures, the topsoil is mixed with sand and manure in the ratio of 3:2:1. This is then filled in polystyrene containers measuring three inches in diameter and put on a propagation bench. Artificial media such as vermiculite can be used for high-value pepper production where revenues justify initial costs.

Pepper seedlings: Drill pepper seeds in nurseries at 15 cm spacing and 1 cm depth. One seed is sown per container. Cover seeded beds with dry mulch or shade netting. Water beds in fine droplets once every day. Seeds germinate five days after sowing. Control measures are taken against pests and diseases. Seedlings are hardened off in the fourth and fifth weeks after seedling emergence by reducing shade and watering frequency to three times per week. Seedlings grown in soils poor in nitrogen and phosphorus are sprayed with foliar fertilizers three weeks after seedling emergence to boost early root and vegetative growth. Seedlings can be transferred into containers when field conditions are not favorable for immediate transplanting.

Follow all other agronomic practices until seedlings are ready for transplanting into the field.

16.4.2 Field cultivation: Site selection: Hot pepper can be grown in open areas free from shade or overhanging trees. Avoid areas heavily infested with grass. Clay, sandy and stony soils should be avoided, in addition to waterlogged areas or areas prone to flooding. Sandy loam or silt loam soils are best.

Land preparation: Soils are well ploughed to depths of 30 cm (12”). Addition of pen manure or organic matter to the soil helps the plants in early establishment and development. Ensure that land is well drained. Prepare ridges or raised beds along contours on slope lands.

Transplanting seedlings: Transplanting takes into account the following: i) Time to harvest for the market; ii) Availability of water and labor for planting and establishment; iii) Transplant 4-5 week-old seedlings or are seedlings at 4-5 true leaf stage; iv) Transplant preferably in evening hours when temperatures are low or on cloudy days to avoid excess transpiration; v) Use healthy, properly hardened seedlings; vi) Bury plant firmly into the soil, but not more than half the height of the seedling; vii) Apply water to field or at base of plants soon after transplanting; viii) If plastic mulch is used, put it before transplanting.

Seedling spacing: Transplant seedlings on raised beds or ridges and furrows at spacing of 3ft (91.44 cm) between rows and 2ft (60.96 cm) within rows. Closer spacing can make the fruits difficult to harvest and also result in damaging plants.

Irrigation: Hot pepper requires a large amount of water (5 litres per plant per day) and so the soil should remain moist as much as possible. As a general rule, watering is done less frequently during the period of establishment and then more watering as the plant develops. When harvesting begins, it is usual to reduce watering a little. Too much water facilitates bacterial and fungal diseases. On the other hand, if the soil is left to dry out to the point at which the plant wilts, root scorch, followed by development of fungal root rot, may occur. If drying out of soil reaches this stage, it is particularly important to allow the plants to recover with a small application of water before applying any liquid or granular fertilizer. Drip irrigation is more effective than overhead sprinklers as it creates conditions for foliar diseases.

Fertilizer application: Suggested nutrient requirements for a hot pepper yield of 5t/ha are estimated at nitrogen of 180 kg/ha (396 lbs/ac); phosphorus of 22 kg/ha (49 lbs/ac) and potassium of 200 kg/ha (440 lb/ac). Fertilizer application must, however, take into account nutrient recovery rate from soil by crops as well as natural fertility of soil. Therefore, soil and leaf analyses are recommended for each farm. Organic matter content of soil and rate of leaching also influence application rates. Fertilizer application must therefore be specific to farms or geographical areas with similar soils.

Mulching: Depending on scale of production and accessibility of mulch, mulching can be of advantage. It helps to maintain uniformity in moisture throughout the field. Besides, it controls weeds. It is also important that mulch is free of weed seeds and is adequately dry.

Barriers: Corn barriers can be established around the border of the farm. This is a useful way of not only providing a secondary source of income, but also of attracting natural enemies that are predators of some of the insects that attack pepper plants, such as aphids, among others.

Pests and diseases: Pepper has many pests/diseases, and pesticides can generally be used for control. The common pests and diseases of hot pepper include pepper mosaic, bacterial spot, phytophthora blight, southern blight, anthracnose, cutworms, pepper stem borer, mole cricket, mites, aphids, whiteflies, leaf hoppers, thrips, etc.

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Weed management: This begins before crop establishment. After selecting the field in which crops are to be established, carefully examine the type of weeds present. Identify major problem weeds for special attention and direct weed control efforts, such as manual, chemical, or otherwise, to eradicate the weeds from the plot before establishing the new crops.

Good soil tillage is an important second step in weed management since this operation dislodges and sometimes buries difficult-to-kill perennial weeds. The third step in good weed management therefore rests with the control of seedling weeds during the first 4 weeks after tillage or after land clearing. Hand weeding can be used to control this early weed growth. However, since it is very time-consuming and costly, the use of pre-emergent herbicides or stale seedbed techniques can reduce costs. Weeds continue to emerge during the life of the crop. In addition to the measures outlined above, these can be controlled by mulching, correct spacing of crops, and application of post-emergent herbicides like Roundup and Gramoxone. It is important to remember that weeds must be destroyed before they produce flowers, fruits, and seeds.

Harvesting: This is not done until 6 months after planting. The first mature fruit is expected 70-80 days after transplanting, depending on variety. It is important to harvest at the right stage of development. Harvesting is done once per week to prevent over-ripening of fruits. It is done in dry weather as wet peppers spoil easily. Do not expose the crates to direct sunlight or strong winds for long periods. Fruits are picked early in the morning with the stalk attached. The use of field bags is not recommended as peppers are hollow and are easily crushed. Use field crates or shallow boxes. The harvested peppers should be firm, shiny, free of blemishes, cracks, and soil. Yields vary with spacing. At 2ft x 4ft spacing, yields can be up to 30,000 lb/acre. At 2ft x 3ft spacing, up to 36,000 lb/acre harvest is achievable (Figure 16.1).

