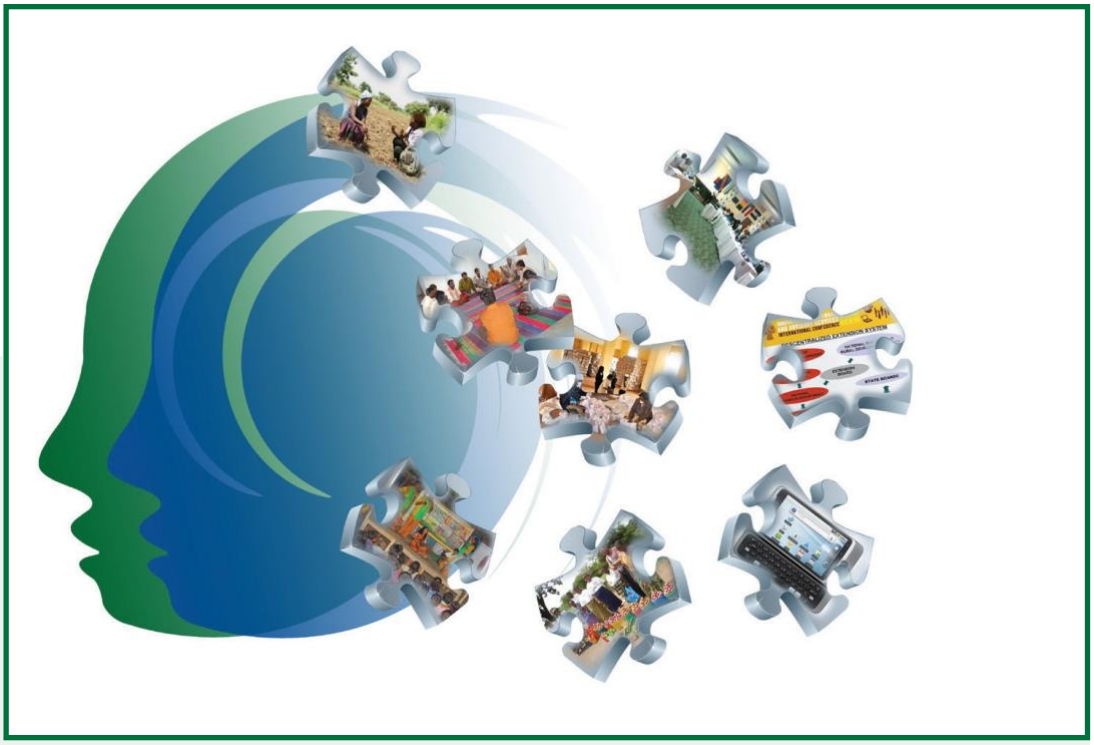
Thematic Module 8: Extension Support for Climate Adaptation and Mitigation



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In 2012, GFRAS developed the document "New Extensionist," detailing the role of extension in an agricultural innovation system and the strategies and capabilities needed at individual, organisational, and systemic levels. Based on this document, the GFRAS Consortium on Education and Training in Agricultural Extension was established to promote the "New Extensionist" principle through training, curriculum revision, and extension research.

The "New Extensionist" learning kit (https://www.g-fras.org/en/knowledge/new-extensionist-learning-kit-nelk.html) contains several modules designed for self-directed, face-to-face, or blended learning and can be a valuable resource for field staff, managers, and trainers. The module "Extension Support for Climate Adaptation and Mitigation" is developed within the framework of the New Learning Kit for Extensionists.

We thank everyone who participated in the module review, especially Malamine Ouattara, Hlami Ngwenya, Nimisha Mittal, and María Auxiliadora Briones. We also thank the Latin American Network for Rural Advisory Services (RELASER) for coordinating the development of this module.

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Contents

1. Before you begin

1.1. General instructions

This module should be used in conjunction with the workbook provided. As you read through the module, you will find different visual features designed to help you navigate the document.

					
Activity	Further reading	Did you know	Example	Keywords	Take note

Figure 1: Icons used to highlight important information throughout the manual

The module uses keywords (difficult or technical words essential to understand). To ensure that you receive the full benefit from the module, keywords will be marked the first time they occur and defined in a box containing the keywords symbol. Ensure that you read the definitions of any words you are unsure about.

1.2. Activities

Each session in the module will contain various types of activities to help you become knowledgeable and competent. The module includes the following types of activities:

A **pre-assessment** is to be completed before reading through the module overview and introduction, and a **post-assessment** is to be completed once the entire module has been covered. This will measure the degree to which your knowledge has improved by completing the module.

Each session contains one or more **activities to be completed in the workbook,** as indicated in the module. These activities measure your ability to recall and apply theoretical knowledge.

You must complete a summative assessment at the end of each study unit. These assessments are longer than the session activities and will test your knowledge of all the work within the study unit.

1.3. Assessment instructions

Keep the following in mind before doing any of the assessments:

- All assessments are to be completed in the provided workbook.
- The manual contains all the relevant information you need to complete the questions; facilities, such as online sources, will be made available if additional information is required.
- Work through the activities in a study unit and ensure you can answer all the questions before attempting the summative assessment. If you are unsure of any part of the training material, repeat that section until you feel confident.
- At the end of your learning period, you must complete the summative assessment under the supervision of your trainer.

THEMATIC MODULE 8: EXTENSION SUPPORT FOR CLIMATE ADAPTATION AND MITIGATION

2. Module information

2.1. Module outcomes

After completing this module, you will be able to:

- Explain concepts such as climate change, adaptation and mitigation.
- Understand the main effects of climate change and its consequences on agrifood systems from a global perspective.
- Understand and explain the factors that cause climate change and the measures that can be taken to adapt and mitigate different agroecological conditions.
- Know how EAS promote adaptation and mitigation strategies among farmers to combat the effects of climate change in different conditions and the availability of natural resources.

2.2. Module overview

Rural and farming communities directly experience the impact of climate change, emphasising the urgent need for action. As a future extension professional, you hold the key to unlocking rural and farming communities' resilience in the face of climate change. This module presents a comprehensive overview of climate change, its impact on agriculture, and the crucial role of Extension and Advisory Services (EAS) in supporting farmers in adapting to it and contributing to mitigation. This module is organised as three study units, each containing three sessions. By going through this module, the participants can gain essential knowledge and skills to empower farmers to address climate challenges.

2.3. Module objectives

After completing this module, you will be able to:

- Equip extension professionals with a thorough understanding of climate change, its causes, effects, and other essential concepts.
- Explore the vulnerabilities of agriculture to climate change and its contribution to greenhouse gas emissions.
- Introduce different approaches and measures to adapt to climate change and mitigate its effects on agriculture with supporting case studies from other countries
- Highlight the critical role of EAS in promoting and enforcing climate adaptation and mitigation strategies among farmers.

Study Unit 1 lays the foundation by defining climate change and examining its causes and effects while learning key concepts such as adaptation, mitigation, vulnerability, and resilience. It explores the intersection of climate change and agriculture, emphasising the vulnerabilities of farmers and the agriculture sector and the role of Extension and Advisory Services (EAS) in addressing these challenges.

Study Unit 2 discusses climate adaptation and why adaptation to climate change is critical. It also discusses different adaptive actions and approaches. The unit also provides several examples of adaptation in other contexts and highlights the pivotal role of EAS in promoting climate adaptation among farmers.

Study Unit 3 centres around climate mitigation. It starts by exploring why farmers must support climate mitigation and discussing various available mitigation strategies. The unit then shows the different approaches and measures used in international case studies and highlights the importance of EAS in promoting climate-mitigating strategies among farmers.

This module empowers extension professionals to become essential role players in facilitating climate action in agriculture. By acquiring the knowledge and tools presented, participants will be equipped to guide farmers towards climate-resilient practices, ensuring a sustainable agrifood system in the face of changing environmental conditions.

2.4. Module introduction

The world is shifting. Climate change is altering landscapes, disrupting weather patterns and posing unprecedented challenges for farmers around the globe. As extension professionals, you must guide these individuals through uncertain times and empower them to navigate the challenges of climate change.

This module, 'Extension and Advisory Services (EAS) for climate adaptation and mitigation', equips you with the foundation knowledge and tools needed to become a champion for climate-smart agriculture. Through three intensive units, you will understand the complexities of climate change, explore effective adaptation and mitigation strategies, and discover how EAS can act as a bridge between science and practice, empowering farmers to build resilience and thrive in a changing world.

This training is about learning new concepts and understanding the skills to translate knowledge into action through various cases discussed across the sessions. Through the varied sessions, cases and real-world examples, you will gain the confidence to:

- Explain climate change and its impact on agriculture clearly and concisely.
- Guide farmers in selecting and implementing effective adaptation and mitigation strategies tailored to their needs and contexts.
- Facilitate collaboration between farmers, researchers and policymakers to create a supportive ecosystem for climate action.
- Become a trusted advisor, empowering farmers to make informed decisions and navigate the challenges of a changing climate.

We want you to join us on this journey and be the changemaker. Together, we can learn, ensure a sustainable food system for future generations, and protect the future of agriculture and the farming communities it supports.

Complete the pre-assessment in your workbook.

STUDY UNIT 1: INTRODUCTION TO CLIMATE CHANGE AND ITS IMPACT ON AGRICULTURE

3. Unit information

3.1. Unit outcomes

After completing this study unit, you will be able to:

- Define climate change, its primary causes and effects;
- Explain the interrelationship of climate change and the agriculture sector;
- Explain how Extension and Advisory Services (EAS) can aid in combatting climate change.

3.2. Unit overview

This study unit is organised as follows:

Session 1 provides the basics of climate change by defining it, exploring its causes and effects, and discussing the key concepts. It clarifies the meanings of several terms, helping participants comprehend the nuances between climate and weather, adaptation and mitigation, vulnerability and resilience, and more.

Session 2 focuses on the intersection of climate change and agriculture. It explains the vulnerabilities of farmers and the agriculture sector to climate change and how agriculture contributes to it. It discusses examples across countries and provides hints towards the forms of responses to climate change that will be discussed in detail under study units 2 and 3.

Session 3 discusses the importance of EAS in addressing climate change, the challenges EAS faces, and the capacities EAS needs to promote climate change adaptation and mitigation.

3.3. Unit introduction

Dealing with climate change has become crucial in today's rapidly changing world. International summits and discussions are actively seeking solutions to this pressing challenge.

The recent COP28 UAE declaration, centred on sustainable agriculture, resilient food systems and climate actions, highlighted the urgent need to transform agriculture and food systems in response to the impact of climate change. One of the key objectives of the declaration is to scale up adaptation and resilience activities, reducing the vulnerability of farmers, fisherfolks and other food producers. This involves providing essential financial and technical support, capacity building, infrastructure, and innovative solutions, including early warning systems; the aim is to promote sustainable food and nutrition security while conserving, protecting and restoring nature. As facilitators and knowledge intermediaries working closely with farmers, Extension and Advisory Services (EAS) have a key role in supporting farmers to better adapt to the changing climate.

This study unit is tailored to empower EAS professionals with knowledge of basic concepts of climate change, help them explain the interactions between climate change and agriculture, and appreciate the role of EAS in promoting climate adaptation and mitigation strategies. It also outlines the types of functions they need and the capacities necessary to perform them effectively.

4. Session 1.1: Introduction to climate change

4.1. Session outcomes

After completing this study unit, you should be able to:

- Explain the concept of climate change, its causes and effects,
- Explain the key terminologies associated with climate change and their major differences.

4.2. Session overview

Climate change refers to a significant variation in the average state of the climate or its variability that persists for an extended period (typically decades or longer). Natural processes may cause climate change, or external (human-related) events that cause long-term changes in the atmosphere's composition or land use could cause it.

In simple terms, climate change results in a change in average weather patterns in a region over the long term. It can be due to natural phenomena or caused by human activities such as releasing greenhouse gases into the atmosphere.

Climate change can cause various local or global changes, such as rising temperatures, rising sea levels, shrinking mountain glaciers, increased extreme weather events, and changes in ecosystems. These changes can affect human health, the environment, and the economy.

4.3. Effects of climate change

To explain what climate change is all about, let us consider the following effects of climate change with examples of happenings around the world:

- **Heat waves:** Heat waves are periods with abnormally high temperatures, higher than the usual values recorded in a given place.

EXAMPLE

Large areas of the US, Mexico, Southern Europe, and China experienced extreme heat in July 2023, breaking many local high-temperature records.

- **Heavy precipitation and storms:** More heavy rain or snowfalls occur in many areas, leading to floods and extreme weather. Warmer seas also make coastal storms like hurricanes more common and damaging.

EXAMPLE

A deadly storm called 'Daniel' in Libya killed around 4000 people in September 2023.

- **Sea level rise:** The sea level has risen about 8-9 inches since 1880 because ice is melting and seas are getting warmer. With more warming, sea levels could rise further, harming communities on islands and near coasts.

EXAMPLE

Melting ice in Greenland, Antarctica, and the Arctic are the best proof of this.

- **Threats to habitats and animals:** Climate change's warmer temperatures and rising seas put many plants and animals at risk of extinction.

EXAMPLE

Some exotic Arctic animals, such as polar bears, snow leopards, and common insects like bumblebees and dung beetles, are near extinction due to the consequences of climate change. Giant pandas, Asian elephants, and blue whales are also near extinction.

- **Ocean acidification:** Extra carbon dioxide in the air makes the ocean more acidic. This makes it hard for corals and shell-forming organisms to survive, affecting the food chain of other sea animals.

- **Wildfires:** These are big, uncontrolled fires that get out of control, burning through forests and towns, posing significant threats to human populations and ecosystems. These large-scale infernos rapidly cover vast tracts of forests, encroaching upon residential areas and jeopardising lives and infrastructure.

  Many vulnerable communities lack fire-resistant materials, defensible space and evacuation plans, putting them at significant risk. Additionally, limited access to resources and infrastructure can hinder safe evacuation during these events. Moreover, smoke and toxic gases generated by wildfires pose health hazards, especially for those with respiratory issues. Climate change further worsens the situation by increasing the frequency and intensity of these destructive events.

FURTHER READING

The following research will further enhance your understanding of this topic. See references 1,2,3,4,5 and 6 in the "Further reading" section.

EXAMPLE

A recent wildfire in Viña del Mar, a city and commune on the central coast of Chile, is an extreme example of the effects of climate change.

- **Water scarcity:** Water scarcity is another issue resulting from climate shock, which means there is a lack of freshwater resources to meet the standard water demand. Recently, UNICEF has reported that more than 347 million children under 18 were exposed to extreme water scarcity in South Asia, which is leading to food insecurity, malnutrition and exposure to health risks such as diarrhoea.

The consequences of climate change disrupt the food web, resulting in an imbalance in the earth's systems, making the survival of many species difficult. The consequences are leading to the displacement of millions every year, particularly in vulnerable regions, worsening existing socio-economic challenges.

DID YOU KNOW

Climate change is causing the ocean to become more acidic. This occurs due to human activities such as burning fossil fuels, deforestation, and others releasing excess carbon dioxide (CO_2) into the atmosphere. About 30% of CO_2 emitted gets absorbed by the ocean. Once absorbed, CO_2 reacts with seawater to form carbonic acid, which increases the concentration of hydrogen ions (H^+), making the ocean more acidic by lowering the pH of the water. Ocean pH has dropped from about 8.2 to 8.1 in just 200 years, the fastest change in millions of years.

This increase in acidity has significant consequences for marine life, particularly organisms such as corals, shellfish, and certain types of plankton, whose calcium carbonate shells or skeletons can dissolve in acidic conditions. It makes it harder for them to build and maintain their structures, hindering growth and survival. This disrupts marine ecosystems, impacting food webs and fisheries, with potential consequences for fisheries and human food security.

In addition to acidification, climate change also warms the ocean, further stressing marine life. The combined effect of these factors can lead to coral bleaching, mass die-offs, and changes in species distribution.

4.4. Causes of climate change

Climate change is mainly due to the following human interventions:

- **Burning fossil fuels:** The burning of fossil fuels, particularly coal, oil, and gas, is the primary contributor to global climate change. They account for over 75% of global greenhouse gas (GHG) emissions, of which nearly 90% is CO_2.

These emissions create a blanket of greenhouse gases, trapping the sun's heat and leading to global warming. While some progress has been made in reducing the use of fossil fuels, with approximately a quarter of electricity coming from renewables (solar, wind, etc.), a significant portion of electricity is generated from fossil fuels.

- **Industrial manufacturing processes:** Emissions arise from burning fossil fuels to produce energy for manufacturing goods such as cement, iron, steel, electronics, plastics, and clothing, making the manufacturing industry one of the most significant contributors to GHG emissions.
- **Deforestation and land use changes:** Cutting down forests, often for agriculture or pasture, releases stored carbon and contributes to roughly a quarter of GHG emissions. Deforestation limits the earth's natural ability to absorb carbon dioxide.
- **Transportation:** The transportation sector, including cars, trucks, ships, and planes running on fossil fuels, results in the emission of GHG. Road vehicles, in particular, account for a significant portion of the combustion of petroleum-based products.
- **Agricultural practices:** Food production contributes to emissions through various processes, including deforestation, livestock digestion, fertiliser use, and energy consumption in farming.
- **Energy consumption in buildings:** Residential and commercial buildings relying on coal, oil, and natural gas for heating, cooling, and electricity contribute significantly to emissions. The growing demand for energy in buildings has caused increased carbon dioxide emissions in recent years.
- **Consumer lifestyles and overconsumption:** Individual behaviours, including energy use, transportation choices, dietary habits, and overall consumption patterns, contribute to GHG emissions.

Realising the multiple climate change effects and causes around the globe, recent international summits such as COP 28 and reports have highlighted the urgent need for swift, coordinated climate actions to combat this crisis in the best possible ways.

DID YOU KNOW

The term "greenhouse", as used in climate change, is derived from the analogy of greenhouses used in cold areas to preserve heat and grow plants. A greenhouse is made of glass that permits short-wave solar radiation to enter but prevents the reflected long-wave radiation from leaving, thereby increasing the temperature inside the glasshouse structure.

An example of the greenhouse effect can be experienced when you enter a car or a bus on a day when the sun is shining – it is much warmer inside than outside.

FURTHER READING

The following research will further enhance your understanding of this topic. See references 7,8 and 9 in the "Further reading" section.

4.5. Key climate change concepts

Understanding the fundamental concepts in the climate change literature is essential for fully comprehending the impact of climate change and implementing effective climate adaptation and mitigation strategies. To explain these key terms, refer to the GFRAS NELK module 13 (Session 2.1).

Weather vs climate

Weather refers to atmospheric conditions at a specific place and time. Common aspects of weather experienced by everyone throughout the day include rain, humidity, wind, sunshine, cloudiness, and temperature. It also encompasses extreme events like tornadoes, droughts and tropical cyclones. Weather is dynamic, capable of change within a very short period, even within the same day.

In contrast, *Climate* is the aggregate of weather conditions prevailing in an area over a long time, typically three consecutive decades. The term "climate" involves considering long-term temperature and precipitation averages and the type, frequency, duration, and intensity of weather events such as heat waves, cold spells, storms, floods, and droughts.

For example, when someone says, "It is raining a lot today," or "It has been raining a lot this season," they talk about the weather. When someone says, "It always rains here for six months of the year," or "It never snows here," they talk about the climate.

Climate variability and climate change

While climate variability and climate change are often used interchangeably in everyday conversations, it is essential to recognise their nuanced distinctions.

Climate variability is the natural fluctuation within the climate, including swings above and below the mean state and other parameters. It reflects the different weather conditions over a day, a month, a season or a year.

Let's consider the rainfall over a given period in a particular region of the world. The variability can be low, meaning there is not much difference in the quantity or timing of rain from one year to another. There may be high variability in another region, meaning that rainfall quantity swings from far below average to far above average from year to year, and the timing is unpredictable.

Climate variability affects weather conditions, including cyclone activity, temperature, and rainfall. It results from natural internal processes within the climate system, such as the El Niño Southern Oscillation, or variations in natural external forces, such as volcanic eruptions.

On the other hand, Climate change refers to a significant variation in the average state of the climate or its variability, persisting for an extended period (typically decades or longer). Climate change results from natural processes or is caused by human interventions leading to long-term changes in the atmosphere's composition or land use.

For example, climate change can significantly impact agriculture through shifts in weather patterns. This may lead to prolonged periods of drought or excessive rainfall that can disrupt traditional planting seasons, affect crop productivity, and increase crops' susceptibility to pests and diseases.

Natural disasters are rare phenomena such as earthquakes, hurricanes, floods, tornadoes, volcanic eruptions, and tsunamis. Their effects are often severe and immediate. They can cause widespread destruction, loss of life, and extensive environmental, infrastructure, and property damage.

For farmers, hurricanes and floods can devastate agricultural lands, destroy crops, and cause severe soil erosion. This can lead to the displacement of communities and substantial financial setbacks for farmers.

These events are part of the earth's natural processes and are not directly linked to human activities. While climate change can influence the frequency and severity of some natural disasters, the events are not caused by it.

Vulnerability and resilience

When we try to explain climate change, vulnerability and resilience are closely interconnected. Vulnerability is the degree to which physical structures, individuals, or natural and economic assets are exposed to the risk of loss, injury or damage resulting from the impact of a hazard. In the context of climate vulnerability, it is broken down into three components directly related to climate hazards:

- the **degree of exposure** to climate-related hazards,
- the **capacity** available to deal with climate-related hazards, and
- the **sensitivity** to the given climate-related hazard.

Resilience refers to Extension support for Climate Adaptation and Mitigation by either resisting or changing to reach and maintain an acceptable level of function and structure. This is often determined by the social system's ability to organise itself to increase its capacity for describing past disasters, thereby improving risk reduction measures.

Resilience introduces a time dimension to the idea of vulnerability. A system is considered resilient when it is less vulnerable to shocks over time and can recover from them promptly. Resilience is achieved through exposure sensitivity reduction and increased adaptive capacity. These can be undertaken across biophysical, economic- or social domains. Like resilience, resistance is often applied in the context of climate change, referring to resistance to the ability of a population (or a community) to withstand the disturbance. In contrast, resilience refers to the ability to recover after the disturbance.

TAKE NOTE

Adopting crop diversification and cultivating climate-resilient varieties enhance climate resilience, whereas cultivating crops with inherent resistance to specific threats is an example of climate resistance.

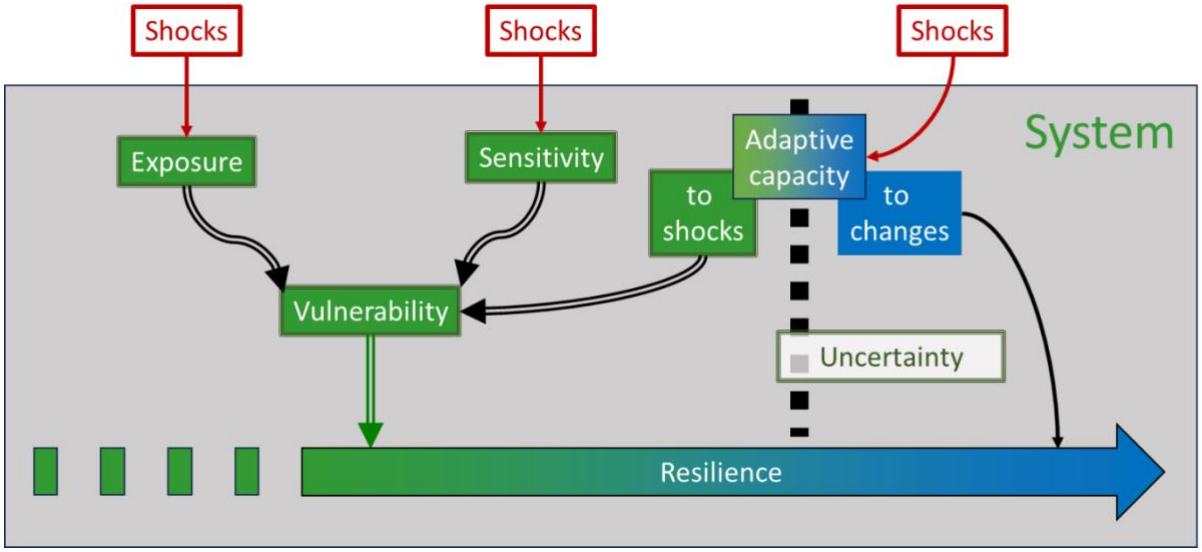

Figure 2: Vulnerability and Resilience[10]

Climate hazard and climate sensitivity

The harmful effect of climate change on livelihoods and ecosystems is known as climate hazards. These hazards can be caused by gradual climate variability or extreme weather events. Some hazards are continuous phenomena that start slowly, such as the increasing unpredictability of temperatures and rainfall. Others are sudden but relatively discrete events like heat waves or floods.

