Building Resilient Food Systems 4 Smallholder Farmers

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Figures, Acronyms & Pictures

Farmer Training Schedule

TIME/DAY	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5
8:30 AM - 8:45 AM	Orientation	Recap	Recap	Recap	Recap
8:45 AM - 10:30 AM	Introduction to the workshop	Concepts in Drought Resilient Techniques	Drought resistant inputs	Post-Harvest Water Management	Summary and recommendations, training evaluation and way forward
10:30AM - 11:00 AM	TEA BREAK	TEA BREAK	TEA BREAK	TEA BREAK	TEA BREAK
11:00 AM - 12:45 PM	Impact of climate change on the agricultural sector in Eastern Africa	Drought-resistant techniques	Integrated Pest Management	Nurturing Crops in a water-scarce system	Brainstorming- way forward after training
12:45 PM - 1:45 PM	LUNCH BREAK	LUNCH BREAK	LUNCH BREAK	LUNCH BREAK	LUNCH BREAK
1:45 PM-3:30 PM	What is Resilient Agriculture?	Farm visit-Drought Resilience	Sustainable management of scarce resources	Agroecology and regenerative agriculture	Evaluation, wrap up and certificates
3:30 PM - 3:45 PM	SNACKS BREAK	SNACKS BREAK	SNACKS BREAK	SNACKS BREAK	SNACKS BREAK
3:45 PM - 4:30 PM	Group work to evaluate current practices	Farm visit-Drought Resilience	Farm visit-sustainable resource management	Visit to ecological inputs provider	Departure

Pre-training session, monitoring and evaluation

Overview:

This pre-training session is designed to give participants and facilitators a chance to get acquainted and initiate a two-way communication and interactive discussion on governance.

Objectives:

By the end of this session, participants will be able to:

1. Create an informal tone is set for the workshop.
2. Develop relationships with each other and together with the facilitators, work towards achieving the workshop goals.
3. Establish a two-way communication with the trainer by sharing their expectations of the workshop and be able to come up with a work plan at the end of the session.

Duration

1 hour 45 minutes

Method

- Introduction
- Presentation
- Discussion

Material

Sketch pens

Instructions for Trainer:

Participatory methods of engagement by all who are present, including through open group discussions

Activity 1: Getting to know one another and leveling of expectations

Step 1: Welcoming of participants.

Step 2: Participants to share their (i) Name and organisation; (ii) Current job title/ profile/ background; (iii) Current work activity and/ or interest related to climate change, resilience, and sustainability; (iv) Previous experience in resilience and sustainability

Activity 2: Review of expectation of farmers

Step 1: Establish clear objectives - Define specific, measurable, and achievable objectives for the farmer training programme. These objectives will guide the monitoring process and provide a basis for evaluating success.

Step 2: Baseline assessment - Conduct a baseline assessment before the training begins to understand the existing knowledge, skills, and practices of the participating farmers. This baseline data will serve as a reference point for measuring changes.

Step 3: The participants will be taken through the timetable, the goals and objectives of the training.

Step 4: Participants will review the timetable and state if it addresses their goals and objectives.

Activity 3: Regular assessments

Step 1: Integrate regular assessments throughout the training programme using quizzes, tests, or practical exercises to evaluate participants' understanding and application of the training content.

Step 2: Adjust training programme based on the regular feedback from the assessment data and participant feedback as needed. This will involve refining content, adapting delivery methods, or addressing specific challenges faced by participants.

Step 3: At the end of the training, feedback will be collected directly from the trained farmers using a semi-structured questionnaire to understand their perspectives on the training content, overall impact, delivery methods, and the practicality of applying what they've learned.

Activity 4: Post-training monitoring and evaluation

Step 1: On-site visits to observe participants in their actual farming environments will be conducted. This will assess how well farmers are applying the learned techniques and identify any challenges they may be facing. Technology such as mobile apps, web-based platforms, and data collection tools will be utilized for efficient monitoring to enable real-time monitoring and analysis of training activities.

Step 2: Long-term follow-up will be implemented to track the sustained impact of the training. This will be through periodic check-ins, surveys, and additional training sessions to reinforce and build upon the initial learning.

Step 3: Throughout the training sessions, detailed records of monitoring activities, assessments, and feedback will be maintained. Regular reports summarising the progress and outcomes of the farmer training programme for stakeholders, funding agencies, and programme evaluators will be conducted.

Session 1: Introduction to the workshop

Purpose of this Session

To introduce the farmers to climate-smart solutions, resilient farming, and sustainable farming techniques.

Expected Learning Outcomes

By the end this session, the learner should be able to:

1. Outline the impact of climate change on agricultural systems
2. Discuss the current practices related to resilience building and resource use management.

Duration

One session of 1 hour 45 minutes

Method

- Brainstorming
- Presentation
- Question and answer session

Material

PPT, white board and marker, audio-visual system

Instructions for Trainer

Explain the objective of the workshop to the participants.

Participants' expectation from the workshop to be written on a drawing sheet and to be placed for display. Formation of ground rules. Participants are encouraged to come up with the ideas to make the workshop effective such as use of mobile phones during the workshop, participation protocol within the participants and with the facilitator, punctuality, etc.

Introduction

This training manual targets smallholder farmers across Eastern Africa and plays a pivotal role in empowering individuals and organisations with anticipatory knowledge and choices to engage in climate-smart and resilience building activities. This comprehensive guide imparts essential knowledge and information on climate-smart solutions, resilient farming practices, and sustainable farming techniques. By addressing the unique challenges faced by farmers resulting from climate change and diminishing natural resources, the training sessions becomes a catalyst for enhancing farmers' adaptative capacity, improving their agricultural productivity, increasing their income stability, and ultimately improving the overall sustainable development and resilience of farming communities across Eastern Africa.

The specific objectives include:

1. The identification of drought-resilient techniques in farming, especially focusing on inputs such as plant and seed selection, alternative fertilizers (use of organic), and integrated pest management (IPM) techniques; and
2. The identification of climate-smart agricultural innovations and practices, focusing on sustainable use of scarce resources like fresh water for irrigation, post-harvest activities, as well as soil enhancing and moisture retention mechanisms (absorbers, organic soil conditioner, seaweed products)

Areas of Training

This manual will cover the following areas of training:

1. Impact of climate change on agricultural sector in Eastern Africa
2. What is resilient agriculture?
3. Concepts in drought- resilient techniques
4. Drought-resistant inputs: plants, seeds, fertilizers, and organic inputs
5. Integrated Pest Management
6. Sustainable management of scarce resources
7. Post-harvest water management
8. Nurturing crops in a water-scarce system: enhancing additives, moisture retention mechanisms and organic conditioners
9. Agroecology and regenerative agriculture

Icebreaking Tips:

There are many ways the facilitators will make participants feel comfortable and make the entire ambience more informal. It's important that the trainer and participants know each other well. The process/ games could be place/ participants-specific yet there should be some unique ways of getting the participants concentrated.

Session 2: The impact of climate change on the agricultural sector in Eastern Africa.

Purpose of this Session

To introduce the farmers to the impact of climate change on the agricultural sector in Eastern Africa, including crop and livestock production, and the increased/ outbreak/ spread of pests and diseases.

Expected Learning Outcomes

By the end of the session, the learner should be able to:

1. Describe the concepts in climate, weather, and climate change
2. Outline both the short-term and long-term impacts of climate change on agricultural production, diseases, and pests
3. Understand that interventions are context-and-site specific

Duration

One session of 1 hour 45 minutes with smaller breaks in between

Method

- Brainstorming
- Presentation
- Question and answer session

Material

PPT, white board and marker, audio-visual system

Instructions for Trainer

This session will introduce participants on the impact climate change has on agriculture, pests and diseases. The Fermer organizations and their group members should be able to understand how these effects in each particular country within the East African region. Delivery of the session will involve face-to-face presentations, demonstrations, and discussion. A field visit will be scheduled on day 2.

Introduction

Weather: Whatever is happening outdoors at a particular time over a specific area. Weather happens minute to minute – wind, barometric pressure, precipitation (rain or snow) or temperature. The weather can change a lot within a concise timeframe.

Climate: Refers to the average change of weather experienced in a place over a long period of time, typically 30 years.

Climate change: Refers to changes that have been observed since the early 1900s. Climate change is primarily attributed to human activity that alters the composition of the global atmosphere and the natural climate variability observed over comparable time periods.

