



TRAINING MANUAL

CLIMATE-SMART AGRICULTURE PRACTICES FOR
FOOD NUTRITION AND WATER SECURITY FOR
POTATO AND MAIZE CULTURE

CLIMATE-SMART AGRICULTURAL PRACTICES FOR FOOD, NUTRITION AND WATER SECURITY

TRAINING - MANUAL

**A REFERENCE MANUAL FOR AGRICULTURAL OFFICIALS, DEVELOPMENT
SECTOR PRACTITIONERS AND FARMERS
PUNJAB, PAKISTAN**

ACKNOWLEDGEMENTS

This training manual on “Climate Smart agricultural practices for food, nutrition and water security” was prepared by the CARE Internationals, FDO and Himmat consulting private limited as an output of the project entitled as “Climate Smart Agricultural Practices for Food, Nutrition and Water Security” founded by the project from CARE Internationals that is entitled as “She feeds the world (SFtW)”.

The project has developed and tested climate smart agricultural practices in the different regions of the Punjab, Pakistan. The practices and group exercises included in this manual are taken from training materials constructed by FDO, the partner organization and consultants during the implementation of the project and have been tested in training workshop with farmers in the districts of Punjab.

The development of the manual has been coordinated and guidance of Mr. Waleed Ahmad, Climate Smart Agriculture Expert CARE, Pakistan. A number of FDO experts provided valuable contributions including the current and latest practices of climate smart agriculture in that particular region. I highly appreciate the dedicated efforts of Dr. M. Habib-Ur-Rahman, CSA author and team leader and Dr. Idrees Haider Co Author and trainers for drafting of this training manuals in Vehari and Okara district. Last but not least, I am thankful to CIP management for giving HCPL to conduct this strategic assignment.

Himatullah
CEO,
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FOREWORD

I am delighted to record the generous response extended by the CARE international Pakistan's through the project "She feeds the World (SFtW)" and "Climate Smart agricultural practices for food, nutrition and water security". Climate smart agricultural technologies and practices for the arid region of the Punjab, Pakistan.

This training manual is designed to educate farming communities and other stakeholders representing the governmental and non-governmental organizations working in these areas on climate smart agricultural practices. These efforts are mainly objected to the ecosystems to mitigate the negative impacts of climatic challenges affecting the sustainability of the forest and agroecosystem in this context. I hope that well planned partnerships of all sectors will help achieve these goals. My wish is that the training program scheduled to begin in due course would help remodel the ecosystems of the Vehari and Okara districts while enhancing the livelihoods of the farming communities and the work environments of the respective service providers in those areas.

EXECUTIVE SUMMARY

Climate change is a global phenomenon that disrupts socio-ecological systems and biodiversity at all scales. Common observations of climate change are more pronounced in recent years (heatwaves, drought, floods, biodiversity and soil health losses, changes in seasons etc.). Climate change is mainly caused by Green House Gas (GHG) emissions from various practices and sectors including agricultural systems. To minimize the effect of climate change and reduce the emission of GHGs emissions for the agricultural sector the FAO introduced the concept of climate smart agriculture (CSA). CSA has three basic pillars i.e. sustainable production, climate change adaptation, and mitigation of GHG emissions. CSA covers those practices which can effectively, efficiently, and sustainably improve agricultural production, increase the resilience of agricultural production systems to climate change, and where possible reduce GHG emissions from the agriculture sector.

This training manual is particularly designed to enhance the awareness and understanding of climate change and the practice of CSA for extension workers, Farmer Development Organisation staff, and small to medium farmers. The manual includes interdisciplinary presentation of science and policies related to climate, environment, agriculture, and socio-economics, with a focus on local practices and technologies to develop climate resilience in the agricultural production systems of Pakistan.

Participants are provided with understandable knowledge about climate change, its causes, and its effects on socio-ecological systems and biodiversity. To make knowledge sharing easy this training manual organized under three basic modules;

MODULE-A: CLIMATE CHANGE AND ITS EFFECTS

MODULE- B: CLIMATE CHANGE, AGRICULTURE, AND FOOD SECURITY

MODULE-C: CLIMATE SMART AGRICULTURE (THE MOST IMPORTANT) LOCAL CSA PRACTICES FOR MAIZE AND POTATO PRODUCTION.

Each module is further divided into sub sections to make it easy to understand, with key objectives and key questions in each module to help participants learn. Key questions include: What is climate change and what are its causes and indicators? How climate change affects agricultural systems through, crop production, gender dynamics, agriculture value chain and food security? What can be done to support agricultural producers, gender dynamics, and other stakeholders to adapt to the new environmental and climatic conditions? What are practical solutions and interventions that agricultural producers and other stakeholders can put into practice for sustainable production from agriculture (crops)? What types of changes will be needed by agricultural producer unit, farmers, and other stakeholders to introduce climate-smart agriculture practices and technologies to reduce GHG emissions?



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LIST OF ACRONYMS

AEZ	Agro-Ecological Zone
AFOLU	Agriculture, Forestry and Other Land Use
CH4	Methane
CC	Climate Change
CA	Conservation Agriculture
CI	Climate Information
CO2	Carbon Dioxide
CSA	Climate-Smart Agriculture
CCA	Climate Change Adaptation
ENSO	El Niño Southern Oscillation
FAO	Food and Agriculture Organization of the UN
F-gases	Fluorinated gases
FYM	Farmyard Manure
GHG	Greenhouse Gas
GWP	Global Warming Potential
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land Use, Land-Use Change and Forestry
PMD	Pakistan Meteorological Department
N2O	Nitrous oxide
NO2	Nitrogen dioxide
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
WMO	World Meteorological Organization



INTRODUCTION

Population increase, urbanization, and nutritional changes are putting enormous strain on agricultural systems, especially in developing countries like Pakistan. Prediction of 2050 by FAO that 50% more food will be required to fulfill the demands of ever-increasing population under current challenges of financial constraints, food dietary habits and globally changing climatic scenarios (Alexandrite's and Bruinsma, 2019). Climate change's consequences and challenges will also vary across the regions and countries and livelihood and socio-economic conditions will be affected in a different pattern depending on their exposure to climate extremes , system resilience and adaptability to climate change.

Changes and fluctuations in normal climatic patterns due to climate change leads to different challenges in different regions across the country as certain regions are more likely to be more drought prone and warmers while at the same time others will get more erratic and intense rainfalls that leads to sever challenges for sustainable crop production in Pakistan (Rahman et al., 2018). Rising temperatures will result in shorter growing seasons and reduce food yields in the bulk of the country, while changed rainfall patterns would benefit drier and dry climate regions. This increased variability modifies the conditions under which agriculture is conducted, necessitating context and site-specific methods and responses to these global and regional changes, including variance in climate patterns (Rahman et al., 2022). Changes in normal climatic conditions endanger current agricultural and food production systems and livelihood of the farmers particularly those located in most climate prone regions with weaker adaptation and more vulnerability to climate change. Furthermore, to develop resilience in current vulnerable agricultural and food production systems, it is essential to cope with these challenges while also reducing the GHGs emissions as a climate change mitigation measure. As it is estimated by IPCC that 24 percent of global GHGs emissions is from agriculture and deforestation (IPCC, 2014a).

Increased agricultural output in an environmentally friendly way to meet rising global demand, while also adapting to a changing climate and reducing GHG emissions in the environment represent three interlinked difficulties that the farming and food industries must solve in the coming decades.

To help overcome these climatic challenges and achieve sustainable food production FAO introduced Climate Smart Agriculture (CSA) in 2010. Climate smart agriculture is an innovative concept that links three main pillars (adaptation, mitigation and sustainability) within agriculture systems at multiple scales from field to regional scale, and even nationally and globally to cope with climate change and development of sustainable production systems.

This training manual is particularly designed for the capacity building of extension agents, implementing partners, Farmer development organization (FDO) agents, and small to medium farmers most affected by climate change and its impacts.

It will enhance their awareness and understanding, through an interdisciplinary presentation of science and policies related to climate, environment, agriculture, and socio-economics, with a focus on local practices and technologies to develop climate resilience in the agricultural production systems of Pakistan. This manual will cover a diversity of CSA themes, particularly the local climate smart and environment friendly practices, and it will also facilitate the farmers to develop their own local climate smart production plans for rural households and communities in Pakistan under changing climate scenarios.

It should be emphasized that climate-smart agricultural practices are site and even household specific: there is not one approach for every area, or even a group of solutions, that can address all scenarios and concerns. Nonetheless, we can establish some broad recommendations to follow, with examples that readers can adapt to their own situations.

STRUCTURE OF THE TRAINING MANUAL

Manual on this training is arranged in two parts. The first step is to provide a solid theoretical foundation of information on many aspects of climate and agriculture to understand the fundamental concepts and knowledge.

The second step is for learners to apply their knowledge from practical examples, exercises, activities, and group work tasks.

FOLD 01. The climate specialist will transfer knowledge through an interactive session and a presentation. Give an overview to the participants, either by a climate specialist who will provide background information or by going directly to examples and exercises.

FOLD 02. Practical tasks in where people or teams of participants discuss a topic or try to solve an issue before reporting back to the plenary. These exercises are designed to draw on the participant' own knowledge and experience. Participants in the training session are likely to have substantial knowledge and experience with farming in area. Participants apply this knowledge as much as possible.

This training document is intended to be adaptable to different contexts. The content should be tailored to the needs of those taking part and the circumstances in your location. Where possible, examples should be relevant to local conditions. The stated time for the exercises is simply a rough estimation and may be changed. Feel free to adapt the tasks or create your own, substituting the examples with ones that will be more applicable to your audience's experiences and situations.

DURATION OF THE TRAINING

This handbook has a flexible framework, so the duration of training components can be adjusted, ranging from one day for certain parts to four days for the entire training course. The duration for every session is suggestive and can be changed based on the trainers' demands and the conditions of the participants. This training handbook is intended to assist workshop participants in developing climate-smart agriculture instructions for practical implementations.

INDEPENDENT LEARNING

This document is intended to assist the design of group instruction in a workshop sitting with 30-40 people, it can also be used for self-directed learning on climate-smart agriculture. Participants can review the introduction materials for each session before proceeding with the exercises on their own. Think about all of them as if you were in a group. Many of the benefits of exercises stem from discussions and gaining knowledge from people with diverse backgrounds.

NOTE ON TERMINOLOGY!

The topic of climate change is saturated with technical terms. We attempted to avoid using them whenever feasible and explained the terminology we did use. Agriculture is a broad term that refers to all agricultural activities, although it mostly concerns crops. Agricultural producers, such as farmers, pastoralists, and foresters, comprise both men and women.

MODULE A

UNDERSTANDINGS OF CLIMATE CHANGE

The initial section of this training manual provides a background to climate change science, which is required to grasp the overall notion of climate change. It seeks to improve the knowledge and understanding of participants about climate change, including its causes, indications, and difficulties. The module also discusses how the Agroecosystem is affecting from climate change and how agricultural sectors contribute to climate change by emitting greenhouse gases through various crop management and agricultural practices.



KEY QUESTIONS

1. What is climate and climate change?
2. What is the difference between climate change and natural climate variability?
3. What are the causes of climate change?
4. How does agriculture contribute to climate change?
5. What are other sources of greenhouse gas emissions?

OBJECTIVES

After completing this module, participants will be able to:

- Explain the difference between weather and climate.
- Distinguish between climate change and climate variability.
- Describe the greenhouse effect and global warming.
- List the main causes of climate change.
- Describe the likely effects of climate change.
- Explain the effects of climate change on Agroecosystems.
- Describe how different agricultural practices contribute to greenhouse gas emissions.
- Describe the causes of global warming and how contributions to greenhouse gas emissions differ across world regions.
- Analyze the gender dimensions of climate change.
- Duration for this module
- 5 hours

SESSION 01 WHAT IS CLIMATE CHANGE?

The course teaches learners the fundamentals of climate change, distinguishing it from weather and climatic variability. The activity encourages learners to think about climate trends and recent extreme weather events in their area.

WEATHER AND CLIMATE

To fully understand whether climate change truly indicates it is necessary to distinguish between weather and climate:



WEATHER is the state of the atmosphere at a specific location and time. Rain, humidity, wind, sunshine, cloudiness, and temperature are the most prevalent components of meteorology that everyone experiences during the day, but there are also extreme events such as tornadoes, droughts, and tropical cyclones. The weather is dynamic and can vary quickly, sometimes within the same day.



CLIMATE is the set of weather conditions that persist in each place over a longer period, usually three decades (IPCC, 2021). Climate is defined by several elements, including averages over time of precipitation and temperature, as well as the kind, frequency, duration, and intensity of meteorological events like heatwaves, cold spells, hurricanes, droughts, and floods.