Climate sensitivity measures how much the atmospheric temperature will react to greenhouse gases, aerosols, and changes in solar radiation. It is expressed as the temperature change associated with a doubling of the concentration of carbon dioxide in the Earth's atmosphere due to a given factor.

FURTHER READING

The following research will further enhance your understanding of this topic. See reference 11 in the "Further reading" section.

EXAMPLE

Suppose a family grows rice in a valley bottom that is starting to have higher floods that submerge their rice plants every 3 to 4 years for the first time in memory. In that case, the farm's exposure to climate change damages is increasing, resulting in yields that are less than half of past yields in flood years. Most rice varieties will die if completely submerged for a few days, as they are sensitive to deep flooding. When you recommend that the family adopt a new rice variety that can tolerate submerging, the family can reduce its sensitivity to the change in the flooding pattern. Your knowledge and work with the family have increased its adaptation capacity to the changing conditions.

Climate risk

Understanding is another related concept. Risk is generally involved in any action taken for gain where the outcome is uncertain and carries the potential for failure or loss.

ISO 31000 defines risk as the effect of uncertainty on objectives. Risk is a measure of uncertainty, which refers to situations where the outcome is unknown. (For more details, Read GFRAS module 13, which focuses on Risk Mitigation and Adaptation in Extension and Advisory Services.)

Climate response vs climate action

The challenges of climate change require two distinct approaches: climate action and climate response. While they sometimes overlap, they differ in their emphasis.

Climate response encompasses reactive measures taken in response to observed or anticipated climate change impacts. This includes adapting agricultural practices to withstand changing weather patterns, managing droughts and recovering from extreme events.

On the other hand, climate action focuses on proactive measures to mitigate the effects of climate change and reduce its overall impact. This involves reducing greenhouse gas emissions from agriculture, promoting sustainable land management practices and developing climate-resilient crops and livestock.

Both climate action and response are integral components of a comprehensive strategy for climate-smart agriculture, contributing to the resilience and sustainability of food production systems in the face of a changing climate. For example, while improving irrigation techniques can be a climate response to manage water scarcity, adopting precision agriculture technologies that optimise fertiliser use can be both a climate response (reducing emissions) and climate action (mitigation).

However, it is essential to carefully assess an intervention's specific context and goals to determine whether it falls primarily under one category or contributes to both.

EXAMPLE

The climate response in agriculture might involve shifting planting schedules or introducing heat-tolerant crop varieties in response to increasing temperatures. Climate action in agriculture would also involve adopting precision farming techniques, such as water and nutrient management, to reduce climate change impacts on the environment and enhance resource use efficiency.

The United Nations (UN) provides three forms of Climate change actions: Adaptation, Mitigation and Financing.

- **Adaptation** is understood as the things we do, planned or not planned (autonomous), that result in adjustments to climate-induced hazards. It refers to adjustments in ecological, social or economic systems in response to actual or expected climatic stimuli and their effects.

  It refers to changes in processes, practices, and structures that moderate potential damages or benefit from opportunities associated with climate change. In simple terms, countries and communities must develop adaptation solutions and implement actions to respond to current and future climate change impacts.

- **Mitigation** should be considered human actions to reduce the intensity or severity of climate change. It refers to any action governments, businesses, or people take to reduce or prevent greenhouse gas emissions or enhance carbon sinks that remove these gases from the atmosphere.

TAKE NOTE

Both climate change adaptation and mitigation are focused on lessening the impact of climate change but from different perspectives.

Climate change adaptation focuses on actions to reduce the impact of global warming on human and natural systems despite climatic conditions and atmospheric greenhouse gas concentrations.

Climate change mitigation focuses on addressing the root problem cause of global warming, i.e., decreasing the amount of greenhouse gases in the atmosphere. In reality, addressing global warming via mitigation has been slow and complicated by political and economic positioning. Inevitably, while mitigation solutions evolve, the earth's climate will keep changing and impacting the vulnerable. Thus, adaptation efforts are needed to adjust to inevitably new climatic conditions.

Adaptation differs from climate resilience since adaptation looks at 'what to do' to lower vulnerability to climate change—for example, increasing household water storage capacity. Resilience building promotes the development of community and society systems, e.g., establishing a community-managed emergency water storage facility.

Climate finance encompasses local, national, or transnational funding from diverse sources, including public, private, and alternative channels. Its primary objective is to support mitigation and adaptation actions that address climate change.

Mitigation activities, necessitating substantial investments, focus on significantly reducing emissions. Simultaneously, adaptation activities require significant financial resources to respond to adverse climate impacts and minimise their consequences effectively. These finances are needed to mobilise resources and support initiatives contributing to emission reduction and resilience.

When the world is in a state of emergency, we need to shift our developmental gears towards Climate emergency. It implies an urgent and critical situation urging immediate attention and action to address the escalating impacts of climate change. It is an action governments, scientists, and others have taken to acknowledge that humanity is in a climate crisis.

The climate crisis suggests a more sustained and overarching challenge, emphasising the complex and interconnected nature of climate-related problems. It is a term describing global warming and climate change and their impact.

Climate change and global warming have served as wake-up calls to the unpredictable and extreme consequences we now face. The extreme term 'global boiling' highlights the urgency and gravity of increasingly devastating and irreversible consequences to our oceans, ecosystems, and weather patterns. As Antonio Guterres, the U.N. chief, warned: "The era of global warming has ended; the era of global boiling has arrived," emphasising the need for action beyond just mitigation.

While reducing greenhouse gas emissions remains important, we must also prioritise adaptation and resilience measures to survive the immediate impacts of a boiling planet. Governments, scientists, practitioners and individuals must collectively shift their developmental gears towards emergency mode, prioritising actions and building resilience in this unprecedented crisis.

TAKE NOTE

Global boiling is a term used to emphasise the more extreme and immediate consequences of global warming.

EXAMPLE

Extreme weather events, rising sea levels, and ecosystem threats are regarded as pressing issues requiring timely intervention. A climate crisis could include widespread agricultural disruption, loss of biodiversity, and long-term shifts in weather patterns, indicating a broader, systemic issue that demands comprehensive solutions.

FURTHER READING

The following research will further enhance your understanding of this topic. See references 12,13,14,15 and 16 in the "Further reading" section.

Complete Activity 1.1 in your workbook.

5. Session 1.2: Climate change and agriculture

5.1. Session outcomes

After completing this session, you should be able to:

- Understand the impact of climate change on agriculture and farmers
- Learn about the contribution of agriculture towards climate change and
- Realise the responses needed in the agriculture sector to address climate change impacts.

5.2. Session overview

The anticipated global population increase, projected to reach 9.7 billion by 2050, emphasises a pressing need to increase food production. Any changes in weather and climate patterns can incur significant costs for farmers, the agriculture sector and overall food production.

The vulnerability of the agriculture sector to climate change is rooted in the regional climate, which determines the nature and characteristics of vegetation and crops, with temperature, sunlight, and water serving as the main drivers of crop growth. The agriculture sector is not only susceptible to the effects of climate change, but it is also a significant contributor to climate change, emitting greenhouse gases (GHG) that further exacerbate the challenge of climate change. The global agri-food system alone is responsible for emitting one-third of all GHG emissions at present.

KEYWORDS

Greenhouse gases are the gases that contribute to the greenhouse effect by absorbing infrared radiation. E.g., Carbon dioxide (CO_2), methane (CH_4), Nitrous oxide (N_2O), Industrial gases: hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur hexafluoride (SF_6), Nitrogen trifluoride (NF_3), water vapour and ozone.

The *greenhouse effect* is the process by which greenhouse gases trap heat near the earth's surface.

In this context, it is essential to explain how climate change affects agriculture and farmers while acknowledging the reciprocal relationship where agriculture, in turn, contributes to climate change through GHG emissions. Understanding the dynamics is crucial for developing strategies to address both climate change and the need for a sustainable food production system.

5.3. The effect of climate change on agriculture

Climate change affects agriculture through multiple pathways: an increase in temperature, an increase in CO_2 concentration, and frequent extreme weather events, to name a few. These events can cause substantial crop yield reductions and lower their nutritional quality, affecting farmers' livelihoods at the micro level and threatening food security at the macro level.

Using different regional studies, Hasegawa et al. (2018) conclude that by 2050, climate change can lower the yields of major crop types by 17%, increase market prices by 20%, and reduce related consumption by 3% even after global adaptation.

The Intergovernmental Panel on Climate Change (IPCC) reports that this can potentially lead to an increase of 1–183 million additional people at risk of hunger across different climate change projected scenarios compared to a no-climate-change scenario.

This highlights the need to optimise climate-smart and climate-resilient agricultural practices and technologies to mitigate the impacts of climate change on food production. Changes in temperature and precipitation can also lead to outbreaks of pests and diseases, thereby reducing harvests and ultimately affecting the food security of the entire country.

It is crucial to explain these effects of climate change on agriculture, which is the primary source of occupation and income for millions of smallholder farmers in several low- and middle-income countries.

Crop productivity

Climate change can have a mixed impact on crop cultivation. Increased CO_2 in the atmosphere increases photosynthesis in plants and extends the growing season with both longer maturing time and the possibility of more crop cycles per season.

Negative effects include increased demand for irrigation due to warmer conditions, the adverse impact of air pollution on plant health, increased risk of wildfires, expansion of pests and diseases and potential disruptions to pollination processes that may affect crop yields. Farmers must carefully consider positive and negative factors for effective mitigation and adaptation of agricultural strategies.

It is estimated that a 1°C increase in temperature can cause a 10–20% decrease in crop yield globally. Similarly, a 1–3°C increase in temperature is estimated to reduce yield by 20–30% in potato crops. This effect can be even worse by the end of this century when a 2–4°C increase is expected, affecting crop production even more. Changes in weather conditions ultimately caused a permanent extreme climate shift and affected agriculture throughout the world. These extreme temperature changes during sensitive stages like flowering, anthesis, and milking stage affect wheat yield, grain weight, and grain size at the end of the season significantly.

FURTHER READING

The following research will further enhance your understanding of this topic. See reference 17 in the "Further reading" section.

Water resources

Climate change significantly impacts water resources in agriculture in several ways. Altered precipitation patterns, with more intense and uncertain rainfall events, lead to waterlogging, soil erosion, and nutrient leaching, affecting crop health and water quality.

Rising temperatures increase evaporation rates, amplifying water demand for irrigation and growing water scarcity in arid regions. Changes in snowmelt timing, influenced by shifts in temperature patterns, impact downstream freshwater availability, which is crucial for irrigation practices. Intensified storms and floods associated with climate change damage crops and soil erosion and contaminate water sources with sediments and pollutants.

Rising sea levels in coastal areas contribute to saltwater intrusion into freshwater sources, of which around 70% are used for agriculture. Saltwater intrusion adversely affects soil and water quality and impacts overall agricultural productivity.

Furthermore, changing water temperatures, increased drought frequency, and disruptions to the hydrological cycle pose additional challenges to water availability and management in agriculture. Extreme weather events damage crops and contaminate water resources with salt water and pollutants. The multifaceted impacts emphasise the intricate relationship between climate change and water resources, indicating the need for adaptive strategies for sustainable agricultural practices.

EXAMPLE

The MENA (Middle East and North Africa) region is experiencing a water crisis due to changing precipitation patterns and increased evaporation rates caused by rising temperatures. This has led to water scarcity for irrigation, affecting crop production and food security. Additionally, increased storms and floods have resulted in soil erosion and contamination of water sources, further compromising agricultural productivity. These challenges highlight the need for adaptive measures to ensure sustainable water use and farming practices in the face of climate change.

FURTHER READING

The following research will further enhance your understanding of this topic. See reference 18 in the "Further reading" section.

Soil resources

Climate change has significantly affected the essential soil systems for agriculture. This impact results in reduced fertility, increased reliance on chemical fertilisers, and changes in weathering stages that influence nutrient availability. The changing climate alters the delicate balance of soil components, affecting crops' overall health and productivity.

These impacts are diverse and region-specific, shaped by complex interactions among climate change drivers. Soil degradation, erosion, compaction, nutrient imbalance and biodiversity loss reduce soil's ability to support plant life and grow crops. These changes are expected to deteriorate food security and environmental sustainability, emphasising the need to manage these risks.

DID YOU KNOW

Weathering stages play an essential role in nutrient availability within the soil. During weathering, rocks and minerals break down into smaller particles due to various environmental factors such as temperatures, moisture, and microbial activity. This process releases essential nutrients into the soil. The extent and rate of weathering can influence the availability of these nutrients for plant uptake.

FURTHER READING

The following research will further enhance your understanding of this topic. See references 19, 20 and 21 in the "Further reading" section.

Risk to farmers

Smallholders often lack the necessary resources to adapt to climate change and mitigate the impacts of extreme weather events. Farmers in the tropics are increasingly vulnerable to extreme weather events, such as droughts, hurricanes, and floods, which can cause loss of income, food insecurity, and increased environmental pressures on farmers.

The lack of risk-targeted training for these farmers fails to explain how the existing adaptation and mitigation strategies perform in the face of extreme weather events, resulting in enhanced vulnerability of farmers to climate change and agricultural risks.

FURTHER READING

The following research will further enhance your understanding of this topic. See reference 22 in the "Further reading" section.

Health risks

Farmers' exposure to excess heat, extreme weather, degraded air quality, and increased pesticide exposure make them more prone to disease-carrying pests such as mosquitoes and ticks. These risks can result in varied health issues, including communicable and non-communicable diseases, mental health challenges, and occupational health and safety concerns.

For example, agricultural workers labouring in hot conditions are at an increased risk for workplace injuries due to increased fatigue and reduced alertness. Migrant smallholder farmers may also encounter migration-related health issues, such as psychological ill-health and exposure to environmental risks in their new locations. These impacts highlight the need to address and mitigate the health risks of climate change for farmers.

FURTHER READING

The following research will further enhance your understanding of this topic. See references 23,24 and 25 in the "Further reading" section.

EXAMPLE

In the Democratic Republic of the Congo, more intense rainfall and rising temperatures will likely significantly hamper development goals, as they will likely impact crop productivity and necessitate significant changes to current farming practices. The projected change in rainfall intensity will continue to damage crops and erode fertile soils, potentially leading to the introduction of novel crop diseases and the intensification of others. Prolonged dry spells and rising temperatures will stress plants and reduce yields, forcing farmers to expand their cropland into forests.

While potatoes and maize have a high tolerance to weather conditions, pests and diseases, producing other crops, such as dry beans, will be adversely impacted by heat stress and climate-sensitive diseases such as bean root rot. Farmers will find it difficult to address these issues. A temperature rise is likely to adversely impact the yields and quality of plantains, soy, dry beans, and coffee.

It will also adversely affect pest and pathogen dynamics, particularly for diseases such as cassava mosaic virus and coffee rust. Prolonged dry spells could lead to significant livestock losses and spoilage of livestock products. Heavy rainfall and floods may force shifts in the timing of the planting and harvesting seasons. Heavy rains and floods will also continue to damage road networks, decreasing market access and isolating rural communities.

In contrast, some crop yields, such as rice, could increase.

FURTHER READING

The following research will further enhance your understanding of this topic. See references 26 and 27 in the "Further reading" section.

5.4. Contributing to climate change

Agriculture contributes significantly to greenhouse gas emissions, with various sources accounting for different percentages of total emissions. IPCC 2022 report indicates that the agriculture, forestry, and land use sectors contribute 22% of GHG emissions among all economic sectors globally.

The agriculture sector has the largest source of anthropogenic methane emissions. An FAO study on emissions due to agriculture reveals that in 2018, global agriculture emissions were nearly 4 Gt CO_2-eq., of which a significant portion is CH_4 and N_2O. The sector is also responsible for non-CO_2 emissions by converting natural ecosystems into agricultural land, primarily forests and peatlands.

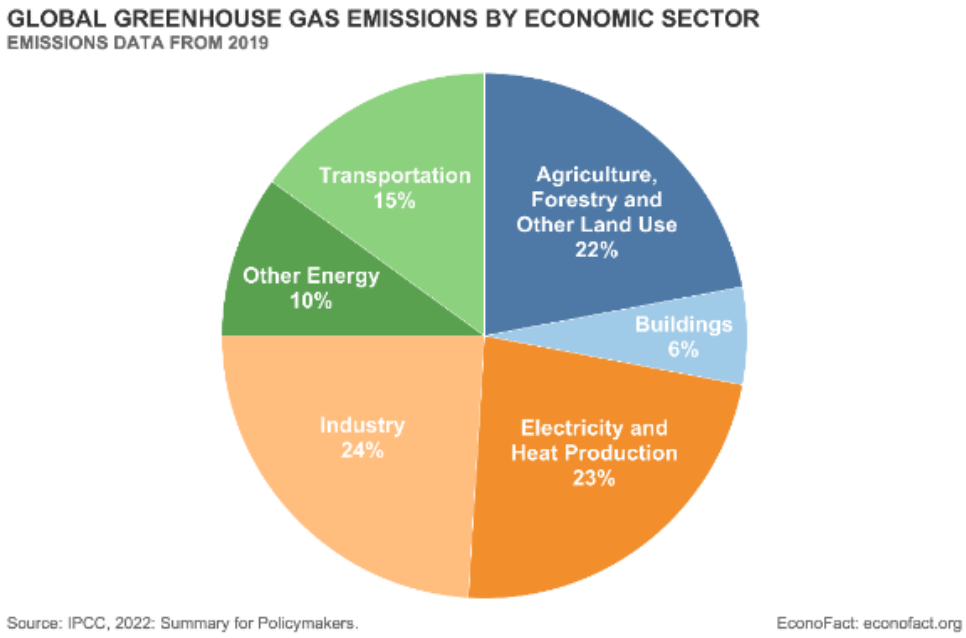

Figure 3: GHG emissions by economic sector

FURTHER READING

The following research will further enhance your understanding of this topic. See references 28 and 29 in the "Further reading" section.

The major contributors to GHG emissions stem from the following *intensive agriculture practices*:

- **Industrial agriculture** often treats farms as crop factories with minimal biodiversity over vast land areas, relying heavily on fertilisers and pesticides. This approach can lead to soil degradation, reduced biodiversity, and increased GHG emissions.

- **Extensive cultivation** of crops like rice or corn increases methane emissions. Biogenic methane emissions from organic waste also have a 25 times greater warming effect than carbon dioxide.

  For example, it is reported that in the year 2021, 91.9% of waste emissions were biogenic methane generated by the decomposition of organic waste (such as food, garden, wood, and paper waste). While waste contributes a small percentage of the total emissions, biogenic methane has a warming effect 25 times greater than carbon dioxide.

Industrial agriculture is more commonly practised in developed countries such as the United States, Canada, part of Europe, and some Asian regions. These areas have adopted intensive farming methods, large-scale monocultures and heavy use of chemical inputs to maximise production. The prevalence of industrial agriculture in these regions is often associated with the high demand for food, feed and fibre and the availability of resources and technology to support large-scale farming operations.

FURTHER READING

The following research will further enhance your understanding of this topic. See reference 30 in the "Further reading" section.

- **Livestock production:** Livestock production contributes 15% of global greenhouse gas emissions, mainly due to methane (CH_4). This is more than any other sector except for electricity production.
- Use of **synthetic fertilisers and pesticides**: The widespread use of synthetic fertilisers and pesticides in modern agriculture can increase GHG emissions, contributing to nitrous oxide (N_2O) emissions. N_2O emissions from synthetic fertilisers account for 75% of total N_2O emissions.
- Deforestation and land use changes are major causes of CO_2 emissions contributing to climate change. According to the IPCC, 80% of global deforestation is caused by agriculture, and sustainable agricultural practices are crucial for reducing GHG emissions and promoting biodiversity conservation.
- **Long-term water scarcity and decline in crop productivity:** In situations of long-term water scarcity, farmers may resort to increased use of harmful agrochemicals and inefficient irrigation systems to arrest the decline in productivity. This can increase soil pollution and its impact on climate change.

The Organisation for Economic Cooperation and Development (OECD) states that farming uses around 70% of the world's water today and contributes to pollution from excess nutrients, pesticides, and other chemicals.

To mitigate these environmental impacts, sustainable water and land management strategies in agriculture are called for.

5.5. Responses to climate change

Climate change has significant implications for agriculture; globally, the sector is responding to these challenges. These responses include changes in farming practices, farming approaches, development of varieties, ecosystem services and policies.

Changes in farming practices

These agricultural practices and technologies boost productivity, enhance resilience, and reduce GHG emissions. They include Climate-Smart Agriculture (CSA), regenerative agriculture, nature-based solutions, permaculture, and natural farming.

KEYWORDS

Climate-smart agriculture (CSA) involves a set of agricultural practices and technologies that boost productivity, enhance resilience, and reduce GHG emissions. It encompasses a range of practices tailored to specific agroecological systems.

FURTHER READING

The following research will further enhance your understanding of this topic. See reference 31 in the "Further reading" section.

Changes in farming approaches

These are farming approaches that focus on sustainability and working with natural processes. Natural farming, agroforestry, permaculture, biodynamic farming and other sustainable farming approaches focus on working with natural processes and promoting environmental health. These approaches prioritise crop diversity, soil conservation and reduced chemical inputs to achieve sustainability.

EXAMPLE

Natural farming systems in Andhra Pradesh and Karnataka in India emphasise resilience, soil conservation, and the use of local resources such as cow dung and cow urine to improve soil conditions and reduce reliance on external synthetic inputs. These approaches aim to protect the environment, maintain soil fertility, and support the well-being of current and future generations. By adopting these eco-friendly farming practices, such as preserving soil health and promoting local food systems, sustainable agriculture contributes to biodiversity conservation and climate change mitigation.

Development of climate-resilient varieties

This involves developing crop varieties that are resilient to climate stressors such as drought, heat, and pests. Stress-tolerant and resilient varieties (STRVs) are an example.

EXAMPLE

Stress-tolerant and resilient crop varieties (STRVs) have been developed to cope with climate stressors such as drought, heat, and pests. In South Asia, particularly in countries like India and Bangladesh, developing and adopting climate-resilient rice varieties have been a focus. For instance, the International Rice Research Institute (IRRI) has been involved in developing and disseminating climate-resilient rice varieties for water-short areas of South Asia and Southeast Asia to address water scarcity and climate stress in rice cultivation. In addition, efforts are being made to develop stress-tolerant rice varieties, including those with enhanced tolerance to submergence, salinity, and heat stress, to ensure high yields under adverse conditions. These initiatives demonstrate the ongoing work in Asia to develop and promote the adoption of STRVs to enhance agricultural resiliency in the face of climate change.