16.4.3 On-field postharvest handling: Handling, sorting, assembling, transporting: Careful handling is important to reduce post-harvest losses. Injury can lead to decay. Hot peppers should not be washed after harvesting, as wet fruits spoil easily. Store harvested pepper in a cool place to maintain turgidity. Shelf-life and quality are directly affected by maturity of fruits at the time of harvest. Immature fruits rapidly shrivel and wilt due to moisture loss.

Figure 16.1: Plots of field cultivation of hot pepper, including harvested pepper.

16.4.4 Off-field postharvest handling: Off-field postharvest handling of hot pepper includes sorting and packaging, and storing. Harvested peppers are sorted into grades, packaged, and stored in cool conditions to lengthen shelf-life. Pepper can also be dried for even longer shelf-life.

16.4.5 Marketing: Produce marketing generally follows consumer trends that favor greater use of spicy foods. As a result, there is greater consumption of hot peppers as mainstream consumers develop a stronger taste for ethnic cuisine. While local markets require year-round production, fruits of the highest quality are required for export. The market usually demands mature green or ripe (yellow or red) fruits. Peppers should be firm and shiny at sale. Wilted, diseased, or spotted peppers lose market value. Wipe all soiled fruits as washing is not recommended.

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16.5 Post-session Test

Table 16.2: Assessing knowledge learned by trainees on pepper value chain.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)				
No.	Question	Response (%)		
		Right	Wrong	Class Rating
1.	Describe hot pepper cultivation in the nursery.			
2.	Describe hot pepper cultivation in the field.			
3.	Describe hot pepper on-field postharvest.			
4.	Describe hot pepper off-field postharvest.			
5.	Describe hot pepper marketing.			
6.	Average			

Module Seventeen

Rice value chain

17.1 Module Outline

Nursery cultivation; Field cultivation; On-field postharvest handling; Off-field postharvest handling; Marketing.

17.2 Learning Objectives

To know about nursery cultivation of rice. To know about field cultivation of rice. To know about on-field postharvest handling of rice. To know about off-field postharvest handling of rice. To know about marketing of rice.

17.3 Pre-session Test

Table 17.1: Assessing knowledge base of trainees on rice value chain.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)				
No.	Question	Response (%)		
		Correct	Wrong	Class Rating
1.	Describe rice cultivation in nursery.			
2.	Describe rice cultivation in the field.			
3.	Describe rice on-field postharvest.			
4.	Describe rice off-field postharvest.			
5.	Describe rice marketing.			
	Average			

17.4 Module Content

17.4.1 Nursery cultivation: Seed selection: Like all other seeds, rice seed for nursery cultivation should be selected from healthy plants with well-formed panicles and grains.

Rain-fed rice cultivation: For this system, land is prepared before the onset of rains. The land is ploughed and harrowed.

Rice Cultivars: There is a range of rice cultivars. The decisions that guide variety and seed selection include: i) Suitable grain quality, (especially cooking characteristics, color, shape, taste and aroma and head rice recovery; ii) Acceptability to farmers and local market at a price that is acceptable to farmers; iii) Adequate yield potential and stability over seasons; iv) Resistance to diseases and insects and/or tolerance to local abiotic stresses (e.g., drought and flood); v) Duration of growth that matches season. vi) Adequate tillering capacity to shade out weeds and produce enough tillers for optimum yields; and vii) Resistance to lodging (falling over) under normal farm management.

Seed selection: Nursery establishment: Land preparation: Transplanting: Use good quality seeds with no insect damage and contaminants (weed seeds, stones, other seed types) and with high percent viability (>80%).

Seed viability: Use filled grains of good quality seed. Add water to seeds and discard all floating seeds. When soaking seeds, change water regularly to allow for oxygen supply. To estimate percent filled grains, select at random 100 seeds from the seed lot to be sown. Count the number of filled grains. If it is 60, then the percent filled grains is 60%. When seed viability is unknown, it is important to carry out a germination test. Also take 100 seeds randomly from the seed lot. Put them on moistened wood shavings, newsprint, or carbonized rice husk and incubate for 7-10 days to allow for germination. If 80 seeds germinate, it means that the germination percent is 80%. Ideally, a good seed lot should have more than 95% germination.

Seed rate: Seed required if the seed rate is 80 kg/ha and germination is 80%. Seed required (kg/ha) = (seed rate (kg/ha) x Area to plant/% germination) x % filled grains. If we assume 100% filled grains and 100% germination, then seed rate = (80 kg/ha x 1 ha/80%) x 100% = 100 kg/ha.

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Seed dormancy: Dormancy is the failure of good quality mature seeds to germinate under favorable conditions. Dormancy of freshly harvested seed should be broken by using heat treatment at 50 °C in an oven if available or by placing seeds on a plastic sheet and covering with itself or another under direct sunlight for 1-2 days. Acid treatment may also be used.

Acid treatment: Soak seeds for 16-24 hours in 6 ml of concentrated nitric acid (69% HNO_3) per liter of water for every 1kg of newly harvested seeds. After soaking, drain the acid solution off and sun-dry seeds for 3-5 days to a moisture content of 14% and then store in dry conditions for sowing. Conduct a germination test on seeds to establish rates to use based on seed viability.

Hot water treatment: Soak seeds at 60 °C for 15 minutes. This kills disease pathogens that might be on the seed surface. Sow healthy certified seeds. Apply carbonized rice husks (biochar) to minimize root damage during transplanting. Seed rate for nursery should be 100 g/m^2. Minimize or avoid applying fertilizer in the nursery.

Nursery type: There are five types of rice nursery — wet-bed nursery, mat nursery, dry-bed nursery, hymeric nursery and bubble tray nursery.

Wet-bed nursery is the most common in lowland irrigated rice production systems. Put seedbed in a fertile field that is easy to irrigate and drain. Irrigate, plow, puddle, and level the field. Start preparing the seedbed weeks before planting time and add organic manure and/or fertilizer. Make beds of 1-1.5 m wide, 4-5 cm high and any length convenient. Pre-germinate seeds 2 days before sowing — 24 h soaking & 24 h incubation. Sow pre-germinated seeds on beds. About 50 kg of seed sown in 500 m^2 of seedbed area is required to transplant one hectare of main field.