Climatic variation is the natural variety of the climate, that involves oscillations above and below the mean condition, among other variables. It depicts the changing weather conditions over a specific day, month, season, or year. For instance, if we take rainfall over a given period in a specific location of the world, the variability can be modest, implying that the quantity or timing of rains does not fluctuate significantly from year to year. In another place, rainfall quantity may be highly variable, ranging from much below normal to well above average year after year, with unexpected timing.

CLIMATE CHANGE AND CLIMATE VARIABILITY

The main difference between climate variability and climate change is that a trend over a time scale indicates a change in climate. While fluctuations over shorter terms of days, seasons, years or several years and in cycles is climate variability, a consistent linear trend will define climate change as patterns shift over decades. Climate change is detected when the long-term pattern of climate variability and the mean exhibit significant measurable changes. For example, on average the climate gets warmer or cooler, or wetter or drier, over decades.

CLIMATE CHANGE AND GLOBAL WARMING

The weather on Earth has always changed because of natural causes such as volcanic eruptions and variations in the earth's rotation. However, scientists have observed trends toward greater average global temperatures that are rising faster than ever seen and can't be explained by natural sources. Instead, experts conclude that this long-term warming is anthropogenic or driven by human activity.

As a result, the United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as: **"Change of climate that is attributed, directly or indirectly to human activity, that alters the composition of the global atmosphere, and that is in addition to natural climate variability observed over comparable time periods" (UNFCCC, 1992).**

According to the studies, the amounts of molecules that capture heat in the atmosphere, known as GHGs, have increased significantly since the beginning of the modern days. Temperatures are anticipated to rise by 0.3 to 4.8 degree Celsius by 2100, depending on the conditions (IPCC, 2020). The last four decades, from 1981 to 1990, 1991 to 2000, 2001 to 2010 and 2011 to 2020 have all been warmer at the earth's surface than any other decade since temperature measurements initiated.

The hottest decade ever measured was 2001-2010, and 2016 was the warmest year on document, with a 1.1 °C rise over the pre-industrial period. (WMO, 2017). Although they appear to be little changes, when compared to long-term observations of stable conditions, the difference is obvious. Long-term global warming causes climate changes on a regional and local scale, having significant implications for the planet's socioecosystems.

CLIMATE CHANGE ASSESSMENT TOOLS AND METHODS

Scientists employ a variety of methods to study how the climate evolves over time and forecast potential changes, including prediction models, emission scenarios, and climate predictions. Scientists utilize models to gain insight into the long-term implications of climate change. For example, they can model the consequences of various future climate conditions on agricultural output and population health.

Since the future circumstances are unknown, scientists frequently investigate a variety of different scenarios which are likely to unfold in the following years. Scientists use two types of tools or methods: one defined by high temperatures but no adoption of new technologies, and the other by high temperatures plus the use of new efficient agricultural technology in farmers' activities.

Climate change's future consequences include and are dependent on numerous elements, including temperature and precipitation patterns of rainfall, the potential influence of CO₂ on plant development, the incidence of pests and diseases, and other factors that might complicate simulations of agricultural productivity. However, successful simulations of these conditions provide crucial information for the development and execution of environmentally friendly agricultural strategies that reduce the negative consequences of climate change on agricultural production and people's livelihoods.

Tools. The 'Cool Farm Tool' is for the estimation of greenhouse gas emissions from different sectors, especially from the agriculture sector, and crop production process and management. For the sowing time estimation and management practices in relation to weather and climate models can be used based upon temperature, (Mean temperature – base temperature). There are some other tools as well from United states (climate indicators, pest and disease, crop yield and development, carbon footprint calculators). Crop growth models can also be used for simulation (DSSAT, APSIM, AquaCrop, Crop Grow, Epic etc.).

SESSION 02 CAUSES OF CLIMATE CHANGE

This session focuses on the underlying factors of climate change. The exercises help participants comprehend the greenhouse effect and see how different human activities influence greenhouse gas emissions.

GREENHOUSE EFFECTS

The Earth's weather and climate are driven by solar energy, which arrives in the form of ultra violet light. It heats the Earth's surface land and oceans, which then heats the atmosphere through infrared radiation. Most of that energy is reflected into space, but some remains trapped in the land, ocean, and atmosphere (Figure 1).

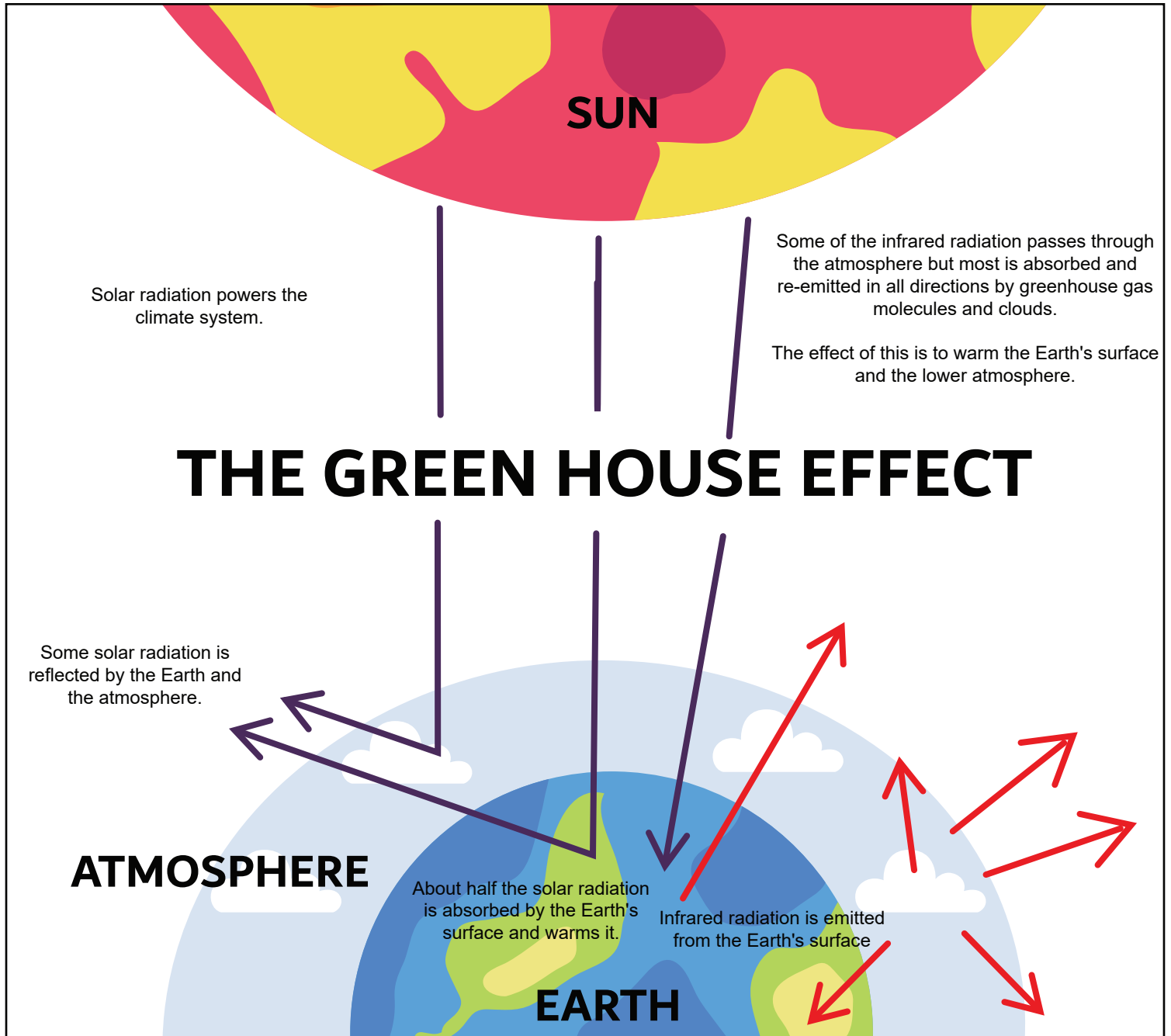


Figure 1. The phenomenon of greenhouse effect in the atmosphere

The atmosphere of the earth is primarily composed of nitrogen, oxygen, and argon, which have no effect on the climate. This also includes the traces of other gases such as water vapor, carbon dioxide, methane, and nitrous oxide, those are known as greenhouse gases due to the similarity to the glass in a greenhouse. They prevent heat from escaping in the atmosphere and atmosphere warms up day by day. The atmosphere, in turn, warms the land and oceans.

MAJOR GREENHOUSE GASES IN AGRICULTURE

There are several GHGs present in the atmosphere which are as following:

Water vapor (H₂O) is the water which evaporates from the ocean, lakes, rivers, and soil surface, transpires by plants, and is commonly perceived as humidity. Human activity has minimal direct impact on the vast amount of water vapor and clouds in the atmosphere (Coulibaly et al., 2015).

Carbon Dioxide (CO₂) Volcanoes and geysers emit carbon dioxide (CO₂) naturally. Carbon dioxide emitted by human activities such as transportation and energy production using combustion engines that burn fossil fuels including coal, mineral oil, and gas. All animals exhale it during breathing, as do plants at night when they are not photosynthesizing. It also enters the atmosphere through the breakdown of organic matter, deforestation, burning plants, and some industrial operations such as cement production.

Methane (CH₄) is released into the atmosphere by cattle, as well as bacteria in the soil and water, such as those found in flooded rice fields. It is discharged when the perennially frozen ground in mountains and arctic regions thaws, as well as when wetlands, marshes, swamps, bogs, and peatlands dry out.

Humans produce fluorinated gases (F-gases), which are then employed in freezers, air conditioning units, foaming agents, beauty products, and firefighting equipment.

Nitrous oxide (N₂O) Agriculture, including the use of organic and synthetic fertilizers, industrial operations, and the combustion of fossil fuels all produce nitrous oxide (N₂O). It is important to note that nitrous oxide is not the same as other nitrogen and oxygen compounds. N₂O (nitrous oxide) is a greenhouse gas. Motor vehicles emit pollutants such as nitric oxide (NO) and nitrogen dioxide (NO₂). They cause pulmonary difficulties, but not global warming. They are collectively referred to as NO_x.



WHAT ARE THE MAIN SOURCES OF GREENHOUSE GASES?

Anthropogenic activities: Anthropogenic activities refer to actions and processes that are carried out by humans. These activities often have an impact on the natural environment. Examples of anthropogenic activities include industrial production, mining, agriculture, transportation, and deforestation.

These activities can lead to changes in the environment, such as air and water pollution, soil degradation, and climate change. The term "anthropogenic" is often used in the context of discussing human-induced climate change. It's important to note that while some anthropogenic activities have negative impacts on the environment, others can be managed or modified to reduce their environmental impact.

Significant contribution to the emission of GHGs.

The concentration of carbon dioxide emitted by each country is determined by the nature and proportion of its primary economic activity. As a result, carbon dioxide emission shares vary by region of the world. The most recent estimates of human-caused emissions reached more than 46 billion metric tons of greenhouse gasses, measured as carbon dioxide equivalents, a 35% increase over the preceding decade (IPCC, 2014a). Electricity and heat production are the largest sources of greenhouse gas emissions worldwide, owing to the combustion of coal, oil, and natural gas. Food and Agriculture, forests, and other land-based (AFOLU) industries are the world's second-biggest emitters, accounting for approximately 24%. Other industries include business, which is responsible for 21% of total emissions; transport, which accounts for 14%; other forms of energy, which counts for 9.6%; and structures, which accounts for 6.4%.



Carbon dioxide equivalents

The effects of various greenhouse gases vary, depending on their concentration in the atmosphere, ability to alter the radiation balance, and time in the atmosphere. The IPCC (IPCC, 2014a) defines global warming potential (GWP) as a measure that "represents the combined impact of the differing periods. These substances remain in the atmosphere and how successful they are in causing radiation forcing" to compare the global warming impacts of various gases. The higher the GWP value, the greater a gas's warming effect compared to carbon dioxide over a specified period, which is usually 100 years. For example, one ton of methane is comparable to 25 tons of carbon dioxide, whereas one ton of nitrous oxide is equivalent to 298 tons of CO₂. (IPCC, 2007b).

The effect of CO₂ on climate is less than some of the other important GHGs, but due to the quantity of emissions from anthropogenic activities its effect is greatest on the climate.

Carbon dioxide's GWP is consistent across time and acts as a benchmark for comparing other gases. The greenhouse gas carbon dioxide makes up around three-quarters of all emissions, and its role in warming is increasing. It is difficult to provide only one life for carbon dioxide since it does not decay with time, instead, it moves through the Earth System. So far, the bulk of the excess has been absorbed into the oceans over decades, with the rest remaining in the environment for thousands of years. Methane is a stronger greenhouse gas than carbon dioxide, however sunlight transforms methane molecules to carbon dioxide after around 12 years. Methane has an average global warming potential of 28 over 100 years. Other gases emit more heat and remain in the atmosphere for significantly longer periods of time. Nitrous oxide lasts 121 years and has a GWP of 265, however other fluorinated gases can last thousands of years and have a GWP greater than 6500.