FURTHER READING

The following research will further enhance your understanding of this topic. See references 32 and 33 in the "Further reading" section.

Ecosystem services

These are services provided by agriculture that enhance the delivery of ecosystem services, such as carbon sequestration and climate-smart farming methods.

EXAMPLE

Common Agricultural Policy (CAP) has promoted the adoption of sustainable farming practices that enhance European ecosystem services. For example, the CAP has supported implementing agroforestry systems, which combine trees and crops to enhance biodiversity, soil health, and carbon sequestration.

There have been efforts in Latin America to apply the ecosystem services approach to agriculture. Recent studies have shown that this approach can help understand the links between ecosystem services and regional inequalities.

Additionally, there have been cases in Latin America demonstrating the potential of sustainable agriculture to enhance ecosystem services. For instance, a study in Brazil showed that agroforestry systems can improve carbon sequestrations, soil fertility and biodiversity while providing economic benefits to farmers.

FURTHER READING

The following research will further enhance your understanding of this topic. See references 34,35 and 36 in the "Further reading" section.

Policies

Policies in response to climate actions can be found in various countries, providing examples of how governments address climate change and promote sustainable agriculture. These policies support sustainable agrifood systems, financial support, climate change action plans, and adaptation and mitigation strategies in response to climate change. Examples include OECD Climate Action, State Climate Policy Maps in the US, the European Commission's 2030 Policy Framework for Climate and Energy, European climate law, G20, COP28, and others.

FURTHER READING

The following research will further enhance your understanding of this topic. See references 37,38,39,40,41,42,43,44 and 45 in the "Further reading" section.

Complete Activity 1.2 in your workbook.

6. Session 1.3: EAS and climate change

6.1. Session outcomes

After completing this module, you will be able to:

- Explain why extension and advisory services (EAS) should address climate change;
- Discuss the role of EAS in addressing climate change;
- Explain how EAS is addressing climate change
- Discuss the kind of challenges EAS faces when addressing climate change and
- Discuss the capacities needed to empower the EAS to address climate change.

6.2. Session overview

Following the descriptions from sessions 1.1 and 1.2, this session shows how EAS can aid farmers in adapting and mitigating climate change. We all recognise that climate change poses a significant challenge to farmers, particularly smallholders.

They are more vulnerable to climate change impacts as they have limited capacity to adapt to changing climate or contribute to mitigation. Lack of sufficient knowledge on responding to changing climate and limited resources to take measures to deal with it primarily contribute to their limited capacity.

Climate change can lead to reduced crop yields, increased pest and disease outbreaks, and extreme weather events, negatively affecting farmers' livelihoods and food security. EAS can play a crucial role in helping farmers adapt to climate change by providing them with need-based information, training, and resources to improve resilience and reduce farmers' vulnerability.

KEYWORDS

Extension and Advisory Services (EAS), also called *Rural Advisory Services (RAS)*, consists of all the different activities that provide the information and services needed and demanded by farmers and other actors in rural settings to assist them in developing their own technical, organisational, and management skills and practices to improve their livelihoods and well-being. It recognises the diversity of actors in extension and advisory provision (public, private, civil society); much broadened support to rural communities (beyond technology and information sharing), including advice related to farm, organisational and business management; and facilitation and brokerage in rural development and value chains.

FURTHER READING

The following research will further enhance your understanding of this topic. See reference 46 in the "Further reading" section.

6.3. Addressing climate change

Over the last several decades, EAS has supported farmers in enhancing their farm production and productivity primarily through their advice on adopting new technologies and practices. They are the primary individuals whom the farmers trust and rely upon when they need advice on solving specific problems. In addition, there are several other reasons why EAS should address climate change issues.

- EAS staff have close working relationships with rural communities, especially at the field level.
- Farmers will be more receptive and willing to experiment with advice related to climate-smart agriculture if supported by EAS.
- EAS providers often have a thorough explanation of farmers' vulnerabilities and the prevailing conditions under which they operate.
- Their explanation extends to the assets of farm households, the social dynamics within and between communities, and farmers' adaptive capacities.

- EAS providers are often aware of the local support and services and the different types of user groups.
- EAS providers can play the needed mediation role for the extensive scaling up of climate-smart agriculture. Their expertise in mediation will be useful for supporting wider interactions among these stakeholders, including those in the private sector, to promote climate-smart agriculture.
- During and after natural disasters and extreme weather events, EAS often assists rural communities to cope with crises by providing relief and rebuilding rural livelihoods after the disaster.

6.4. Supporting adaptation and mitigation

EAS perform varied functions beyond their traditional ones of informing and educating farmers. They support farmers in adopting improved technologies, changing farm practices, providing weather advisories, and strengthening client-resilient value chains.

Actions to adapt to climate change can range from behavioural shifts (e.g. farmers planting more drought-resistant crops or more farmers buying crop insurance) to large-scale infrastructure projects (e.g., building coastal defences to protect against sea-level rise or setting aside land corridors to help species migrate).

In many areas, successful adaptation to the impacts of climate change will require adjustments to existing systems (e.g., changes in crop management practices) and transformation (e.g., shifting to entirely different production systems). EAS play a crucial role in helping farmers adjust to changing conditions and adapting to new practices. An essential aspect of the support provided by EAS to farmers to help them adapt to climate risks is the delivery of climate information (Refer to GFRAS module 13 to describe risk adaptation). EAS can use traditional media, such as radio, and new communication tools like mobile phones and social media (websites, applications like Facebook, and WhatsApp) to communicate climate information, including early warning weather advisories to farmers (FAO 2018).

EAS contribute to climate change mitigation by promoting practices that increase the amount of soil organic carbon and reduce the relative rate of carbon dioxide released through mineralising soil organic carbon (e.g., returning organic matter to the soil as plant residues and manure).

Other practices promoted by EAS that support climate change mitigation optimise using external agrochemicals, such as pesticides and fertilisers with a high carbon footprint (e.g., promoting integrated and ecological pest management) (FAO 2018).

EAS can contribute to mitigation efforts, for example, by strengthening farmer groups and rural organisations in their efforts to implement farming approaches and technologies that reduce emissions or sequester carbon as a co-benefit of increased productivity or climate change adaptation, supporting them in their efforts to access voluntary and regulated carbon markets; and promoting payment for ecosystem services programmes (David 2016). While supporting adaptation and mitigation, EAS should help farmers increase their productivity and incomes.

EAS can support climate change adaptation and mitigation by performing several functions (Table 1).

Table 1: Functions performed by EAS in promoting adaptation and mitigation

Sl. No.	**Functions performed**	**Examples**
1.	Demonstration of new technologies and practices	Demonstration plots/trials in farmer fields to show the performance of new climate-resilient technologies/practices (e.g., Drought Tolerant Maize in Africa (DTMA), Tolerant Rice Varieties in Asia, Systems of Rice Intensification (SRI), etc.)
2.	Organising training & learning events and producing educational/training materials	Training to farmers and farmer groups on: • Sustainable and climate-resilient production practices; • Organising farmer field schools on integrated pest management; • Training community resource persons/para extension workers • Development of training modules (e.g., climate-smart agriculture)

3.	Promoting agro-meteorological advisory	Through mobile apps, radio, press, TV, local groups of farmers, farmer social media groups, videos and presentations
4.	Mobilising communities	Women seed producer groups to promote stress-tolerant varieties Farmer groups (to promote community forest management, solar irrigation, etc.)
5.	Promoting digital tools	Site-specific nutrient management (Rice Crop Manager); climate-smart rice cultivation (Rice Knowledge Bank)
6.	Awareness generation	Production and broadcasting of radio programmes (DTMA and CA); Documentation of indigenous knowledge and practices (conservation of indigenous crop varieties)
7.	Enhancing access to inputs	Organising women as seed producer groups (STRVs); Organising seed fairs (to exchange and promote seeds of indigenous varieties).
8.	Stakeholder coordination	Innovation Learning Platforms with multiple stakeholders
9.	Advocacy	Evidence-based advocacy (SRI in Vietnam) and recognition of rights of native communities (forest management).

6.5. Challenges to promoting adaptation and mitigation

In most developing countries, EAS faces several challenges in supporting farmers. Public sector EAS often have limited staff and operational funds to support farmers efficiently.

The private sector usually focuses on selling inputs and services in areas with business potential. Non-governmental organisations (NGOs) provide broader livelihood support (beyond production advice), but they are not present everywhere. They also work in a few locations with a small number of farmers. All these affect EAS delivery, including its ability to support climate change adaptation.

However, EAS faces several other challenges when dealing with climate change issues, as discussed below.

- Climate change is a complex subject. Interventions need to rely on technically and functionally skilled facilitators. Continuous in-service capacity development is needed for individuals, organisations, and the people working within the broader enabling environment to support farmers.

- The results of some restoration measures or crop rotations might not be immediately visible to farmers. Maintaining the motivation of farmers and ensuring that benefits can be seen over different periods is crucial.

- Addressing the intertwined challenges of sustainable livelihoods, climate change adaptation and mitigation require working across different geographic scales, from individual plots and farms to entire farming systems, landscapes, or territories. This adds to the complexity of climate-smart interventions.

- Implementing interventions in the field that address climate change at the community level often requires multidisciplinary teams with stakeholders who have diverse working methodologies, education and motivation. This can be a significant challenge regarding human resources, institutions, and policies that must be enabled to overcome and ensure lasting contributions are made to community resilience to climate change and sustainable livelihoods.

6.6. Capacities needed to promote adaptation and mitigation

In the climate change context, extension personnel must enhance their capacities to embrace and promote climate-smart agriculture among farmers. So yes, extension personnel must develop new and strengthen existing capacities.

EAS should have the following capacities to support farmers in this regard:

- EAS personnel need to be well-informed about the nature of risks associated with climate change that farmers face in their area of activity and should have the attitude and skills necessary to identify and promote appropriate CSA interventions among women and socially marginalised groups more vulnerable to climate change impacts.
- Considering the bridging and brokering role among organisations in different sectors that EAS staff should perform to promote CSA, they need to reorient their core expertise about co-describing, sensitivity to gender and diversity issues, managing power and conflict dynamics, intermediation, and facilitation.
- Considering climate change's ever-evolving impacts, EAS managers need to develop long-term visions for their approach to climate change adaptation in agriculture.
- Personnel need expertise to undertake participatory scenario development and future visioning exercises by evaluating alternative scenarios, prioritising investments, contributing to policy formulation, and describing policy and programme implementation.

In other words, EAS personnel should have the following capacities to support climate change adaptation and mitigation

- Conduct local climate change impact and vulnerability assessments;
- Greater respect for Indigenous and local knowledge;
- Stronger engagement with research;
- Organize a broader search for solutions;
- Expand the focus of RAS from households and farmer fields to the entire landscape.

FURTHER READING

The following research will further enhance your understanding of this topic. See references 47,48,49,50,51,52,53,54 and 55 in the "Further reading" section.

Complete Activity 1.3 in your workbook.

STUDY UNIT 2: CLIMATE ADAPTATION

7. Unit information

7.1. Unit outcomes

After completing this study unit, you will be able to:

- Explain the concept of climate adaptation and its impact on agriculture and rural livelihoods
- Explain the approaches and measures of climate adaptation for the current and future agrifood systems
- Familiarise learners with EAS approaches, tools and strategies essential for integrating climate adaptation information and practices in agriculture.
- Incorporate climate adaptation recommendations and actions into rural community plans

7.2. Unit overview

This study unit is organised as follows:

Session 1 explores the need for farmers to adapt to climate change, establishing the reasons behind their adaptive actions. It will help us comprehensively understand climate adaptation, its types, and associated key concepts.

Session 2 focuses on varied approaches and climate adaptation measures with supporting cases across different countries and contexts.

Session 3 informs about the critical role of EAS in enforcing and promoting climate adaptation measures among farmers, supported by evidence from different countries.

7.3. Unit introduction

Although some people think climate change is not real, we are already experiencing it. Every day, when we watch the news on TV or social media, we see the worldwide consequences of climate change.

Most of us have experienced them through floods, heat waves, and extreme cold temperatures. Countries worldwide have had several meetings and agreements, such as the recent COP28. Beyond doing those activities, we must adapt to climate change consequences to continue producing food from agriculture to feed our communities. It is widely known that adapting to climate change and its impacts is a big challenge. However, it is essential and urgent as increased risks to people and communities become apparent. The ability that we have to adapt ourselves to climate change can help us keep people safe.

The present study unit will cover the meaning of climate adaptation and associated key concepts. It will also discuss some examples of measures and approaches that different countries and territories worldwide have planned or stated. Knowledge of these measures will give EAS information that it could use to prepare farmers' adaptation plans to adapt their food production systems better to continue producing food for future generations. Also, EAS can help motivate and encourage farmers to take action to address the significant challenges posed by climate change.

8. Session 2.1: Introduction to climate adaptation

8.1. Session outcomes

After completing this session, you will be able to:

- Explain the meaning and the scope of climate adaptation
- Give a detailed explanation of different concepts behind climate adaptation
- List the different types of adaptations
- Describe why it is essential that farmers need to adapt to climate change

8.2. Session overview

Several initiatives have defined Climate Adaptation; one of them, the Global Center of Adaptation, defines it as "taking action to prepare for and adjust to the current and projected impacts of climate change." With climate change bringing more frequent and intense extreme weather events such as heatwaves, droughts, and floods, individuals and communities can reduce their vulnerability and increase their resilience by adapting now.

Another definition given by the Intergovernmental Panel on Climate Change (IPCC) for climate adaptation is: "the process of adjustment to actual or expected climate and its effects, to moderate harm or exploit beneficial opportunities (in human systems). And in natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects".

To survive and thrive, we must adapt to climate changes and limit the warming by reducing greenhouse gas emissions. Climate models, which provide future climate change scenarios, can help us understand the impacts of climate change that we need to adapt to, allowing us to plan so that communities can be less vulnerable to climate change. More information about climate change scenarios can be found in the IPCC webpage.

FURTHER READING

The following research will further enhance your understanding of this topic. See reference 56 in the "Further reading" section.

Some important considerations for climate adaptation are:

- Climate adaptation strategies range from individual to local, national, and global efforts.
- Changes in government policies fuel some adaptations.
- Other adaptations occur because of technological advances.
- Engineering and planning can allow regions to adapt as the environment changes.
- Globally coordinated efforts to adapt, which ensure that as many places as possible are livable, can help as climate change causes people to migrate to new places.

DID YOU KNOW

Climate adaptation protects people and places by making them "less vulnerable" to the impacts of climate change. Taking steps to adapt to climate change can make us more resilient, which means we're more able to cope with the changes.

EXAMPLE

Communities "might build seawalls" or "relocate buildings to higher ground" to protect against sea level rise and increased flooding.

The severe impact of weather and climate on economic sectors, the natural environment and people's livelihoods makes *adaption to climate change* important to everybody. Climate risks must be factored into development and investment decisions to a much greater and more severe degree than they have been.

The first step in any adaptation process is assessing impacts, vulnerability, and risks. In this case, for climate adaptation, we will see some of the effects on agriculture and farmers and how they become more vulnerable if they do not act now. Secondly, the adaptation plan must be developed once risks and negative impacts have been identified. Then, EAS plays a crucial role in implementing adaptative measures and monitoring and evaluating the adaptation process.

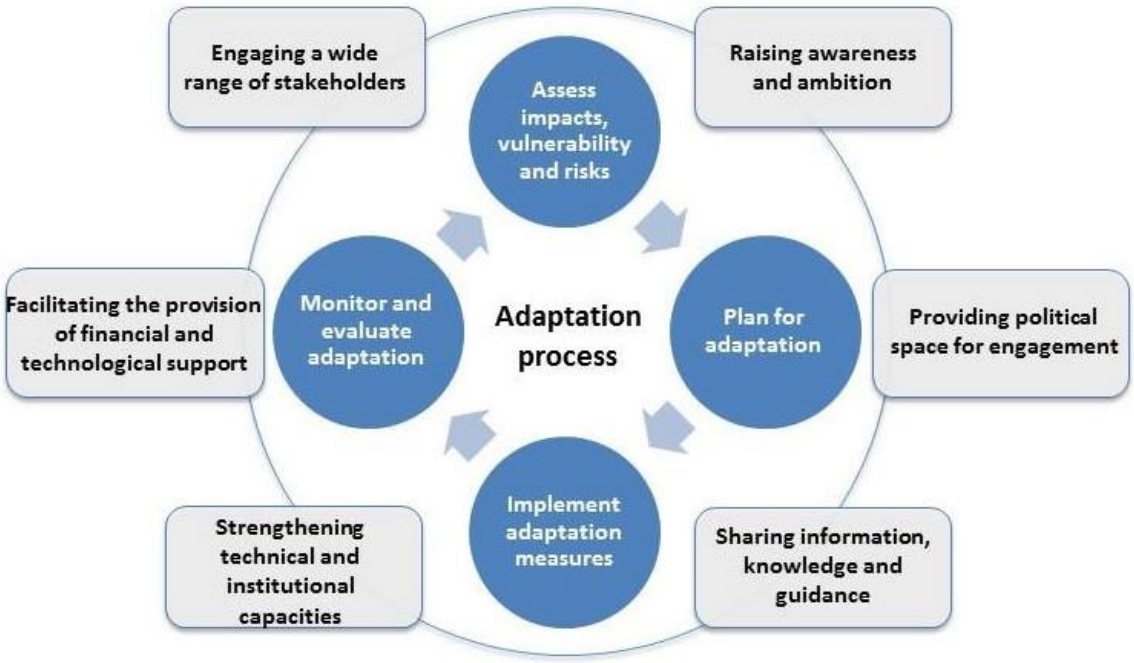

Figure 4: Adaptation policy cycle and support offered under the UN Climate Change regime.[57]

FURTHER READING

The following research will further enhance your understanding of this topic. See references 58,59 and 60 in the "Further reading" section.

8.3. Key concepts associated with climate adaptation

Adaptation deficit

This concept refers to the limited ability of some countries, regions, or territories to adapt to climate change. For example, there is broad agreement that low-income countries are more vulnerable to climate variability and future climate change than rich countries. (Maxmillan and Rasmus 2013). Some people point to the higher exposure of low-income countries to climate risk, for example, due to a semi-arid climate or the concentration of populations in hazard zones.

Others highlight the high sensitivity of low-income countries to such risks because of their heavy reliance on agriculture. Both these factors matter, and it is also important to point out that there is a clear distinction between climate change impacts and natural disasters. Because the developed countries have been historically responsible for most of the GHG emissions (although this is changing soon as China, India and other developing country economies expand their fossil fuel consumption), they have accepted a degree of responsibility for climate change and its impacts. No such responsibility has been accepted for natural disasters.

EXAMPLE

Poor countries are more heavily affected by extreme weather events and future climate change than rich countries. One reason for this is the so-called adaptation deficit, which limits the ability of poorer countries to adapt.

Maladaptation

Maladaptation can be defined as actions that increase greenhouse gas emissions, disproportionately burden the most vulnerable, incur high opportunity costs, reduce incentives to adapt, or set paths that limit the choices available to future generations.

Another definition of maladaptation is poor or insufficient adaptation. In a climate change context, maladaptation refers to actions intended to reduce the impacts of climate change that create more risk and vulnerability – it can do more harm than good. Maladaptation featured heavily in a recent adaptation report by the United Nations-backed Intergovernmental Panel on Climate Change (IPCC).

EXAMPLE

A company wishing to plant trees to sequester carbon but doing so in a location prone to wildfire. Consequently, when the trees start burning, they release more carbon into the atmosphere than they can absorb. A hotspot for carbon offsets, the Californian wildfires in 2021 are a tragic example of what can happen when strategies fail to account for climate risk.

It's not only intensifying climate change that's increasing risk exposure to assets - but also decisions being made without the proper climate intelligence to inform them. The report states with high confidence that non-climatic factors, such as where we've chosen to place infrastructure, contribute to the exposure of more assets to extreme climate hazards and increase the magnitude of losses.

TAKE NOTE

"Adapting to climate change is necessary to ensure that the impacts will not overwhelm societies and ecosystems worldwide. However, planning adaptation is an exercise in uncertainty built on imperfect information, so many adaptation strategies fail. Some go even further, creating conditions that worsen the situation, called maladaptation. Aside from wasting time and money, maladaptation is a process through which people become even more vulnerable to climate change…Until adaptation projects directly address the drivers of vulnerability, maladaptation will continue to be a risk…" – Dr Lisa Schipper.[61]

Adaptive capacity

The IPCC defines Adaptive capacity as the potential or ability of a system, region, or community to adapt to the effects or impacts of climate change. Enhancement of adaptive capacity represents a practical means of coping with changes and uncertainties in climate, including variability and extremes. In this way, enhancing adaptive capacity reduces vulnerabilities and promotes sustainable development. Adaptive capacity can also be defined as the property of a system to adjust its characteristics or behaviour to expand its coping range under existing climate variability or future climate conditions.

DID YOU KNOW

Adaptive capacity is the ability to design and implement effective adaptation strategies or to react to evolving hazards and stresses to reduce the likelihood of the occurrence and the magnitude of harmful outcomes resulting from climate-related hazards. Adaptation requires learning from previous experiences to cope with the current climate and applying these lessons to cope with future climates, including surprises.

Resources available for adaptation

The adaptive capacity inherent in a system represents the set of resources available for adaptation and the ability or capacity of that system to use these resources effectively in the pursuit of adaptation. Such resources may be natural, financial, institutional, or human, including access to ecosystems, information, expertise, and social networks.

Capacity development

Capacity development refers to enhancing adaptive capacity and is discussed as a critical adaptation component. Its role is to expand the coping range and strengthen the coping capacity of a priority system against relevant climate hazards, thus building the system's capacity to adapt to climate change, including variability.

Adaptation strategies

Adaptation strategies refer to all measures or approaches to adapting to climate change. These strategies will not be successful unless there is a willingness to adapt among those affected and a degree of consensus regarding appropriate actions. Therefore, the success of applying these strategies depends on a society's ability to collaborate and resolve conflicts between its members—factors that are heavily influenced by governance.

Implementation can be undermined by refusing to accept the risks associated with climate change or by refusing key actors to take responsibility for adaptation. Such refusals may be ideological or the consequence of vested interests denying the risks associated with climate change. Therefore, large-scale structural economic factors and prevailing ideologies are vital in determining feasible adaptations.

8.4. Types of adaptation

The IPCC[62] distinguishes several types of adaptation:

- Anticipatory Adaptation – adaptation that takes place before the impacts of climate change are observed. It is also referred to as proactive adaptation.
- Autonomous Adaptation – adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and market or welfare changes in human systems. It is also referred to as spontaneous adaptation.

- Planned Adaptation – adaptation that results from a deliberate policy decision based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state.
- Private Adaptation – adaptation initiated and implemented by individuals, households or private companies. It is usually in the actor's rational self-interest.
- Public Adaptation – adaptation initiated and implemented by governments at all levels. It is usually directed at collective needs.
- Reactive Adaptation – adaptation after climate change impacts have been observed.

How communities adapt to climate change will depend on how climate change affects the region where that community is located because the impacts of climate change are not the same everywhere. For example, climate change makes floods more frequent in some areas, while drought is becoming more common in others. Heat waves are becoming more of a hazard in some areas. Below are examples of several types of climate adaptations.

Table 2. Examples of climate adaptation types.

Adaptation strategy: Preventing flood damage	
Results of climate change	**Adaptations**
Climate change causes the sea level to rise	Seawalls and levees can help limit flooding of coastal communities. Wetlands can be built to buffer a coast. Improving stormwater drainage can help keep communities from flooding as climate change increases the amount of precipitation during storms. Homes can be built to reduce the chance of flooding. For example, homes raised on stilts and floating houses help prevent the threat of floodwater.