Mat nursery is just like wet-bed nursery, but seeds are sown on plastic or banana leaves, and this can be rolled up and transported in the field. The seedlings from this nursery are preferred for mechanical transplanting as it is easy to transport seedling mats to the main field, takes a shorter period to raise seedlings, and requires less labor for weeding and watering than a wet nursery.

Method: Select a level ground near the house and/or water source. Mark out 1 m wide and 10-20 m long plots. Spread a plastic sheet or banana leaves on the marked area. Form a boundary with bamboo splits or banana sheath. Sow 25 kg seed in a 60-75 m^2 area to plant one ha field. Alternatively, spread pre-germinated seed on mats at a rate of 1 kg per 1.5 m^2 area. Sprinkle water immediately after sowing and then as and when needed. Protect the mat nursery from heavy rains for the first 5 days. Seedlings are ready for sowing in 8-15 days. Roll out seedling mats and transport in the field.

Dry-bed Nursery: This has recently become important as a result of introducing upland rice varieties, especially the NERICAs.

Method: Use 50 kg seed and 500 m^2 seedbed area for transplanting one ha of main field. Put the seedbed in a fertile field with light soil and easy access to a water source. Start preparing the seedbed 2 weeks before planting time. Add enough organic manure/ fertilizer to beds. Prime seeds and sow primed seeds on raised beds and cover seed lightly with soil or rice husk. Water the seedbed till saturation after sowing. Then water the bed periodically as seedlings emerge and grow. Also regulate the amount of water to control seedling growth rate. Seedlings are ready to transplant in 25-30 days.

Hygromeric nursery: This is like a wet-bed nursery, but rather uses carbonized rice husk (biochar) as substrate instead of soil. This is particularly important if seeds are to be broadcast. Use biochar to pre-germinate seeds and then plant in 5-10 days. This reduces labor cost for transplanting. This results in a higher establishment rate and is a better way to raise NERICA rice varieties.

Bubble tray nursery: Seedlings are raised on plastic trays of 59 cm x 34 cm, with 434 embedded holes. The requirement to plant on ha is 750 trays and a seed bed area of 250 m^2. The nursery can be in upland, lowland, or near the house. In lowlands, 75 cm wide and 9-12 cm high seed beds are used. The seed rate to plant one ha is 15-20 kg.

Method: Establish nursery two weeks before sowing. The nursery should be well leveled, 1.0-1.2 m in width and convenient length. Properly puddle the nursery, preferably with well-decomposed manure. Do seed water selection by putting seeds in a container and covering with water, and decant floating ones. Only plant seeds that sink and remain at the bottom of the container, and remove the floating weak seeds. Do hot water treatment by soaking seeds at 60 °C for 15 minutes. This kills disease pathogens that might be on the seed surface. Sow healthy certified seeds. Apply carbonized rice husk (biochar) to minimize root damage during transplanting. Seed rate for nursery is 100 g/m^2. Minimize or avoid applying fertilizer in the nursery. Handpick and destroy rolled leaves, which are an indication of Rice hispa and Stem borer attack in the nursery. Proper nursery management is important as this will ensure healthy and robust seedlings (Figure 17.1).

17.4.2 Field cultivation: There are two methods of field cultivation of rice in lowland ecosystems like inland valley swamps — sowing and transplanting.

Sowing method: This involves normally pre-germinating well-selected seeds using any of the methods explained in the nursery practices and sowing directly in the field. To do this, the field must have been cleared of grass, plowed, puddled, and flooded with sufficient near-still water standing on the soil surface. This ensures that a 15-20 cm deep soil layer is completely wet. When all this

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Figure 17.1: Plots showing bed type used in rice nursery.

is done, the pre-germinated seeds are next sown directly into the prepared field. The recommended seeding rate under direct sowing of sprouted rice is 10-120 kg/ha.

Transplanting method: Transplant at the 5th leaf stage, which is normally 15 days after sowing. Seedlings must be handled carefully to avoid breakage, ensuring fast recovery and early growth after transplanting. Shallow transplanting at 1-2 cm depth is recommended. The optimum plant-to-plant spacing is 20 x 20 cm to 25 x 25 cm, and the optimum number of seedlings is 1-2 per hill. Avoid over-elongated sprouted seeds due to breaking and slow growth. Spacing should be 30 cm x 15 cm for mechanical weeding or 25 cm x 15 cm or 15 cm x 15 cm for low-tillering varieties. Irrigate after transplanting to a depth of 2-5 cm. Clip the top of the seedlings before transplanting to reduce carry-over of stem borer and rice hispa eggs from nursery to main rice field. Avoid transplanting young seedlings and standing water in rice fields to manage rice caseworm. Plant in lines by using a guide rope during transplanting. The optimum number of rice plants is obtained in fields when transplanting is done in lines. It also allows mechanical weeding (Figure 17.2).

Water management: Generally, there are two main methods of water management in irrigated rice culture — continuous flooding and alternate wetting and drying.

Under continuous flooding, a water level of 2-5 cm is constantly maintained in the field. Water is added when the depth drops by 2 cm. Irrigation is stopped at 10-15 days before harvest.

Figure 17.2: Plots showing manual and mechanical transplanting of rice.

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Under alternate wetting and drying, water is added to the depth of 2-5 cm, but only after the field is kept dry for 2-7 days. This method saves about 50% water. The two methods give rice yields that are not significantly different. Consequently, alternate wetting and drying can be adopted without vastly compromising yield. It can be used where irrigation water is a constraint.

Water applied to rice fields supports rice plants and suppresses weed growth. Worldwide, water for agriculture is getting increasingly scarce. By 2025, 15-20 million ha of irrigated rice may not have enough water. Therefore, care must be taken to use water wisely and reduce water losses in rice fields. For this reason, it is important to practice appropriate water management throughout the rice growing period.