GROUP EXERCISES (A1 TO A3)

- A1. Understandings of climate change and climate variability
- A2. Causes of climate change
- A3. Effects of climate change

INSTRUCTIONS FOR EXERCISES AND GROUP ACTIVITIES

For each exercise participants have 1 hour to complete. The exercise is grouped base, so all the group members participate actively in their collaboration in exercises. This exercise will be beneficial for all types of people like government officials, development sector and particularly for the farmers of maize and potato. Congratulate participants on their active participation in this exercise and learn many new things about climate change and climate variability, causes, effects, and common observations related to climate change and effects on crop production and particularly the challenges being faced by the farmers in the field.

MODULE- B

CLIMATE CHANGE IMPACTS ON AGRICULTURE AND FOOD SECURITY

The purpose of this module is to investigate the links between climate change, agriculture, and food security. It does so by reviewing some of the potential effects of climate change on Agro-ecosystems and how this affects agricultural development and food security, placing vulnerable groups at danger and considering how men and women are affected differently. In the first session, the module discusses some of the potential effects of climate change on agricultural industries. The second session includes an introduction of the idea of food security as well as an explanation of why, in the absence of adequate policy interventions, climate change can be deleterious to all four dimensions of food security and nutrition in both the short and long term. Participants are asked to debate how a changing climate will affect a specific component of human activity in their community.



KEY QUESTIONS

1. How is the agriculture sector affected by climate change?
2. How is agriculture contributing to climate change?
3. What is food security and what are its dimensions?
4. Why is it important to understand the relation between climate change and food security?
5. What are the means through which climate shocks can put food security and nutrition at risk?
6. How are male and female agricultural producers affected by climate change in similar and different ways?

OBJECTIVES

After completing this module, participants will be able to:

- Identify possible effect of climate change on agriculture and food security
- Identify farmers' capabilities and vulnerabilities.
- Explain the concept of food security and its four dimensions.
- Explain the difference between short-term and long-term food security, the causes of food insecurity and measures to address.

SESSION 03 CLIMATE CHANGE AND AGRICULTURE

This session emphasizes the significance of comprehending the change of climatic conditions in agricultural output. This session describes how climate change impacted on agriculture products such as crops, animals, forests, fisheries and aquaculture, and livelihoods of human beings. It also accounts for the impact of agriculture on climate change and how agriculture contribute to both emission of GHGs and carbon sequestration in soil and biomass of the crops. Finally, it investigates the differences in greenhouse gas emissions among agricultural techniques.

UNDERSTANDING THE EFFECTS OF CLIMATE CHANGE ON AGRICULTURE AND CROP PRODUCTION

Climate change has a variety of direct and indirect impacts on plants and animals. Keeping in view the impact of climate change on ecosystems is critical for developing policy and adaption methods (Table 1). Climate change can affect Agro-ecosystems in a variety of ways, including increased variability and unpredictability of weather and climate events, such as changes in seasonal rainfall, longer dry periods, higher or lower temperatures, and heat-waves (Allen et al., 2010). Seasonal timing changes, for example, certain locations are experiencing an earlier arrival of spring, which impacts the lives of migrating animals; yet planting times and wet seasons start late or end early.

Drought influences crops at various phases of development. Harsh weather conditions i.e. heavy rains and storms, floods, droughts, and cyclones, have become more severe. Pest and disease outbreaks have increased, as have many other environmental concerns resulting from climate change.

TABLE 1. EXAMPLES OF EFFECTS OF CLIMATE CHANGE ON SEVERAL ASPECTS OF HUMAN LIFE AND ECOSYSTEMS

Natural Resources	Decline in freshwater supplies for consumption, sanitation, and irrigation; rivers, and tube wells could dry as rainfall diminishes.
	Vegetation: Agro-ecological zones vary, tree and flora range move to higher elevations.
	Wildlife: changing habitat of animals, some plants and animals migrated from moderate to higher elevations.
	Climate change is anticipated to threaten the diversity of plants and animals. This will have an influence on the environmental stability.
	Grasslands, forests, and arid regions: The areas appropriate for forests and grasslands are changing. In some areas, deserts are expanding. The risk of forest fires is rising. Other areas are growing wetter, promoting the growth of certain species.
Society and Economy	Glaciers are melting and disappearing, influencing the volume or time when river flows.
	Migration: As situations change, people must shift in order to survive. People might relocate within the country or worldwide. Those who have fled to coastal areas would very certainly be evicted again, with rising sea levels.
	Conflicts arise when people compete for basic necessities like food and water.
	Poverty: Some people are less flexible than others. Poverty rates are anticipated to rise.
	Economy: Climate change will affect businesses and the economy. It might cost 5 to 20% of the annual GDP.

THE IMPACTS OF CLIMATE CHANGE ON AGRICULTURE

Climate resilience is critical to the agricultural industry, which includes crops, cattle, forestry, fisheries, and aquaculture. Temperature increases have a wide-ranging impact on ecosystems and human activities. Melting of glaciers due to higher temperatures releases water into the oceans which when combined with the expansion of warmer water will cause rising sea levels to flood coastal areas of the rivers, particularly during high tides and storms. Furthermore, when the temperature of the sea rises then a variety of the plants, corals and animals are affected by the climate change. Some fields may become unsuitable for farming activities. The key climate-related implications for each agricultural sub-sector can be explained (IPCC, 2014b; FAO, 2016b).

Agricultural crops react differently to variations in temperatures and patterns of precipitation, and extreme weather events directly affect the production of maize and potato. In cooler regions, where low temperature is limiting crop growth and development now, an increase in temperature and carbon dioxide concentrations may boost plant growth and development of crops. However, in moderate and tropical regions, higher temperatures and precipitation can injure crops and diminish yields, providing significant challenges for farmers seeking to ensure production.

Furthermore, these challenges increase the labor requirements of women who are concerned with food, water and fuel supply chains.

A rise in the temperature can disrupt the structural integrity of the soil, the chances of soil erosion increases, and fertility of the soil is also lost (FAO, 2013a). Climate-related changes are expected to have a detrimental impact on yields in the medium to long term, with the consequences likely to escalate (Table 2). These consequences will be greater in lower latitudes than in higher ones. This scenario particularly effects most of the developing countries while the developed countries claim a greater portion of the potent good products from climate change (FAO, 2016b).

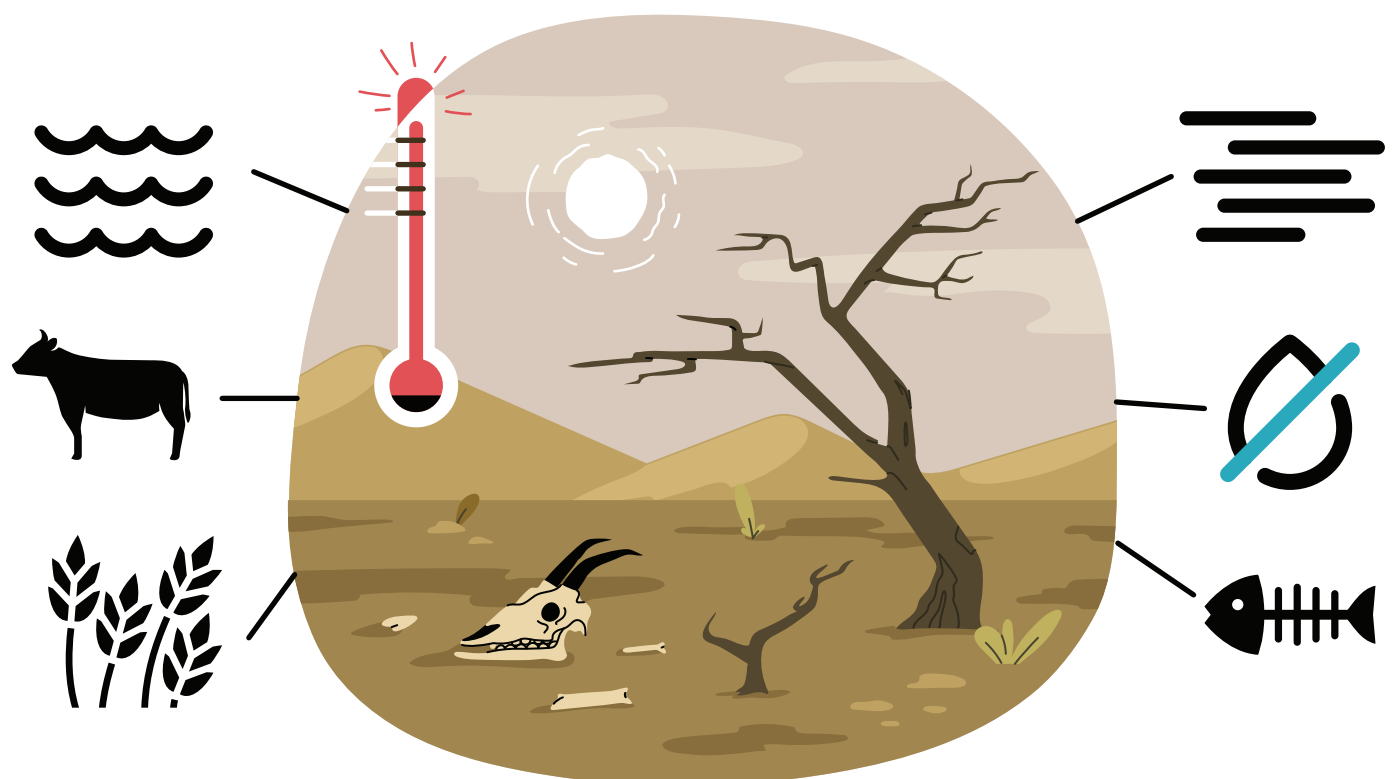
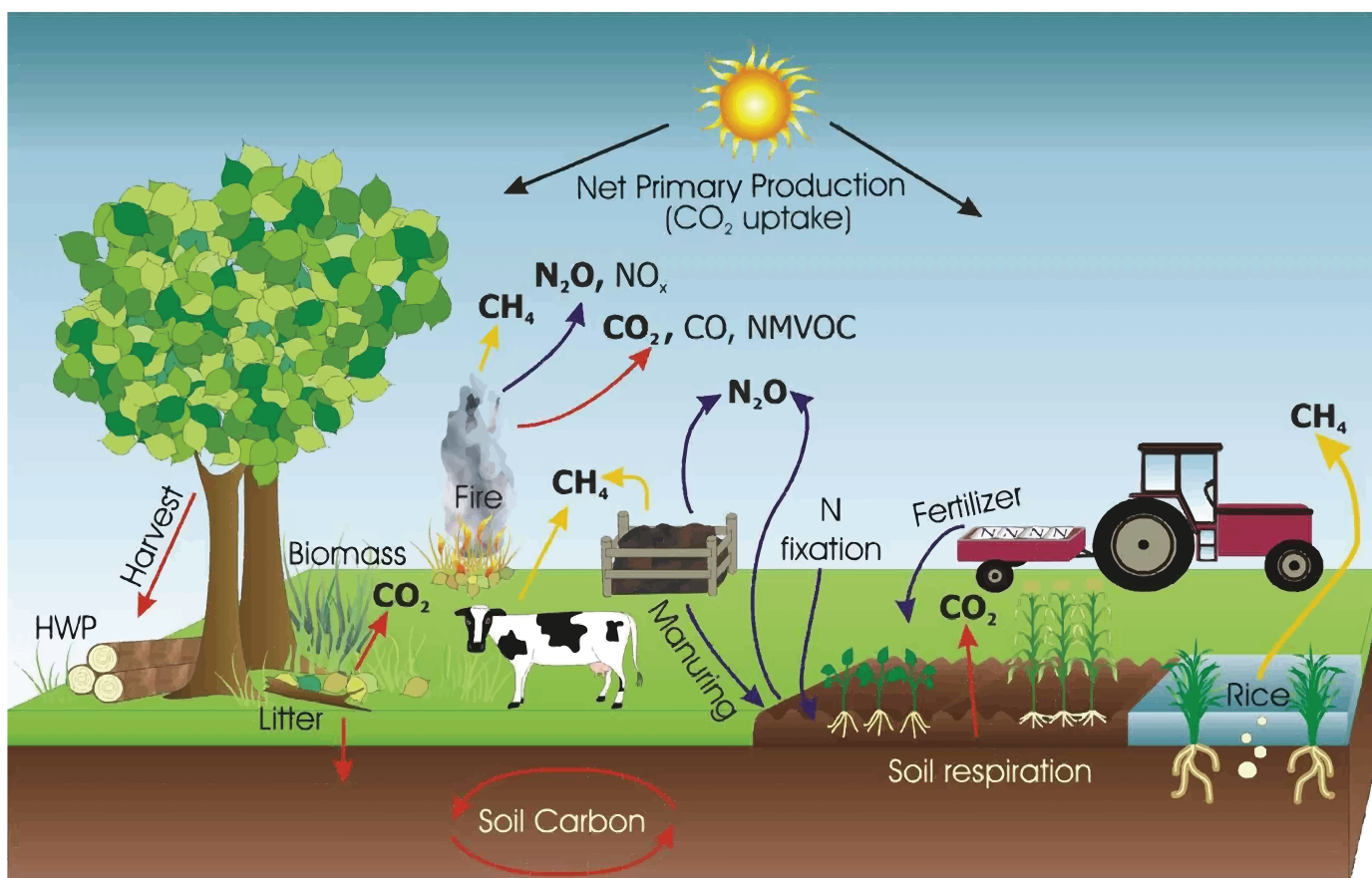