Adaptation strategy: Ensuring there's enough freshwater	
Results of climate change	**Adaptations**
Due to climate change, some places receive more precipitation while others receive less. There are also places where water availability is inconsistent throughout the year. This can mean too little or too much water, making it difficult to ensure consistent access to safe drinking water.	Communities can adapt by building water storage systems, enforcing water safety regulations, and using desalination technology to create freshwater in coastal areas prone to drought.

Adaptation strategy: Adapting to heat	
Results of climate change	**Adaptations**
In a warmer climate, dangerous heat waves are becoming longer and more frequent.	People can outfit buildings with more insulation and efficient cooling technologies to adapt. Shade trees can help keep things cool, and so can roofs with plants installed, called green roofs.

Adaptation strategy: Adapting farms and food	
Results of climate change	**Adaptations**
Changes in the amount of precipitation are making farming a challenge.	Farmers adapt their techniques, plant drought-resistant crops, and make irrigation more efficient. Managing fisheries and setting fishing quotas help ensure that fish are not overharvested. Communities are also making changes to improve food storage and preservation and running food banks to help distribute food to needy people.

Adaptation strategy: Ensuring ecosystem health	
Results of climate change	**Adaptations**
Restoring and protecting ecosystems helps wildlife deal with the changing climate.	Using indigenous, traditional, and local methods can help ensure that natural resources are managed sustainably. Managing natural resources and ensuring that environments are healthy benefit all of us. For example, healthy wetlands filter water, are home to juvenile fish and crustaceans, and buffer the coast during storms.

Adaptation strategy: Dealing with disaster	
Results of climate change	**Adaptations**
Climate change is increasing the risk of disasters. For example, hurricanes are getting stronger, storms are becoming rainier, heat waves are becoming hotter and longer, and wildfire risk is increasing.	Communities can reduce the risk by mapping the hazards, installing warning systems, and creating evacuation routes and storm shelters. They can also build disaster funds and ensure individuals have enough insurance to bounce back after hazards. Public health and emergency medical services also help keep people safe.

8.5. The need to adapt to climate change

Rising temperatures, changing rainfall patterns, and more frequent extreme weather events can lead to crop failures, soil degradation, and water scarcity – all of which can negatively impact food production and distribution. As the global population continues to grow, the demand for food will also increase, making it even more critical to ensure that food systems are resilient to the effects of climate change.

AgriFood systems can be adapted to the impacts of climate change in several ways, such as:

- Developing crop varieties that are more resilient to extreme weather and other effects of climate change.

  If the crop varieties used by farmers in a flood-affected area are not resistant to floods, farmers may regularly experience crop losses. In this case, an adaptation strategy focussing on flood-resistant crop varieties will benefit farmers.

- Using smart irrigation systems to optimise and reduce water use

  Under drought scenarios, the smart irrigation systems will allow the farmer to continue producing food.

- Fostering online digital marketplaces connecting farmers with buyers, reducing the need for long-distance transportation and reducing emissions

  Food sold and bought in the same territory produced is a smart way to enhance local food security.

- Using technology like sensors and drones to collect data on weather, soil moisture, and crop growth to help farmers make more informed decisions about when and how to plant, irrigate and harvest crops

  A farmer with access to detailed information about the season's weather will be more likely to succeed during harvest time. Also, with the necessary data, he can ensure his crop and recover some losses from the insurance.

- Using digital sensors to monitor the health and well-being of livestock to help pastoralists identify and address issues such as heat stress and disease

  Healthier livestock means saving and reducing emissions that will be rewarded in the production cycle.

FURTHER READING

The following research will further enhance your understanding of this topic. See references 63 and 64 in the "Further reading" section.

Complete Activity 2.1 in your workbook.

9. Session 2.2: Climate adaptation

9.1. Session outcomes

After completing this session, you will be able to:

- Explain the meaning and the scope of climate adaptation in agriculture
- List different approaches and adaptation measures to climate change adaptation
- Identify different adaptation practices in agriculture

9.2. Session overview

Agriculture is essential for providing food and sustaining life but is also a significant contributor to global warming. Therefore, ways to increase agricultural productivity while reducing its environmental impact are necessary.

Since agricultural productivity is weather—and climate-related and fundamentally depends on climate stability, climate change poses many diverse challenges to agricultural activities. The negative impacts of climate change are expressed in terms of reduced crop yields and crop area, impacts on biotic and abiotic factors, economic losses, and increased labour and equipment costs.

9.3. Approaches and adaptation measures to climate change

Adaptation strategies depend on the local context, region, or country; limiting the discussion of options and measures to only one type of approach—"top-down" or "bottom-up"—may lead to unsatisfactory solutions for those areas most affected by climate change but with few resources to adapt to it.

Biodiversity-based, or "ecologically intensive", agriculture and climate-smart agriculture are low-impact strategies with substantial ecological modernisation of agriculture, aiming to sustainably increase agricultural productivity and incomes while addressing the interrelated challenges of climate change and food security. To combat the adverse effects of climate change on agriculture, varied adaptation approaches, and measures are implemented at the field level.

At local and regional levels, the agricultural adaptation strategies that can be emphasised are:

- crop varieties and management
- land use change
- innovative breeding techniques
- water and soil management
- new agronomic practices
- farmer training
- knowledge transfer

At regional and national levels the strategies are:

- financial schemes
- insurance
- migration
- culture
- agricultural
- meteorological services
- R&D
- development of early warning systems

TAKE NOTE

Climate change's effects on agriculture vary by region depending on economic, social, and environmental patterns, thus calling for a diverse mix of adaptation actions across regions. At the field level, adaptation might involve planting new species or hybrids. At the farm level, strategies could include diversification or obtaining insurance coverage. On regional or national scales, adaptation may entail changes in the number of farms or adjustments to compensatory programs. On a global level, it might necessitate shifts in international food market patterns.

9.4. Impact of climate change on agriculture

The impact of climate change on agriculture is felt both at the level of individual producers and the entire population. Two levels of agricultural adaptation are often discussed:

- Farm-based measures, which are built on the rational personal interests of farmers;
- Policy-driven adaptation with government involvement, which is based on collective needs.

Most severe repercussions of these changes are felt within local agricultural communities, as they directly affect employment, income sources, and agricultural production. These communities rely heavily on the agricultural sector, making them more susceptible to such impacts.

The most vitally damaging effects are expressed in:

- reducing food security (availability, accessibility, stability, and use);
- aggravating water shortages (availability and quality of freshwater);
- causing damage to vital infrastructure (economic damage from floods);
- damage to infrastructure from the melting of polar ice caps);
- intensifying droughts (desertification);
- increasing poverty in local communities.

At the same time, the choice at the national level related to the national policy in agriculture and development is crucial. The main difference between them is that at the local level, private farms and households can make autonomous adaptation decisions, while at the regional or national level, planned adaptation decisions are made by institutional or governmental authorities

9.5. Agricultural adaptation strategies and actions

As was reviewed above, adaptation strategies have different action levels when they are developed. Some are at the national level, while others are at the local or regional level. Examples of current adaptation strategies are given at different levels and in different climate conditions around the globe (Grigorieva, Livenets., and Stelmakh, 2023).

Table 3. Agriculture adaptation strategies and actions from areas around the world with consideration of climate conditions, scale and location.

Area: Europe **Scale:** Nation to Local **Climate condition:** Boreal, Atlantic-to temperate-to-alpine, Mediterranean
Agriculture adaptation strategy: Changing crop sowing days; growing heat-resistant cultivars; improving soil structure; contour plugging to improve soil drainage and reduce waterlogging; increasing the water-holding capacity of soils; increasing the collection of winter rainwater to increase the supply for subsequent irrigation; pests and diseases: the introduction of resistant or less-susceptible varieties; vaccination as a measure of adaptation to livestock diseases.
Area: Russia **Scale:** Region to Nation **Climate condition:** Temperate
Inventory and reassessment of agricultural resources and the assortment of cultivated plants; revision of the principles of environmental protection measures; formation of the ecological framework of natural zones due to new agricultural technologies; developing farming systems and agro-technologies on a landscape basis. Expanding the cultivation of drought-resistant crop varieties and hybrids; undertaking land reclamation; transitioning to minimal or zero tillage technologies to prevent soil erosion; enhancing moisture retention; increasing use of fertilisers and plant protection products.

Area: China **Scale:** Nation **Climate condition:** Tropical in the far south, Subarctic in the far north, Alpine in the Tibetan Plateau
Strengthening agricultural infrastructure; breeding stress-resistant crop varieties; developing new agricultural technologies (including biotechnology); promoting the large-scale planting of superior crop varieties in suitable areas for bolstering the agricultural sector's resilience to disasters. Nation: Focus on smaller-scale irrigation and drainage projects, construction of water storage facilities, optimisation of water utilisation, and encouraging research into seed varieties resistant to drought, waterlogging, high temperatures, diseases, and pests. Local (farm): choosing more adaptive, multi-functional, and high-yield crops; embracing water-saving technologies like plastic sheeting, drought-resistant varieties, stubble retention, low-till methods, and surface-level plastic irrigation pipes.
Area: India **Scale:** Nation, Region and Local **Climate condition:** Tropical to subequatorial, subtropical humid with a dry winter
Conservation agriculture: reasonable disturbance of soil cover; contiguous crop rotation; conservation tillage, or without tillage; preservation of plant residues; organic farming; green manure application; mixed crop-livestock systems; biodiversity conservation approach. Changes in agricultural and farming practices as a passive response: transition of sowing and harvesting dates, cultivation of short-duration varieties, inter-cropping, changes in the structure of crops, investment in irrigation and agroforestry. Adaptation between crops: types of crops, e.g., for growing more heat-resistant varieties of rice; cultivation of sorghum and maize, more resistant to heat than rice; transition to wheat as a crop that grows in cooler seasons; intra-crop adaptations: investments in irrigation to protect against heat and drought stress; transition of sowing dates to avoid heat stress; application of fertiliser or other agricultural resources for heat control; shading trees and planting to protect crops from high temperatures.

Area: Africa **Scale:** Local to Nation **Climate condition:** Equatorial, temperate and semiarid
Agriculture adaptation strategy: Variations and management of crops; water and soil management; financial schemes; migration, insurance, and culture; agricultural and weather services. Dominant strategies: crop diversification (51.5%), planting drought-tolerant varieties (45%), changing planting dates (42%), and planting early-maturing crops (22%). Building more infrastructure for irrigation, water, and soil management; promotion of crop insurance; use of improved varieties; expansion of opportunities for diversification of livelihood and using established adaptation practices.
Area: South-central Mexico **Scale:** Local **Climate condition:** Subtropical to temperate
Agriculture adaptation strategy: Use of different crops and crop varieties, shade tree planting, soil conservation, transition of planting dates, irrigation, changing cultivated land area, and animal feed supplementing. Use coffee agroforestry systems with diversified species of multipurpose trees and shrubs; use shade cover to avoid water stress during heatwave periods; slow down the speed of downstream runoff water to reduce soil loss due to water erosion by using living barriers—greenhouse construction; compost use; dripping irrigation.
Area: USA **Scale:** Region to Nation **Climate condition:** Temperate to tropical and subtropical humid
Agriculture adaptation strategy: The shift of land use from cropping to grazing decreased cropland and increased pasture land. Improvement of roof materials, water-retaining gels, mulching, and subsurface irrigation systems to enhance the management of extensive green roofs for food production; supplemental irrigation to maximise quality and yield.

9.6. Adaptation practices cases

Different climate-resilient practices have been used to adapt to climate change in agriculture, such as natural resource management and conservation, food security and sovereignty, agroecology, and CSA.

- **Natural resources** come from the natural environment and can be harnessed to meet the needs of man and other living things. Common examples of natural resources are air, water, land, natural gas, wood, oil, coal, etc.

- **Natural resource management** can be explained as the judicious use of resources found in the natural environment in a manner that does not jeopardise future generations harnessing the same resources to meet their needs.

Natural resources management and conservation

Here is a real-life example from Sri Lanka:

EXAMPLE – AGROFORESTRY AND HOME GARDENS IN SRI LANKA

Young women from the highland region of Nuwara Eliya District learnt how to manage their home gardens sustainably. They were made aware of the benefits of agroforestry and home gardens to them and the local community. They also realised their valuable contribution to preserving their local environment's fragile ecological balance.

The mixed home gardens of these central highland villages, often described as the 'Kandyan Forest Gardens', are a type of agriculture that imitates the energy cycle and the tiered canopy structure of the forest. The tall dominant trees, the mid-storey perennials, the lower level of shrubs and grasses, the creepers and climbers, and the yams underground are cultivated to produce the maximum amount while conserving soil fertility, moisture, and biodiversity.

Birds, insects, fungi, and bacteria contribute to this system without chemical fertilisers or pesticides. Ecologically one of the most balanced agricultural systems in the world, the home gardens contributed enormously towards soil and biodiversity conservation after clearing the highlands for tea plantations. Easily managed by women, they represent centuries of knowledge of the importance of forests. Apart from the forests and the tea plantations, these gardens are the only areas in Kotmale that do not show soil erosion and land degradation.

FURTHER READING

The following research will further enhance your understanding of this topic. See reference 65 in the "Further reading" section.

DID YOU KNOW

Strip Cropping is a soil conservation technique in which farmers combine high-growing crops with low-growing ones for wind protection, like when corn grows in strips with forage crops. This practice works even better when more high-growing crops are grown on the sides where winds blow most frequently. An extra benefit is the organic matter from the low crops. In addition, strip cropping is one of the cheapest conservation methods available to farmers for halting the spread of sheet erosion because its costs are comparable to those of field preparation.

Conservation agriculture

The foundation for conservation agriculture is healthy soil with three underlying principles[66]:

- Minimum or zero tillage and direct seeding;
- Cover cropping and soil cover with crop residue and
- Crop rotation.

Conservation agricultural practices rarely use good tillage practices. In this system, organic fertilisers, not chemical fertilisers, are adopted to maintain optimal production levels and natural and normal biological processes.

KEYWORD

Conservation agriculture refers to an agricultural crop production system involving resource efficiency and environmental sustainability. It is practised to attain sustained high output levels without destroying the soil's fertility while preserving the environment and earning a profit.

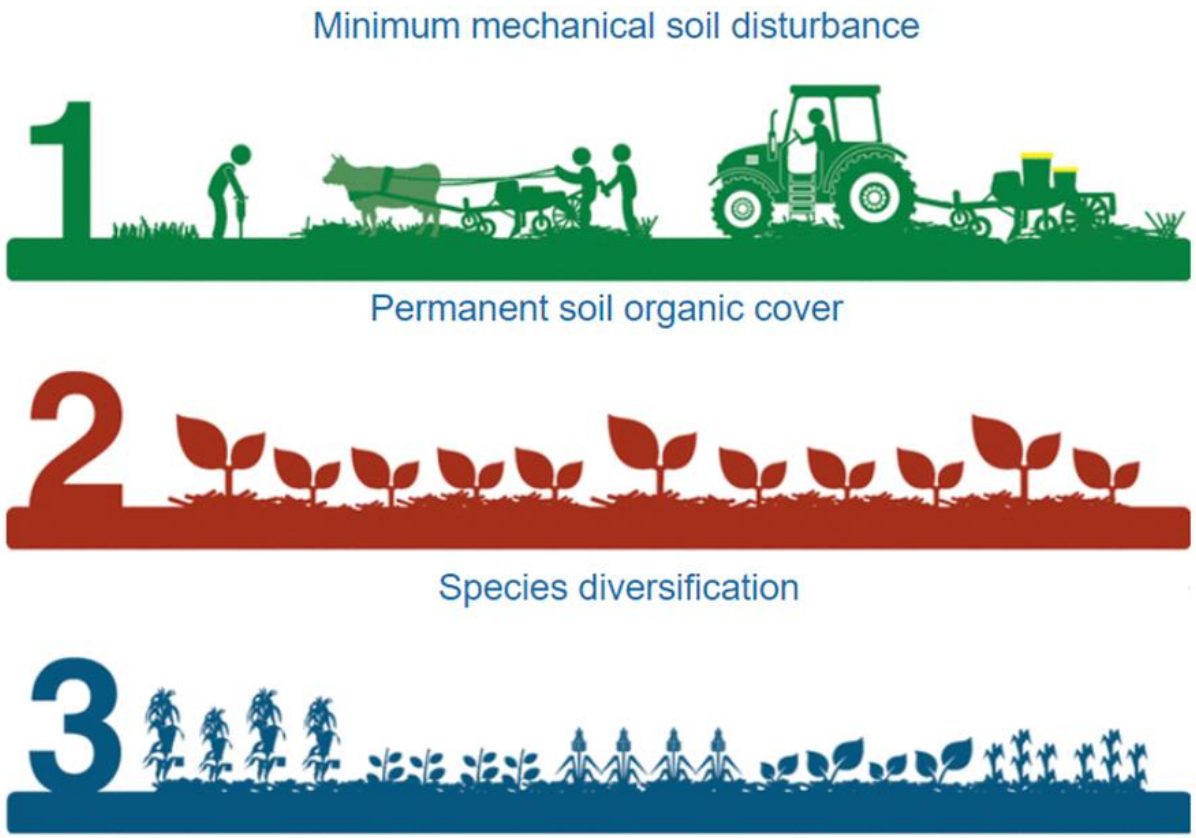

Figure 5: The principles of conservation agriculture

DID YOU KNOW

Most of the world's arable lands are being used or exhausted due to unsustainable practices and are no longer productive. The previously productive and fertile lands have now become degraded. The global rate of degradation of lands has been accelerated by climatic changes coupled with excessive use of inputs to maintain or increase yield levels.

Here is a real-life example from Lesotho:

EXAMPLE – LIKOTI PLANTING BASINS IN LESOTHO

Subsistence farmers in Lesotho have boosted agricultural yields and increased food production by adopting conservation agriculture. The locally adapted practice, known as likoti, also contributes to combating soil erosion and enhancing fertility. The practice of likoti was first introduced in Tebellong—a harsh mountainous area in the south-eastern highlands of Qacha's Nek district—by the local NGO 'Growing Nations'. A planting basin system was developed and adapted to the local conditions, and it began to promote it with a Sesotho name, likoti, which means 'holes'.

According to the likoti method, about 15 × 30 cm diameter pits and 15 to 20 cm deep (or smaller) are dug in a 75 × 75 cm grid. A small quantity of fertiliser (either inorganic or organic) and seeds (the number depends on the desired crop density) are placed in each basin and covered with soil. Farmers must also leave enough crop residues on the field as mulch and practice crop rotation and inter-cropping. Farmers must plant in the same pits next season without turning the soil. Although likoti was initially used to produce maize and beans, innovative farmers have used it to grow sunflower, sorghum, potato, and tomato crops.

FURTHER READING

The following research will further enhance your understanding of this topic. See reference 67 in the "Further reading" section.

Food security and sovereignty

This involves ensuring access to sufficient, safe, nutritious food to meet their dietary needs and preferences for an active and healthy life.

Food sovereignty more fully embodies the right to food because it adds a human dimension to food security, acknowledging that one should have a say in their relationship with food.

The current **food system** (production, transport, processing, packaging, storage, retail, consumption, loss, and waste) feeds most of the world's population and supports the livelihoods of over 1 billion people. However, the food system is under pressure from non-climate stressors (e.g., population and income growth, demand for animal-sourced products) and climate change. These climate and non-climate stresses impact food security's four pillars (availability, access, utilisation, and stability).

FURTHER READING

The following research will further enhance your understanding of this topic. See references 68,69 and 70 in the "Further reading" section.

DID YOU KNOW

Since 1961, the food supply per capita has increased by more than 30%, accompanied by greater use of nitrogen fertilisers (an increase of about 800%) and water resources for irrigation (more than 100%). However, an estimated 821 million people are currently undernourished, 151 million children under five are stunted, 613 million women and girls aged 15 to 49 suffer from iron deficiency, and 2 billion adults are overweight or obese.

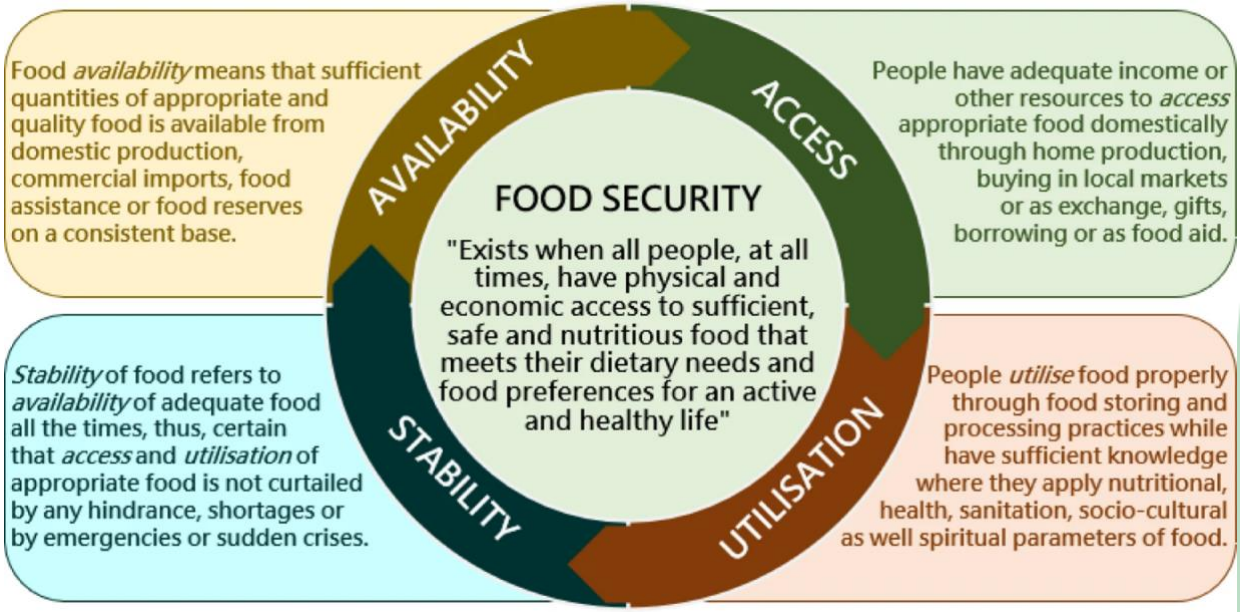

Figure 6: Food Security (Source: Gunaratne, Firdaus and Rathnasooriya 2021)

In recent years, the concept of 'food sovereignty' has gained increasing ground among grassroots groups, taking the form of a global movement. However, there is no uniform conceptualisation of what food sovereignty constitutes. Indeed, the definition has been expanding over time. It has moved from its initial focus on national self-sufficiency in food production ('the right of nations') to local self-sufficiency ('the rights of peoples'). There is also a growing emphasis on the rights of women and other disadvantaged groups, as well as consensus building and democratic choice (Agarwal 2011).

EXAMPLE – URBAN AGRICULTURE FOR FOOD SOVEREIGNTY IN QUITO[71]

In this case, tackling climate change, poverty and food provision is done by supporting urban gardens on public or private land with community participation. The aims are food security and sovereignty, environmental management, employment and income improvement, social inclusion, sustainability and resilience.

Quito's urban orchards have a production capacity of 1.35 million kg of healthy food each year, of which producers and their families consume 57 % (769 000 kg), and 43 % (581 000 kg) is sold via various short supply chains. About 11 tons of fresh and healthy food are delivered weekly to the city's most vulnerable neighbourhoods. Due to the proximity between producers and consumers, the substantial reduction of the carbon footprint within the food chain is one of the initiative's leading climate change mitigation contributions by minimising the need for transportation, packaging, refrigeration and warehousing. In addition, the practice increases urban biodiversity, carbon sequestration, and rainwater infiltration, reducing the urban heat island effect.