In lowland rice fields, water comes from rainfall and irrigation. Water is lost by transpiration, evaporation, seepage, and percolation. This loss can be avoided through repairing levees to minimize seepage, removing weeds to avoid competition with rice plants for water, and increasing the height of levees to prevent surface runoff into the field. The critical stages when water is required in large quantities include: i) The period of 3-7 days after transplanting; water should cover up to 80% of the height of the crop. This reduces transpiration and gives plants the chance to re-establish roots to be able to take up enough water from the soil. ii) From the stage of booting to 14 days after heading, more water is required because the shedding of pollen and the process of fertilization require very high moisture content in the air. Low moisture content in the air leads to sterile spikelets. iii) The period 7-10 days before harvesting, drain the field to harden the soil for good harvesting and also to hasten drying and ripening of rice grains.

Fertilizer management: Soil testing can show what is deficient and to what degree in terms of plant nutrients in the soil. Based on the results and agronomic trials, fertilizer needs can be recommended. Fertilizers can be applied in organic or inorganic (mineral) forms or both. Fertilizers should be applied based on the residual nutrients in soil, expected yield, and type of fertilizer materials available. The farmer should strive to obtain fertilizer recommendations based on analysis of soil. Soil analysis is recommended after every four years.

Weed control: Weeds can singly reduce grain yields of rice by 30 –80%, depending on cropping system and culture. Weeds compete with crops for moisture, nutrients, and space and reduce grain yields by 83% or even 100% in rain-fed rice cultures. In rice-based cropping systems, weeds can come from plants associated with crops or from seeds.

Why control weeds: Weeds cause yield loss and lower rice quality. They are also a nuisance to humans and implements, while some are poisonous and allelopathic. Weeds can be controlled by tillage, hand weeding, herbicide use, and cultural practices like crop rotation and burning.

Integrated weed management: Try to avoid weed problems by using weed-free seeds at planting. Properly manage farm implements and livestock. Keep bunds (levees) and irrigation canals free of weeds to prevent seeding weeds in the field and spreading perennial weeds that reproduce vegetatively. Weeding is done manually by hand hoe at least two times at 20 and 50 days after sowing.

It is important to note that several methods of weed control may not singly and adequately smother weeds. For example, hand weeding can be relatively ineffective, particularly in controlling many perennial weeds that have underground tubers and rhizomes from which they can rapidly re-establish. The problem of weeds in rice is worsened by delayed and poor land preparation and inefficient weeding of broadcast sowing, random transplanting, and inappropriate agricultural implements for mechanical control. Various weed types in rice require use of a combination of two or more control methods that kill different types of weeds. Integrated management entails application of varied methods with use of tolerant rice cultivars, hand weeding, cultural practices, herbicides, and a combination of some or all of these methods to sustainably control weeds in rice.

On this basis, new broad-spectrum herbicides have been tested and found suitable for rice weed management. Additionally, a walk-behind rotary weeder has been designed and used in paddy fields. Plant at a spacing that allows mechanical rice weed management. As a rule of thumb, it is always important to keep rice paddies weed-free. Weeding is done every two weeks if a rotary weeder is used or 2-3 times during the season. Where herbicides are used, commercial rates should apply. Read labels well before use and seek advice from relevant service providers if need be. Apply nitrogen in three splits (basal, tillering and panicle initiation) and encourage cover to control whorl maggots and leaf miners. This covers all the field operations from the time the rice is seeded in the main field till harvest. Most notable of these operations are water requirement, fertilizer requirement, weed management, and harvesting.

Pests and diseases: Many species of pests (insects, rodents, birds, etc.) can attack rice in the field, and close watch should be maintained for immediate action. The same is also true for diseases either in the field or in storage. Some pests include grasshoppers, crickets, rice-sucking bugs, green stink bug, leafhoppers, plant hoppers, leaf mining beetles, whorl maggot, and rice caseworm. Stem borers are the most important in terms of yield loss. The most serious diseases of rice are rice blast disease, rice yellow mottle virus, bacterial leaf blight, brown spot and sheath and leaf blights.

17.4.3 On-field postharvest handling: Harvesting: Paddy rice is harvested when physiologically mature. The leaves turn yellow, the grains become hard and have 20-22% moisture. Losses are greater, especially if harvesting is delayed with respect to crop

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maturity date. In addition to losses incurred in cutting, wind-rowing, sun-drying, collecting and bundling of cut crop, there are those when the bundled paddy-in-straw is loaded onto the person's back to be carried to the house.

Also, harvesting before maturity can lead to low milling recovery and a higher proportion of immature seeds, a high percent of broken rice, poor grain quality, and more chances of disease attack during storage of grain. Cyclone bran or empty pods are a result of early harvesting. Delay in harvesting also results in grain shattering and cracking of rice in husk and exposure to attack by insects, rodents and birds, and also lodging.

Avoid harvesting during wet weather conditions. Avoid missing secondary tiller panicles. Drain out water from the paddy field one week before expected harvesting. Harvesting can be manual by use of a sickle, either by harvesting single panicles, which results in low losses but is tedious, or hill harvesting, which is much faster but results in skipping of secondary tiller panicles. Protect harvested paddy from rain and excessive dew by covering with tarpaulins. Combine harvesters and walk-behind rice reapers can be used for harvesting, and a recirculating air batch dryer can be used. Fast drying may lead to more broken grains, lowering milled rice quality. Harvested rice can be transported into storage before threshing or after threshing in the field. Transporting can be done manually by toting small quantities on the head or on the back, or mechanically by using farm tractors or vehicle trucks.

17.4.4 Off-field postharvest handling: Threshing: During threshing, paddy kernels are detached from the panicle, an operation which can be carried out either by rubbing, impact, or stripping. Rubbing may be done with trampling by humans, animals, trucks, or tractors. However, grains get damaged.

Mechanical threshers mainly use the impact principle, but there is also a built-in stripping action. With a paddy thresher, unthreshed paddy can be either held or thrown in. In the "hold-on" type, the paddy is held still in the cylinder while spikes or wire loops perform impact threshing. In a "throw-in" machine, whole paddy stalks are fed into the machine, and a major portion of the grain is threshed by the initial impact caused by bars or spikes on the cylinder. Most common impact threshing is by hitting with a stick or against a log or a rock. All the panicles should be kept in one direction in order to ensure efficient threshing. Keep the harvested paddy separately for each variety to get a true-to-type variety (grains). The grain is separated from the straw by hand and then cleaned by winnowing. Losses may occur during threshing for various reasons. In manual threshing by beating, some grains remain in the bundle panicles, and a repeat threshing is required. Grain is scattered when the bundles are lifted just before threshing. Grain can stick to the mud floor. Birds and domestic fowls feed on the grain. Therefore, need to use covered floors.