Figure 2: How climate change effects agricultural system (Source FAO)

TABLE 2. EXAMPLE OF PROJECTED CLIMATE CHANGE EFFECTS ON CROP PRODUCTION

Enteric fermentation	Intestinal fermentation produces methane gas in ruminant and nonruminant digestive tracts, which contributes to greenhouse gas emissions. 40% of GHGs emission of agriculture
Manure left on pasture	GHGs emission from the sullary emits nitrous oxide gas from the addition of nitrogen to the managed soils from the pastures. 16% of agricultural GHG emissions
Synthetic fertilizers	Emissions of greenhouse gases from synthetic fertilizers include nitrous oxide gas from nitrogen inputs to managed soils. 12% of GHGs emission from agriculture
Rice cultivation	Rice production generates methane gas by anaerobic decomposition of organic debris in paddy fields, contributing to GHG emissions. 10% of GHGs emission of agriculture
Manure management	Emissions of greenhouse gases from the handling of manure include methane and nitrous oxide gases from both aerobic and anaerobic dung decomposition processes. 7% of agricultural GHG emissions
Crop residues	Plant residue GHG emissions include nitrous oxide gas produced by the breakdown of fertilizer in crop residues that have been left on managed soils. 4% of agricultural GHG emissions



BOX 2. GENDER-DIFFERENTIATED IMPACTS OF CLIMATE

The negative effects of global warming affect both men and women, boys and girls, in different ways. Therefore, it is crucial to evaluate how technologies might be better planned to satisfy the diverse requirements throughout the value chain and reduce existing gender bias and associated inequities, especially in agriculture and crop production. Women are also agricultural producers and are more vulnerable to climate risk than men, for many of the same reasons that farm production is, on average, lower for female farmers than male farmers. Women have less accessibility to agricultural produce and control over productive resources and services, including climatic information, with fewer work prospects. Due to this they are often less mobile for cultural and for economic reasons . (FAO, 2011).



GROUP EXERCISES (B1 TO B6)

- B1. What is food security and how it is under threat due to climate change?
- B2. What are greenhouse gases?
- B3. What is the role of gender in the emission of greenhouse gases?
- B4. Which greenhouse gases are emitted from the agriculture sector?
- B5. How much greenhouse gases are emitted from the agricultural sector?
- B6. How to calculate greenhouse emission from different agricultural practices?

INSTRUCTIONS FOR EXERCISES AND GROUP ACTIVITIES

For each exercise participants have 1 hour to complete. The exercise is grouped base so all the group members participate actively in their collaboration in exercises. This exercise will be beneficial for all types of people like government officials, development sector and particularly for the farmers of maize and potato. Congratulate participants on their active participation in this exercise and learn many new things about climate change and climate variability, causes, effects and common observations related to climate change and effects on crop production and particularly the challenges being faced by the farmers in the field. What are the greenhouse gases and how they are emitting from the agricultural sector particularly from fertilizer application, burning of crop residues and tillage operations at farm field level.

SESSION 04 CLIMATE CHANGE AND FOOD SECURITY

one of today's most pressing concerns is to ensure food security for the rapidly growing population across the world.

Previous sessions examined the consequences of climate change on ecosystems, while this one addresses food security and defines its four components. Participants will also be introduced to a framework for understanding how climate-related hazards have direct or indirect effects on the availability of food. Finally, the idea of vulnerability is presented.

FOUR DIMENSIONS OF FOOD SECURITY

Food availability is the result of an effective food system, which contains all the aspects of the production, distribution, and consumption of food that contributes to human's nutritional quality and health. An effective food system improves all the four pillars of food security (Fig.5).

BOX 3. WHAT IS FOOD SECURITY?

Food security is defined as the state wherein all people have physical and socio-economic access to adequate, safe, and nutritious food that matches their dietary demands and food preferences for an active and healthy life (World Food Summit, 1996).

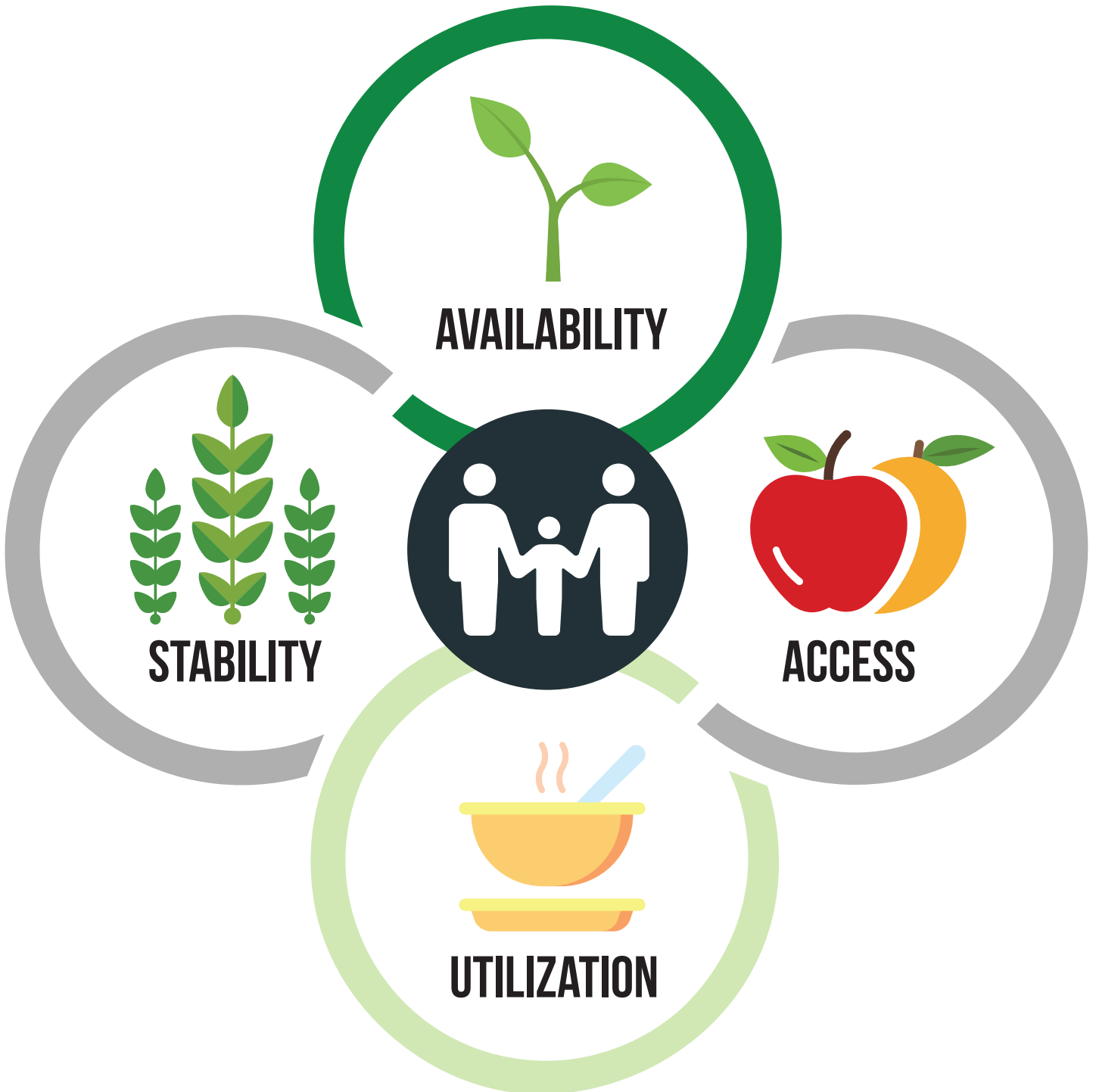


FIGURE 4. PILLARS OF FOOD SECURITY

MODULE- C

CLIMATE SMART AGRICULTURE

The previously discussed modules focused upon the causes and effects of climate change on ecosystems, agriculture and livelihoods. This module introduces the idea of climate-smart agriculture as an approach to overcoming climate change challenges, including maintaining or improving food security, supporting farmers to adapt to climate change, developing resilience in the production system, and reducing greenhouse gas emissions. This lesson focuses on contemporary farming practices and how they affect the environment due to climate change.



KEY QUESTIONS

1. Climate-smart agriculture, the way towards ecosystem restoration?
2. How climate smart agriculture improves adaptation, mitigation, and food security?
3. How climate smart agriculture is different from current agricultural practices?
4. How gender plays a crucial role in climate smart agriculture?

OBJECTIVES

After completing this module, participants will be able to:

- The significance of sustainable agricultural practices that can contribute to food security.
- How climate smart agriculture is a long-term approach.
- How to enlist the strategies by which farmers can boost resilience to climate change.
- The adaptation and mitigation pillars of CSA.
- List examples of adaptation and mitigation practices.

DEFINITION AND CHARACTERISTICS

You must devise measures to boost agriculture, adapt to changing weather patterns, and prevent further climatic damage, all while ensuring equitable opportunities for men and women working in food production.

To address these interconnected challenges, food systems must become more efficient and responsive to alterations and shocks. Agriculture needs to adapt and better utilize the environment, producing greater quantities using less water, energy, land, and other sources. In 2010, the FAO established the concept of climate-smart agriculture, sometimes known as CSA. The method tackles food security and climate concerns simultaneously, integrating the three pillars of sustainable growth: economics, society, and ecology. It is a plan for creating the scientific, policy, and investment conditions needed for long-term growth in agriculture and food safety in the face of global warming (FAO, 2013a).

OBJECTIVES OF CSA

- Sustainability in agricultural productivity
- Adaptation through climate resilient strategies
- Mitigation of GHG emissions from various sectors

PILLARS OF CSA

Productivity: This pillar focuses on enhancing agricultural productivity in a sustainable manner using a variety of methods, including improved crop types, soil fertility management, control of water, and combined pest management.

Adaptation: CSA strives to improve agricultural systems' adaptive ability to climate change impacts such as change in rainfall, rise in mean temperatures, and harsh weather conditions. Crop diversification, enhanced water management, and the use of hardy crop types are all examples of such techniques.

Mitigation: CSA aims to minimize greenhouse gas emissions from agriculture through strategies such as conservation agriculture, agroforestry, and better livestock management.

FIGURE 5. SOME EXAMPLES OF SUSTAINABLE AND CLIMATE SMART AGRICULTURAL PRACTICES (FAO)