Table 4. Legume and cereal crop food choices are recommended to combat nutritional and water deficits (Singh and Conway 2021).

Nutritional and health challenges	**Recommended food**		**Recommended food choice-limited water conditions**	
	Legume	**Cereal**	**Legume**	**Cereal**
Protein	White lentils, soybean	Sorghum, wheat	Bambara groundnut, groundnut	Sorghum
Carbohydrates	Bambara groundnut, lentils	Equally suitable	Bambara groundnut	Sorghum, millet
Energy	White lentils	Equally suitable	Groundnut	Sorghum, millet
Fat	Groundnut	Equally suitable	Groundnut	Sorghum, millet
Vitamin-A	Common pea	-	-	-
Micronutrients	Soybean	Equally suitable	Bambara groundnut	-

FURTHER READING

The following research will further enhance your understanding of this topic. See references 72 and 73 in the "Further reading" section.

Agroecology

Agroecology is a *practical approach to farming* that encourages researchers, educators, and students to embrace the wholeness and connectivity of systems. It stimulates a focus on each place's uniqueness and solutions appropriate to its resources and limitations. In this regard, agroecology is seen as an approach to transforming the food system in ways that provide environmental and social benefits.

KEY WORD

Agroecology is "the integrative study of the ecology of the entire food system, encompassing ecological, economic and social dimensions". It entails various practices and processes that differentiate it from conventional agriculture.

Agroecology has three subcategories:

- **A scientific discipline:** which evolved mainly from two disciplines - agronomy and ecology, but also other disciplines, such as zoology and botany/plant physiology, and their applications in addressing agricultural and environmental issues
- **Agricultural practices:** principles that can be applied to food production in a particular context, realised through various sustainable land management practices, including mulching, agroforestry, legume integration, crop rotation, mixed farming, living fences, biological corridors, microbial and botanical inputs, plants for soil cover, organic fertilisers and composting.
- **Social movements:** In some regions, agroecology developed from agrarian social thought and movements that arose in response to rural industrialisation, which emerged as an unexpected outcome of the Green Revolution. Agroecology social movements envision food production systems that rely on traditional ecological knowledge, innovation, and the use of local resources.

Agroecology aligns with food sovereignty, "the right of peoples to healthy and culturally appropriate food produced through ecologically sound and sustainable methods, and their right to define their food and agriculture systems".

Thus, agroecology as a social movement empowers farmers and defends their fundamental rights, such as access to land and markets, free use of plant genetic resources, and a more inclusive political economy.

Fundamental agroecology principles include:

- co-production of knowledge between producers, scientists and other stakeholders,
- reducing the use of toxic and synthetic inputs and using natural means for controlling insects/pests and diseases,
- using biological means such as organic matter to enrich the soil,
- conservation to minimise energy, water, nutrient and genetic resource loss,
- farm-level and landscape-scale genetic diversification (Kpienbaareh 2022)

EXAMPLE – AGROECOLOGY TRANSFORMING DRYLAND IN TANZANIA

The Farmer and Pastoralists Collaboration Project (FPC) is located in the Mvomero, Kilosa, Same, and Hanang District Councils of Tanzania. The beneficiaries are farmers and pastoralist communities (3,536 persons). The FPC provides farmers with training on adopting agroecology practices focusing on soil and water conservation, agroforestry, crop rotation, cover cropping, intercropping, and integrating livestock into crop production systems.

Climate change has severely affected sub-Saharan Africa, negatively impacting livelihoods and food systems and posing a significant threat to food security and nutrition. Despite its extensive land resources—94.5 million hectares in Tanzania, with 44 million hectares suitable for agriculture—conflicts between farmers and pastoralists persist. Dryland areas in Africa face unsustainable and competing food systems, exacerbating pressure on natural resources and communities.

Factors contributing to this issue include climate change, population growth, limited knowledge of agroecological farming and livestock production, inadequate land use planning, increased land pressure, lack of income diversification, restricted access to financial services, underdeveloped value chains, and insufficient water availability for domestic and economic use. The consequences include land degradation, higher production costs, low income, land conflicts, injuries and fatalities, migration, and reduced food security.

Achievement: They have significantly improved household food security and nutrition, with 80% of the participants having an average of three meals daily. Additionally, households can maintain food security for an average of 8 months through self-produced food. Conflict in the area has notably decreased, as reported by over 65% of farmers who did not experience any conflicts in the past year.

There has also been an average income increase of 15%. Farmers have increased their use of farm residues and animal droppings, leading to enhanced crop health, reduced pesticide usage, and improved soil biology. Around 63% of farmers are now applying botanical extracts for pest and disease control, reducing reliance on chemicals and preserving biodiversity at the farm level.

Farmers have become more aware of the importance of avoiding slashing and burning practices. They achieved significant progress in pasture establishment, covering 283.75% more land. Farmers actively engage in pasture production and conservation, and the value of crop residues as animal feed has increased at the community level, indicating improved awareness and adoption of climate-resilient measures.

Additionally, there has been an increased awareness among farmers regarding ecosystem services, leading to a higher rate of tree planting. Farmers have exceeded the targeted number of trees by 218%, contributing to enhanced biodiversity conservation, improved crop health and soil biology, reduced chemical inputs, and increased climate resilience.

FURTHER READING

The following research will further enhance your understanding of this topic. See reference 74 in the "Further reading" section.

Climate Smart Agriculture (CSA)

The CSA approach pursues the triple objectives of sustainably increasing productivity and incomes, adapting to climate change and reducing greenhouse gas emissions where possible.

This does not imply that every practice applied in every location should produce "triple wins." Instead, the CSA approach seeks to reduce trade-offs and promote synergies by considering these objectives to inform decisions from the local to the global scales and over short and long-time horizons to derive locally acceptable solutions.

Different elements of climate-smart agricultural systems include:

- Managing farms, crops, livestock, aquaculture and capture fisheries to balance near-term food security and livelihood needs with priorities for adaptation and mitigation.
- Ecosystem and landscape management to conserve vital ecosystem services essential for food security, agricultural development, adaptation, and mitigation.
- Services for farmers and land managers to enable better management of climate risks/impacts and mitigation actions.
- Changes in the wider food system, including demand-side measures and value-chain interventions, enhance the benefits of CSA.

KEYWORD

Climate-smart agriculture (CSA) is an approach to helping the people who manage agricultural systems respond effectively to climate change.

TAKE NOTE

The three pillars of CSA are:

1. To sustainably increase agricultural productivity and improve the incomes and livelihoods of farmers;
2. To build resilience and adaptation to climate change;
3. To reduce or remove GHG emissions, where possible.

DID YOU KNOW

Rice is one of the food crops with the highest carbon (3.5 kg CO_2 eq/kg) and water (2 500 L/kg) footprints.

EXAMPLE – CLIMATE-SMART RICE PRODUCTION IN CHILE

In Chile, a Climate-smart rice production system has been validated in farmers' plots. It is based on new rice varieties that use water more efficiently and in agronomic practices such as reducing seed dose, mixed weed control using mechanical weed control, which oxygenate the soil, activate soil microorganisms, and do not use flooding at all, with high yields. As there are no methane emissions, it can be combined with carbon markets to increase profit for the rice growers.

FURTHER READING

The following research will further enhance your understanding of this topic. See references 75 and 76 in the "Further reading" section.

EXAMPLE – CLIMATE-SMART AGROFORESTRY IN CENTRAL AMERICA

The Dry Corridor is located in Central America's ecoregion of dry tropical forests that cover the lowlands of the Pacific coastal areas of El Salvador, Guatemala, Honduras and Nicaragua. The Dry corridor has a distinct and prolonged dry season, but at the same time, the region experiences excessive rainfall and severe flooding. These impacts are accentuated by climate change every year and significantly impact agricultural production and land degradation, especially on hillside plots.

In this case, to replace the traditional slash-and-burn method of clearing their plots of land, a traditional knowledge farming system, the Slash-and-Mulch Agroforestry System, known as the Quesungual farming system in Honduras and Kuxur rum in Guatemala, was spotlighted. This system relies on conservation agriculture principles to grow grains interspersed with native multipurpose nitrogen-fixing trees planted along the plots' contour lines.

Strategically planting grains and trees together improves soil erosion control on drought-prone hillsides impacted by land degradation.

Trees from this integrated climate-smart production system provide vital services:

- shading, which reduces evapotranspiration;
- soil retention through the root systems, thus reducing erosion and landslides;
- fertilisation through leaves releasing to the soil, especially if nitrogen-fixing species are used;
- diversification of households' production (wood, fruits, leaves, etc.); and
- protection of crops and soil from rain and wind.

This agroforestry system was promoted and validated in eastern Guatemala and the Lempira region of Honduras. It has proved to be "climate-smart" through improved soil and water conservation, increasing productivity and resilience to agro-climatic risks, and reducing GHG emissions.

FURTHER READING

The following research will further enhance your understanding of this topic. See references 77 and 78 in the "Further reading" section.

Complete Activity 2.2 in your workbook.

10. Session 2.3: EAS to promote climate adaptation

10.1. Session outcomes

After completing this session, you will be able to:

- Explain why extension and advisory services (EAS) should address climate adaptation;
- Describe the role of EAS in climate adaptation planning; and
- Name and elaborate on best practices for adaptation climate.

As reviewed in sessions 2.1 and 2.2, climate adaptation is crucial to allow farmers to continue producing food for the growing population under the challenge of the climate change scenario. EAS must have a comprehensive understanding of climate adaptation, its associated key concepts, strategies and practices that can be applied in agricultural food systems to help and encourage the farmers to continue producing despite the adverse conditions.

Also, EAS plays a vital role in climate adaptation because it creates a bridge between the vast amount of research information and the busy farmer who has no time to absorb too much information. For that reason, the better the understanding of EAS, the better the adoption of climate adaptation strategies or actions by farmers.

FURTHER READING

The following research will further enhance your understanding of this topic. See reference 79 in the "Further reading" section.

10.2. Session overview

As was reviewed in previous sessions, enhancing agricultural innovation is considered an essential process for adapting the agricultural sector to climate change. This process involves an interactive, dynamic, collaborative, and flexible way of dealing with the complex nature of agriculture under the continual effects of climate change.

To support agricultural innovation, strengthening innovation networks is critical. An innovation network is "a diverse group of actors that voluntarily contribute knowledge and other resources (such as money, equipment, and land) to jointly develop or improve a social or economic process or product". EAS agencies are considered the key players in helping to strengthen innovation networks and are recognised as an engine for supporting agricultural innovation (Kamruzzaman et al. 2021).

Also, as stated before, the amount of information generated worldwide about agriculture and climate change is exponentially growing daily. Most affected farmers are the poor and those living in poor rural areas with adaptation deficits, who are often more prone to maladaptation. For these reasons, EAS is crucial in effective communication between farmers and the best adaptation practices. EAS can convey adaptation information clearly to farmers who would be more willing to adopt it from them rather than from a book or a researcher.

FURTHER READING

The following research will further enhance your understanding of this topic. See reference 80 in the "Further reading" section.

10.3. How adaptation measures are enforced

All the strategies and measures that were reviewed in session 2.2 can be reinforced by EAS. As stated above, EAS is critical in the relationship between farmers and knowledge. EAS should be close to the farmers and have their trust to be effective. Try to use different approaches to reach farmers and build innovation networks. EAS can plan climate adaptation with farmers one-on-one or in groups that trust each other. Working in networks would be more efficient because financial resources may be limited. However, this strategy cannot be used when farmers are isolated in remote areas where climate change usually severely damages agrifood systems. In farmer networks, EAS can direct the demonstration of adaptation practices in farmers' plots and work with them to validate them in the field.

Also, EAS can connect with other participants in their network who can help with demonstration plots using new practices or adaptation measures. These participants can be related to the market, food dealers, and people from agricultural input industries.

EXAMPLE – ADAPTING RICE CULTIVATION TO FLASH FLOODING IN BANGLADESH

In Bangladesh, the Department of Agricultural Extension (DAE) is responsible for ensuring sustainable rice farming, which is damaged by flash flooding every year.

They based the study on the fact that innovation networks can accumulate diversity in resources and capabilities from varied actor types. Diversity enhances the flow of different and new information and ideas to the networks and increases the innovativeness of the actors.

Through discussions with EAS agents, 20 functional farmer groups were identified. They randomly selected five groups that accounted for 150 DAE(EAS)-farmers. With the help of local representatives, the same number of non-DAE farmers (i.e., 150) were randomly selected from the blocks where DAE-formed groups were initially identified. Initially, informal discussions were conducted with both groups of farmers following a name-generator approach. Farmers were asked to name five important actors for securing information and farm inputs to adapt Boro rice production to flash flooding. Consequently, two lists of actors were prepared: 1 for performing agronomic activities (e.g., seed sowing and fertiliser application) and another for conducting harvesting activities.

The results indicated that while DAE intended to strengthen farmers' innovation networks to adapt rice cultivation to flash flooding, it only supported the facilitation of the agronomic network development and missed the opportunity to enable the harvesting networks' efficacy. As the harvesting activities are highly exposed to flash flooding, the absence of adequate support from the DAE indicates that farmers are still at significant risk of production losses due to flood-related damages.

FURTHER READING

The following research will further enhance your understanding of this topic. See reference 81 in the "Further reading" section.

10.4. Adaptation challenges in agriculture

Uncertainty of the exact effects and their spatial distribution is the key challenge in adapting to climate change. However, it is possible to assess local vulnerability based on climate scenarios and exceptional situations in the past. Active, correctly timed adaptation measures are required to benefit from climate change. Ecological sustainability is the fundamental prerequisite of successful adaptation solutions. Climate change scenarios are not future weather forecasts.

The models illustrate the challenges of long-term average temperature and precipitation trends, whereas weather conditions will vary naturally year after year, now and in future. However, climate models facilitate the assessment of seasonal climate variations in future. The global development of greenhouse gas emissions is another significant source of uncertainty related to climate change. In the end, it ultimately determines the intensity of future change.

FURTHER READING

The following research will further enhance your understanding of this topic. See reference 82 in the "Further reading" section.

10.5. Role of EAS in climate adaptation

Study unit 1, session 1.3 discusses EAS's critical role in combating climate change. EAS uses the following roles and tools to address climate change.

Climate adaptation planning

To prepare a good climate adaptation plan, climate risks should be identified, and actions should be prioritised so different organisations at different levels can implement or integrate climate adaptation into their planning, programs, operations, and management. Adaptation is an iterative process that will evolve based on lessons learned and emerging climate risks.

Early identification of adaptation needs allows time to react, chart various options, and divide costs over a longer term. Simultaneously, areas can be reserved as required by later adaptation measures, and temporary, safe use for the public benefit can be planned for these areas, e.g. use as recreation areas or cultivation plots.

Careful planning facilitates benefiting from change. Adaptation needs vary both by region and by sector. When assessing vulnerability, the local conditions must be known and proportioned with change. What if rainfall in a particular area increases, particularly in wintertime? What if summers get hotter and hot periods longer? What if there is no snow cover in most winters? Uncertainty of the intensity of impacts does not need to prevent adaptation, as most climate change impacts can be taken into account easily and affordably. This is the case, especially if the impacts are already taken into consideration at the planning stage.

FURTHER READING

The following research will further enhance your understanding of this topic. See references 83 and 84 in the "Further reading" section.

Mapping key actors

There is a categorisation of 'actors' in climate change adaptation built closely on the Global Adaptation Mapping Initiative (GAMI) methodology (The first global systematic mapping of peer-reviewed literature on climate change adaptation) to provide the highest possible consistency. The EAS can use this tool to implement climate-resilient practices in the field. In the GAMI database, actors in climate change adaptation are categorised into groups (organised by sector and level):

- individuals or households
- civil society
    - sub-national or local
    - international
    - multinational or national
- government
    - local
    - sub-national
    - national

- international or multinational governance institutions
- private sector
    - small and medium-sized enterprises (SMEs)
    - corporations.

GAMI findings reveal several patterns indicating which actors are likely to take on specific adaptation roles.

Individuals and households are the most frequent actors overall (representing 64% of the actions) and also as implementers of adaptation measures.

The role of financing is mainly associated with international or multinational governance institutions, the private sector, civil society organisations and national governments.

Government actors often do the planning, with no particular pattern discernible at different government levels. Civil society organisations are essential in coordinating the interaction between other actors and raising awareness.

Academia is relevant in raising awareness, assessing climate impacts, and monitoring adaptation efforts. While there is little reporting on private sector actors across all regions, their documented roles are mainly related to financing and implementing adaptation responses.

FURTHER READING

The following research will further enhance your understanding of this topic. See reference 85 in the "Further reading" section.

Identifying the responses at different levels

The response to adaptation, in the sense of adapting to life in a changing climate, involves adjusting to the actual or expected future climate. The goal is to reduce our risks from the harmful effects of climate change (like sea-level rise, more intense extreme weather events, or food insecurity). It also includes making the most of any potential beneficial opportunities associated with climate change (for example, longer growing seasons or increased yields in some regions).

Throughout history, people and societies have adjusted to and coped with changes in climate and extremes with varying degrees of success. Climate change (drought in particular) has been at least partly responsible for the rise and fall of civilisations. Earth's climate has been relatively stable for the past 10,000 years, which has allowed for the development of our modern civilisation and agriculture. Our modern life is tailored to that stable climate, not the much warmer climate of the next thousand years. As our climate changes, we will need to adapt. The faster the climate changes, the more difficult it will be.

FURTHER READING

The following research will further enhance your understanding of this topic. See reference 86 in the "Further reading" section.

Digital Climate-Informed Advisory Services (DCAS)

DCAS promotes and upscales climate adaptation. DCAS have tools, platforms, and activities that integrate climate information into agricultural decision-making, helping users adapt to climate variability and change. These services range from digital mobile apps, radio, and online platforms to digitally enabled printed bulletins based on climate models and extension services utilising climate information platforms. DCAS can help agricultural producers and other value chain actors build resilience to the climate impacts that threaten present and future agri-food systems. However, small-scale producers' access to these services remains limited worldwide. Scaling up efforts while leaving no one behind is critical to safeguarding the millions of small-scale producers vital to our global food security. Current DCAS efforts are insufficient, marked by fragmented efforts, limited understanding of best practices, and misaligned policy and investment incentives.

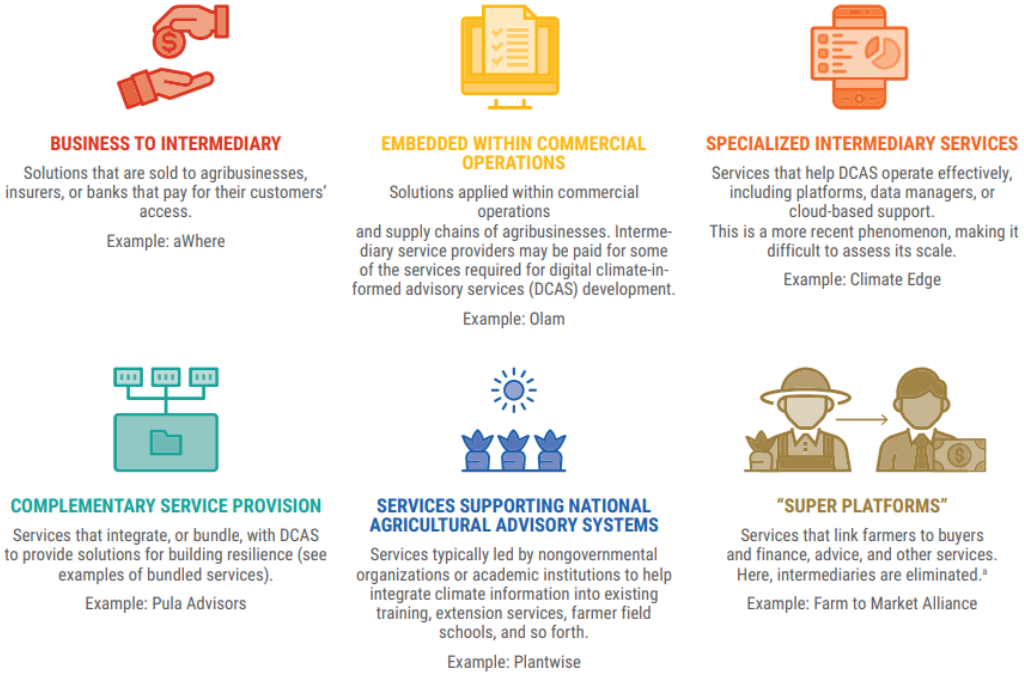

Figure 7: DCAS model ecosystem[87]

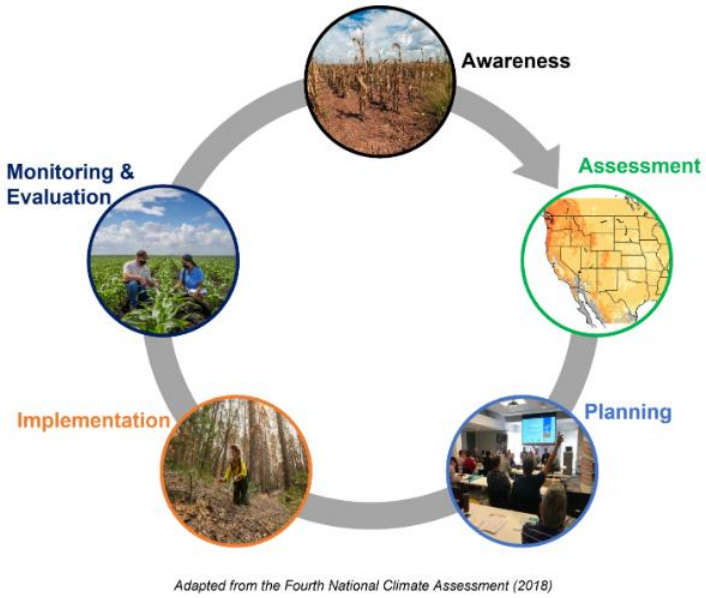

Figure 8: Climate adapting process[88]

Complete Activity 2.3 in your workbook.

10.6. Concluding remarks

All the sessions in this module highlighted the importance of climate adaptation and discussed ways different actors can support adaptation at various levels. The agricultural sector must adapt to climate change to continue feeding the growing global population. EAS plays a crucial role in providing relevant advice on adaptation options appropriate to their farming and resource context. Without EAS support, millions of small farmers would find it difficult to understand and adapt to the changing climate and continue farming.

STUDY UNIT 3: CLIMATE MITIGATION

11. Unit information

11.1. Unit outcomes

After completing this study unit, you should be able to:

- Explain the fundamental concepts of climate mitigation, its different types, definitions, and meanings of relevant terms.
- List mitigation measures and approaches in agriculture;
- Fulfil the role of EAS in climate mitigation.

11.2. Unit overview

In this study unit, Session 1 focuses on the foundations of climate mitigation, covering the need for a farmer to mitigate climate change, the meaning of climate mitigation, and associated concepts. It also introduces the learners to various mitigation strategies.

Session 2 discusses the climate mitigation approaches and measures in agriculture with the support of relevant cases across countries.

Session 3 concludes the study unit by highlighting the critical role EAS plays in promoting climate mitigation strategies among farmers.

11.3. Unit introduction

Climate change poses a complex challenge for the agriculture sector, requiring climate actions such as adaptation and mitigation.