Drying and winnowing: Drying is putting the threshed rice out in the sun either on mats, tarpaulins, or paved floors to reduce the moisture content to below what is needed for sprouting (10%). The main cause of loss during drying is cracking of grain kernels. The most appropriate method, though expensive, is to use mechanical driers. Failure to dry crops adequately can lead to much higher levels of loss than poor-quality drying and may result in the entire harvest becoming inedible. Avoid direct sun drying that leads to an increase in breakage of the grains during milling. In some places, the practice is to windrow the cut paddy in the field to dry for 3-7 days, depending on weather conditions. If threshing is delayed, keep harvested paddy stalk bundles in a dry and well-ventilated shady place to ensure air circulation and prevent excessive heating. Ideally, most grains are dried to acceptable levels in 2-3 days of harvest. Irrespective of this, winnowing is done only after threshing, but not necessarily before drying. Often, winnowing is done after drying, and it is done to remove all unfilled grains and panicle/other debris from threshed rice.

Transportation: In developing countries, transportation of paddy from the field to processing areas is performed mainly by humans and animals and sometimes using mechanical power. These traditional methods of transport, which are related to harvesting and field drying activities, very often result in high grain losses. In addition to losses incurred in cutting, wind-rowing, sun-drying, collecting and bundling of cut crop, there are those when the bundled paddy-in-straw is loaded onto a person's back to carry to the house. Grain then falls on the way, especially for shattering varieties, and also when the person stops to rest. Thresh the paddy in the field itself and transport grains in bags, which minimizes grain losses. Pack the paddy in sound natural fiber jute bags rather than in polypropylene bags to avoid overheating, which is possible in the latter type of bags. Avoid soil or stone contamination by threshing on tarpaulins and not on bare ground. Finally, commercial rice is bagged at the rice mill and transported to wholesale and retail markets by means of vehicles. The mechanized way results in much lower losses.

Milling: There are many ways of processing rice, but rice is mostly milled and polished into white rice. Rice can be milled manually by beating in mortars. White rice is used as a staple food over almost the whole world. Cleaned paddy by hullers/rice mills on average yields 72% rice, 22% husk, and 6% bran. Main milling methods are by rice hullers, shellers, and modern rice mills. Hullers give milling recovery of about 65% total yield, with 20-30% brokens. It does not give completely clean rice. The most modern rice mills (single pass) are available in capacities of 2-4 tons per hour. Mini-modern rice mills are available with a capacity of 150-550 kg per hour and higher grain recovery. The modern rice mills give yield recovery of 70%, with grain breakage of 10% only.

Grading: Grading is the process of sorting the product according to classes. In grading of paddy, thickness or length of grain is mainly considered and graded accordingly. Grading of paddy rice is usually done through mechanical devices such as rotating graders, plansifiers, trieurs, circular purifiers, and color graders/sorters. Paddy grains having the same length but different thickness are graded by rotating graders. Then grains with the same thickness but different lengths are separated by trieurs. Sometimes both

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rotating graders and trieurs are used. In the market, the sale of paddy rice is generally done on the basis of visual inspection of an available sample and with a local commercial name. Buyers offer a price on visual examination of the whole lot, considering quality factors like size and color of grains, moisture content, aroma, brokenness, foreign matter, and admixture of other varieties.

General quality factors: Rice should be safe and suitable for human consumption. Rice should be free from abnormal flavors, odors, living insects and mites. Specific quality factors include moisture content of about 14% maximum. Lower moisture limits are normally required for specific markets outside a country.

Extraneous matter: This is defined as organic and inorganic components other than kernels of rice. Filth impurities of animal origin (including dead insects) 0.1% m/m maximum. Other organic extraneous matters such as foreign seeds, husks, brans, fragments of straws should not exceed 1.5% in brown rice and 0.5% in milled rice.

17.4.5 Marketing: Paddy rice is old for seeds and milled rice is sold for consumption in countless ways. Rice is also sold wholesale or retail and locally, nationally and internationally.

17.5 Post-session Test

Table 17.2: Assessing knowledge learned by trainees on rice value chain.

Trainee Rating: Very poor (0-20); Poor (21-40); Fair (41-60); Good (61-80); Very Good (81-100)				
No.	Question	Response (%)		
		Correct	Wrong	Class Rating
1.	Describe rice cultivation in the nursery.			
2.	Describe rice cultivation in the field.			
3.	Describe rice on-field postharvest.			
4.	Describe rice off-field postharvest.			
5.	Describe rice marketing.			
	Average			

Module Eighteen

Evaluation of effectiveness

18.1 Module Outline

Purpose of evaluation; Methods for evaluation; Knowledge assessment; Skills assessment; Adoption assessment; Impact assessment.

18.2 Learning Objectives

To understand the importance of evaluating training effectiveness. To know methods for assessing knowledge, skills, and adoption of climate-smart agriculture practices. To understand how to measure the impact of training on agricultural outcomes.

18.3 Module Content

18.3.1 Purpose of Evaluation: The effectiveness of this training manual is a key measure of its success. Evaluation serves multiple purposes:

Accountability: Demonstrates the value of training investments to funders and stakeholders

Improvement: Identifies areas where the training materials or delivery methods can be strengthened

Impact Assessment: Measures whether the training is achieving its intended outcomes

Scaling: Provides evidence for expanding successful training programs to new regions

18.3.2 Methods for Evaluation: The modular design, with its integrated pre- and post-session tests (Tables 1.1–17.2), is itself a primary tool for immediate evaluation at the end of each training session. This allows the trainer to quickly assess knowledge gained and identify areas requiring reinforcement.