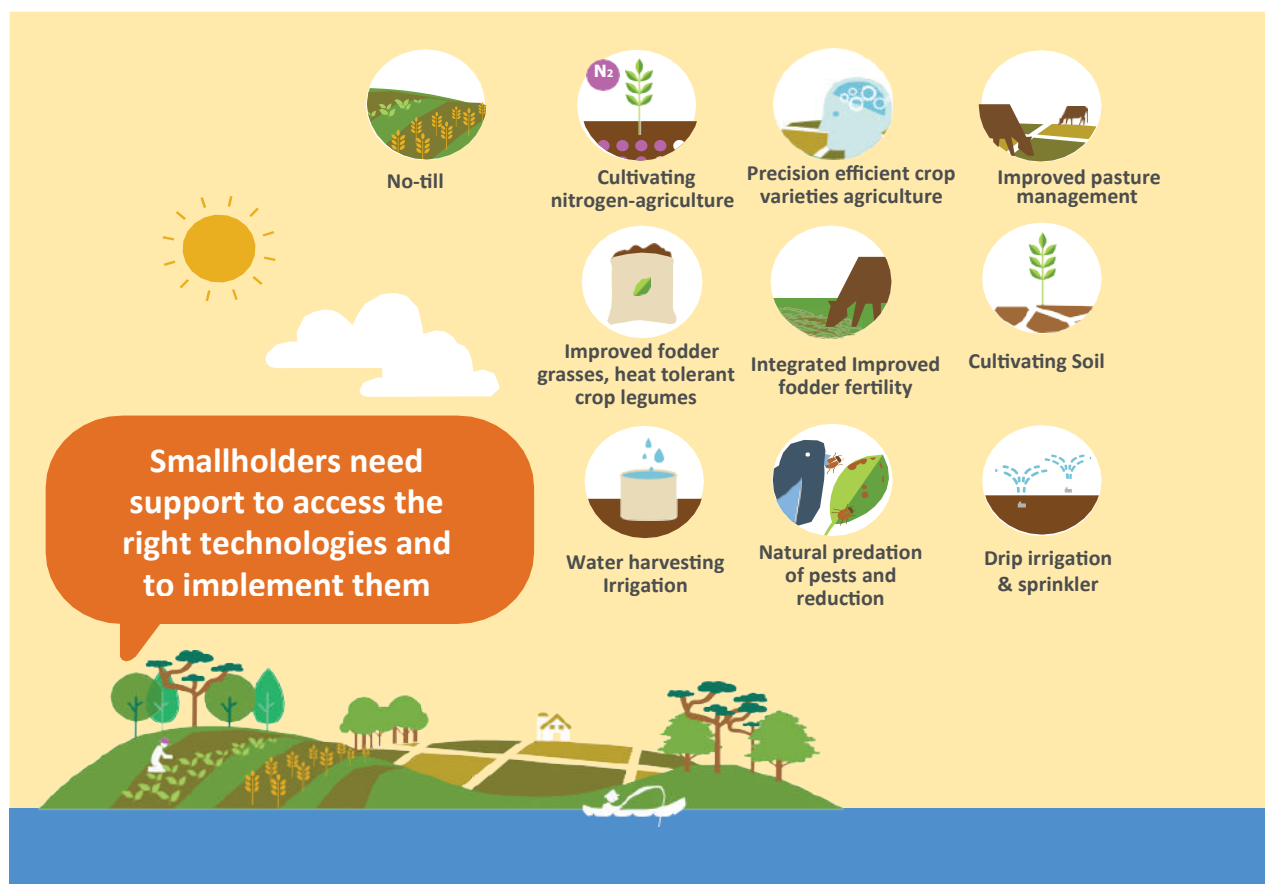
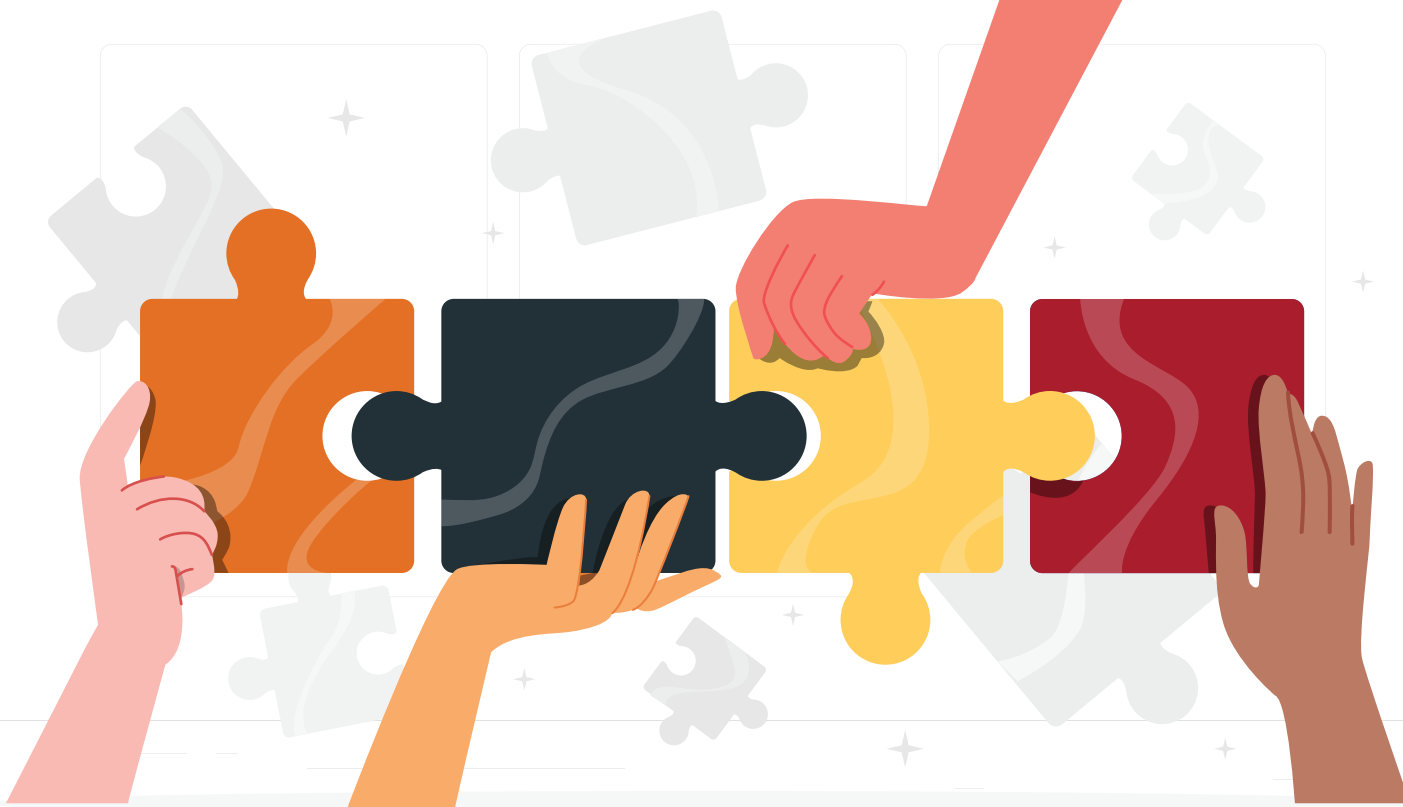


TABLE 4. COMPARING CURRENT AGRICULTURAL PRACTICES AND CLIMATE-SMART AGRICULTURE

	Current agricultural practices	Climate-smart agriculture
Land	The destruction of forests and cropland conversion to increase agricultural land area.	Increase utilization of current regions rather than expanding into new ones.
Natural resources	Most of the water, land, trees and soil utilized for crop production without knowing the sustainability	Use of natural resources in a sustainable way
Varieties and breeds	Rely on some harvesting and/or high-yielding varieties and breeds.	Combine conventional and new, locally appropriate varieties and breeds to preserve output, increase yields, and ensure sustainability in the face of climatic change.
Inputs	Increase the use of fertilizers, pesticides, and herbicide.	To control pests and weeds, apply integrated management strategies to increase the effectiveness of pesticides use. Apply organic matter, manure, and green fertilizer. Mix crops with legumes to fix nitrogen and reduce the need for synthetic fertilizers.
Energy use	Use machinery for farming that is often powered by fossil fuels, such as tractor and diesel pumps.	Use energy-saving strategies like sunlight and biofuel
Production and marketing	Concentrate in production and marketing to boost efficiency.	Diversify both production and distribution to improve stability and reduce risk.



GROUP EXERCISES (C1 TO C11)

- C1 What is Climate Smart Agriculture (CSA) and why is it important?
- C2 What are the Pillars of Climate-Smart Agriculture?
- C3. How does Climate Smart Agriculture help farmers adapt to changing weather patterns?
- C4 What are some key practices of Climate Smart Agriculture?
- C5 How does Climate Smart Agriculture contribute to reducing greenhouse gas emissions.
- C6 What role does technology play in implementing Climate Smart Agriculture?
- C7 How does Climate Smart Agriculture promote sustainable water management?
- C8 What are some benefits of integrating biodiversity conservation into Climate Smart Agriculture?
- C9 How does Climate Smart Agriculture enhance soil health and fertility?
- C10 Can small-scale farmers also benefit from practicing Climate Smart Agriculture?
- C11 How can policymakers support the adoption of Climate Smart Agriculture practices?

INSTRUCTIONS FOR EXERCISES AND GROUP ACTIVITIES

For each exercise participants have 1 hour to complete. The exercise is grouped base, so all the group members participate actively in their collaboration in exercises. This exercise will be beneficial for all types of people like government officials, development sector and particularly for the farmers of maize and potato. Congratulate participants on their active participation in this exercise and learn many new things about climate smart agriculture its pillars adapted climate smart agricultural practices that are contributing to mitigate the GHGs. Sustainable methods for sowing of maize and potato as well as their intercultural operations. Climate smart soil health and nutrient management for climate smart production of potato and maize. Climate smart integrated plant protection for climate smart production of maize and potato.

SESSION 06 CSA PRACTICES FOR FOOD, NUTRITION AND WATER SECURITY

Climate Smart Agriculture (CSA) refers to methods of farming, policies, and initiatives that improve production, resilience, and adaptive ability while lowering greenhouse gas emissions. It is a comprehensive method that considers the entire agriculture system, encompassing crop and animal management, water use, and soil health.

CLIMATE SMART INTEGRATED SOIL & LAND MANAGEMENT

Climate Smart Integrated Soil & Land Management (CS-ISLM) is an approach that integrates sustainable land management practices with climate-smart strategies to enhance soil health, productivity, and resilient agriculture. This strategy recognizes the interdependence of soil, land, and climate and seeks to optimize their management to mitigate and adapt to climate change impacts. Here are specific components of CS-ISLM tailored to maize and potato cultivation in Punjab, Pakistan:

- Crop Productivity Smart Farming
- Climate Smart Intercultural Operation
- Climate Smart Tillage for Maize and Potato

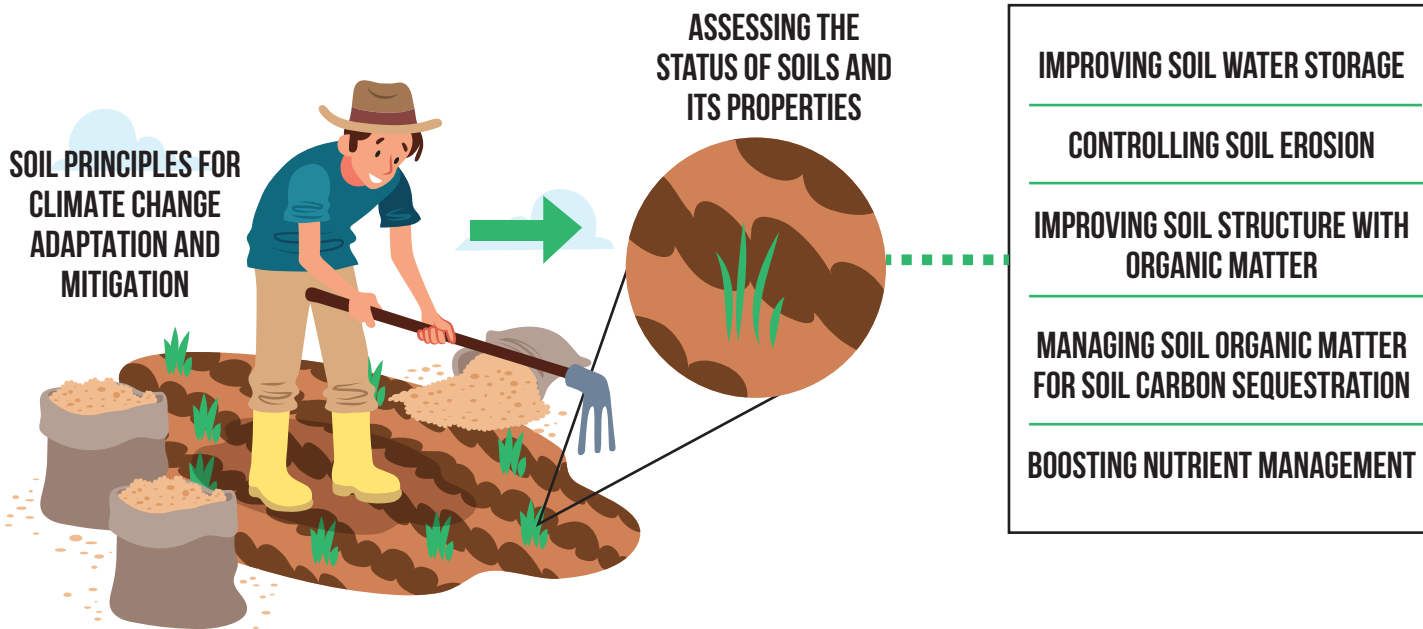


FIGURE 6. PRINCIPLES FOR CLIMATE CHANGE ADAPTATION AND MITIGATION FOR SOIL STATUS ASSESSMENT

Conservation Agriculture:

Conservation agriculture strategies are designed to reduce soil disturbance, maintain soil cover, and encourage crop rotation. This includes reduced tillage or no-till systems, where soil is left undisturbed or minimally disturbed to conserve soil structure, organic matter, and moisture. Keeping the soil covered with crop residues or cover crops helps reduce erosion, improve water infiltration, and enhance carbon sequestration.

- 1** minimum soil disturbance
- 2** permanent soil cover: crop residue or live mulch
- 3** crop rotation and or intercropping



FIGURE 7. OBJECTIVES OF CLIMATE SMART AGRICULTURE



Farm Progress

Soil Organic Matter Management:

Soil Organic Matter Management: Managing soil organic amendments is crucial for maintaining soil fertility, water-holding capacity, and carbon sequestration. Practices such as adding organic amendments (compost, manure), adopting agroforestry systems, and using cover crops can enhance soil organic carbon content. Enhancing soil organic amendments improves soil structure, nutrient availability, and resilience to drought and extreme weather events.