This study unit focuses on climate mitigation, building upon your understanding of climate adaptation from Unit 2. Using real-world examples and case studies, we'll explore the concepts, approaches, and measures for mitigating climate change within the agricultural sector. We'll also learn the crucial role of EAS in supporting farmers in implementing these mitigation strategies.

By engaging with this unit, you will gain a comprehensive understanding of climate mitigation in agriculture and how EAS can encourage farmers to build more sustainable and resilient food systems addressing climate change challenges.

12. Session 3.1: Introduction to mitigation

12.1. Session outcomes

After completing this session, you will be able to:

- Explain the role of farmers play in climate change mitigation;
- List the key concepts related to climate change mitigation;
- Broadly explain different options for climate change mitigation.

12.2. Session overview

From study unit 1, we learned about the impact of climate change on agriculture. Agriculture has a dual role as both a vulnerable sector as well as a contributor to climate change. Traditionally, the increase in food production has been linked to agricultural expansion and unsustainable consumption of resources, leading to a rise in GHG emissions.

With a growing global population, rising emissions, and the harmful impacts of climate change, it's crucial to mitigate these effects by reducing GHG emissions and enhancing sinks, such as increasing forest areas. The need for farmers, the primary food producers, to actively engage in climate mitigation efforts is more apparent than ever.

12.3. Mitigating climate change impacts

- The repercussions of changing climate disproportionately affect the farmers who toil on the land, making them vulnerable;
- Farmers, particularly small and marginal ones, find themselves at the forefront of the consequences of climate change;
- Farmers are one of the primary agents in the pursuit of sustainable solutions for climate change;
- Mitigating climate change is not merely an option for farmers; it is essential for preserving livelihoods, ensuring food security and safeguarding the foundation of our agrarian societies.

Climate mitigation is one of the primary responses to climate change. Efforts to reduce emissions and enhance sinks are referred to as "mitigation."

In essence, climate mitigation refers to deliberate efforts aimed at reducing or preventing the mission of GHG and countering the adverse impacts of climate change. IPCC defines climate mitigation as "a human intervention to reduce emissions or enhance the sinks of greenhouse gases." Within the agricultural sector, this involves adopting practices and systems that increase productivity and minimise the carbon footprint.

KEYWORD

The **carbon footprint** is the total amount of greenhouse gases (specifically CO_2 and CH_4) generated by human actions.

In the face of alarming statistics projecting a potential decline in global agricultural productivity by 2050 and the increasing emissions from the agrifood sector, one needs to promote holistic approaches like CSA to reduce or neutralise the effects of climate change. Such approaches integrate strategies to enhance food security, promote sustainable development and address climate change issues concurrently. By embracing climate-smart practices involving agroforestry, integrated pest and disease management, livestock management, nutrient management, soil and water management practices, and cultivating climate-resilient crop varieties, farmers can play a pivotal role in not only adapting to the challenges posed by a climate change but also actively contribute to global efforts in mitigating the climate change.

FURTHER READING

The following research will further enhance your understanding of this topic. See references 89,90,91 and 92 in the "Further reading" section.

12.4. Key concepts of climate change mitigation

Decarbonisation

Decarbonisation is the process of reducing carbon dioxide (CO_2) emissions from human activity. This can include using zero-carbon renewable energy sources like wind, solar, hydropower and geothermal.

Carbon sequestration

Carbon sequestration is capturing and storing carbon dioxide from the atmosphere to stabilise carbon in solid and dissolved forms, preventing it from contributing to atmospheric warming. Various methods, including natural carbon sequestration, have evolved to create a balance of carbon dioxide in our atmosphere suitable for supporting life.

Plants and animals release carbon dioxide at night, but nature has established a system of carbon sinks or sponges, including soil, oceans, plants and animals. All organic life on Earth is carbon-based, and when plants and animals perish, a significant portion of the carbon returns to the ground, where it has minimal effect on global warming.

Another method is artificial carbon sequestration, which involves capturing carbon emissions at the source, such as factory chimneys, and burying them. One suggested technique is ocean sequestration, where carbon dioxide is injected deep into the ocean to create lakes of CO_2. Theoretically, the surrounding water's pressure and temperature will keep the CO_2 deep, allowing it to dissolve slowly into the water over time. Geological sequestration is another example of carbon dioxide injected into inaccessible subsurface sites like aquifers, coal seams, and old oil reserves.

Carbon Capture and Storage (CCS)

CCS involves capturing carbon dioxide emissions from sources like power plants and industrial facilities and storing them underground to prevent them from entering the atmosphere.

Carbon sink

A carbon sink is anything that absorbs more carbon from the atmosphere than it releases, such as plants, the ocean, and soil. In contrast, a carbon source is anything that releases more carbon in the atmosphere than it absorbs, such as the burning of fossil fuels or volcanic eruptions.

DID YOU KNOW

Century Plant is the world's largest standalone carbon capture and storage facility. It started operating in November 2010 and is in West Texas' Pecos County. SandRidge Energy creates a high concentration of carbon dioxide locally and processes it at the Occidental Petroleum (Oxy) plant, where it is separated and captured. A 160 km pipeline then transports the high concentration of carbon dioxide to the Denver City industrial hub.

Carbon Dioxide Removal (CDR)

CDR refers to approaches that remove CO_2 from the atmosphere. In one method, CO_2 is captured from the air and stored safely in the ground. There are also ways to increase the amount of carbon stored in soil, remove carbon from plants, use oceans to capture carbon, and plant more trees. By planting trees, CO_2 is absorbed during photosynthesis, reducing CO_2 in the atmosphere.

Carbon emission trading

Carbon emission trading is a market-based system that limits climate change by creating a market for emissions. It is also known as carbon trading or emission trading. In agriculture, farmers and landowners can participate in carbon markets by implementing practices that store carbon or reduce/avoid carbon emissions, which can benefit them financially and environmentally.

Financial benefits include additional income streams from the carbon market, new revenue streams and the potential to turn carbon sequestration into cash with carbon credits.

The environmental benefits include reduced carbon emissions, increased soil carbon levels, enhanced soil health and the potential to address climate change challenges by sequestrating carbon in the soil. These initiatives offer farmers economic incentives and contribute to environmental sustainability and climate change mitigation.

Carbon pricing

Carbon pricing is a tool designed to account for the hidden costs associated with GHG emissions, such as crop damage, healthcare expenses due to extreme weather, and property loss from events like flooding.

It works by placing a carbon tax on the CO_2 emitted during the production of goods and services. making emitters financially responsible for their environmental impact.

FURTHER READING

The following research will further enhance your understanding of this topic. See reference 93 in the "Further reading" section.

DID YOU KNOW

European Union Emissions Trading System (EU ETS) is one of the largest and most well-known carbon trading systems globally. It works based on a) Cap and Trade system where a cap is set on the total amount of GHG emissions allowed by participating industries, representing an overall reduction target. Within this cap, emission allowances are distributed to companies. Each allowance permits a certain amount of emissions.

Companies that reduce their emissions below their allocated allowances can sell their surplus allowances to those exceeding their limits. This creates a market for carbon allowances, where companies that can reduce emissions more cost-effectively have an economic incentive to do so. Conversely, companies facing the highest costs for emission reductions may find it more economical to purchase allowances.

The system provides flexibility for industries to meet reduction targets efficiently. It encourages innovation in cleaner technologies and processes because companies can financially benefit from reducing their emissions.

Companies that exceed their allowances without purchasing additional allowances face penalties. This further incentivizes compliance with emission reduction target. The EU ETS had shown the world the potential for carbon trading to facilitate emission reductions in a cost-effective manner while allowing businesses to adapt and innovate in a climate friendly way.

FURTHER READING

The following research will further enhance your understanding of this topic. See references 94 and 95 in the "Further reading" section.

12.5. Different options for climate mitigation

OECD identified four broad options that could be implemented in the agriculture sector to mitigate GHG emissions:

1. Introduce farm practices that reduce agricultural non-carbon dioxide (non-CO_2) emissions, including methane (CH_4) and nitrous oxide (N_2O). The farm practices include cover cropping, manure digesters, slow-release fertilisers, no-till farming, irrigation management, rotational grazing and others.

EXAMPLE – ALTERNATE WETTING AND DRYING IN INDONESIA

The 3-year experiment conducted in a paddy field in Central Java, Indonesia, focused on evaluating the feasibility of Alternate Wetting and Drying (AWD) water management in mitigating GHG emissions from irrigated rice fields.

The main result emphasises the effectiveness of AWD in reducing methane (CH_4) emissions. When AWD, along with a site-specific version (AWDS) was optimised for greenhouse gas reduction, it significantly decreased the total seasonal CH_4 emission compared to continuous flooding (CF). On average, CH_4 emissions were 35% and 38% less than CF for AWD and AWDS, respectively. Remarkably, this CH_4 reduction was achieved without compromising rice productivity, as rice growth remained normal and grain yields did not significantly differ among the three methods.

Additionally, AWD and AWDS demonstrated their effectiveness in the dry and wet seasons, facilitated by the field's location on an inland, upland area that facilitated drainage. These findings underscore AWD as a promising and sustainable water management option for reducing CH_4 emissions while maintaining rice productivity in tropical regions.

FURTHER READING

The following research will further enhance your understanding of this topic. See references 96 and 97 in the "Further reading" section.

2. Introduce practices to remove CO_2 from the atmosphere and accumulate as carbon in vegetation and soils or reduce emissions from these carbon stocks' degradation and removal.

The practices include Agroforestry, soil carbon sequestration (conservation tillage and no-till farming), reforestation and afforestation, carbon farming practices including rotational grazing, cover cropping and optimising nutrient management to improve soil health and increase carbon content and others.

KEYWORD

Agroforestry is a land-use management system that involves the intentional integration of trees and shrubs into crop and animal farming systems to create environmental, economic, and social benefits. It is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. Agroforestry systems are multifunctional and can provide a wide range of sociocultural and environmental benefits.

Reforestation and afforestation are both practices aimed at restoring forested areas and mitigating climate change. It involves planting and growing trees in forests that has seen a decrease in tree cover, primarily to increase the number of trees and the range of species within a woodland, and to improve their biodiversity.

Afforestation refers to the process of growing trees in an area that was previously not forested, creating a new forest.

Both practices are important for addressing deforestation and promoting sustainable land use, and they contribute to mitigating climate change, conserving biodiversity, and ensuring the sustainable use of natural resources. Reforestation is crucial in combating or preventing deforestation or forest degradation, while afforestation can help restore degraded land and increase carbon sequestration.

Carbon farming practices refer to a set of agricultural practices that aim to sequester atmospheric carbon into the soil and in crop roots, wood, and leaves. These practices are designed to increase the rate at which carbon is sequestered into soil and plant biomass, and they include a variety of techniques such as no-till farming, conservation tillage, cover cropping, rotational grazing, manure digesters, and slow-release fertilisers. Carbon farming practices can help mitigate climate change by reducing greenhouse gas emissions and increasing carbon sequestration in soils and vegetation. They can also improve soil health, increase crop yields, and reduce pollution.

3. Introduce measures encouraging consumers to shift to healthier, lower-emission diets.

EXAMPLE – SUBSTITUTIONS IN DIETARY CHOICES IN THE USA

A study co-authored by a Tulane University researcher and published in the journal Nature Food found that making simple substitutions in dietary choices can reduce the average American's carbon footprint from food by 35% while also boosting diet quality by 4-10%. The study analysed diet data from over 7 700 Americans and identified commonly eaten foods with the highest climate impact, simulating the replacement of these foods with nutritionally similar, lower-emission options.

Key findings from the study include:

Substitutions: The largest projected reductions in emissions were seen in mixed dishes like burritos, pastas, and similar popular dishes where it's easy to substitute a lower-impact protein instead of beef

Children: The study expanded on past research by including dietary data for children, showing that switching children to plant-based milk can have a "meaningful impact on the carbon footprint" and help start positive habits earlier

Healthy Alternatives: Identifying healthy alternatives to high-carbon foods was not the intent of the study, but swapping to lower carbon foods showed "sizable improvements in how healthy the diets were".

Small Changes: The study highlights the potential of a "small changes" approach, which could encourage more consumers to adopt climate-friendly eating habits.

The study suggests that simple dietary swaps, such as switching from beef to chicken or drinking plant-based milk instead of cow's milk, can significantly reduce carbon emissions and improve diet quality. These substitutes are not intended as a cure-all for climate objectives or personal health goals, but they demonstrate that small changes can have a significant impact.

FURTHER READING

The following research will further enhance your understanding of this topic. See reference 98 in the "Further reading" section.

4. Introduce measures that reduce product losses along food supply chains and consumer food waste.

EXAMPLE – REDUCING EMISSIONS FROM FOOD LOSS AND WASTE IN THE USA

In the information from Project Drawdown, the UN and the U.S. Environmental Protection Agency (EPA) emphasise the impact of reducing food loss and waste on mitigating climate change. Food loss and waste emissions result from the production of unconsumed food and the potent GHG, CH_4, emitted when waste food rots. By preventing food loss and waste, these emissions can be avoided. This is crucial for achieving the goals of the Paris Agreement.

Reducing food loss and waste can also help feed more people without expanding cultivated areas, thus mitigating deforestation and its associated GHG emissions. The U.S. has set a goal to halve food loss and waste by 2030, emphasising the importance of this strategy at a national level. The draft strategy features four objectives:

1. Prevent the loss of food where possible;
2. Prevent wasting food where possible;
3. Increase the recycling of all organic waste;
4. Support policies incentivising and encouraging food loss, waste prevention and organics recycling.

The strategy lists actions that EPA, FDA, and USDA can take for each objective. Examples of actions include a national campaign to teach consumers how to reduce food waste, testing new approaches to reduce food waste across the supply chain, supporting the development of organics recycling infrastructure through financial grants, and expanding the market for products made from recycled organic waste.

FURTHER READING

The following research will further enhance your understanding of this topic. See references 99,100 and 101 in the "Further reading" section.

Complete Activity 3.1 in your workbook.

13. Session 3.2: Climate mitigation

13.1. Session outcomes

After completing this session, you will be able to:

- Discuss different mitigation measures used in agriculture and approaches to climate change both in general and specifically as applied to different contexts across countries
- Discuss case studies and global examples of mitigation measures

13.2. Session overview

In session 3.1, we discussed the importance of climate mitigation and associated concepts and introduced the various mitigation strategies covering the need for a farmer to mitigate climate change. Also, the meaning of climate mitigation and associated concepts introduce the learners to various mitigation strategies. Both adaptation and mitigation to climate change are critical to ensure the sustainability of agrifood systems. To reduce farmers' vulnerability to climate change, different measures and approaches to adapt and mitigate the effects of climate change must be part of farm planning. Session 3.2 presents various mitigation measures and techniques used in agriculture.

DO YOU KNOW

Agriculture contributes substantially to global climate change. The sector accounts for roughly a fifth of greenhouse gas (GHG) emissions when considering the entire production life cycle, including agriculture's role in deforestation. (The IPCC 2022 report indicates that the agriculture, forestry, and land use sector contributes 22% of GHG emissions among all economic sectors worldwide). This massive number is comparable in scale to the transportation sector. Further, this ratio can be even higher in developing countries where the agriculture and forestry sectors often account for most of total emissions.

13.3. Approaches to climate change mitigation

Multiple intervention options are available for every source of GHG emissions, and the effectiveness of any single intervention will depend greatly on the specifics of the relevant agricultural system. Interventions that reduce the emissions intensity of production are typically in line with productivity gains and cost savings and are thus often in the best interest of the farmers, who are the supply side of the agri-food systems. However, emissions intensification practices also carry the risk of environmental or social trade-offs. In other cases, mitigation practices do not impact productivity. Still, they may help farmers meet other objectives (e.g., water quantity savings from mid-season drainage in rice systems or water quality improvements from better management of stored manure).

On the other hand, the discussions on food security and agriculture mitigation over the last two decades have almost exclusively focused on increasing productivity and reducing net GHG emissions from production. However, as the global population grows and incomes rise, we must also pay attention to the demand side of the equation, including which products we consume, how much we consume, and how much food we waste.

Table 5. Different climate mitigation strategies are used on the supply side and demand side of agrifood systems.

Supply-side strategies	**Demand side strategies**
Sustainable intensification	Reducing food loss and waste
Improving nitrogen management and production	Shifting dietary trends
Reducing emissions from enteric fermentation	Subsidies and trade
Sequestering carbon in agricultural systems	Finance and investments
Reducing methane emissions from rice cultivation	Corporate supply chains
Managing manure	Tracking emissions in agriculture

Major demand shifts have the technical potential to reduce overall emissions associated with agriculture by roughly 55% by 2030, compared with a baseline. Although the potential to reduce the agricultural sector's GHG footprint through changes to consumption patterns is enormous, the certainty around the mitigation estimates is very poor, and the literature on this topic is only beginning to emerge.

13.4. Supply-side strategies

Sustainable intensification

Increasing the efficiency of land and resource use will be essential to meet the rising demand for agricultural products and to improve food security for a growing global population. Closing yield gaps for crops, especially livestock, increases production's emissions efficiency (e.g., lower emissions per unit of product) and can decrease land use change emissions by reducing pressure on forests. Sustainable intensification is a concept broadly aimed at increasing yield and meeting future demand by optimising the efficiency of agricultural production across social, environmental and ethical dimensions of sustainability.

Specific interventions:

- Assess mitigation effectiveness of intensification strategies for Reduce Emissions from Deforestation and Degradation plus conservation (REDD+) finance;
- Develop assessment tools to identify mitigation opportunities with high co-benefits and low/manageable trade-offs.

FURTHER READING

The following research will further enhance your understanding of this topic. See references 102 and 103 in the "Further reading" section.

DID YOU KNOW

Since 2008, USD 5.6 billion has been pledged to multilateral climate funds supporting efforts to reduce deforestation and degradation emissions plus conservation (REDD+). REDD+ became prominent after recognising that land-use change, principally deforestation is responsible for 12%–20% of global greenhouse gas (GHG) emissions. Furthermore, tropical forests provide multiple ecosystem services and support the livelihoods of an estimated 1.6 billion of the world's poorest people dependent on forest resources. REDD+ has the potential to help promote environmental and socially sustainable use and conservation of forest resources as part of development strategies, provide safeguards and inclusive gender-responsive beneficiary schemes, and ensure traditional and indigenous usage rights are acknowledged and protected.

Improving nitrogen management and production

Nitrous oxide emissions stem from nitrogen fertilisers (both synthetic and organic) on croplands that plants have not absorbed and leach instead into the environment. Fertiliser run-off contaminates surface and groundwater quality and creates GHG emissions in the form of nitrogen oxide. To better manage fertiliser application, the basic approach is to increase the nitrogen use efficiency within the cropping system by better matching the nitrogen supply from fertilisers with the nitrogen demands of the crops. Although many practices are effective in improving nutrient use efficiency, and most are low-cost, they tend to be labour and knowledge-intensive.

Specific interventions:

- Evaluate the Soil Testing and Fertilizer Recommendation program in China and additional measures to reduce fertiliser application support efforts in knowledge dissemination to farmers on correct fertiliser management
- Improve fertiliser production by engaging the fertiliser industry through investment or outreach

FURTHER READING

The following research will further enhance your understanding of this topic. See reference 104 in the "Further reading" section.

Reducing enteric fermentation emissions

Enteric fermentation accounts for nearly half of direct agricultural emissions. It is part of the digestive process in herbivorous animals ('ruminants' such as cows, buffalos, goats, and sheep). These animals have a rumen, a four-compartment stomach with a complex microbial environment, which allows these animals to digest complex carbohydrates, a process that produces methane as a byproduct.

KEYWORD

Enteric fermentation is the digestive process in which sugars are broken down into simpler molecules for absorption into the bloodstream. This process also produces methane as a by-product. However, a small percentage of methane is also produced and released in the cow's large intestine.

Ultimately, the best way to reduce enteric fermentation emissions is to reduce ruminant populations. When animals are held in unproductive systems or are kept for purposes other than meat production, they are kept alive for a long time. When it takes a long time for a single animal to reach slaughter weight, it does not only have high emissions per unit of product, but a larger herd is needed to support a given production level.

There are three main ways to reduce enteric fermentation emissions per unit of meat or milk:

- improving the quality and digestibility of feed
- provide supplements and additives to reduce methane
- optimising the health and reproductive capacity of the herds.

Both feeding and herd management practices aim to lower the number of animals necessary to sustain a given level of production. By improving the diets of these animals, lower emissions could be achieved while keeping production levels constant.

Because these interventions align with productivity gains, reductions in enteric fermentation emissions for many of the world's animal populations provide some of agriculture's most cost-effective mitigation potentials.

Specific interventions:

- Improve grazing lands management in beef production by promoting awareness and capacity of cattle ranchers through outreach and vertical integration of the supply chain
- Increase the effectiveness of the Low Carbon Agriculture program in Brazil (Agricultura de Baixa Emissão de Carbono; ABC) to reduce agricultural emissions
- Improve feeding practices in dairy production in India by making a business case and supporting outreach campaigns to processors, producers and farmers

Sequestering carbon in agricultural systems

Numerous land and crop management practices can increase the soil organic carbon in agricultural soils, including protecting existing carbon in soils by;

- Slowing decomposition of organic matter and reducing erosion (e.g. reduced tillage or no tillage, cover crops, contour strops),
- Increasing the amount of carbon in soils (e.g., retention of crop residues, biochar),
- Add carbon to the agricultural system through above-ground biomass (e.g. agroforestry or silvopasture),
- Increasing carbon stores in grazing lands (e.g., managing stocking rates, timing and rotation of livestock, introducing grass species or legumes with higher productivity, and applying biochar, compost, fertiliser, or irrigation to increase productivity).

Most practices that increase the carbon content in agricultural soils are good farming practices, leading to increased yields and water retention. Considering the need to intensify agricultural production, active consideration of increasing soil carbon within existing agricultural programs requires comparatively little effort with potentially significant benefits.

One way to prioritise support for increased soil carbon sequestration is to identify those geographies where soil carbon content is particularly low and where the links to food security, poverty reduction, and productivity gains are the highest.

Specific interventions:

- Initiating and supporting research and dialogue to establish better practices
- Support awareness campaigns targeted at producers to communicate best practices
- Increase below and above-ground carbon sequestration in agricultural systems by facilitating the development of methods and decision-support tools for trade-off assessment
- Support scientific network to collect and analyse long-term data series of soil carbon stocks and fluxes
- Support the development of biochar by testing and scaling up biochar production and use in key markets (e.g. China, Brazil)
- Enhance credibility and knowledge on biochar by promoting standards in biochar production

Reducing methane emissions from rice cultivation

Rice is one of the most important cereal crops in the world. It grows on over 170 million hectares and consumes more than any other staple food. Close to 90% of rice is grown in Asia; of that, 90% is grown in flooded or partially flooded paddy fields.

- When fields are flooded, material decomposition depletes oxygen in the soil and water, causing anaerobic conditions that generate methane.
- The rice cultivation water management system is one of the most important factors affecting and causing GHG emissions.
- Other factors, including soil type, tillage management, residues, and fertiliser, also play a role.
- Methane emissions from rice production account for 11% of GHG emissions from the agricultural sector and a third of emissions from crops, making it the crop with the highest GHG footprint.

- The top rice-producing countries—China, India, Indonesia, Bangladesh, Vietnam, and Thailand—account for more than 75% of global rice production.
- Many interventions to reduce rice emissions (e.g. improved water management, rice straw management, and more precise nutrient management) complement productivity gains. For example, irrigation can be added to control water better, allowing double cropping.