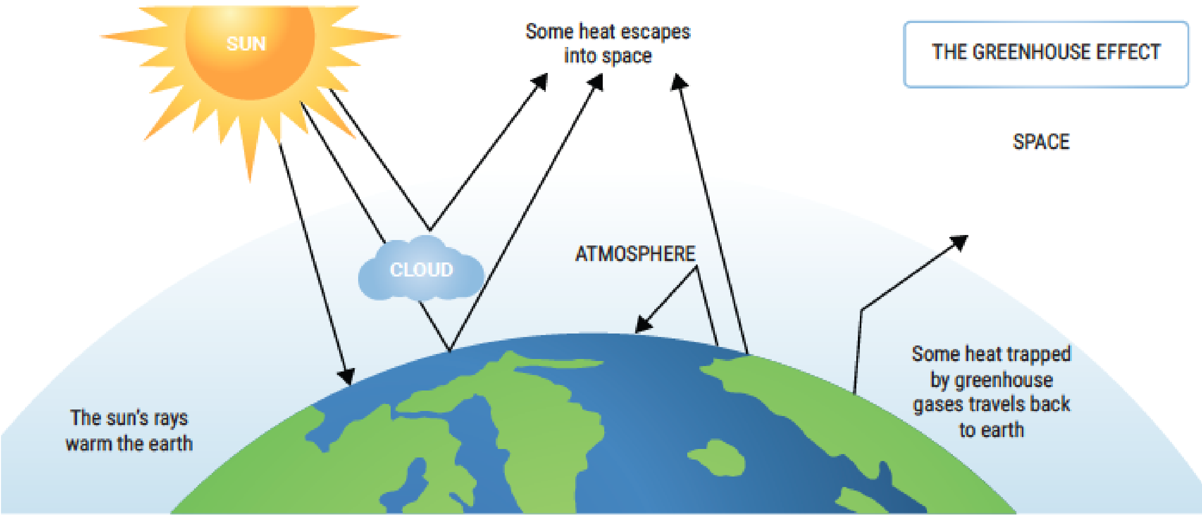

Figure 1: Climate change process (adopted from Environmental Protection Agency)[1]

Figure 2 Impacts of climate change on agricultural systems (adopted from Karavolias et al., 2021) [2]

Effects of climate change

One key aspect of climate change is global warming which results to dynamic changes in temperature and rainfall patterns and the future trends being unexpected. One of the critical aspects of climate change is the increase in the global mean temperature, attributable primarily to the greenhouse effect. In addition, the frequency and intensity of extreme weather events are also certain over time, including the increase in frequency and intensity of extreme precipitation events as well as drought.

Agricultural systems are the primary link between the climate system and

[1] https://www.epa.ie/resources/faqs/climate-change/climate-change

[2] Karavolias NG, Horner W, Abugu MN and Evanega SN (2021) Application of Gene Editing for Climate Change in Agriculture. *Front. Sustain. Food Syst.* 5:685801. doi: 10.3389/fsufs.2021.685801

grasslands, crops, and livestock production. Climate regulating services, e.g., temperature, carbon dioxide, solar radiation, or precipitation, directly impact grassland, cropping systems, livestock production, and pest dynamics. The water cycle is a critical part of agricultural systems, and variation in precipitation governs the amount of water available to the grassland or cropping system. Variation in water availability is directly related to variability in production and is tempered by variation in temperature. Linkages and feedback among the components in the conceptual diagram encompass the direct effects of climate on production and pests and the indirect effects induced by societal demands on ecosystem services and responses to energy and food production. Climate change alters the basic parameters of productive ecosystems, especially temperature and rainfall; it also impacts natural resources, such as land and water availability. Consequently, it negatively affects food production and food security. Farmers face reduced yields, water shortages, increased weed and pest proliferation, and loss of agricultural biodiversity.

Climate change creates global risks such as:

- Unpredictable weather patterns, such as short rainy seasons and prolonged dry spells during the rainy season
- Water scarcity and droughts
- Flooding
- Heat waves
- Landslides
- Increased prevalence of pests and parasites
- Increased prevalence of human, livestock, and crops diseases,
- Loss of biodiversity
- Sea-level rise
- Ocean warming and ocean acidification. Emergency of hitherto forgotten pests e.g. locusts.

Impact of climate change on the agricultural sector

Agricultural systems are the primary link between the climate system and grasslands, crops, and livestock production. Climate regulating services, e.g., temperature, carbon dioxide, solar radiation, or precipitation, directly impact grassland, cropping systems, livestock production, and pest dynamics. The water cycle is a critical part of agricultural systems, and variation in precipitation governs the amount of water available to the grassland or cropping system. Variation in water availability is directly related to variability in production and is tempered by variation in temperature.

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Eastern African countries include Kenya, Uganda, Tanzania, Ethiopia, Somalia, Rwanda, Burundi, Democratic Republic of Congo (DRC), Somalia, South Sudan. The climate change effects on these trading partners in terms of food security and economic livelihoods are intertwined. Since they lie along or around the equator, the climatic conditions and crops grown are similar, hence any climate change like the rise in the sea level, its ripple effect goes all the way into DRC and Mozambique.

The economies of Eastern African countries are agro-based, hence Agriculture, which accounts for over 40% of Uganda's GDP, employs 80% of the labor force and supplies 85% of exports, is primarily rain-fed, making it vulnerable to drought. The effects of higher average temperatures and more frequent and severe climatic changes in Uganda are seen primarily in the reduction in food security, decline in the quantity and quality of water and degradation of ecosystems, and negative impacts on health, settlements, and infrastructure. (UN Climate action, Information and communication technology 2023). While in Kenya, agriculture accounts for 20 percent of Gross Domestic Product (GDP) and 27 percent indirectly through its linkages with other sectors. The sector also accounts for over 40% of the total employment and more than 70% of employment for the rural populace (Central Bank of Kenya Survey, July 2023). Most of these agricultural benefits trickle down to the base of the pyramid (BoP), with almost 60% in Uganda and 40% Kenya. With climate change effects, if not well embraced by the BoP in the agriculture systems, then the impacts of the climate change, will erode them away.

Fig.3. Map of East African countries

Climate change impacts on crops

Climate change has significant impacts on crops affecting their quality, growth, and quantity. IPCC projections suggest that warming scenarios risk having devastating effects on crop and livestock production and food security. Risks to agriculture include reduced agricultural productivity associated with heat and drought stress and increased pest damage, disease damage and flood impacts on food system infrastructure, resulting in serious adverse effects on food security and on livelihoods at the regional, national, and individual household level. Important aspects of the impact of climate change that have a direct effect on crops include:

1. **Temperature Changes:** Rising temperatures can cause heat stress in crops which may affect their physiological processes. Crops have specific temperature ranges for optimal growth and deviations from these ranges affect quality and yield. In addition, altered temperature patterns can disrupt traditional growing seasons which interfere with the timing of planting and harvesting.

2. **Water Availability:** Climate change can cause changes in precipitation patterns, leading to more frequent water scarcity in some regions which can impact quality and quantity. On the other hand, climate change can cause other areas to experience increased precipitation and flooding, which can lead to waterlogged soils, nutrient loss through leaching, and damage to crops.
3. **Extreme Weather Events:** intense and frequent weather events (strong winds, typhoons, tsunami) can cause physical damage to crops, uproot crops, leading to quality and yield losses which may increase financial burdens on farmers.
4. **Pest and Disease Dynamics:** Changes in temperature and humidity can alter the geographic distribution of pests, exposing crops to new threats. Warmer conditions may accelerate the life cycles of pests, leading to increased infestations. Climate change also influences the prevalence and spread of crop diseases, as conditions conducive to pathogens may change.
5. **Carbon Dioxide (CO_2) Levels:** Elevated levels of atmospheric CO_2 can stimulate photosynthesis in crops, potentially leading to increased growth and yield under certain conditions.
6. **Adaptation Challenges:** With climate change, certain regions become less suitable for crops which may require farmers to adapt by changing crop types or agricultural practices. In addition, changes in climate may necessitate adjustments in irrigation systems, storage facilities, and other agricultural infrastructure, posing additional challenges for farmers.

By the middle of this century, major cereal crops grown across Africa will be adversely impacted by climate change, albeit with regional variability and differences between crops. This includes primary sources of carbohydrates in African diets, such as maize, rice and millet, with each vulnerable to temperature increases, irregular rainfall and other deteriorating growing conditions. Other crops such as cassava may be more resilient to droughts and heat but have far less support in terms of production related research or infrastructure developed to provide sufficient substitute sources of nutrition.

Impact of climate change on Livestock

Climate change also has significant impacts on livestock, affecting their health, productivity, and overall well-being. Important aspects of the impact of climate change that have a direct effect on livestock include:

1. **Temperature Stress:** Rising temperatures cause heat stress in livestock, particularly those that are more sensitive to heat. This can result in reduced feed intake, lower reproduction rates, and increased susceptibility to diseases.
2. **Water Scarcity:** Changes in rainfall patterns and increased evaporation can lead to water scarcity, affecting both the quantity and quality of water available for livestock. Lack of adequate water causes dehydration, decreased milk production, and overall stress on the animals.
3. **Feed Availability and Quality:** changes in temperature and precipitation influence the distribution and composition of vegetation, affecting the availability

and nutritional quality of grazing lands. Climate-related events such as droughts, floods, and extreme weather can lead to crop failures, reducing the availability of feed crops for livestock.