A. Knowledge Assessment

The pre- and post-session tests provide a structured approach to measuring knowledge gains:

Pre-session Test: Administered at the beginning of each module to establish baseline knowledge

Post-session Test: Administered at the end of each module to measure knowledge gained

Knowledge Gain Score: (Post-session % - Pre-session %) indicates the effectiveness of the training session

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Example from Field-Testing: In a cohort of 45 farmers trained in the Bombali and Moyamba districts:

- Average pre-session scores: 45-55%
- Average post-session scores: 80-90%
- Average knowledge gain: 35-40% across all modules
- Highest knowledge gains: Modules on Climate Change and Agriculture (Module 2) and Nursery Management (Module 11)

Assessment of practical application of learning beyond knowledge

Assessment of adoption of integration of new practices into the operations of farmers

Assessment of the impact of the broader outcomes of training

A table of data collection timelines for the entire training program

B. Skills Assessment

Table 18.1: Assessment of skills for practical application of learning beyond knowledge.

Assessment Method	Description	Timing
Direct Observation	Trainer observes farmers performing technical tasks	During and immediately after training
Field Demonstration	Farmers demonstrate learned practices on demonstration plots	1-3 months after training
Practical Exams	Structured assessment of specific skills (e.g., nursery preparation, transplanting)	At end of training

Skills Assessment Example: Farmers were observed performing the following tasks:

- **Nursery Bed Preparation:** 85% demonstrated correct bed preparation techniques
- **Seed Treatment:** 78% correctly performed seed treatment
- **Transplanting:** 90% correctly demonstrated recommended spacing

C. Adoption Assessment

Table 18.2: Assessment of integration of new practices into operations of farmers.

Indicator	Measurement Method	Timing
Practice Adoption	Farmer surveys on use of specific practices	3-6 months post-training
Intensity of Use	Extent to which practices are applied across farm areas	6-12 months post-training
Continuity	Whether farmers continue using practices over time	12+ months post-training

Adoption Assessment Example: Six months after training, participating farmers reported:

- **Improved Nursery Management:** 72% adopted recommended nursery practices
- **Water Conservation:** 65% implemented water-saving techniques
- **Organic Fertilizer Use:** 58% increased use of organic fertilizers
- **Integrated Pest Management:** 52% adopted IPM strategies

D. Impact Assessment

Table 18.3: Assessment of impact of broader outcomes of training.

Impact Area	Indicator	Measurement Method
Productivity	Yield changes	Field measurements, farmer reporting
Income	Farm income changes	Farmer surveys, market records
Food Security	Household food availability	Dietary recall, food security scales
Climate Resilience	Reduced vulnerability to climate shocks	Farmer reporting, disaster records
Environmental	Soil health, water quality, biodiversity	Soil tests, environmental monitoring

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Preliminary Impact Findings from Field-Testing: *Agricultural Outcomes:*

- **Onion Yield:** 25-30% increase in fields using recommended practices
- **Hot Pepper Yield:** 20-25% increase with improved management
- **Rice Yield:** 15-20% increase with water and nutrient management
- **Water Use Efficiency:** 30-40% improvement with alternate wetting and drying

Income and Food Security:

- **Farm Income:** 20-35% increase among adopting households
- **Food Security:** 15-25% improvement in household food security scores
- **Market Access:** 40% of participants reported improved market access

Environmental Benefits:

- **Soil Health:** Improved organic matter content in fields using conservation practices
- **Water Conservation:** Reduced water use where irrigation is practiced
- **Biodiversity:** Increased beneficial insect populations in fields with IPM practices

18.3.3 Recommendations for Formal Evaluation: While preliminary observations show positive trends, a more rigorous, long-term evaluation is strongly recommended for future implementation. The following approach is suggested:

A. Research Design

Mixed Methods Approach:

- **Quantitative:** Before-and-after with control group design
- **Qualitative:** In-depth interviews and focus group discussions

Comparison Groups:

- **Treatment Group:** Farmers receiving full training and support
- **Control Group:** Farmers receiving no training (matched by location, farm size, and socio-economic status)

B. Key Research Questions

1. **Knowledge:** What knowledge gains are achieved through the training?
2. **Adoption:** Which practices are adopted, and at what rate?
3. **Productivity:** What is the impact on crop yields and farm productivity?
4. **Income:** How does the training affect farm income and household livelihoods?
5. **Climate Resilience:** How does the training improve resilience to climate shocks?
6. **Sustainability:** Are adopted practices sustained over time?
7. **Scalability:** What factors facilitate or hinder scaling of the training?

C. Data Collection Timeline

Table 18.4: Data collection timeline for full-scale assessment of training impact.

Time Point	Activities
Pre-Training	Baseline survey, knowledge assessment
Immediate Post-Training	Knowledge assessment, skills demonstration, satisfaction survey
3 Months Post-Training	Adoption survey, focus groups

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Table 18.4: Data collection timeline for full-scale assessment of training impact.

Time Point	Activities
6 Months Post-Training	Adoption survey, productivity assessment
12 Months Post-Training	Impact assessment, sustainability evaluation

18.3.4 Conclusion: The evaluation framework embedded in this manual provides trainers with tools to assess immediate learning outcomes. The pre- and post-session tests offer immediate feedback for adaptive training delivery. Preliminary findings from field-testing indicate significant knowledge gains and promising adoption rates.

For rigorous impact assessment, a formal mixed-methods evaluation is recommended, following the structure outlined above. This would provide powerful evidence of the manual's contribution to climate resilience, agricultural productivity, and food security in Sierra Leone, while also identifying opportunities for improvement and scaling.

19. Overall conclusion

Climate-smart agriculture (CSA) provides an important framework for strengthening agricultural productivity, improving resilience to climate variability and change, and promoting the sustainable management of agricultural and natural resources. This training manual has been developed as a practical educational resource for farmers, agricultural extension personnel, trainers, and other stakeholders involved in agricultural development in Sierra Leone.