FIGURE 8: SOIL ORGANIC MATTER

Nutrient Management:

Efficient nutrient management is crucial for optimizing crop productivity while minimizing nutrient losses and environmental impacts. This includes soil testing to determine nutrient requirements, applying fertilizers in a targeted manner, and using precision agriculture techniques. Balancing nutrient inputs with crop needs helps reduce nutrient runoff, which can contribute to water pollution, and improves nutrient use efficiency.



FIGURE 9. NUTRIENT MANAGEMENT



FIGURE 10: EFFICIENT WATER MANAGEMENT

Water Management:

Climate-smart soil and land management and effective water management strategies to optimize water consumption and reduce water-related risks. This involves procedures like precise water supply such as drip irrigation, and water-saving technologies. Implementing water-harvesting techniques, such as constructing small-scale reservoirs or contour bunds, can help capture and store rainfall, improving water availability during dry periods.

Climate Information and Decision Support Systems:

Access to climate information and decision support systems is crucial for climate-smart soil and land management. Farmers can benefit from weather forecasts, climate risk assessments, and agro-climatic data to make informed decisions about cropping patterns, timing of operations, and resource allocation. Climate information can help optimize land use, reduce vulnerability to climate-related risks, and enhance adaptive capacity.

Agroforestry and Biodiversity Conservation:

Integrating trees into agricultural landscapes through agroforestry systems benefits soil health, biodiversity, and climate resilience. Agroforestry provides shade, windbreaks, and additional organic matter inputs to the soil, enhancing its fertility and moisture retention capacity. Promoting biodiversity through the preservation of natural habitats, buffer zones, and the use of native plants supports ecosystem services and resilience in agricultural systems.

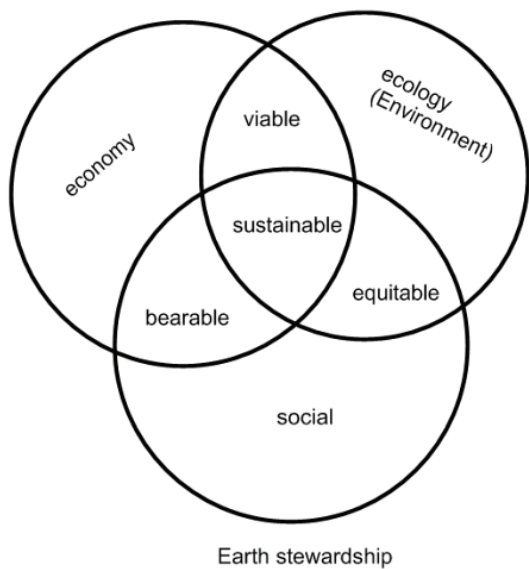


FIGURE 11. CLIMATIC INFORMATION FOR DECISION MAKING FOR SUSTAINABLE PRODUCTION.

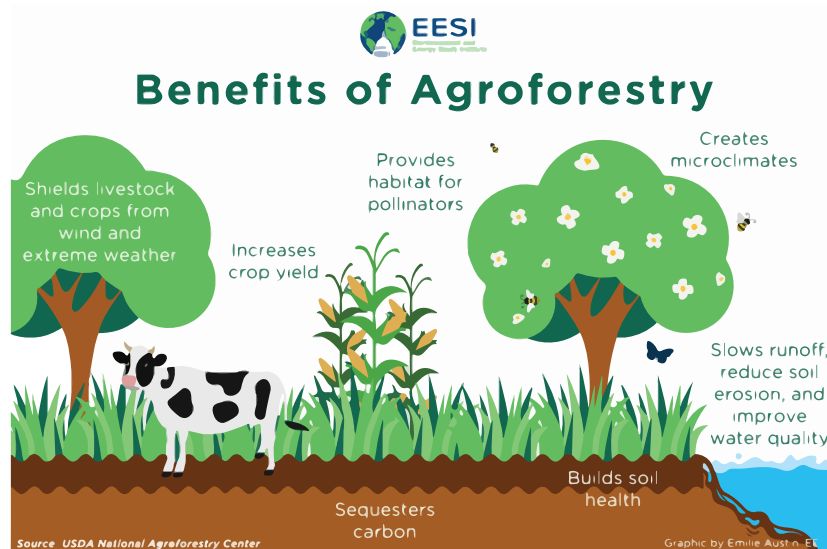


FIGURE 12. ROLE OF AGROFORESTRY FOR BIODIVERSITY CONSERVATION

Knowledge Transfer and Capacity Building: Encourage sharing of expertise and capacity growth among farmers, extension services, and researchers is essential for the adoption of climate-smart soil and land management practices. Training programs, demonstrations, farmer field schools, and knowledge exchange platforms facilitate the dissemination of information and good practices. Engaging stakeholders in participatory approaches promotes local ownership, innovation, and the adoption of context-specific solutions.

CLIMATE SMART AND RESILIENT VARIETIES OF CS POTATO AND MAIZE PRODUCTION

Selecting climate-smart and resilient varieties of potato and maize is crucial for ensuring food security and agricultural sustainability in the face of climate change. Here's how the selection process for these crops typically unfolds:

Drought Tolerance: With changing precipitation patterns and increased water scarcity, potato varieties with drought tolerance traits are essential. These varieties can withstand periods of water stress and maintain productivity even under limited water availability.

Heat Tolerance: Rising temperatures can negatively impact potato growth and development. Heat-tolerant varieties are better equipped to cope with high temperatures during critical growth stages, ensuring consistent yields in warmer climates.



Pest and Disease Resistance: Climate change may lead to shifts in pest and disease pressure, making resistance traits crucial for potato varieties. Selecting varieties with built-in resistance to common pests and diseases can reduce the need for chemical pesticides and mitigate yield losses.

Adaptability to Variable Conditions: Potato varieties that exhibit adaptability to variable climatic conditions, such as fluctuations in temperature and precipitation, are desirable. These versatile varieties can thrive in diverse environments, providing stability to potato production systems.

Yield Potential and Quality: While resilience to climate stressors is essential, potato varieties should also possess high yield potential and desirable quality attributes. Selecting varieties with good tuber yield, size uniformity, and desirable culinary characteristics ensures market competitiveness and economic viability.

FIGURE 13. CLIMATE SMART POTATO PRODUCTION

Early Maturity: In regions prone to climate extremes, early-maturing maize varieties offer a strategic advantage. These varieties have shorter growing cycles, allowing farmers to avoid exposure to adverse weather conditions and harvest before the onset of unfavorable conditions, such as drought or excessive rainfall.

Yield Potential and Nutritional Quality: High-yielding maize varieties with good nutritional quality are essential for food security and human nutrition. Varieties that combine high grain yield with desirable nutritional attributes, such as enhanced protein content or vitamin A enrichment, contribute to sustainable and nutrition sensitive maize production systems.

Climate Smart Sowing Methods for Climate Smart Maize and Potato Production: Implementing climate-smart sowing methods is essential for enhancing the resilience and productivity of maize and potato crops in the face of climate change.

Here's how climate-smart sowing methods can be tailored to each crop:

CS Sowing Methods and Tillage for Climate Smart Maize and Potato Production

Timely Planting: Climate-smart maize production begins with timely planting to optimize crop development and minimize exposure to adverse weather conditions. Farmers should aim to plant maize when soil temperatures are conducive to germination and early growth, typically during the onset of the rainy season or after the last frost date.

Conservation Tillage: Adopting Conservation tillage measures, such as no-till or reduced tillage, decreases soil disturbance and retains soil moisture. and reduces erosion. These practices enhance soil health and resilience while mitigating the effects of climate variability on maize production.

Crop Diversification: Intercropping maize with legumes or other complementary crops can improve soil fertility, suppress weeds, and enhance resilience to pests and diseases. Diversified cropping systems also provide farmers with alternative sources of income and food security.

Seed Priming: Pre-sowing seed treatments such as seed priming can enhance seedling emergence, vigor, and stress tolerance. Priming involves soaking maize seeds in water or nutrient solutions before planting to initiate germination processes and improve early root growth, enabling crops to establish more effectively under variable climatic conditions.

Micro-Dosing of Fertilizers: Micro-dosing involves applying small, targeted amounts of fertilizers directly to the plant root zone, minimizing nutrient losses and optimizing nutrient uptake efficiency. This practice improves nutrient use efficiency, reduces input costs, and mitigates environmental impacts associated with conventional fertilizer application methods.



Conventional tillage: Due to conventional tillage in maize and potato crop maximum soil disturbance occurs from this activity with a maximum rate of GHGs emissions as well as soil organic matter decomposition.

No till or conservation tillage: In this method no soil disturbance occurs and no GHG emissions take place. Due to this soil organic matter improves and use of fossil fuel decreases.

Strip Tillage: This type of tillage runs in specific lines and a minimum soil disturbance occurs. Also, minimum GHG emissions take place. In strip tillage less soil organic matter decomposition occurs with a minimum use of fossil fuel..

Optimized Planting Dates: Like maize, selecting appropriate planting dates is crucial for climate-smart potato production. Planting should coincide with favorable soil and weather conditions to promote uniform emergence and vigorous early growth. In regions with variable climates, staggered planting dates may be necessary to spread risk and optimize yield potential.

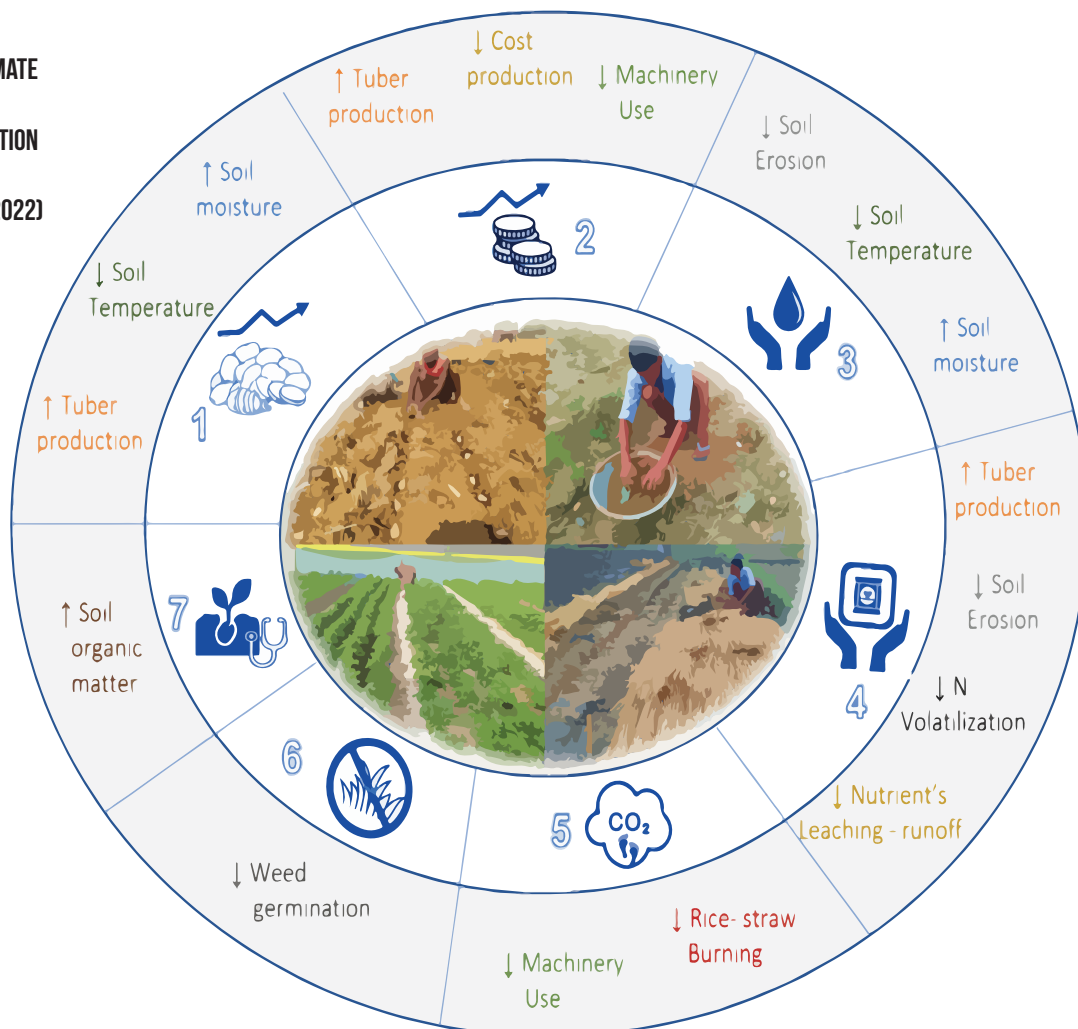
Raised Bed Planting: Raised bed planting systems improve soil drainage, aeration, and root development, particularly in areas prone to waterlogging or heavy rainfall. By elevating the planting surface, raised beds facilitate timely planting and reduce the risk of waterlogging-induced stress and disease incidence in potato crops.