4. **Disease Spread:** Variability in temperature and humidity levels can alter the distribution and abundance of disease vectors, potentially expanding the geographic range of vector-borne diseases that affect livestock. In addition, climate change can increase the spread of waterborne diseases among livestock.
5. **Extreme Weather Events:** storms and flooding can injure, displace, and increase mortality among livestock. Infrastructure, such as barns and shelters, may be damaged, further exposing animals to the elements. Extreme cold events can also negatively impact livestock, especially in regions where animals are not adapted to cold temperatures.
6. **Adaptation Strategies:** Examples include (i) developing and promoting breeds that are more resilient to heat stress, diseases, and other climate-related challenges; (ii) implementing water conservation and management practices to ensure adequate water supply for livestock; (iii) diversifying feed sources, improving pasture management, and exploring alternative feed options to mitigate the impact of changing vegetation patterns; and (iv) implementing robust health monitoring and disease prevention programs to address emerging challenges related to climate change.

In summary, the climate-related challenges to the livestock sector include the decline in quality and quantity of animal feeds and forage; a reduction in water availability; heat stress; biodiversity change; changes in the distribution and occurrence of livestock pests and diseases; and increased livelihood and income vulnerability affecting food security, purchasing power and resilience.

Impact of climate change on Agriculture in Eastern Africa

Rising temperatures in Eastern Africa contribute to heat stress in livestock, including cattle, goats, and sheep. Prolonged exposure to high temperatures can lead to reduced feed intake, lower reproduction rates, and overall decreased productivity. In addition, the increasing frequency and intensity of droughts result in water scarcity for livestock which not only affects hydration but also leads to challenges in maintaining the health and well-being of the animals. Climate change facilitates the spread of diseases affecting livestock. For example, the expansion of suitable habitats for disease vectors increases the prevalence of diseases such as Rift Valley fever, posing health risks to both animals and humans in Eastern Africa.

Erratic weather patterns and the degradation of pasture lands impact traditional grazing patterns for pastoral communities. Livestock herders are forced to travel longer distances in search of suitable grazing areas, leading to overgrazing and land degradation.

Climate-induced factors such as drought and changes in vegetation distribution disrupt the migratory patterns of pastoralist communities and their herds. This can lead to conflicts over resources and challenges in maintaining the sustainable management of rangelands in Eastern Africa.

Simultaneously, climate change in Eastern Africa is felt more as it is contributing to unpredictable and irregular rainfall patterns. This variability can lead to droughts or floods, affecting crop growth and yield. Crops that depend on specific rainfall conditions, such as maize and beans, are particularly vulnerable. Increased frequency and duration of dry spells are becoming more common in Eastern Africa which have extended periods of drought which can lead to water stress for crops, hindering their development and reducing overall productivity.

This phenomenon is a significant challenge for rain-fed agriculture in the region. The rising temperatures in can negatively impact crops by affecting their physiological processes. Heat stress reduce photosynthesis, inhibit pollination, and decrease overall crop yields. Crops like coffee, which are sensitive to temperature changes face challenges in maintaining optimal growth conditions.

Changes in climate conditions can influence the prevalence and distribution of pests and diseases affecting crops. The expansion of suitable habitats for pests and altered life cycles due to temperature changes can lead to increased infestations, posing a threat to staple crops and cash crops alike. In addition, climate change can alter the suitability of certain regions for specific crops.

As temperature and rainfall patterns change, farmers may need to adapt by shifting to alternative crop varieties or changing their cropping calendars to maintain productivity. This requires careful planning and adaptation strategies to ensure food security in the face of a changing climate.

Climate change and increasing climate variability present a growing threat to food security and nutrition in Africa because of the region's heavy dependence on climate-sensitive activities (FAO, 2016).

The threat of these climatic uncertainties is linked to all determinants of malnutrition, ranging from underlying factors such as socio-economic status and environmental conditions to direct determinants such as droughts, floods, diseases and inadequate food and nutrient intake. It exacerbates malnutrition through three main pathways: household food security, child feeding and care practices, and health. There is growing evidence that these effects are exacerbated by gender and social disparities between and within households and communities. Africa (along with Southern Asia) is projected to be most exposed to an increased risk of hunger due to climate change.

Malnutrition is a major cause of morbidity and mortality on the continent and statistics show that a quarter of a billion Africans suffered chronic undernutrition. 426 million experienced moderate food insecurity, 51% could not afford "nutrient-adequate" diets, and 11.3% could not afford "energy-sufficient" diets. Health status affects how nutrients are absorbed and used by the body (Bain et al., 2013).

Other impacts of climate change include reduced health status affects food utilization and nutrition through increased incidence and prevalence of diseases such as diarrhoea, limiting nutrient uptake and further driving undernourishment. In addition, increasing frequency of very hot days is already having effects on the capacity of people to work in the fields, with major implications for livelihoods based on human labour, such as non-mechanized agriculture.

Climate change adaptation measures - Eastern Africa scenario

The East African countries have been developing mechanisms to mitigate the challenges posed by climate change. The countries of focus include: Tanzania, Uganda, Rwanda, Burundi, South Sudan, Democratic Republic of Congo, Kenya, Ethiopia and Somalia.

Through sensitization on the global scale on climate change, most countries have put in place mechanisms to combat this emerging climate change challenges.

Tanzania

In Tanzania, as part of adaptation to climate change, System of Rice Intensification (SRI) which is an agroecological methodology for increasing the productivity of irrigated rice by changing the management of plants, soil, water, and nutrients. Its methodology is based on early, quick, and healthy plant establishment, reduced plant density, improved soil conditions through enrichment with organic matter and reduced and controlled water application. Adoption of this technology was not as successful initially due to fewer farmers having been introduced via IFAD. Through Agricultural Council of Tanzania (ACT), SRI is being implemented in Mvumero region of Morogoro in irrigation schemes of Mkindo and Dakawa.

Rice being second most food commodity in Tanzania 18%, just behind maize, means all efforts need to be developed to ensure its sustainability. The SRI have resulted in increased yields of up to 50%, increasing household incomes. Despite success stories with this project, there is also challenges like initial capital to implement it.[3]

Democratic Republic of Congo

Democratic Republic of Congo (DRC) is endowed with rich biodiversity, good agricultural soils, good climate, rich in minerals, but also political conflict prone. Its agricultural production is basically rain-fed.

The 2021 Notre Dame Global Adaptation Initiative Index ranked the DRC as the fourth least ready country to address climate shocks and the seventeenth most vulnerable country to climate change in the world. The majority of DRC's agriculture is rain-fed, which is highly vulnerable to the impacts of climate change. Agriculture accounts for 40 percent of national gross domestic product (GDP) and is the primary source of livelihood for most Congolese, employing 70 percent of the country's population. (USAID Climate Country profile)

The primary contributors to the DRC's greenhouse gas (GHG) emissions are land-use change and forestry (86 percent), followed by waste (11 percent), energy (0.86 percent), and agriculture (0.61 percent). Since 2010, deforestation in the DRC has increased significantly, and was second highest in deforestation only to Brazil in 2020.

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[3] https://www.usaid.gov/sites/default/files/2023-11/2023-USAID-DRC-Climate-Change-Profile.pdf

Land Use

Climate change impacts imperil agricultural livelihoods for millions of Congolese and increase the risks

to this important driver of economic growth in the DRC.DRC is a signatory to all climate mitigation protocols. Through NDC, the government is implementing climate adaptation measures through partnerships like Feed the Future projects, that is promoting climate smart agriculture (CSA) interventions in increasing the quantity and quality of maize and cassava resulting from improved soil, water, and pest management techniques. The initiative is also supporting new research on climate-

resilient varieties of cassava. The project is also promoting use of green manure and pest control mechanisms esp. in combating Fall army worms in maize.

Rwanda

Rwanda is a small country with an area of 2,633,800 ha, of which 76.62% (1.9 million ha) is dedicated to agriculture.

Around 62.9% of the country's land is arable, where crops such as wheat, maize, and rice are grown. The main crops grown in the country are beans, banana, cassava, and maize, accounting for 18.1%, 17.3%, 9.2%, and 9.5% of total harvested area (2008–2012 averages)

Rwanda has a diversity of agriculture production systems spread throughout its various agro-ecological zones. The northern and western highlands are predominantly dedicated to monocrop cultivation, such as potatoes, tea, maize,

wheat, climbing beans, and pyrethrum. The eastern lowlands are popular for banana, maize, bush bean, sorghum, and

Main Crops

cassava production. In the central and southern regions, farmers cultivate sweet potatoes, bush beans, tea, coffee, and wheat.