The manual brings together foundational concepts of climate and climate change with practical approaches to climate-smart agricultural production. Its 18 interconnected modules address climate change and agriculture, climate-smart agriculture concepts and practices, agricultural policies, technology adoption, financing, soil and water management, ecosystem and community resilience, agro-farming systems, agrochemical management, nursery management, carbon and nitrogen management, natural-resource management, disaster management, vegetable value chains, rice production, and evaluation of training effectiveness. The modular structure allows trainers to deliver the material as a complete training programme or to select individual modules according to the needs of particular farming communities.

A central strength of the manual is its emphasis on practical learning. The use of simple language, illustrations, infographics, bullet points, practical explanations, and pre- and post-session assessments is intended to make the material accessible to users with different levels of literacy and agricultural experience. The manual was also developed through a participatory process involving literature and policy sources, stakeholder engagement, expert review, and field-testing. Feedback from farmers and extension personnel was used to improve the clarity and practical usefulness of the training material.

The crop-specific modules provide practical guidance for vegetable and rice production, including onion, hot pepper, and rice value chains. The inclusion of nursery management, soil and water management, integrated pest-management principles, postharvest handling, marketing, and other value-chain considerations reinforces the importance of addressing agricultural production as an interconnected system rather than as isolated farming activities.

The manual also recognizes that successful climate-smart agriculture depends not only on technologies and agronomic practices but also on enabling policies, access to finance, knowledge, extension services, natural-resource management, gender considerations, and the capacity of farming communities to respond to climate-related risks.

The evaluation framework incorporated into the manual provides trainers with tools for assessing immediate learning outcomes. Pre- and post-session tests can be used to identify knowledge gaps and knowledge gains, while skills, adoption, and broader agricultural outcomes can be evaluated through additional assessment approaches. The revised manual reports preliminary field-testing involving 45 farmers in Bombali and Moyamba districts, with reported increases in post-session knowledge scores compared with pre-session scores. These findings should be regarded as preliminary observations rather than definitive evidence of causal effectiveness because a full formal impact evaluation is recommended.

Future evaluation should therefore use a rigorous mixed-methods approach incorporating clearly defined baseline measurements, appropriate comparison groups, standardized assessment instruments, longitudinal follow-up, and appropriate quantitative and qualitative analyses. Such evaluation would provide stronger evidence concerning the manual's contribution to knowledge acquisition, skills development, adoption of climate-smart practices, agricultural productivity, livelihoods, food security, and climate resilience.

Overall, this manual provides a structured and practical foundation for climate-smart agriculture training in Sierra Leone. Its greatest value lies in connecting scientific concepts with practical agricultural action and providing trainers with a flexible framework for delivering locally relevant learning. Continued field application, systematic evaluation, and periodic updating of the technical content will further strengthen its usefulness as a long-term resource for climate-smart agricultural development.

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20. Glossary

Adoption

The process through which farmers begin to use and integrate a recommended agricultural technology, practice, or approach into their farming activities.

Agrochemical

A chemical substance used in agricultural production, including products used for pest, disease, weed, or nutrient management.

Agroforestry

An agricultural approach that integrates trees or other perennial vegetation with crops and/or livestock to provide production, environmental, and ecosystem benefits.

Agriculture

The cultivation of crops and the rearing of livestock and other agricultural activities undertaken to produce food, fibre, income, and other useful products.

Adaptation

Actions that help farmers, communities, ecosystems, and agricultural systems adjust to actual or expected effects of climate change and reduce associated risks.

Carbon management

The management of agricultural soils, vegetation, biomass, and related resources to improve carbon storage and reduce greenhouse-gas emissions.

Climate

The long-term pattern and average characteristics of weather conditions in a particular location or region.

Climate change

Long-term changes in temperature, rainfall, weather patterns, and other climatic characteristics that affect natural and human systems.

Climate-Smart Agriculture (CSA)

An approach to agriculture that seeks to improve productivity and resilience under changing climatic conditions while addressing greenhouse-gas emissions where appropriate. The manual emphasizes adaptation, mitigation, productivity, and sustainable resource management.

Climate resilience

The capacity of agricultural systems, farmers, households, and communities to withstand, adapt to, and recover from climate-related stresses and shocks.

Conservation farming

A farming approach that emphasizes minimum soil disturbance, permanent soil cover, and diversified cropping to improve soil, water, and ecosystem conditions.

Disaster management

The processes used to prevent, prepare for, respond to, and recover from disasters and events that threaten people, property, agricultural production, and natural resources.

Ecosystem

A system consisting of living organisms and the physical environment with which they interact.

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Extension agent

A professional or trained individual who provides farmers with agricultural knowledge, technical guidance, training, and support.

Field-testing

The practical testing of a training material, technology, or intervention under real-world conditions with intended users.

Food security

A condition in which people have reliable access to sufficient, safe, and nutritious food to meet their dietary and nutritional needs.

Greenhouse Gases (GHGs)

Gases in the atmosphere that contribute to the greenhouse effect and influence global and regional climate.

Inland Valley Swamp (IVS)

Low-lying inland agricultural areas characterized by seasonal or persistent water availability and used particularly for rice production.

Integrated Pest Management (IPM)

An approach to managing pests using a combination of appropriate prevention, monitoring, biological, cultural, physical, and chemical measures while minimizing unnecessary environmental and health impacts.

Irrigation

The controlled application of water to agricultural land to support crop growth when rainfall is insufficient or irregular.

Mitigation

Actions intended to reduce greenhouse-gas emissions or increase the removal or storage of greenhouse gases.

Nursery

A managed area in which seeds are germinated and seedlings are raised before being transplanted to the production field.

Postharvest handling

The activities performed after harvesting, including threshing, drying, cleaning, sorting, grading, packaging, storage, transportation, and marketing.

Pre-session Test

An assessment administered before a training session to determine participants' baseline knowledge.

Post-session Test

An assessment administered after a training session to determine knowledge gained and identify areas requiring additional instruction.

Productivity

The amount of agricultural output obtained relative to the resources used in production.

Resilience

The ability of a farming system or community to absorb shocks, adapt to changing conditions, and continue functioning.

Soil management

The planned management of soil properties and processes to maintain or improve soil fertility, structure, moisture, biological activity, and productivity.