Mulching: Applying organic or plastic mulch to potato beds conserves soil moisture, inhibits the development of weeds, and regulates soil temperature fluctuations. Mulching also reduces soil erosion, enhances soil structure, and promotes root development, contributing to improved crop resilience and productivity under changing climatic conditions.

Use of Certified Disease-Free Seed: Planting certified disease-free potato seed is essential for minimizing the spread of soil-borne pathogens and ensuring healthy crop establishment. Certified seed tubers are rigorously tested and treated to eliminate pathogens, reducing the risk of yield losses due to diseases such as late blight, bacterial wilt, and viral infections.

Precision Planting: Precision planting technologies help farmers improve seed assignment, spacing, and depth ensuring uniform stand establishment and maximizing yield potential. By precisely controlling planting variables, such as seed density and depth, farmers can enhance resource use efficiency, minimize input costs, and mitigate risks associated with climate variability.

FIG. 13: PROCESS OF CLIMATE SMART PRACTICES FOR CLIMATE SMART PRODUCTION OF MAIZE AND POTATO
SOURCE: (DAVID ET AL., 2022)



CLIMATE SMART NUTRIENT MANAGEMENT FOR CLIMATE SMART MAIZE AND POTATO PRODUCTION

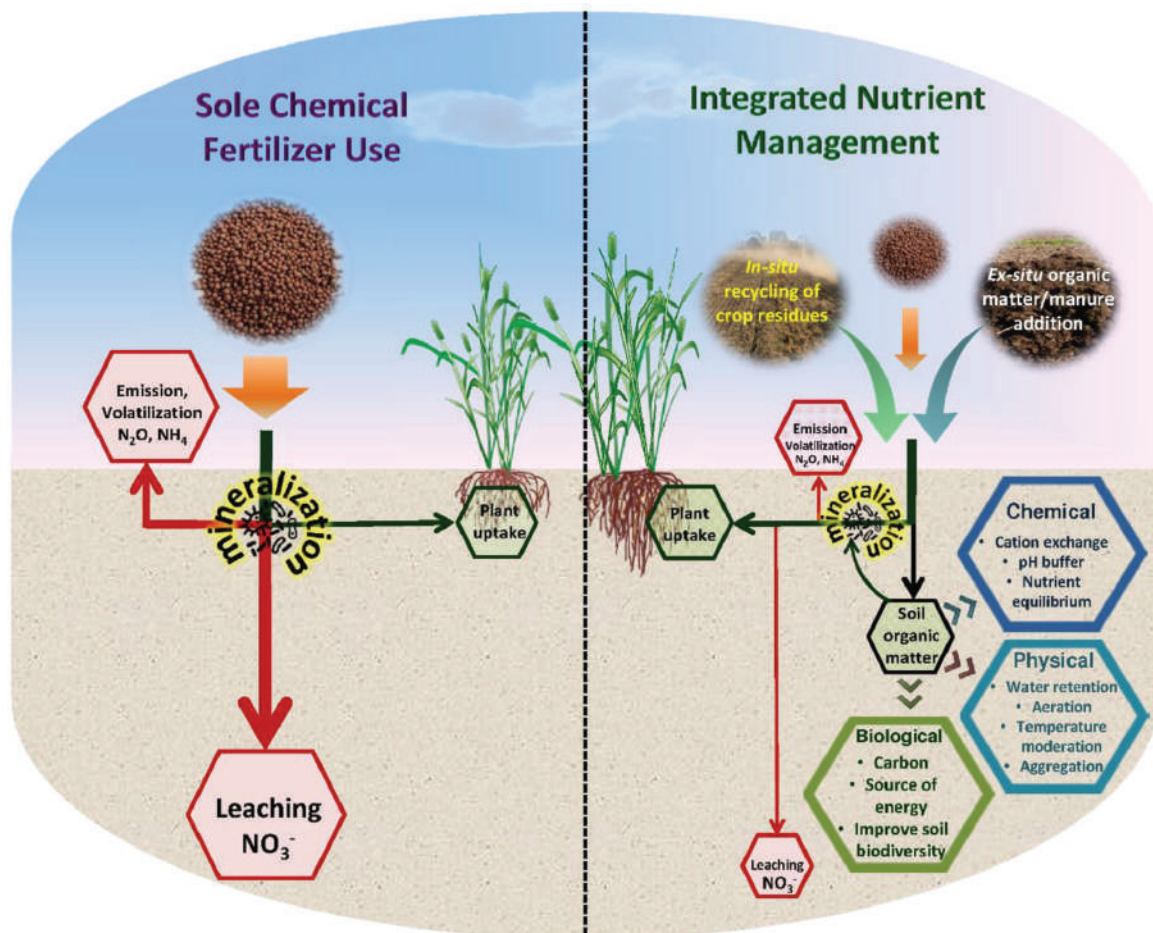
Climate Smart Nutrient Management is critical for optimizing crop productivity, minimizing environmental impacts, and enhancing resilience to climate change. Here's how it can be tailored for maize and potato crops:

Soil Testing and Nutrient Balancing: Climate-smart fertilizer management begins with soil testing to assess nutrient levels and pH. Based on soil analysis results, farmers can develop tailored nutrient management plans that optimize fertilizer application rates and balance essential nutrients, such as nitrogen (N), phosphorus (P), and potassium (K), to meet maize crop requirements.

Precision Fertilizer Application: Adopting precision fertilizer application techniques, such as variable rate application and site-specific nutrient management, enables farmers to apply fertilizers more efficiently, targeting areas with nutrient deficiencies and minimizing wastage. This approach improves nutrient use efficiency, reduces input costs, and mitigates environmental pollution risks associated with fertilizer runoff and leaching.

Integrated Nutrient Management: Sources of integrated organic amendments, such as compost, manure, and crop residues, with inorganic fertilizers promotes soil health, enhances nutrient cycling, and reduces dependence on synthetic fertilizers. Incorporating organic amendments into maize cropping systems improves soil structure, water retention, and biological activity, contributing to long-term sustainability and resilience.

FIG. 14. INTEGRATED NUTRIENT MANAGEMENT FOR CLIMATE SMART MAIZE AND POTATO PRODUCTION

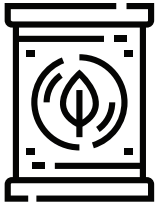
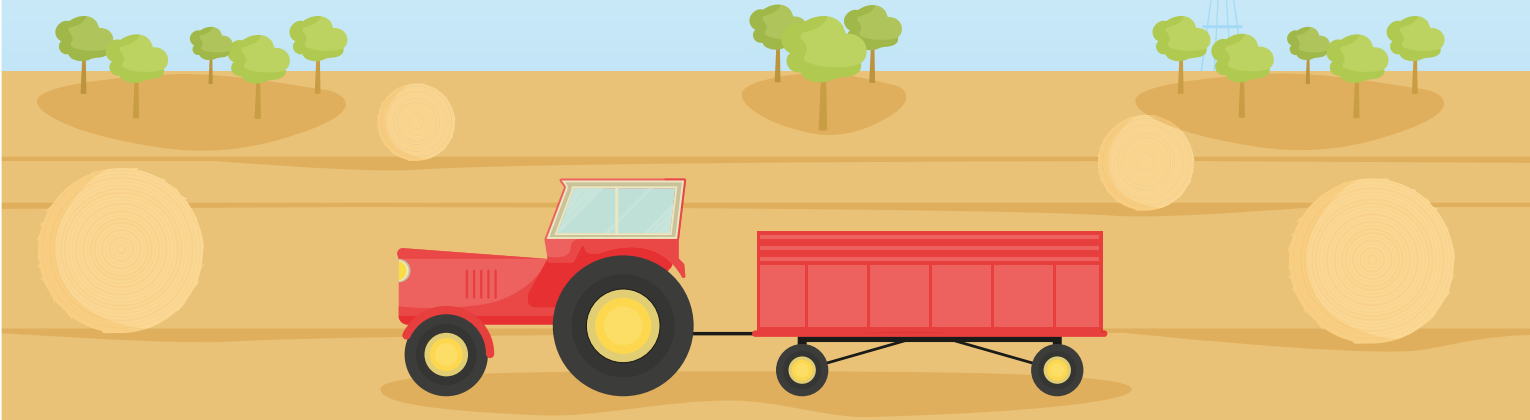


Slow and Controlled Release Fertilizers: Utilizing slow-release and controlled-release fertilizer formulations prolong nutrient availability and reduce nutrient losses through volatilization, leaching, and runoff. These innovative fertilizer technologies enhance nutrient uptake efficiency, minimize environmental impacts, and support sustained maize growth and yield under variable climatic conditions.

Fertilizer Timing and Placement: Timing fertilizer applications to coincide with crop growth stages and nutrient demand helps maximize nutrient uptake and utilization by maize plants. Banding or side-dressing fertilizers near the root zone of maize plants promotes efficient nutrient uptake and minimizes nutrient losses, particularly in soils prone to leaching or denitrification.

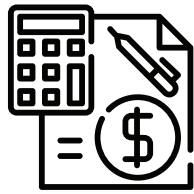
FIG. 15. 4R PRINCIPLE FOR CLIMATE SMART NUTRIENT MANAGEMENT

The 4Rs promote best management practices (BMPs) to achieve cropping system goals while minimizing field nutrient loss and maximizing crop uptake.



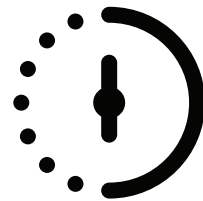
RIGHT SOURCE

Matches fertilizer type to crop needs.



RIGHT RATE

Matches amount of fertilizer to crop needs.



RIGHT TIME

Makes nutrients available when crops need them.



RIGHT PLACE

Keeps nutrients where crops can use them.
100%.

Application of organic matter amendments: Organic matter amendments play a significant role in improving soil health, fertility, and overall agricultural productivity. They are applied to the soil to increase organic carbon content, enhance nutrient availability, improve soil structure, and promote beneficial microbial activity. Amendments include farmyard manure, composting, vermicompost and mulching.



FIG. 16. ORGANIC MATTER AMENDMENTS (FYM, GREEN MANURING, COMPOSTING, BIOCHAR AND MULCHING) FOR CLIMATE SMART SOIL HEALTH

CLIMATE SMART INTEGRATED APPROACHES FOR WATER AND IRRIGATION MANAGEMENT FOR CLIMATE SMART MAIZE AND POTATO PRODUCTION

Water Conservation Practices: Implementing water conservation practices, such as mulching, ridge and furrow planting, or controlled traffic farming, reduces water losses through evaporation, runoff, and deep percolation in potato cropping systems. Mulching conserves soil moisture, while ridge and furrow planting improve water infiltration and reduce surface runoff, enhancing overall water productivity.



FIG. 17. USE OF RENEWABLE PLASTIC MULCH FOR CS MAIZE PRODUCTION

Efficient Irrigation Systems: Installing efficient irrigation systems, such as sprinkler irrigation, furrow irrigation, or subsurface drip irrigation, optimizes water application and distribution in potato fields. These systems minimize water losses, improve water-use efficiency, and support uniform crop growth and tuber development.



FIG. 18. DRIP IRRIGATION SYSTEM IN MAIZE CROP

Soil Moisture Management and Water Harvesting: Managing soil moisture through techniques like scheduling irrigation based on crop water requirements, monitoring soil moisture levels, and adopting precision irrigation technologies ensures optimal water availability for potato growth and tuber bulking. Maintaining adequate soil moisture throughout the growing season supports healthy plant development and high-quality tuber production.



FIG. 19. WATER HARVESTING AND STORAGE AT FARMER FIELD

Crop Rotation and Diversification: Incorporating crop rotation and diversification practices into potato production systems enhances soil health, reduces pest and disease pressure, and improves water-use efficiency. Rotating potatoes with legumes or cover crops replenishes soil nutrients, breaks pest cycles, and reduces water demand, contributing to sustainable water and irrigation management.

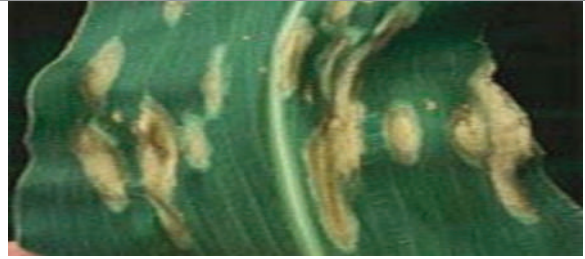


FIG. 20. CROP ROTATION TO CONSERVE SOIL MOISTURE.