Rwandan government has partnered with projects geared towards mitigating climate change effects, especially on its agricultural production. The CSA project aims at increasing adaptability and productivity by investing in land husbandry, water harvesting, and

hillside irrigation that can increase resilience to climate change, reduce water erosion and soil loss, halt land

degradation, and increase land productivity.

For crops that require higher nitrogen fertilizer levels (such as rice, maize, potatoes), deep placement of large, coated granules (pellets) can increase fertilizer use efficiency and thus contribute to reductions in agricultural greenhouse gas (GHG) emissions.

With Rwanda sandscape being hilly, terracing is one major intervention is widely practiced. Terracing, Terracing, the establishment and maintenance of

agro-forestry nurseries, and post-harvest activities can increase resource availability and use, while also building smallholder farmers' resilience through the creation of new job opportunities.

Zero grazing as a means of livestock keeping, is a practice that is widely promoted. This ensures use of livestock droppings in biogas production, reducing deforestation and hence reduction in GHG emissions. Livestock keeping is both small and large scale. Common animals kept include sheep, goats, pigs, cattle, chicken, and rabbits.

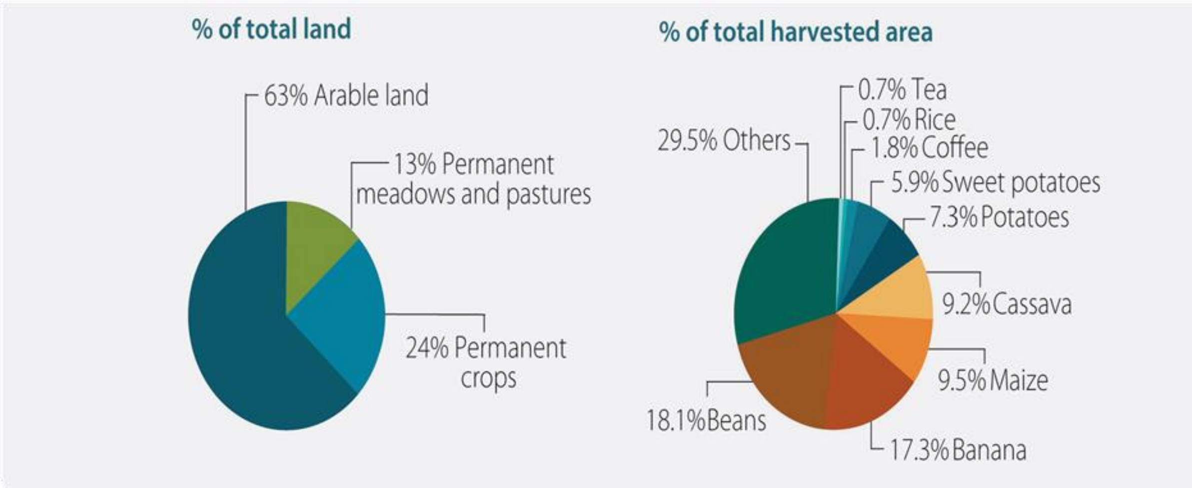

Fig.4. Land use for settlement, GHG emissions and cultivation in Rwanda

Agricultural gas emissions

Agricultural activities contribute about 46% of total GHG emissions in Rwanda, but still slightly lower than the total regional contribution. Below is the chart for the total GHG of Rwanda vs the region.[4]

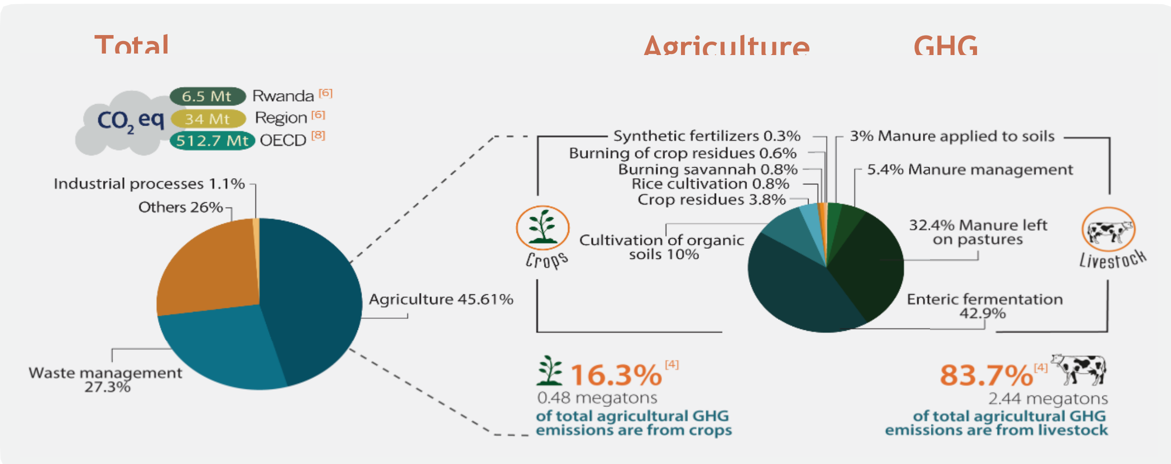

Figure 5. GHG Emissions

4 https://climateknowledgeportal.worldbank.org/sites/default/files/2019-06/CSA%20RWANDA%20NOV%2018%202015.pdf

Rwandan smallholder farmers have been forced to work in groups (*Imbaraga*) so that they can raise funds to co-finance some of the interventions like terracing. Those in marshlands, which are common in the eastern province, tend to grow crops near these wetlands. This has the negative effect on not only pollution with pesticides/fertiliser residues, but also depleting these scarce water bodies, as more farmers encroach on them.

Through CSA pillars, most of these adverse practices to soil and water are being reversed.

Burundi

The climate change effects in this country, are similar to its neighbor Rwanda as they share so much in common, in terms of cultural and human activities and food systems.

Burundi faces challenges of landslides, prolonged droughts, high temperatures and heavy rains. It is projected that temperature rise will be around 1.5-2.5 degrees, by 2050. Rainfall patterns will also be very extreme, leading to protracted dry seasons, more flooding and increased erosion. This will put a mounting strain on agriculture, food security and access to safe water across the country.[5]

Interventions:

Burundi, in conjunction with UNDP, through the Adaptation Fund, is supporting over 2000 smallholder farmers to implement some measures geared towards reversing effects of climate change, including soil erosion; by planting over 230,000 trees (avocados and grevillea). These tree's roots help bind soils, slowing down erosion, with their leaves covering the ground, hence locking the moisture in the soil away from equatorial sun.

Climate change adaptation mechanisms in Burundi, can be explained better by the following video.

https://www.youtube.com/watch?v=-KrFUeXbBQM

Other adaptation measures being implemented include, growing of elephant grasses and terracing. The grasses are food for goats, and also control soil erosion and landslides.

The eroded nitrogen rich soils, running into lakes like Rweru, can upset the lake ecosystem, leading to low fish stocks due to lack of oxygen. Also, the silt from the deforested areas clog fish gills, and spawning grounds.

These initiatives in combating climate change adverse effects, are now being scaled up via UNDP to over 45million users of Lake Victoria, to eliminate siltation of the water, hence increasing fish stocks.

Uganda

Ugandan agriculture contributes up to 40% GDP and over 90% in foreign exchange earnings. Unfortunately, the agriculture sector contributes to 27 percent of emissions, followed by the land-use and

[5] https://www.unep.org/news-and-stories/story/farmers-adapt-climate-crisis-burundis-precarious-hillsides

forestry sector with approximately 60 percent of emissions. (FAO).

Fortunately, the country has ratified all treaties to climate change adaptation, including drafting its own National Climate change Act 2021. Among key areas of intervention include the agriculture and livestock, forestry, sustainable land management (SLM), and sustainable natural resources management (mainly wetlands and natural forests restoration, open water bodies protection), are considered as the country's greatest source of emissions.

Challenge implementing Climate adaptation plans.

Smallholder farmers and particularly women, youth and poorer households are facing challenges to implement climate adaptation and mitigation measures such as erratic food prices, limited knowledge and skills for climate smart agriculture, and lack in transportation and processing infrastructure. Moreover, limited agricultural insurance schemes, inadequate access to finance and limited access and control of land and other production resources makes it hard for them to invest in climate action plans.

Climate adaptation interventions

Uganda through partnerships with development partners, especially the Germany governments' International Climate Initiative (IKI), has been working on Scaling up Climate Ambition on Land Use and Agriculture through NDCs and

NAPs (SCALA). The programme is designed to support transformative climate action in the land use and agriculture sectors to reduce GHG emissions and/or enhance removals, as well as strengthen resilience and adaptive capacity to climate change in participant countries

In Uganda, this project focusses on promoting climate-resilient agriculture solutions in the cattle corridor. Its aim is to interpret 2021 NDCs and 2018 NAPs into actionable district-level adaptation and development plans, with a strong focus on integrating gender considerations and promoting[6] private sector engagement.