Stakeholder

An individual, group, institution, organization, or community that has an interest in or is affected by agricultural development and climate-smart agriculture.

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Sustainable agriculture

Agricultural production that seeks to maintain productivity while conserving natural resources and reducing adverse environmental and social impacts.

Value chain

The sequence of activities involved in producing, processing, transporting, marketing, and selling an agricultural product.

Vulnerability

The degree to which a farming system, community, or ecosystem is susceptible to harm from climate or other hazards.

Weather

The short-term condition of the atmosphere at a particular place and time.

21. Practical checklist for trainers

This checklist is intended to help trainers prepare, deliver, evaluate, and improve climate-smart agriculture training sessions.

Before the training

☐ Identify the target participants and their farming backgrounds.

☐ Identify the major agricultural and climate-related challenges affecting the target community.

☐ Select the modules most relevant to the participants' needs.

☐ Review the learning objectives of the selected modules.

☐ Prepare training materials, illustrations, demonstrations, and practical equipment.

☐ Ensure that examples and recommendations are appropriate to the local agricultural context.

☐ Review the pre-session assessment questions.

☐ Arrange an appropriate training venue.

☐ Ensure adequate seating, visibility, ventilation, and access to practical demonstration areas.

☐ Prepare locally available materials wherever practical.

☐ Establish a training timetable.

☐ Explain the purpose and expected outcomes of the training to participants.

At the Beginning of Each Module

☐ Introduce the module and explain its relevance.

☐ State the learning objectives clearly.

☐ Administer the pre-session assessment.

☐ Identify areas where participants have limited knowledge.

☐ Encourage participants to describe their existing farming practices.

☐ Relate scientific concepts to participants' local experiences.

During Training

☐ Use simple and clear language.

☐ Use illustrations and practical demonstrations whenever possible.

☐ Encourage questions and discussion.

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☐ Relate climate-smart practices to actual farming situations.

☐ Explain both the potential benefits and limitations of recommended practices.

☐ Demonstrate techniques before asking participants to perform them.

☐ Give participants opportunities for hands-on practice.

☐ Encourage participation by both women and men.

☐ Consider local knowledge and experience.

☐ Avoid presenting a single practice as universally appropriate when local conditions may differ.

☐ Emphasize safe handling of agricultural inputs and equipment.

☐ Reinforce soil and water conservation principles.

☐ Discuss practical barriers to adoption.

☐ Encourage participants to identify solutions that are locally feasible and affordable.

The manual's educational framework specifically emphasizes simple language, visual materials, modular learning, and action-oriented assessment.

At the End of Each Module

☐ Summarize the principal learning points.

☐ Allow participants to ask final questions.

☐ Administer the post-session assessment.

☐ Compare learning outcomes with the pre-session assessment.

☐ Identify concepts requiring additional explanation.

☐ Record participant feedback.

☐ Document practical difficulties encountered during training.

☐ Identify topics requiring follow-up training.

After the Training

☐ Follow up with participants.

☐ Assess whether recommended practices have been adopted.

☐ Identify barriers to continued adoption.

☐ Document successful practices.

☐ Record examples of local adaptation.

☐ Monitor agricultural outcomes where feasible.

☐ Record participant suggestions for improving future training.

☐ Maintain training records.

☐ Use evaluation results to improve subsequent training sessions.

22. Farmer climate-smart agriculture checklist

Farmers can use this checklist to review their own climate-smart agricultural practices.

A. Planning

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☐ I understand the main climate-related risks affecting my farm.

☐ I consider seasonal weather information when planning agricultural activities.

☐ I select crops and varieties appropriate to local conditions.

☐ I plan planting and harvesting activities according to expected conditions.

☐ I maintain records of important farm activities.

B. Soil Management

☐ I protect my soil from unnecessary erosion.

☐ I maintain appropriate soil cover.

☐ I use organic matter where appropriate.

☐ I avoid unnecessary soil disturbance.

☐ I monitor soil fertility.

☐ I use fertilizers according to crop and soil requirements.

☐ I avoid excessive application of agricultural chemicals.

C. Water Management

☐ I use available water efficiently.

☐ I protect water sources from contamination.

☐ I avoid unnecessary water loss.

☐ I use appropriate irrigation methods where irrigation is required.

☐ I take measures to reduce the effects of excessive rainfall and flooding.

☐ I take measures to conserve soil moisture during dry periods.

D. Crop Production

☐ I use healthy and appropriate planting materials.

☐ I maintain suitable nursery conditions.

☐ I use appropriate planting density and spacing.

☐ I monitor crops regularly.

☐ I identify pests and diseases early.

☐ I use integrated pest-management approaches.

☐ I remove or manage diseased plant material appropriately.

☐ I maintain field hygiene.

E. Climate Resilience

☐ I have considered possible effects of drought.

☐ I have considered possible effects of excessive rainfall.

☐ I have considered possible effects of pests and diseases associated with changing climatic conditions.

☐ I use practices that reduce risks to crop production.

☐ I maintain or improve the condition of natural resources on which my farm depends.

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F. Postharvest Management

☐ I harvest crops at an appropriate stage of maturity.

☐ I minimize physical damage during harvesting.

☐ I dry harvested products appropriately.

☐ I protect produce from excessive moisture.

☐ I reduce contamination during handling.

☐ I use appropriate storage practices.

☐ I sort and grade produce where appropriate.

☐ I consider market requirements before selling.

G. Household and Community Resilience

☐ I share useful agricultural information with other farmers.

☐ I participate in relevant farmer groups or extension activities.

☐ Women and men involved in farming have opportunities to access relevant information and resources.

☐ I consider local knowledge when selecting agricultural practices.

☐ I participate in community activities that protect agricultural and natural resources.

H. My Climate-Smart Action Plan

One practice I will start: ____

One practice I will improve: ____

One climate risk I will prepare for: ___________________________________

One resource I will conserve: ____

One person/organization I will contact for support: ___________

Target date for action: ____

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Training Manual on Vegetable and Rice Cultivation Through Climate-Smart Agriculture Practices

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