Specific interventions:

- Scale up sustainable rice intensification systems that integrate climate mitigation by building a model for resource-use efficiency practices in rice production with proven mitigation effects and applying it in ASEAN countries.
- Build a mitigation component into food security projects on rice

Managing manure

Manure and urine can cause both nitrous oxide and methane emissions. They cause nitrous oxide emissions when deposited on pastures by grazing animals, used as fertilisers on croplands, or stored in dry agricultural systems.

- Manure and urine stored in wet (anaerobic) systems create methane emissions.
- Mitigation options exist for manure on pasture but are very difficult to implement because of the dispersed nature of the deposits.
- Stored manure accounts for a relatively small amount of direct agricultural emissions, but it is possible to mitigate a very high percentage of these emissions (as much as 70% for most systems).
- Mitigation practices include anaerobic digesters, converting manure into compost, better timing and application of manure onto croplands, and several simple, low-cost ways to improve storage and handling.
- Manure can reduce the need for synthetic fertilisers, displace fossil fuels, create profitable products for producers, and increase the productivity of croplands and pastures.

- Mitigation interventions that target stored manure management do not benefit livestock productivity, and they also present no serious food security risks but have co-benefits such as water quality.

Specific interventions:

- Reduce emissions from stored manure systems by supporting spatial planning for industrial livestock facilities
- Reduce emissions from stored manure systems by supporting biogas production subsidies in key states

13.5. Demand-side strategies

Reducing food loss and waste

According to FAO estimates, approximately one-third of all food intended for human consumption is lost or wasted in the value chain (production, handling and storage, processing and packaging, distribution and market, and consumption).

- Food loss happens before it reaches the consumer through spoilage, spilling or other unintended consequences due to limitations in agricultural infrastructure, storage and packaging.
- Food waste refers to intentionally discarded food, usually during distribution (retail and food service) and consumption.
- 'Food wastage' refers to both food loss and waste.
- In the developing world, losses mainly occur postharvest due to financial and technical limitations in production techniques, storage and transport.
- Losses in the developed world are incurred mainly by end consumers.
- Simplistically calculated, cutting current food wastage levels in half can close the 70% gap of food needed to meet 2050 demand by roughly 22%, potentially making reducing food wastage a leading strategy in achieving global food security.
- China and the U.S. appear to provide the most significant opportunities for GHG mitigation from consumption practices.

Specific interventions:

- Reduce consumer food waste by revising food date labelling practices
- Support consumer education on food waste through communication campaigns
- Measure food waste in food companies along the supply chain
- Reduce food loss in the value chain by improving handling and storage practices by providing technical and financial support to farmers

Shifting dietary trends

Livestock production has a large carbon footprint, accounting for approximately 50% to 70% of direct agricultural GHG emissions. When meat's total life cycle emissions are considered, livestock accounts for 14.5% of total global GHG emissions, or 7.1 Gt CO_2 per year. Addressing rising meat consumption, particularly beef, is important.

- Beef has roughly six times the carbon footprint per kg of food than poultry, and poultry's carbon footprint is approximately ten times that of any of the major cereal crops.
- Beef is also the least resource-efficient meat to produce per kilo than any other meat, requiring large amounts of water, energy, feed and land.
- If global populations adopt U.S. consumption patterns, the associated emissions would be enormous.
- Interventions that can help curtail significant increases in beef consumption in industrialised countries and emerging economies will be critical over the next few decades.
- Given the established links between diet-related diseases and high levels of meat consumption, keeping global average per capita meat consumption at reasonable levels will also have significant health benefits.

Specific interventions:

- Leverage existing food and resource security policies to reduce beef production and imports and promote alternative proteins

- Promote public health policies that incentivise healthy diets and healthy levels of protein intake.
- Curb future demand for beef and decrease per capita meat consumption through media and outreach campaigns. Cross-cutting Strategies

No single strategy or recommendation can address the full mitigation potential of the agricultural sector. This suggests that a coordinated philanthropic strategy should consist of a diversified portfolio. Reducing GHG emissions at the source (supply) and through shifts in consumption (demand) are essential pillars of such a strategy. However, several cross-cutting measures can facilitate the uptake of new practices and spur innovation. Several such measures, with a focus on those that help to channel public or private funds into mitigation or that allow for better accounting of the GHG footprint of the agricultural sector, are presented:

Subsidies and trade

Access to finance, financial support, and access to markets all play key roles in facilitating the transition to climate-smart agriculture.

- Government subsidies are the most common form of agricultural incentive. Only a small percentage of such subsidies are well-aligned with climate or other environmental goals.
- Reform of agricultural subsidies in major agricultural economies, particularly the E.U. and U.S., would be enormously valuable.
- Advocacy around these programs may be worthwhile, even if they are long-term strategies.
- International trade is increasingly important for global food security, particularly where productive capacities are impaired due to climate change.
- Badly designed mitigation policies can also distort trade, negatively impacting food accessibility and availability.

Specific interventions:

- Establish financial incentives for soil management through subsidies reform
- Protect, strengthen and expand conservation programs

- Support farmer advisory programs
- Remove barriers and create incentives for GHG mitigation under the WTO and UNFCCC and support a formal or informal process to examine the trade and clime change interface in the WTO

Finance and investments

Large private and public agricultural investments are required to meet projected agrarian demand.

- FAO estimated investment needs to be USD 9.2 trillion by mid-century (USD 210 billion annually from 2005–2050).
- These projections embody a broad range of capital items related to primary livestock and crop production and several activities in downstream support services but do not account for climate change impacts or other constraints.
- Compared to these numbers, climate finance flowing into agriculture is expected to be marginal.
- It is essential that baseline financial flows into agriculture be directed towards low-emitting, carbon-rich and sustainable agricultural models.

Specific interventions:

- Steer donor support away from high-emitting agricultural activities, especially beef production
- Include GHG data in investment appraisal and program evaluation
- Channel climate finance towards agriculture by incorporating climate-smart agriculture in the design and implementation of the Green Climate Fund

Corporate supply chains

Ensuring the availability and quality of raw materials across supply chains is becoming increasingly challenging. Security of supply is becoming a key concern for businesses, especially in the food and agricultural sectors.

- Companies sourcing from areas affected by climate change are particularly vulnerable.

- To mitigate climatic, environmental, and social risks, companies increasingly look for strategies to ensure a more sustainable supply of raw materials.
- Consumers, especially those in developed countries, but increasingly those in emerging economies as well, have become more concerned about agricultural production's environmental and social impacts.
- Downstream, consumer-facing companies have been under increasing pressure to improve the sustainability of their products across the entire supply chain, particularly concerning deforestation.
- Sustainability can be improved at any stage, from fertiliser production to consumer waste handling, and through various leverage points, depending on the scope and integration of the supply chain.
- Examples of supply chain initiatives include multi-stakeholder dialogues, information disclosures, and corporate social responsibility reports and strategies to technical assistance, guidelines for better practices, standards, certification schemes and industry commitments.
- Greater transparency and accountability in corporate supply chains would strengthen major food and agribusinesses' climate-oriented investments and commitments.

Specific interventions:

- Embed climate change mitigation in certification systems
- Make the business case for certification with a climate mitigation component
- Mobilise support of certification with farmers
- Advocate for government engagement in sustainable sourcing
- Reach out to traders and engage them in sustainable supply chain efforts

Tracking emissions in agriculture

Measuring and monitoring GHG emissions is fundamental for managing emissions effectively. A clear understanding of how much carbon can be sequestered, or how much different practices can reduce GHG emissions, is central to making informed decisions about the most appropriate mitigation strategies.

- Significant gaps continue to exist in developing countries, where there are many questions related to the sources of agricultural emissions, as well as an absence of methods and methodologies that allow the monitoring of emissions through supply chains and the evaluation of GHG impacts of investments.
- Many available emission quantification and monitoring methods are expensive and complex.
- There are still significant uncertainties associated with measurements of livestock, rice, and nitrogen fertiliser emissions.
- Considering the relevance of tracking emissions for any valuable mitigation action and the particular characteristics of philanthropic support, improving GHG monitoring, reporting, and verification (MRV) for governments, the private sector, and NGOs must be a priority action.

Specific interventions:

- Develop GHG monitoring frameworks in developing countries
- Develop simple on-farm monitoring tools
- Increase the traceability of GHG emissions along the supply chain by supporting the development of robust emissions-tracking systems across supply chains
- Develop tools that allow investors to assess the GHG impact of their investments

The pressures on land, natural resources, climate, and people continue to grow. Win-win solutions exist and must be pursued aggressively by all factions collectively charting the course for agriculture in the 21st century. The above discussions on supply and demand-side mitigation measures in agriculture contribute to the progressive reduction of GHG emissions in the effects of climate change from and on agriculture.

FURTHER READING

The following research will further enhance your understanding of this topic. See reference 105 in the "Further reading" section.

13.6. Mitigation measure case studies

The following case studies will give you some insight into the ground-level implementation of mitigation measures.

EXAMPLE - HERD-SIZE MANAGEMENT IN KENYA

Herd-size management strategies aim to increase productivity, enabling the reduction of herd size while maintaining the level of production of agricultural products such as milk or meat.

How it works:

Generally, a small but efficient herd increases animal productivity and lowers net greenhouse gas emissions.

On-the-ground experience:

A project in Kenya aimed to reduce total herd size by 10% in two counties through quicker animal growth that allows slaughter at an earlier age. The project boosted producers' access to inputs (feed and veterinary services), improved market links between livestock producers and buyers and increased the availability of timely market information for livestock producers. This herd-size management strategy was appropriate for Kenya; project developers must adapt strategies to the local context and assess whether incentives or changes to enabling conditions (e.g., insurance, financial services) are needed for a livestock producer to reduce herd size without facing production risks.

Example – Urea Deep Placement (UDP)

Urea deep placement (UDP) is a fertiliser management technology that improves nutrient use efficiency by placing urea briquettes into the soil instead of broadcasting urea granules on the surface.

How it works:

UDP reduces nitrous oxide emissions and unintended nitrogen loss caused by ammonia volatilisation, surface runoff, and nitrate leaching. Compared to surface broadcasting, it also decreases the amount of fertiliser needed. AAPI, a food security project in Bangladesh, promoted using UDP on over one million hectares of rice.

On-the-ground results:

While emission reductions per hectare from UDP are small, AAPI expected a wide uptake of UDP and, thus, large reductions for the project. AAPI also found that farmers who use mechanisation for UDP are more likely to adopt the practice, given the physical demands of manually placing briquettes.

Example – Alternate Wetting and Drying (AWD)

Farmers periodically dry their irrigated lowland rice fields using alternate wetting and drying (AWD).

How it works:

Because submerged soil leads to low-oxygen conditions, organic residue in flooded rice paddies decomposes anaerobically, releasing methane, a potent greenhouse gas. Periodically drying the paddy interrupts this process and can reduce methane emissions by up to half compared to continuous flooding. AWD also reduces water use by up to 30%, conserving water and the fuel required to pump it, often decreasing out-of-pocket costs for farmers.

On-the-ground results:

Analyses revealed that although AWD delivers significant climate change mitigation benefits per area, barriers limit widespread adoption. The extent to which AWD can contribute to climate change mitigation and water conservation depends on identifying where and how to surmount these barriers.

FURTHER READING

The following research will further enhance your understanding of this topic. See reference 106 in the "Further reading" section.

Complete Activity 3.2 in your workbook.

14. Session 3.3: EAS promoting climate change mitigation

14.1. Session outcomes

After completing the session, you will be able to,

- Implement the key mitigation challenges for EAS in agriculture
- Discuss varied EAS approaches to promote the adoption of climate mitigation strategies among farmers

14.2. Session overview

In Session 3.1, we discuss the different terms associated with mitigation, and in Session 3.2, we briefly discuss the different approaches to addressing mitigation. In Session 3.3, we will learn about the challenges EAS experiences in promoting climate mitigation strategies. In Session 3.4, we will see how EAS can better promote these strategies among farmers.

14.3. Challenges faced by EAS while promoting climate mitigation strategies

Farmers could adopt several mitigation strategies to address climate change impacts. However, promoting mitigation is more challenging than promoting adaptation.

Some important challenges are discussed below.

- Adoption of new agricultural practices: Farmers may be hesitant to adopt new practices if they perceive them as risky or require significant investments in new technologies. They also perceive that this may increase yield risks and can be a barrier to mitigating greenhouse gas emissions in agriculture.
- Financial incentives or regulatory requirements: Farmers may require financial support or regulatory requirements to encourage the adoption of new technologies. The need for financial incentives or regulatory requirements can make it challenging for EAS to mitigate GHG emissions in agriculture.

EXAMPLE – CONSERVATION AGRICULTURE

Conservation agriculture is a farming system that aims to prevent the loss of arable land and regenerate degraded lands. It involves a set of farming practices that involve minimum soil disturbance, crop rotation, use of cover crops and restoring organic matter into the soil to improve soil health and reduce GHG emissions.

The CA techniques protect soil from erosion and degradation and improve its quality. This is one of the widely recommended mitigation strategies for farmers. However, promoting such practices among farmers who are used to conventional agricultural practices is a challenge for the EAS in bringing behavioural change towards adopting CA practices.

- Measurement, reporting, and verification of emission reductions: Challenges exist in accurately measuring, reporting, and verifying emission reductions from emission abatement practices like conservation agriculture in the agriculture sector. This involves addressing methodological and technical challenges as well as identifying possible barriers to implementing mitigation practices.

TAKE NOTE

The methodological challenge includes:

1. Establishing a baseline for measuring emission reductions due to variability in emissions and the lack of consolidated data and methodologies for measuring and reporting emissions.
2. Accounting for co-benefits such as improved soil health or increased biodiversity, as these benefits are difficult to quantify and may vary across agricultural systems.
3. There are no standardised methodologies for measuring and reporting agricultural emissions, making it difficult to compare emission reduction efforts across regions and countries.

TAKE NOTE

The technical challenges include:

1. The variability in emissions from agriculture, which can be affected by factors such as weather, soil conditions, and farming practices, can make it challenging to measure and report accurately.
2. Lack of data on emissions from agriculture, particularly in developing countries, can make it difficult to measure and report emissions accurately and
3. The complexity of agricultural emissions, which are affected by multiple factors, makes it difficult to measure and report emissions accurately.

- Knowledge gaps and research and development needs: There is a lack of actionable knowledge on achieving synergies among goals such as increasing productivity and income and appropriate climate action at the farm level. In addition, the agricultural sector needs to be assessed for its vulnerability to climate variability and long-term change. This assessment requires research to understand the nexus between agricultural policy, research, and extension in the context of climate variability and its implications for the sector.

  Research is needed to develop flexible implementation approaches, assess market-based mitigation efforts, and understand the potential impacts of climate change on agricultural production and trade. This research can help address the barriers related to the level of production activities, the use of mitigation technologies and differences in production types and farm size. There is a need to ensure interactive research methods that include researchers and stakeholders to address the uncertainties and knowledge gaps related to climate change and food security.

FURTHER READING

The following research will further enhance your understanding of this topic. See references 107,108,109,110,111 and 112 in the "Further reading" section.

14.4. EAS in mitigating climate change

Implementing climate mitigation measures at the farm level is highly dependent on farmers' willingness to adjust their farms. Different kinds of influences, including economies of scale, sufficient time for farming, developmental subsidy schemes, beneficial climate, and topography, actually lead to the decision and actions of implementing relevant measures. Under such circumstances, EAS can play a crucial role in reaching the farmers and bringing about behavioural change while influencing them to adopt climate mitigation strategies. These are discussed below.

Farmer Field School (FFS)

FFS is a participatory education approach that brings together a group of small-scale food producers to solve production problems through sustainable agriculture. The approach offers space for hands-on group learning, enhances skills for observation and critical analysis, and improves decision-making in local communities.

Although FFS is not explicitly designed to address climate change variability, it will be a beneficial approach for EAS to bring awareness among farmers about the effects of climate change and impart climate adaptation and mitigation strategies via FFS to adopt climate-resilient practices and technologies by farmers, which can increase productivity and incomes while reducing greenhouse gas emissions.

Below is a case of FFS that has influenced Tanzanian farmers to mitigate climate change. This has improved farmers' food security and livelihoods through the adoption of climate-smart agricultural practices.

FURTHER READING

The following research will further enhance your understanding of this topic. See reference 113 in the "Further reading" section.

EXAMPLE – CLIMATE SMART AGRICULTURE IN A FARMER FIELD SCHOOL IN TANZANIA

The FAO's Mitigation of Climate Change in Agriculture (MICCA) project, in collaboration with CARE International and the World Agroforestry Centre (ICRAF), was implemented in the Hillside Conservation Agriculture Project (HICAP) in the Uluguru Mountains in eastern Tanzania between 2011 and 2014. The project aimed to integrate climate change adaptation and mitigation into agricultural development activities for smallholder farmers. Agriculture in the region is characterised by slash-and-burn and rotational fallow systems on hill slopes with a high rate of land degradation through soil erosion combined with poor agronomic practices, leading to low productivity.

Objectives of the MICCA-HICAP project:

- Improve food security and livelihoods among project village communities;
- Support conservation agriculture (CA) and introduce agroforestry and soil and water conservation (SWC).

Awareness meetings and training:

Eight villages held meetings on CSA and related issues, such as gender and land tenure, involving farmers, village leaders, and ward officials. Interested farmers were invited to join the FFS. The FFSs were led by trained local farmers, so-called contact farmers, who set up the experimental plots in their own fields and received initial training from an FFS master trainer.

Project staff and extension staff from the District Agriculture Office also continuously supported contact farmers throughout the FFS and assisted during many training sessions. CA, as part of the CSA approach, was promoted through the FFSs, while the other practices were promoted through targeted demonstrations and practical training sessions for interested farmers (often among the FFS participants).

Farmer Field Schools:

Throughout the project duration of three years, a varying number of FFSs (between five and nine per year) were active, reaching 22 FFSs and about 650 FFS members.

Moreover, when accounting for the CSA/CC awareness sessions, 1418 farmers (41% women) were reached, around 100 experimental plots were established, and 11 tree nurseries (and tree nursery management groups) were set up in the area.

The tree nurseries were to provide farmers with seedlings for SWC measures and agroforestry, offering a range of tree species to satisfy different demands and uses: spices, fruit, timber, fuel wood, construction material, and nitrogen-fixing species.

Nursery managers trained by ICRAF guided tree planting and agroforestry to farmers upon provision of seedlings. In addition to FFSs and targeted training sessions, exchange visits were organised, taking farmers from one village to another in or outside the project area where the adoption of the promoted practices was further advanced. These exchange visits also served as a reward mechanism for championing farmers and to keep interest and motivation among the FFS.

Carbon-Balance Analysis:

An initial socioeconomic survey, capacity assessment, and carbon-balance analysis were conducted and combined with stakeholder consultations to help identify and select the CSA practices and ensure their suitability and potential to reduce GHG emissions.

It was estimated that the HICAP and MICCA projects CSA activities would create a sink of 1.7 t CO_2 eq/ha/year over the next 20 years, compared to a source of 0.8 t CO_2 eq/ha/year in the baseline scenario.

Mitigation Practices promoted through FFS:

Conservation Agriculture (CA) was considered a suitable CSA practice because of its positive effect on soil nutrient intake. Soil moisture conservation helps increase and stabilise yields, thereby mitigating the risk of changing rainfall patterns. It also reduces GHG emissions by avoiding slash-and-burn practices and soil carbon storage.

The core principles of CA, as promoted by the FFSs, were

(i) minimum tillage (after double digging to break the hard pan from repeated tillage);

(ii) permanent soil cover by leguminous cover crops and mulches (as there was no competition with livestock in the area over crop residues); and

(iii) crop rotation without the use of slash and burn.

- Soil and Water Conservation (SWC) practices, such as terracing (including fanya juu and fanya chini), trenches, ridges, and trash lines (depending on the slopes) to reduce soil erosion and increase water infiltration and retention
- Agroforestry for livelihood diversification, income (primarily through fruit and spice trees) and increased landscape resilience
- Improved cooking stoves to save fuel wood and reduce GHG emissions and pressure on forests. The improved cooking stoves reduced wood use by 50%, from six pieces to three pieces per day, thus reducing the workload on women who had to fetch fuel wood and potentially reducing pressure on the forest
- The FFSs also encouraged the combination of CA with SWC practices and agroforestry.

Results and adoption:

- Slash and burn agriculture decreased from 55% to 39%
- Community-level adoption of CSA practices was evaluated through five focus group discussions (FGD) of local stakeholder groups (six to nine members each), including contact farmers, trained farmers, trained women farmers, nontrained farmers, and village leaders.
- The perception of the adopters of CA was that their maize yields increased by more than 100% and allowed them to generate extra income by integrating high-value crops such as pineapples on their newly established terraces.
- All adopters received training, which showcases the importance of capacity building through FFSs and other extension methods.

Farmers considered the presence of contact farmers as an essential element for adopting CA and other CSA practices and underlined the value of their knowledge, which will remain in the village beyond the project period and can further support the promotion of CSA.

This demonstrates that the targeted communities have positively perceived the FFS approach and CSA. The demonstration that they actually bring higher yields was crucial for the acceptance and adoption of a new practice.

Challenges and barriers to adoption:

- The poor governance at village-level and the lack of by-laws to promote the new practices were cited as barriers during the group consultations.
- Farmers, especially women, identified insecure land tenure as a major barrier to the adoption of CA and other CSA practices, particularly terracing and agroforestry.
- Some farmers were reluctant to invest in labour-intensive new practices, such as double digging for CA or terracing, because of the risk that their landlord would take back the land after seeing improvements.

These challenges show that even at the lowest organisational level, FFSs must be linked to governance, gender, and tenure issues.

FFSs demonstrated that upscaling is adaptable to location-specific farmer needs.

FURTHER READING

The following research will further enhance your understanding of this topic. See reference 114 in the "Further reading" section.

Developing contingency planning

Contingency planning involves considering current and future risks related to the changing climate, including both gradual changes and extreme events. These plans aim to reduce climate risks by enabling a rapid, organised response. EAS supports building producers' resilience to climate change by helping farmers develop contingency measures for climate change impacts.

EXAMPLE – CONTINGENCY PLANNING OF NATIONAL INNOVATIONS IN CLIMATE RESILIENT AGRICULTURE (NICRA) PROJECT IN INDIA

The National Innovations in Climate Resilient Agriculture is a network project of the Indian Council of Agricultural Research (ICAR) that aims to enhance the resilience of agricultural systems to climate variability and change. The project consists of four components, including research on adaptation and mitigation for crops, livestock, fisheries, and natural resource management.

Real-time contingency crop planning is a key aspect of the project, as it aims to help farmers cope with climate-related challenges such as delayed monsoon onset or early-season droughts.

The project implemented district agricultural contingency plans, which contain information on alternate crops and varieties, soil conservation, rainwater conservation and utilisation, and crop management practices to be chosen to address climate changes.

These interventions include technology-related aspects such as land, water, soil, crops, and institutional and policy-based measures. Contingency plans are developed in a participatory mode, involving farmers, extension workers, and other stakeholders in the planning process.

FURTHER READING

The following research will further enhance your understanding of this topic. See reference 115 in the "Further reading" section.

Strengthening local resilience

EAS helps farmers understand the impacts of climate change and adopt CSA practices with climate-informed decision-making. The Pragati NGO, which promoted finger millet by strengthening the local farming community while conserving the local millet varieties, is the best example of an EAS mitigation and adaptation strategy for climate change.

EXAMPLE – STRENGTHENING LOCAL RESILIENCE WHILE PROMOTING FINGER MILLETS IN INDIA

In the agricultural area of the Koraput district in Odisha, India, EAS were instrumental in transforming traditional farming practices, particularly in finger millet cultivation. Here, finger millet is a resilient climate-smart crop adaptable to poor soil fertility and prolonged drought conditions.