SCALA contributed to a private sector mapping and profiling initiative in the cassava, cocoa, beef and banana value chains in the cattle corridor. The aim was to identify business opportunities for private sector engagement and investment in transformative climate action solutions.

South Sudan

This is the youngest country, having gained independence in 2011. South Sudan is characterised by expansive grasslands, swamps and tropical rain forest straddling both banks of the White Nile River. The country is situated in the Nile catchment area, receiving water from the highlands of the Central African Republic,

6 https://unfccc.int/files/adaptation/workstreams/national_adaptation_programmes_of_action/application/pdf/south_sudan_final_napa_-_24th_nov-2016.pdf

Democratic Republic of Congo, Ethiopia and Uganda. Due to prolonged conflicts leading to independence, climate change interventions were missing and hence the country has to quickly embrace this new challenge to its livelihoods of its citizens.

Its reliant on oil (98%) for economic growth, means food production isn't well developed, leading to the country being food insecure. This exposes the country to serious external shocks in case of climate change challenges.

Traditional subsistence agriculture is the dominant economic activity in South Sudan with approximately 78% of households reliant upon crop farming and animal husbandry as their main source of livelihood. Typically, such farmers rely upon rain-fed agriculture and use traditional methods of farming. This combination renders them highly vulnerable to climate variability, particularly erratic rainfall. Unfavorable weather conditions – such as persistent droughts and annual flooding – also result in crop and livestock losses. Droughts are also causing encroachment of the desert southwards, while floods have destroyed forests in low-lying areas, particularly in areas close to the Sudd Wetland and White Nile River.

Climate change trend

climate change trends will have an adverse effect on the availability of water

resources and consequently agricultural productivity. Most of South Sudan is covered by the Bahr el Ghazal, Nile and Sobat River catchments that join to form the White Nile. In contrast to the Nile, the Sobat River and the Bahr el Ghazal river catchments have a strong seasonal character. Research on these two catchments suggests that an increase of 2°C in temperature might cause the natural flow to fall to 50% of the current average. Rising temperatures and uncertain rainfall could also impact on the Sudd wetland, which is not only an important source of fish and products, but also a wetland of global biodiversity importance. This may lead to desertification and [7]

National Adaptation Programme of Action (NAPA) had to be developed to guide the country to navigate through these challenges. Unless communities adapt to these climatic changes, climate change will hinder socio-economic development and contribute to existing tensions and conflict.

NAPA had mandate to:

Kenya

Kenya just like its East African neighbors lie on equator. This means all the climatic changes happening in other countries are felt by it as well. The common climatic changes effects like prolonged droughts, rising temperatures, rising water levels in the Indian ocean and landslides/erosion due to deforestation to mention but just a few are very rampant now. The declining

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7 https://www4.unfccc.int/sites/NAPC/Documents%20NAP/Kenya_NAP_Final.pdf

mangrove and eroded coral reefs at the coast to deforested Mau complex, which feeds into rivers like Maara and other water bodies, are all but at the disadvantage of being extinct unless concerted efforts are put in place to combat these devastating effects of climate change. More NAPs need to be put in place to prepare smallholder farmers who are more vulnerable due to their subsistence farming techniques. Since July, 2016, when the country signed Kenya National Adaptation Plan (NAP), there have been concerted efforts to address all these climate change effects by focusing on mitigation and adaptation measures at both international and local levels. Through each county, climate action plans have been developed to address food systems that can survive the adverse effects of climate change.

Kenya has been implementing various climate change adaptation measures in agriculture to mitigate the impacts of climate change and build resilience in the sector.

Kenya has experienced serious adverse weather patterns like *el nino*, and *la nina* which has stretched the country's scarce resources like water and soils. Siltation and filling up of inland lakes like Lake Bogoria and Nakuru, that have come with devastating effects on surrounding infrastructure and farms, especially those growing on riparian areas. Other challenges like drought in Northern frontier counties have led to livestock deaths in thousands, leading to loss of livelihoods in those areas, which rely on pastoralism.

The adaptation strategies cut across all sectors of the economy, as heavy/scarce rains affect power supply, which indirectly affect food production, as irrigation needs power, especially for commercial farming. So, the country has developed strategies that aim at reversing these effects.

All the East African countries share so many climate change effects similarly. Hence these are some of the strategies to adaptation:

1. **Drought-Resistant Crop Varieties**: Promoting the use of drought-tolerant crop varieties that are better adapted to erratic rainfall patterns and water scarcity. Examples include drought-tolerant maize varieties developed through breeding programs.

2. **Improved Water Management**: Encouraging the adoption of water-saving irrigation techniques such as drip irrigation and rainwater harvesting. Efficient water management practices help farmers cope with water scarcity and erratic rainfall.

3. **Agroforestry**: Promoting agroforestry practices, such as planting trees on farms, which help improve soil fertility, conserve water, and provide additional sources of income for farmers. Agroforestry systems also enhance carbon sequestration, contributing to climate change mitigation.

4. **Soil Conservation**: Implementing soil conservation measures like terracing, contour farming, and cover cropping to prevent soil erosion, improve soil structure, and enhance soil moisture

retention. Healthy soils are more resilient to climate variability.

5. **Livestock Management**: Introducing climate-resilient livestock breeds and promoting better livestock management practices to enhance animal health and productivity under changing climatic conditions. Providing veterinary services and fodder conservation techniques also play a crucial role.

6. **Weather Forecasting and Early Warning Systems**: Strengthening weather forecasting and early warning systems to provide timely information to farmers about upcoming weather events, enabling them to make informed decisions on planting, irrigation, and crop protection.

7. **Capacity Building and Extension Services**: Providing training and extension services to farmers on climate-smart agricultural practices, including sustainable land management, crop rotation, and integrated pest management. Building the capacity of farmers and extension agents enhances their ability to adapt to climate change.

8. **Market Diversification and Value Addition**: Promoting diversification of agricultural products and value addition to reduce dependence on climate-sensitive crops and enhance resilience to market fluctuations. Supporting farmers in accessing markets for climate-resilient crops and value-added products can improve their livelihoods.

9. **Policy Support**: Developing and implementing policies that support climate change adaptation in agriculture, including incorporating climate resilience into national agricultural development plans (which are castigated down to counties), with each county coming up with its own climate change resilience strategic plans, providing incentives for climate-smart practices, and mainstreaming climate change considerations into agricultural policies and programs.

10. **Community-Based Adaptation**: Supporting community-based adaptation initiatives that empower local communities to identify and implement climate-resilient agricultural practices suited to their specific needs and contexts. Engaging local communities in decision-making processes fosters ownership and sustainability of adaptation efforts.

These adaptation measures are essential for enhancing the resilience of Kenya's agricultural sector to the impacts of climate change, ensuring food security, and improving the livelihoods of farmers and rural communities. Collaboration among government agencies, research institutions, NGOs, and local communities is crucial for effective implementation and scaling up of climate change adaptation strategies in agriculture

Why learn about Climate change?

- Determines the effects on the type and location of human-managed ecosystems, such as agricultural farmlands.
- It affects the weathering of rock, the type of soil that forms, and the rate of soil formation.
- It affects people and society lifestyles and livelihoods planning
- It helps to determine the quantity and quality of water available for human and agricultural use.
- It helps predict the severity of droughts, storms, and floods.
- Affects the nature and locations of biomes - major terrestrial ecosystems defined based on their plant communities.
- Planning for mitigation measures including GHG reduction strategies