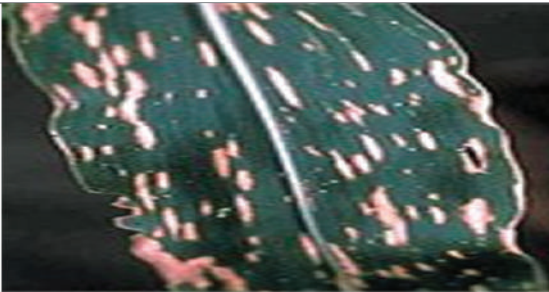
Identification of Insect and Diseases for Maize and Potato



Maize Streak Virus



Maize Smut



Gray Leaf Spot



Maize Dwarf Mosaic Virus



Maize Smut



Sclerotial Wilt



Fusarium wilt



Wart of potato

FIG. 21. DISEASES OF MAIZE AND POTATO

Identification of Pests for Climate Smart Production of Maize and potato



Fall armyworm



Corn earworm



Aphids



Maize weevil



Stalk borers



Colorado potato beetle



Potato tuber moth



Wireworms

FIG. 22. INSECTS OF MAIZE AND POTATO

CLIMATE SMART INTEGRATED APPROACHES FOR PLANT PROTECTION

Disease-Resistant Varieties: Selecting potato varieties with resistance or tolerance to common diseases such as late blight and bacterial wilt can reduce disease incidence and minimize yield losses.

Crop Rotation and intercropping: Rotating potatoes with crops that are not hosts breaks disease cycles and lowers the accumulation of soilborne pathogens, which aids in controlling diseases and reduces reliance on chemical pesticides.

Seed Certification: Using certified disease-free potato seed tubers ensures that planting material is free from pathogens, reducing the risk of introducing diseases into potato fields.

Bio fumigation: Incorporating biofumigant cover crops, such as mustard or rapeseed, into potato cropping systems can suppress soilborne pathogens and nematodes, reducing disease pressure and improving soil health.

Precision Application of Pesticides: Employing precision application techniques, such as spot spraying or targeted application, minimizes pesticide use while effectively controlling pests and diseases in potato crops.

Early Detection and Monitoring: Implementing regular scouting and monitoring programs allows for early detection of disease outbreaks, enabling timely intervention and management measures.

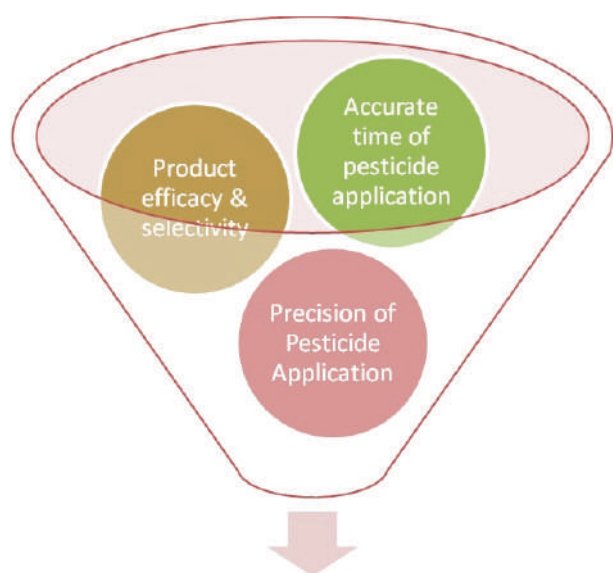


FIG. 23. PRECISE APPLICATION OF PESTICIDES



Integrated Disease Management: Integrating cultural, biological, and chemical control methods in disease management strategies enhances efficacy and reduces the risk of pesticide resistance and environmental contamination.

Climate-Responsive Crop Management: Adapting crop management practices, such as adjusting planting dates or irrigation schedules, based on climate forecasts and disease risk assessments helps minimize disease incidence and maximize crop resilience to changing environmental conditions.

Capacity Building and Extension Services: Providing farmers with training, information, and resources on climate-smart disease management practices empowers them to effectively cope with diseases and sustainably protect their crops in a changing climate.

Biological Control: Introducing natural enemies such as parasitoids, predators, or microbial agents helps regulate pest populations and minimize pesticide use.

Cultural Practices: Implementing crop rotation, intercropping, or trap cropping diversifies habitats and disrupts pest life cycles, reducing pest pressure on maize crops.

Resistant Varieties: Planting maize varieties with inherent resistance or tolerance to specific pests, such as fall armyworm or maize weevil, helps minimize damage and yield losses.



FAO

Integrated Pest Management (IPM): Integrating various eradication tactics, including cultural, natural, and chemical control methods, optimizes pest control efficacy while minimizing environmental impacts.

Crop Rotation: Rotating potatoes with non-host crops breaks pest cycles and reduces buildup of pest populations in potato fields, reducing reliance on chemical pesticides.

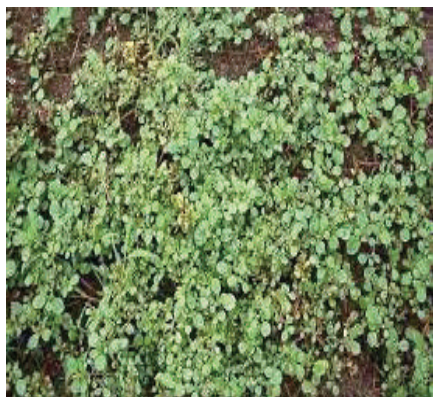
Mechanical Control: Hand-picking or vacuuming Colorado potato beetles and their larvae from potato plants reduces pest populations and prevents damage to foliage.

Biopesticides: Using biopesticides derived from natural sources, such as botanical extracts or microbial agents, targets specific pests while minimizing harm to beneficial insects and the environment.

Traps and Monitoring: Deploying pheromone traps or sticky traps helps monitor pest populations and provides early detection of pest outbreaks, enabling timely intervention and management.

IDENTIFICATION OF WEEDS FOR CLIMATE SMART PRODUCTION OF MAIZE AND POTATO

Itsit Weed



Dumbi Sitti/Sitti Booti



Javi



Bathu



Madhana



Jangli Palak



FIG. 24. COMMON WEEDS OF MAIZE AND POTATO CROP



CLIMATE SMART INTEGRATED APPROACHES FOR WEEDS

Integrated Weed Management (IWM): Implementing IWM strategies combining cultural, mechanical, and chemical control methods helps manage weed populations while minimizing environmental impacts.

Cover Crops: Planting cover crops, such as legumes or grasses, as living mulches or green manures suppresses weed growth and enhances soil health in maize fields.

Mulching: Applying organic or plastic mulches suppresses weed emergence, conserves soil moisture, and reduces the need for herbicide applications in maize crops.

Crop Rotation: Rotating maize with non-host crops disrupts weed cycles and reduces weed pressure, improving overall weed management effectiveness.

Herbicide-Tolerant Maize Varieties: Utilizing maize varieties engineered for herbicide tolerance allows for selective herbicide applications, minimizing crop damage while effectively controlling weeds.

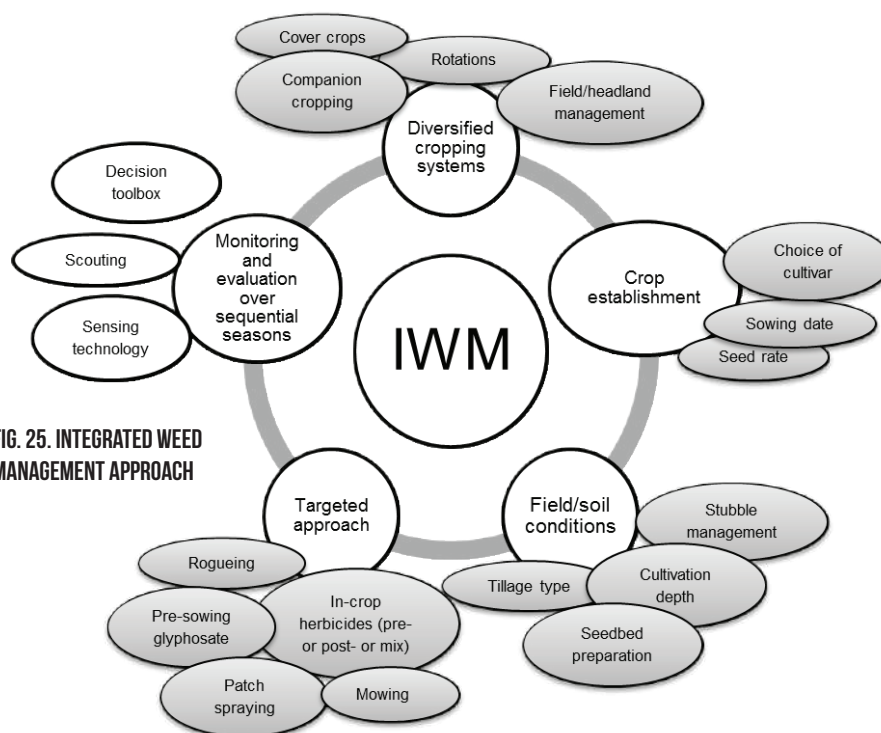


FIG. 25. INTEGRATED WEED MANAGEMENT APPROACH

HARVEST AND POST HARVEST MANAGEMENT

HARVEST AND POST-HARVEST LOSSES OF MAIZE

Harvesting Challenges: Harvesting maize at the right maturity stage is crucial to prevent yield losses. Delayed harvesting can lead to shattering of mature kernels, while harvesting too early results in lower grain quality and yield. Moreover, weather conditions such as rain and high humidity during harvesting can increase grain moisture content, leading to mold growth and spoilage. Harvesting potatoes involves careful timing to ensure optimal tuber size and skin set. Mechanical harvesting can cause bruising and damage to tubers if not done properly, leading to increased post-harvest losses. Additionally, exposure to sunlight during harvesting and handling can result in greening of potatoes, rendering them unmarketable.

Post-Harvest Losses: Post-harvest losses in maize occur due to inadequate drying, improper storage, and pest infestation. High moisture content in harvested maize promotes fungal growth and mycotoxin contamination, reducing grain quality and market value. Inadequate storage facilities and pest infestation further exacerbate losses, with rodents, insects, and birds causing physical damage to stored grains. Post-harvest losses in potatoes primarily occur due to mechanical damage, sprouting, and storage diseases. Bruising during harvesting and handling reduces tuber quality and increases susceptibility to rotting. Sprouting of stored potatoes leads to weight loss and reduced market value, while storage diseases such as late blight and bacterial soft rot can cause significant spoilage if proper storage conditions are not maintained.

CLIMATE SMART STRATEGIES TO COPE WITH HARVEST AND POST-HARVEST LOSSES

Improved Harvesting Practices: Implementing timely and efficient harvesting techniques, such as using properly adjusted machinery and trained labor, minimizes mechanical damage and ensures higher yields and quality.

On-Farm Drying Facilities: Investing in on-farm drying facilities, such as solar dryers or mechanical dryers, helps reduce moisture content in harvested maize, preventing mold growth and mycotoxin contamination.

Proper Storage Facilities: Constructing well-ventilated and pest-proof storage structures, such as silos or hermetic storage bags, protects harvested maize and potatoes from pests, mold, and moisture, extending their shelf life and preserving quality.

Post-Harvest Handling Practices: Implementing gentle handling practices and avoiding excessive drops and impacts during transportation and storage minimizes mechanical damage to potatoes and reduces post-harvest losses.

Cold Storage for Potatoes: Utilizing cold storage facilities or refrigeration units maintains optimal temperature and humidity conditions for potatoes, delaying sprouting and reducing the risk of spoilage and weight loss.

Integrated Pest Management (IPM): Adopting IPM strategies, including sanitation, monitoring, and biological control methods, helps manage pests and diseases in stored maize and potatoes, reducing losses and minimizing reliance on chemical pesticides.

Market Access and Value Addition: Developing market linkages and value-added processing facilities, such as milling or processing units, diversifies income sources for farmers and reduces post-harvest losses by converting surplus produce into value-added products with longer shelf life.



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GROUP EXERCISES (D1 TO D11)

- D1. What are the locally adapted climate smart practices in your area?
- D2. Each group selects at least two climate smart agriculture practices and describes why these are climate smart.
- D3. Are these practices suitable for your area and how it can be adapted as mitigation practice for climate smart agriculture?
- D4. How and to what extent do they contribute to the three pillars of climate smart agriculture?
- D5. Identify and discuss the factors that might hinder the adoption of a specific climate-smart practice, identified in previous exercises, in their particular community and experience.
- D6. Prepare an action plan for climate smart production of maize and potato for future.

INSTRUCTIONS FOR EXERCISES AND GROUP ACTIVITIES

For each exercise participants have 1 hour to complete. The exercise is grouped base so all the group members participate actively in their collaboration in exercises. This exercise will be beneficial for all types of people like government officials, development sector and particularly for the farmers of maize and potato. Congratulate participants on their active participation in this exercise and learn many new things about locally adapted and described these practices how they are climate smart practices to mitigate the effect of climate change.

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