Functioning as a 'famine crop', its seeds' excellent resistance to storage pests ensures a consistent food supply, mitigating the impact of crop failures on rural populations. This makes it an environmentally sustainable choice amid climate change.

Recent initiatives increased finger millet cultivation after a decline mainly due to low-quality seeds. The Odisha Millet Mission Programme supported the Pragati NGO to increase cultivation to improve food and nutritional security despite climate change.

Intervention:

Promotion of finger millet production, consumption and marketing.

Extension and Advisory Services:

Pragati provided the following services to farmers and women involved in the production, consumption and marketing of finger millet:

- Dissemination of knowledge on the nutritional composition of finger millet;
- Organised nutrition awareness programs, food festivals, and biodiversity festivals;
- Introduced innovative agricultural practices like the System of Millet Intensification (SMI)
- Conducted farmer training programs
- Promoted value-added products and developed marketing strategies and initiatives to raise consumer awareness.
- Formed Farmer Producer Companies (FPCs) to support aiding in market linkages and contribute to the economic empowerment of small and marginal farmers.

Pragati, with the support of other extension professionals within the district, extended the support from sustainable millet production practices to marketing, facilitating post-harvest management and value-addition services.

Impact:

SMI has significantly increased millet yields for 11,385 farmers in Koraput, Odisha. Yields range from 23 to 36 quintals per hectare, driven by efficient water and nutrient uptake facilitated by the method's bushy root system. This not only increases yield but also ensures optimal resource use, contributing to water conservation and reduced reliance on chemical fertilisers.

The vigorous plant growth resulting from SMI practices aids in carbon sequestration. Millet crops absorb carbon dioxide from the atmosphere during photosynthesis, helping mitigate the impacts of GHG emissions.

The SMI practices emphasise sustainable practices, such as reduced reliance on chemical inputs and mechanical weeders, which can decrease the overall carbon footprint associated with conventional agricultural methods.

The incorporation of SMI into the Odisha government policy has led to a 60% to 80% increase in millet yields compared to traditional practices. This has motivated farmers to adopt SMI despite its initial labour intensiveness, contributing to the state and national millet mission programs.

The initiative encourages the cultivation of climate-resilient crops by promoting millet cultivation and incorporating SMI into government policies. Diversifying crops and adopting practices better suited to local climate conditions contribute to the overall resilience of agricultural systems.

FURTHER READING

The following research will further enhance your understanding of this topic. See reference 116 in the "Further reading" section.

Stakeholder coordination and coherence

Developing coordination and coherence between the stakeholders in the mitigation value chain is necessary for successful implementation.

EXAMPLE – LOW CARBON COFFEE IN COSTA RICA 
In response to the climate challenges faced by Costa Rican coffee farmers, the Low Carbon Coffee Nationally Appropriate Mitigation Action (NAMA) Support Project (NSP) played a pivotal role, focusing on sustainable coffee production and processing. Launched in 2014 and implemented by the Ministry of Environment and Energy (MINAE), Ministry of Agriculture and Livestock (MAG), and National Coffee Institute (ICAFE), the NSP received support from the German Development Cooperation (GIZ).
With the goal of reducing GHG emissions and enhancing climate resilience, the NSP provided support to extension and advisory services in various strategic interventions. Under its technical component, the NSP collaborated with coffee farms to adopt lower-emission production practices, worked with processors (mills) for emission reduction facilities, and established a system for monitoring, reporting, and verifying emissions.
Extension services facilitated practical training sessions, enabling stakeholders to learn by doing and encouraging behaviour and cultural change. Additionally, the NSP supported the development of economic, social, and environmentally sustainable standards, promoting transparency and traceability in the supply chain through a certification program.
In the financial component, the NSP collaborated with financial institutions to provide necessary resources for coffee farms and mills to invest in low-emission practices. This included credit lines, subsidy schemes for efficient technologies, and incentives for farmers to plant shade trees.
The project established a Political Steering Committee and a Technical Steering Committee to ensure practical guidance and coordination at both political and technical levels. The project's outcomes highlighted the success of extension and advisory services in promoting sustainable coffee practices.

Over 8,900 producers were trained in applying good agricultural practices, adapting to climate conditions, and minimising the impact of diseases. Collaboration with Fundación Banco Ambiental led to planting over 75,000 shade trees.
The NSP's emphasis on capacity building resulted in 24% of registered Costa Rican coffee mills actively measuring their GHG inventories, contributing to emission reduction, water conservation, and energy efficiency.
The project's impact also highlights the critical role of extension services in improving resilience and sustainability in Costa Rica's iconic coffee sector.

FURTHER READING

The following research will further enhance your understanding of this topic. See references 117 and 118 in the "Further reading" section.

Efforts in climate mitigation through Extension and Advisory Services (EAS) may not always be direct; instances exist where sustainable farming practices, pursued for different purposes, yield co-benefits in climate mitigation. Take the example below, where carbon sequestration becomes a positive outcome of the expanded cultivation of Cacao. EAS methodologies, including the value chain and group approach, have been adopted in this case. These strategies contribute to the project's primary goals and result in positive effects aligning with the broader purpose of climate mitigation.

KEYWORD

The value chain approach is one of several market systems approaches used in agricultural development projects. It involves understanding the actors in a product sector, from input suppliers to end-market buyers.

EXAMPLE – CARBON SEQUESTRATION BENEFITS FROM CACAO EXPANSION IN PERU

The Peru Cacao Alliance (PCA) project aimed to promote sustainable cacao farming practices in the Ucayali, San Martin, and Huánuco regions of the Amazon basin. Peru was the third largest producer of organic Cacao globally, and the project focused on small—and medium-scale farming.

The Amazon Forest covers 60% of Peru, contributing to the country's ecosystem richness and biodiversity. However, it was vulnerable to deforestation and degradation, driven by various factors, including small-scale agriculture and climate change.

The project was implemented as a public-private partnership, initially by Carana Corporation and later continued by Palladium with funding from the United States Agency for International Development's (USAID) alternative development initiative.

The PCA integrated 20,000 small-scale farmers into an inclusive, sustainable cacao value chain, providing legal sources of income and discouraging illegal coca production.

Key approaches adopted under the project were:

- Value chain integration focused on establishing direct, long-term commercial relationships between cacao farmers and buyers. This involved connecting farmers with buyers, technology providers, investors, and government partners to increase Peru's market share in global cacao production.
- Empowering producer organisations by mobilising farmers to enhance their collective bargaining power and promote sustainable farming practices.
- Expansion of Cacao cultivation by farmers with a target planting density of 1,111 cocoa trees per hectare. The expansion was expected to come from grasslands or annual croplands.
- Environmental protection and biodiversity promote expanding perennial systems on previously deforested land. This included the planting of shade trees such as Boalina and Capirona as part of an agroforestry system.

Interventions promoted under the project were:

- Perennial crop expansion contributes to carbon sequestration in soils and tree biomass. New Cacao trees were expected to sequester carbon as biomass grew, and shade trees were incorporated to enhance biodiversity.
- Fertilizer and Pesticide Management practices were implemented to balance nutrient inputs and losses. While fertiliser and pesticide use increased, efforts were made to minimise emissions associated with their production and application.
- The PCA conducted training and monitoring programs to educate farmers on safe pesticide use, fertilisation and composting. This aimed to improve yields and product quality while minimising environmental impact.
- There was much focus on promoting sustainable agricultural practices such as intercropping, rotations and expansion of perennial crops to build agroecosystems that minimise nutrient losses and maximise carbon sequestration.
- There was regular guidance on the selection and management of the adoption of these sustainable agricultural practices.
- There was improved access to fertilisers by smallholders, making working capital available through microfinance institutions, thereby facilitating sustainable agricultural practices.

Climate mitigation impact:

The interventions were projected to significantly increase cacao yields, with an expected harvest of 1.0 to 1.5 tons per hectare by 2021, representing a 67% increase compared to conventional cacao farming.

The expansion of perennial crops was estimated to result in significant carbon sequestration offsetting potential emissions.

The use of fertiliser and pesticides increased GHG emissions, but these were outweighed by the carbon sequestration benefits of perennial crop expansion.

FURTHER READING

The following research will further enhance your understanding of this topic. See reference 119 in the "Further reading" section.

In addition, digital tools help EAS support farmers with real-time information and advisory services. Digital tools like mobile phones can deliver agricultural extension services using applications like messaging, WhatsApp, Facebook, and YouTube. Mobile handsets will offer phone calls, text, voice, video messages, document sharing, and other features to individual farmers/farmer groups, who will be provided access to detailed localised information, adverse weather conditions, market information, and other need-based advisory services.

In addition, several advisories are provided to farmers using radio, television, farmer social media groups, videos and presentations. Several mobile applications are theme or crop-specific digital tools that integrate climate information into agricultural decision-making. For example, Plantwise, Cropin Grow, FarmBetter, AgriMarket, Rice Crop Manager, CropTracker, Agrivi mobile applications, Rice Knowledge Bank portal, Climate change knowledge hub of FAO and others. Such digital tools that EAS can explore for timely advisory and technical assistance to farmers to address climate change.

Though not all digital tools may be explicitly focused on climate change mitigation, they are essential for farmers as they provide access to relevant information, resources, and communication channels, helping them make informed decisions and adapt to and mitigate the challenges of climate change.

Complete Activity 3.3 in your workbook.

15. Concluding remarks

Through this study unit, you have gained a foundational understanding of climate mitigation, including the significance of farmer involvement, the meaning of mitigation, and various implementation strategies.

The real-world examples and cases provided and the content in each session have enriched your understanding of the practical applications and effectiveness of climate mitigation strategies within varying contexts. The discussion on the key role of EAS in facilitating the adoption and implementation of climate mitigation strategies among farmers and the given cases on various EAS approaches support participants in getting guidance for enabling farmers to address the challenges of climate change.

As we conclude the study unit, we need to emphasise that with the support and expertise of EAS, we can empower farmers to contribute to mitigating the effects of climate change while promoting sustainability in agriculture. Moving forward, we need the commitment to implement and scale up these mitigation efforts while promoting collaborative activities among various stakeholders of agriculture involving producers, consumers, policymakers, researchers, EAS and others to build a more sustainable future for agriculture and our planet as a whole.

Complete the summative assessment in your workbook.

Complete the post-assessment in your workbook.

General resources

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Abbreviations

Abbreviation	Meaning
ASEAN	Association of Southeast Asian Nations
AWD	Alternate Wetting and Drying
AWDS	Alternate Wetting and Drying Ste-Specific version
CA	Conservation Agriculture
CAP	Common Agricultural Policy
CCS	Carbon Capture and Storage
CDR	Carbon Dioxide Removal
CF	Continuous Flooding
CH_4	Methane
CO_2	Carbon Dioxide
COP	Conference of the Parties
CSA	Climate-Smart Agriculture
DCAS	Digital Climate-Informed Advisory Services
DTMA	Drought Tolerant Maize in Africa
DTMA	Drought Tolerant Maize in Africa
EAS	Extension and Advisory Services
EPA	Environmental Protection Agency
EU	European Union
EU ETS	European Union Emissions Trading System
FAO	Food and Agriculture Organization
FDA	Food and Drug Administration
FFS	Farmer Field School
FGD	Focus Group Discussions

FPC	Farmer producer Companies
GAMI	Global Adaptation Mapping Initiative
GFRAS	Global Forum for Rural Advisory Services
GHG	Greenhouse Gases
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
H+	Hydrogen ions
HFCs	Hydrofluorocarbons
HFCs	Hydroflurocarbons
HICAP	Hillside Conservation Agriculture Project
ICAR	Indian Council of Agricultural research
ICRAF	International Center for Research in Agroforestry
IPCC	Intergovernmental Panel on Climate Change
MAG	Ministry of Agriculture and Livestock
MENA	Middle East and North Africa
MICCA	Mitigation of Climate Change in Agriculture
MINAE	Ministry of Environment and Energy
MRV	Monitoring, Reporting and Verification
N_2O	Nitrous Oxide
NAMA	Nationally Appropriate Mitigation Action
NF_3	Nitrogen Trifluoride
NGO	Non-Governmental Organization
NICRA	National Innovations in Climate Resilient Agriculture
NSP	NAMA Support project
OECD	Organisation for economic cooperation and development
PCA	Peru Cacao Alliance

PES	Payments for ecosystem services
PFCs	Perfluorocarbons
R&D	Research and Development
RAS	Rural Advisory Services
RCM	Rice Crop Manager
SF_6	Sulphur Hexafluoride
SMEs	Small and Medium-sized Enterprises
SMI	System of Millet Intensification
SRI	Systems of Rice Intensification
STRVs	Stress-Tolerant Rice Varieties
SWC	Soil and Water Conservation
UDP	Urea Deep Placement
UN	United Nations
UNICEF	United Nations International Children's Emergency Fund
USAID	United States Agency for International Development's
USD	United States Dollar
USDA	United States Department of Agriculture

Glossary

Keyword/Phrase	Definition/Description
Adaptation	Adjustments to climate impacts to reduce vulnerability and enhance resilience.
Adaptation deficit	The gap between the current level of adaptation and the level needed to minimize negative impacts of climate change.
Adaptation strategies	Specific actions, policies, and measures implemented to reduce the vulnerability of systems to climate change impacts.
Adaptive capacity	The ability of systems, institutions, humans, and other organisms to adjust to potential damage, take advantage of opportunities, or respond to consequences.
Afforestation	The process of planting trees in an area where there was no previous tree cover to create a forest.
Agricultural emissions	Greenhouse gases released from farming activities.
Agricultural practices	Farming methods for cultivating crops and raising livestock.
Agroecology	An ecological approach to agriculture that views agricultural areas as ecosystems and is concerned with the ecological impact of agricultural practices.
Agroforestry	The integration of trees and shrubs into agricultural landscapes to enhance productivity, biodiversity, and ecosystem services.
Anthropogenic emissions	Greenhouse gases are produced by human activities.
Anticipatory adaptation	Proactive measures taken in advance to reduce the impacts of anticipated climate change.
Autonomous adaptation	Adaptation that occurs naturally without planning, often as an immediate response to climatic stimuli.
Awareness generation	Educating people to increase understanding and promote positive actions.

Keyword/Phrase	Definition/Description
Bridging and brokering role	Facilitating collaboration among stakeholders to address complex issues.
Broader search for solutions	Expanding efforts to find diverse solutions to problems.
Burning fossil fuels	Combustion of coal, oil, and gas for energy, releasing greenhouse gases.
Capacity Needed	Required skills and resources to address challenges.
Carbon Capture and Storage (CCS)	Technologies or techniques for capturing carbon dioxide emissions from sources like power plants and storing it underground to prevent it from entering the atmosphere.
Carbon Dioxide Removal	Techniques and processes that remove CO_2 from the atmosphere and store it in geological, terrestrial, or ocean reservoirs.
Carbon emission trading	A market-based approach to controlling pollution by providing economic incentives for achieving reductions in the emissions of pollutants.
Carbon farming practices	Agricultural methods aimed at sequestering carbon in soil and vegetation, reducing greenhouse gas emissions.
Carbon footprint	The total amount of greenhouse gases emitted by an individual, organization, event, or product, expressed as CO_2 equivalent.
Carbon markets	Marketplaces where carbon emission allowances or credits are bought and sold.
Carbon pricing	Assigning a cost to carbon emissions to encourage polluters to reduce the amount of greenhouse gases they emit.
Carbon sequestration	The process of capturing and storing atmospheric CO_2 in carbon sinks like forests, soils, and oceans.
Carbon sink	Natural or artificial reservoirs that accumulate and store some carbon-containing chemical compound for an indefinite period.
Carbon source	Any process or activity that releases carbon dioxide into the atmosphere.

Keyword/Phrase	Definition/Description
Cassava mosaic virus	Disease affecting cassava crops, reducing yields.
Challenge	A difficult task or problem needing effort to overcome.
Climate	Long-term weather patterns in a specific area.
Climate action	Proactive measures to mitigate climate change effects.
Climate change	Long-term alteration of temperature and typical weather patterns in a place.
Climate crisis	Severe and widespread climate-related challenges.
Climate emergency	An urgent situation requiring immediate action due to climate change.
Climate finance	Funding for climate change mitigation and adaptation efforts.
Climate hazard	Harmful effects of climate change on ecosystems and livelihoods.
Climate protection	Measures and actions taken to safeguard natural and human systems from climate change impacts.
Climate resistance	Ability to withstand climate-related disturbances.
Climate response	Reactive measures to manage climate change impacts.
Climate risk	Potential for adverse outcomes due to climate change.
Climate sensitivity	Temperature response to greenhouse gases and solar radiation changes.
Climate variability	Natural fluctuations in climate patterns over time.
Climate-resilient crops	Crops bred to withstand climate-related stresses.
Climate-smart agriculture	Farming practices that improve productivity and resilience to climate change.
Complexity of climate change	Intricate and interconnected nature of climate change impacts and responses.
Conservation Agriculture	A set of soil management practices that minimize soil disturbance, maintain a permanent soil cover, and diversify crop species.

Keyword/Phrase	Definition/Description
Consumer lifestyles and overconsumption	Excessive use of resources and goods contributes to environmental degradation.
COP 28	The 28th Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC).
Crop diversification	Growing a variety of crops to enhance resilience and reduce risks.
Crop productivity	Output of crops per unit of land surface.
Decarbonisation	The process of reducing carbon dioxide emissions from energy production and consumption.
Deforestation and land use changes	Clearing forests and altering land for agriculture, affecting carbon storage.
Delayed benefits	Benefits from actions that are not immediately visible.
Demonstration of new technologies and practices	Showing the performance of new technologies/practices in real settings.
Ecosystem services	Benefits humans gain from natural ecosystems, like pollination and water purification.
El Niño Southern Oscillation	Climate pattern that describes temperature fluctuations in the Pacific Ocean, affecting global weather.
Energy consumption in buildings	Use of energy for heating, cooling, and electricity in residential and commercial buildings.
Engagement with research	Active involvement in scientific studies to inform practices and policies.
Enhancing access to inputs	Improving the availability of resources like seeds and fertilisers for farmers.
Evidence-based advocacy	Advocacy using reliable data to support policy changes or actions.
Extension and Advisory Services (EAS)	Services that support farmers with information and resources to improve agricultural practices.
Farmer Field School	A group-based learning process that uses experiential learning methods to enhance farmers' skills and knowledge.

Keyword/Phrase	Definition/Description
Food security	The state of having reliable access to a sufficient quantity of affordable, nutritious food.
Food sovereignty	The right of people to define their own food systems and have control over the way food is produced, traded, and consumed.
Food systems	The complex networks of activities involving the production, processing, transport, and consumption of food.
Geographic scale	Different levels at which climate interventions are applied, from local to global.
GFRAS NELK module 13	A reference module from the Global Forum for Rural Advisory Services on climate change adaptation and mitigation.
Global boiling	Term highlighting severe consequences of global warming.
Greenhouse	A structure that traps heat to grow plants, similar to how greenhouse gases trap heat in the atmosphere.
Greenhouse effect	Trapping of heat by greenhouse gases near Earth's surface.
Greenhouse gases (GHG)	Gases that trap heat in the atmosphere, causing global warming.
Health risks (related to climate change)	Potential health issues from climate change impacts.
Heat waves	Periods of abnormally high temperatures.
Heavy precipitation and storms	Increased heavy rain or snow, leading to floods and extreme weather events.
Industrial manufacturing processes	Emissions from producing goods in factories contribute to greenhouse gases.
Intergovernmental Panel on Climate Change (IPCC)	UN body assessing climate change science.

Keyword/Phrase	Definition/Description
Landscape focus	Considering entire landscapes in climate change interventions.
Limited resources	Insufficient staff, funds, or materials to support efforts.
Local climate assessments	Evaluations of climate change impacts in specific areas.
Long-term vision	Planning for future goals and strategies over an extended period.
Maladaptation	Actions that may lead to increased vulnerability to climate change impacts, rather than reducing it.
Mitigation	Actions to reduce or prevent greenhouse gas emissions.
Mobilising communities	Organising groups to take collective action, often for climate adaptation.
Multidisciplinary teams	Groups with diverse expertise working together on complex issues.
Natural disasters	Severe natural events like earthquakes, floods, and hurricanes.
Natural farming	An ecological farming approach that uses natural processes, avoiding synthetic inputs.
Natural Resource Management	The sustainable management of natural resources like land, water, soil, plants, and animals.
Natural resources	Materials and components that can be found within the environment useful for human use, e.g., water, air, soil, minerals.
NGO limitations	Constraints faced by non-governmental organisations, such as limited reach and resources.
Non-CO_2 emissions	Greenhouse gases other than carbon dioxide, like methane and nitrous oxide.
Ocean acidification	Increased acidity of oceans due to excess CO_2 absorption, affecting marine life.
Organic Agriculture	Farming that relies on techniques such as crop rotation, green manure, compost, and biological pest control.

Keyword/Phrase	Definition/Description
Participatory scenario development	Involving stakeholders in creating and evaluating future climate scenarios.
Payment for Ecosystem Services (PES)	Financial incentives given to landowners or farmers to manage their land to provide ecological services.
Permaculture	The development of agricultural ecosystems intended to be sustainable and self-sufficient.
Planned adaptation	Adaptation that is a result of deliberate policy decisions, based on an awareness that conditions have changed or are about to change.
Precision Agriculture	Farming management based on observing, measuring, and responding to inter and intra-field variability in crops.
Private adaptation	Adaptation actions taken by individuals, households, or private businesses to protect their own interests.
Private sector focus	Concentration on profitable areas by businesses, often neglecting broader needs.
Promoting agro-meteorological advisory	Providing weather and climate information to farmers for better decision-making.
Promoting digital tools	Encouraging the use of technology for improved agricultural practices.
Public adaptation	Adaptation actions taken by governments or public institutions to protect the public interest.
Reactive adaptation	Adaptation that occurs after the initial impacts of climate change have been observed.
Reforestation	The process of planting trees in a deforested area.
Regenerative Agriculture	Farming practices that restore soil health, biodiversity, and ecosystem function.
Resilience	Ability to recover from or adapt to climate-related disturbances.
Respect for Indigenous knowledge	Valuing and integrating traditional knowledge into modern practices.

Keyword/Phrase	Definition/Description
Risk	The potential for adverse effects resulting from climate-related hazards.
Risk awareness and skills	Understanding and managing potential hazards and uncertainties.
Saltwater intrusion	Movement of saline water into freshwater sources, impacting water quality.
Sea level rise	Increase in the level of the world's oceans due to melting ice and thermal expansion.
Session activities	Tasks or exercises completed during training sessions to reinforce learning.
Soil degradation	Decline in soil quality due to misuse, affecting its ability to support crops.
Stakeholder coordination	Collaboration among different groups to achieve common goals.
Strip cropping	The practice of growing crops in strips to reduce soil erosion and improve soil fertility.
Sustainable land management	Practices conserving and protecting land resources while enhancing productivity.
Transportation	The movement of people or goods using vehicles contributes to greenhouse gas emissions.
Vulnerability	Degree of susceptibility to harm from climate change impacts.
Water scarcity	Insufficient available water resources to meet demand.
Weather	Atmospheric conditions at a specific place and time, such as temperature and precipitation.
Weathering stages	Processes breaking down rocks and minerals into soil.
Wildfires	Large, uncontrolled fires cause significant damage to ecosystems and human settlements.

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Global Forum for Rural Advisory Services (GFRAS) is about enhancing the performance of advisory services so that they can better serve farm families and rural producers, thus contributing to improved livelihoods in rural areas and the sustainable reduction of hunger and poverty. Rural advisory services help to empower farmers and better integrate them in systems of agricultural innovation.