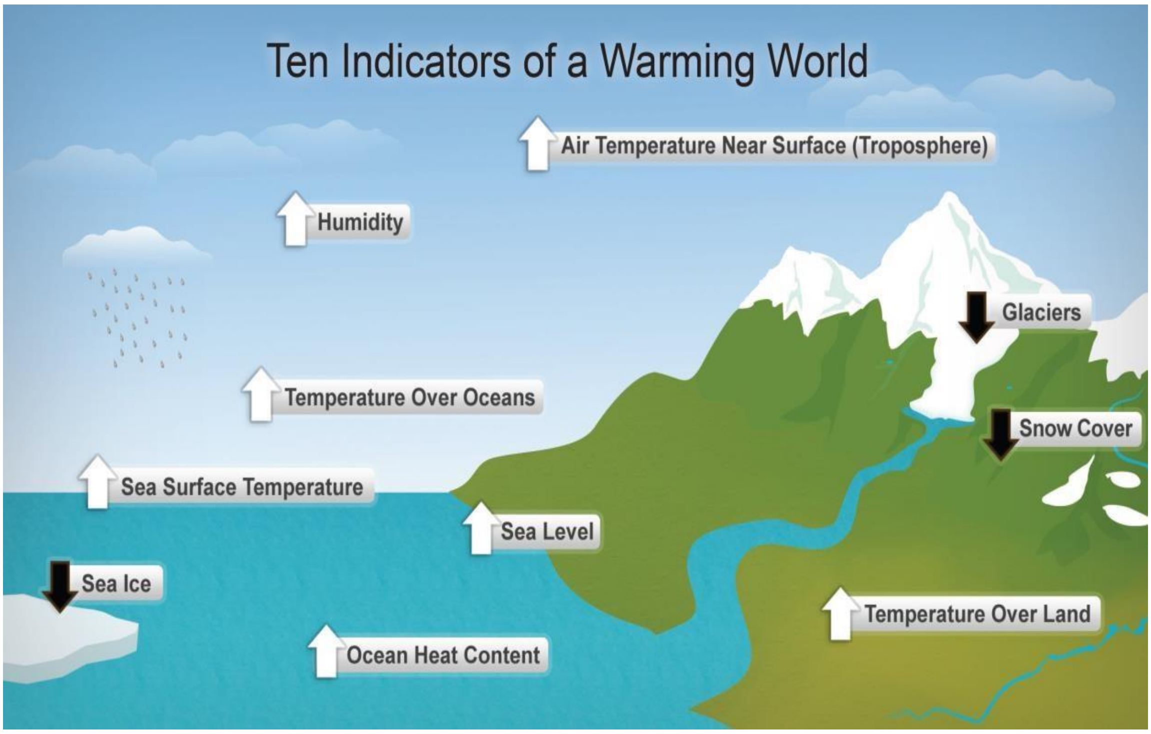

Figure 6: Ten indicators of a warming world (adopted from Wikimedia Commons [Online][8]

[8] Wikimedia Commons [Online], Available: https://commons.wikimedia.org/wiki/File:Diagram_showing_ten_indicators_of_global_warming.png

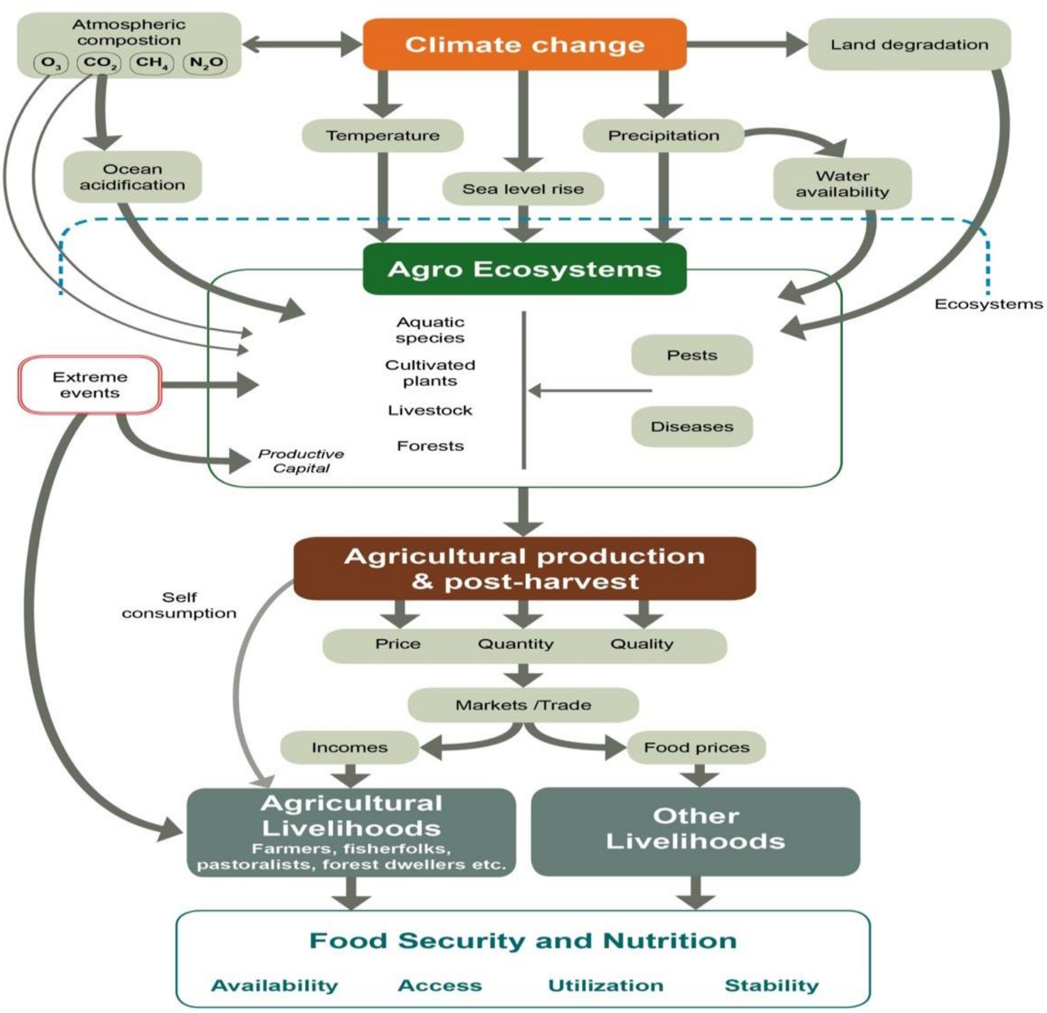

Figure 7 Cascading impacts (Adopted from CIFOR, 2019)[9]

Cascading impacts

Cascading impacts can be roughly divided into two groups:

1. biophysical impacts:
    - physiological effects of climate change on crops, pasture, forests, food security and livestock (quantity, quality);
    - changes in land, soil nutrition (adopted from FAO and water resources (quantity, quality);
    - increased weed and pest challenges;

[9] FAO and CIFOR. 2019. FAO Framework Methodology for Climate Change Vulnerability Assessments of Forests and Forest Dependent People. Rome.

- shifts in spatial and temporal distribution of impacts;
- sea level rise, changes to ocean salinity;
- sea temperature rise causing fish to inhabit different ranges.

2. socio-economic impacts:
   - decline in yields and production;
   - reduced marginal GDP from agriculture;
   - fluctuations in world market prices;
   - changes in geographical distribution of trade regimes;
   - increased number of people at risk of hunger and food insecurity;
   - migration and civil unrest.

Impact of climate change on pest insects

- New diseases associated with established insect species.
- New invasive insect species may introduce new diseases associated with these.
- Re-emergence of "old" pest species due to microclimatic changes.
- Global climate changes have significant impacts on agriculture and agricultural insect pests.
- Crops and their corresponding pests are directly and indirectly affected by climate change. Direct impacts are on pests' reproduction, development, survival and dispersal. In contrast, indirectly, climate change affects the relationships between pests, their environment and other insect species such as natural enemies, competitors, vectors and mutualists.
- Insects are poikilothermic organisms; their body temperature depends on the environment's temperature. Temperature is probably the most important environmental factor affecting insect behaviour, distribution, development and reproduction.
- Likely, the main drivers of climate change (increased atmospheric CO_2, increased temperature and decreased soil moisture) could significantly affect the population dynamics of insect pests and, thus, the percentage of crop losses.
- Climate change creates new ecological niches that allow insect pests to establish and spread in new geographic regions and shift from one area to another.
- Changes in temperature and the increase in carbon dioxide can have a big impact on how crops and pests interact.
- Because of the changing climate, farmers might deal with more and stronger pest issues in the future.
- The spread of crop pests across physical and political boundaries threatens food security. It is a global problem common to all countries and all regions.

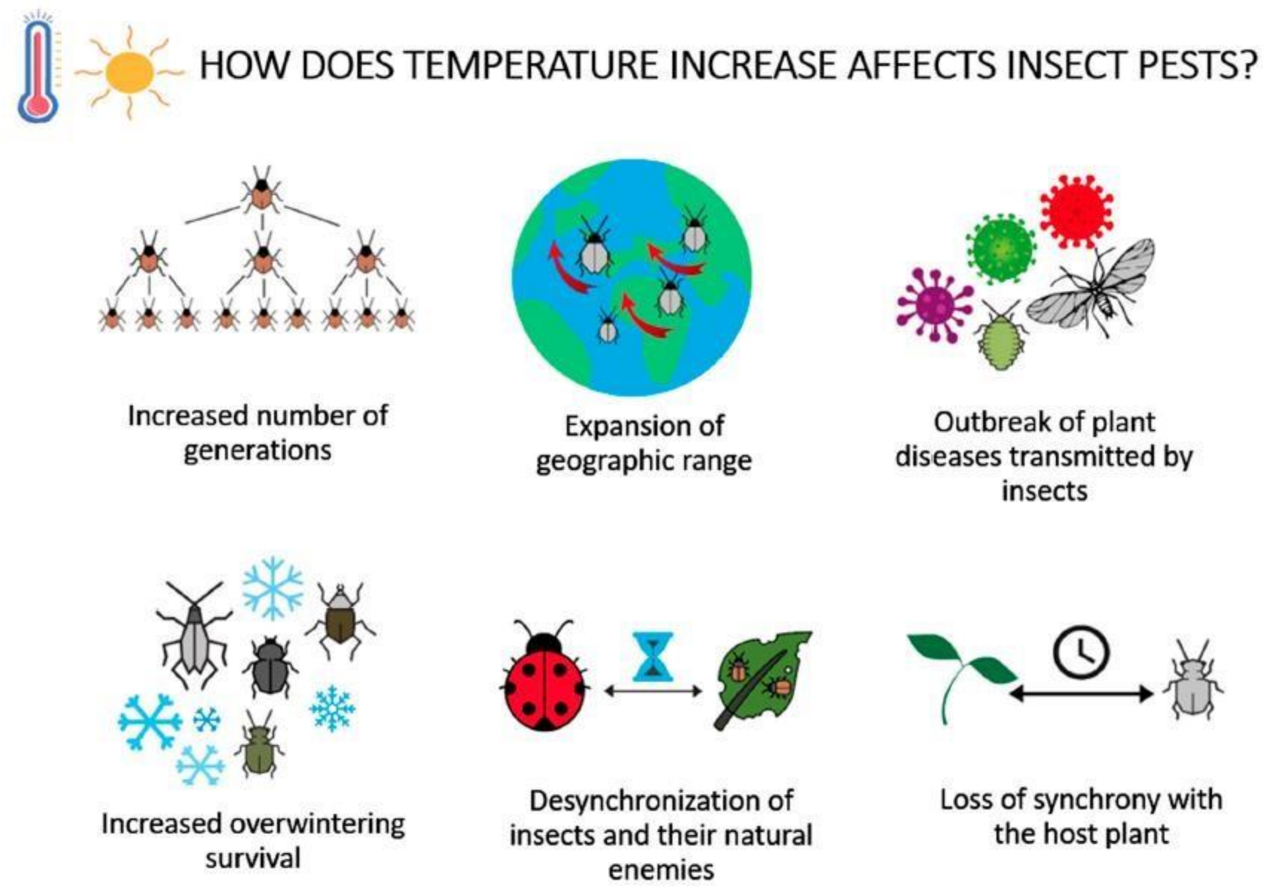

Figure 8 Effects of temperature rise on agricultural insect pests (adopted Skendži´ et al, 2021) [10]

Response of insect pests to increased carbon dioxide (CO2) concentration

- Elevated concentrations of atmospheric CO_2 can affect herbivorous insects' distribution, abundance, and performance.
- Such increases can affect insect pests' consumption, growth, fecundity, and population densities.
- When there's more carbon dioxide in the air, it affects how bugs eat plants, but it depends on the specific bug and the type of plant it likes to munch on
- The effects of increasing CO2 levels on insect pests depend highly on their host plants.
- Increased CO_2 levels would significantly impact crops such as wheat, rice, cotton, etc.
- Increased CO_2 levels will likely affect plant physiology by increasing photosynthetic activity, therefore, better growth and higher plant productivity. This, in turn, would indirectly affect insects by changing both the quantity and quality of plants and vegetation.
- A common feature of plants grown under elevated CO_2 is a change in the chemical composition of leaves, which could affect the nutrient quality of

[10] Skendži´c, S.; Zovko, M.;Živkovi´c, I.P.; Leši´c, V.; Lemi´c, D. (2021) The Impact of Climate Change on Agricultural Insect Pests. *Insects*, 12, 440.

foliage and palatability to leaf-feeding insects.

- In addition, such crops often accumulate sugars and starches in their leaves, which reduces palatability by altering the C (carbon) to N (nitrogen) ratio.
- Nitrogen is the critical element of the insect's body for its development. Therefore, increased CO2 concentration increases plant consumption in some pest groups.
- This can lead to increased levels of plant damage, as pests must consume more plant tissue to obtain an equivalent level of food.
- Increased consumption rates are a typical response in foliage feeders, such as caterpillars, miners, and chewers, to a reduction in nitrogen, as predicted by CO2 fertilization, with compensatory feeding.

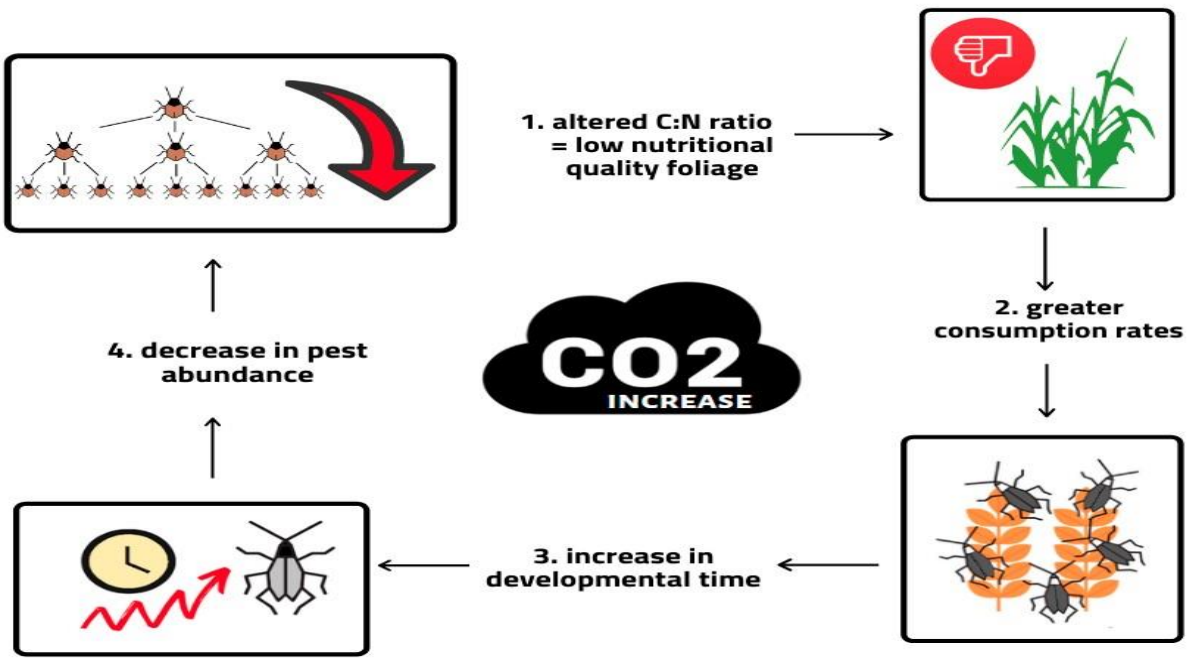

Figure 9 Impact of atmospheric CO2 increase on agricultural insect pest- (adopted Skendži´ et al, 2021).

Why adopt pest-resilient agricultural practices?

- A population/ species-interaction problem
- Distributions are impacted at the edge of a range because of climate and tolerance limits of species.
- Species interactions are not an apparent response to climate and exhibit many non-linear responses, impeding the ability to predict
- Global Change and Terrestrial Ecosystems (GCTE) conclusions on Pests in 1986: Agricultural pests and diseases will not be considered unless the ecology of weeds, pests and diseases under global change are explicitly addressed. It is an area of potentially significant agricultural and forestry impact, but unfortunately, it has not yet progressed.

Effect of climate change on plant diseases

- In 2005, the air had more CO2 (379 parts per million) than it has had for a super long time—like, more than the past 650,000 years (IPCC, 2007).

- When CO2 levels go up, plants might grow more, but how well they grow depends on factors such as water, nutrients, and if they have to compete with weeds or deal with pests and diseases.
- If a plant has lots of carbohydrates in it, it can attract biotrophic fungi rust.
- So, when plants grow more, it can change the area around them and make them more likely to get diseases.
- Basically, if there are more plants close together, their leaves stay wet for longer, and the temperature around them is just right for diseases.
- Understanding how different things stress out plants, like the weather or how much food they get, is super important to figuring out how climate change will affect them. On the flip side, if a plant doesn't have enough nutrients, it can also make them more likely to get pests and diseases because they're stressed out, whether it's from the weather or how much food they get.

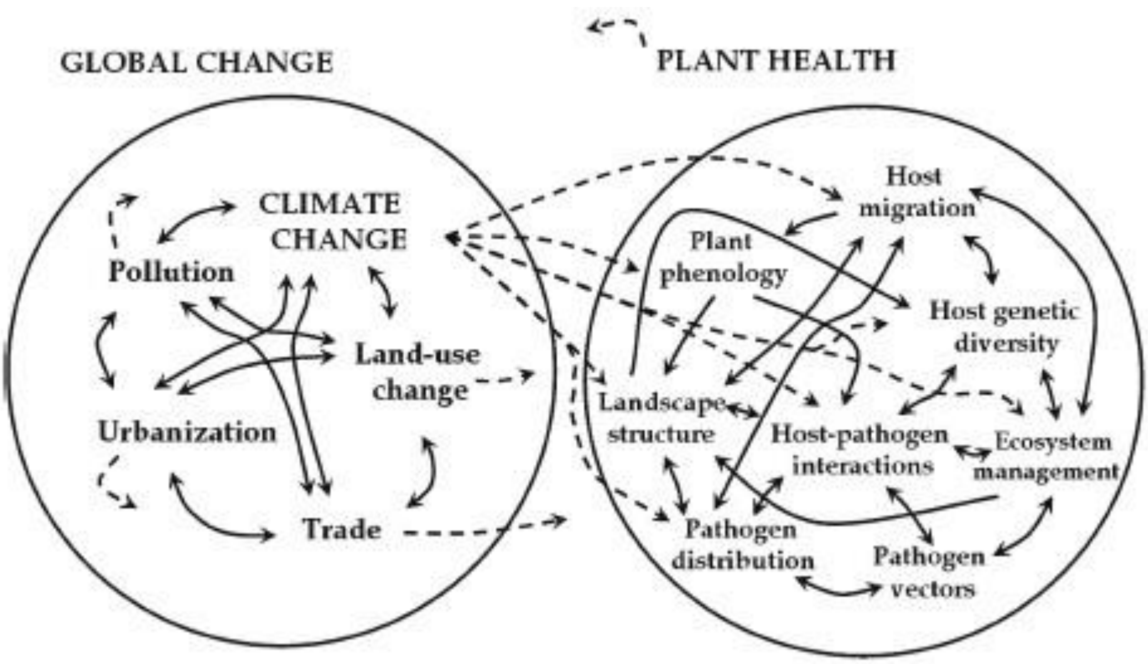

Figure 10 Impact of global change on plant health (Adopted from Pautasso et al., 2012) [11]

[11] Pautasso, M., Döring, T.F., Garbelotto, M. et al. Impacts of climate change on plant diseases—opinions and trends. *Eur J Plant Pathol* 133, 295–313 (2012).

Session 3: What is Resilient Agriculture?

Purpose of this Session

To introduce the farmers to the concepts of resilience, adaptation and mitigation.

Expected Learning Outcomes

By the end the session, the learner should be able to:

1. Outline the key concepts in resilience agriculture.
2. Explore how improving livelihoods can enhance resilience and make better use of limited resources.

Duration

One session of 1 hour 45 minutes with smaller breaks in between

Method

- Brainstorming
- Presentation
- Question and answer session

Material

PPT, white board and marker, audio-visual system.

Instructions for Trainer

This session will introduce participants on resilient agriculture. Delivery of the session will involve face-to-face presentations, demonstrations and discussion.

Key definitions:

Resilience is the ability of a system to recover, absorb, withstand and bounce back to its original state after an adverse event from the effect of climate change.

Climate adaptation: 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 to moderate potential damages or to benefit from opportunities associated with climate change. In simple terms, countries and communities need to develop adaptation solutions and implement actions to respond to current and future climate change impacts.

It involves developing strategies and measures to help individuals, communities, organizations, and ecosystems cope with and respond effectively to the changing climate conditions. Climate adaptation aims to increase resilience, reduce vulnerability, and enhance the ability of various entities to adapt to the challenges posed by climate change, such as rising temperatures, extreme weather events, sea-level rise, and altered precipitation patterns. Adaptation strategies can encompass a wide range of actions, including infrastructure improvements, changes in land-use planning, sustainable agricultural practices, and the development of early warning systems, among others.

Adaptation can be categorized into:

(a) Autonomous - is the reaction of, for example, a farmer to changing precipitation patterns, in that s/he changes crops or uses different harvest and planting/sowing dates
(b) Planned adaptation – These are deliberate conscious policy options or response strategies, often

multisectoral in nature, aimed at altering the adaptive capacity of the agricultural system or facilitating specific adaptations. For example, deliberate crops selection and distribution strategies across different agri-climatic zones, substitution of new crops for old ones and resource substitution induced by scarcity (Easterling 1996).

Climate mitigation: means reducing the net release of greenhouse gas emissions that are warming our planet. Climate mitigation refers to strategies and actions aimed at curbing or preventing the release of greenhouse gases into the atmosphere to alleviate the impact of climate change. These efforts encompass various measures such as transitioning to renewable energy sources, improving energy efficiency, afforestation, and sustainable land use practices. The overarching objective is to minimize the human-induced factors contributing to global warming, limit temperature rise, and mitigate adverse effects on ecosystems, biodiversity, and human societies. Climate mitigation is a crucial component of international climate agreements and national policies geared towards achieving a sustainable and low-carbon future.

In short, farming communities across Africa need better anticipatory planning strategies for effective adaptation mitigation to thrive in a changing climate. Better practices generate healthier soils and may help carbon dioxide sequestration and water storage.

Climate-resilient agriculture

A wide range of conventional agriculture practices at the field level affect soil structure, moisture and fertility and contribute to erosion. On the other hand, keeping the soil bare allows weeds to grow unhindered. Planting the same crop year after year encourages certain weeds, pests, and diseases. As agricultural production remains the primary source of income for most rural communities in Africa, adaptation of the farming sector to the adverse effects of climate change will be imperative for protecting and improving livelihoods and thus ensuring food security. Crop production contributes to climate change and presents opportunities for adapting to and mitigating it. Climate change is projected to negatively affect agricultural productivity, resulting from the deterioration of the production environment.

Climate-smart Agriculture (CSA) is an approach that moves away from conventional agriculture practices and systems and helps to restore degraded agroecosystems. CSA contributes to the goals of making sustainable development tangible by adopting appropriate practices, developing enabling policies and institutions and mobilizing needed finances.

CSA can positively affect soil structure, moisture, and fertility. For instance, using cover crops and mulch to protect the soil surface from heavy rain can be beneficial. The roots bind the soil together, making it less easily eroded. Cover crops or mulch smothers weeds which prevents them from proliferating and breaks the life cycle of pests and disease mechanisms.

The Three Pillars of Climate-Smart Agriculture

CSA has three pillars or objectives that it tries to achieve simultaneously:

1. To strengthen resilience in agriculture (Adaptation)
2. To reduce agriculture's contribution to climate change (Mitigation)
3. To sustainably increase agricultural productivity (Productivity)

1. Strengthen resilience in agriculture (Adaptation)

Adaptation actions help countries and communities respond to current and future impacts. These actions reduce vulnerability by altering exposure, reducing sensitivity and increasing adaptive capacity. There are various adaptation strategies which can be considered when planning agriculture interventions. There is no one-size fits all solution.

Adaptation actions or innovations include:

- **Selective irrigation:** choosing an irrigation system that helps to preserve water
- **Mulching:** covering the ground, using either straw or sawdust, to protect the roots of plants from heat, cold, or evaporation, prevent soil loss, control weeds, enrich the soil, or keep fruit (such as strawberries) clean.
- **Cover crops:** plants planted to cover the soil rather than be harvested. Cover crops manage soil erosion, soil fertility, soil quality, water, weeds, pests, diseases, biodiversity and wildlife in an agroecosystem—an ecological system managed and shaped by humans.
- **Crop rotation:** growing a series of different types of crops in the same area across a sequence of growing seasons. This practice reduces the reliance of crops on one set of nutrients, pest and weed pressure, along with the probability of developing resistant pests and weeds.
- **Agroforestry:** is a land use management system in which combinations of trees or shrubs are grown around or among crops or pastureland
- **Drought-tolerant crops species:** growing crops like corn, wheat, and rice that have become increasingly tolerant to drought with new varieties created via genetic engineering
- **Drought-tolerant livestock species:** breed for resistance to drought, heat and harsh environments. This includes a shift in species, breed and or productions systems (e.g. small ruminants, camels, poultry)
- **Water management for livestock:** introduction of boreholes and other water management solutions
- **Minimum/ zero tillage:** not ploughing but drilling seed directly into the soil, conserving organic matter.
- **Polyculture:** growing annual crops between trees helps protect soils from erosion and stores carbon in the trees.
- **Crop residues:** leaving residues such as stems and leaves on the field after harvesting helps protect soils from erosion.
- **Managing manure:** using manure in anaerobic digesters to produce methane, which can be used to generate power.

All adaptation strategies are based on a combination of:

I. specific actions (e.g. switching from one crop variety to another) and
II. systemic changes (e.g. diversifying livelihoods against risks or an institutional reform to create

incentives for better resource management).

Building farmer response capacity

In this zone of the continuum, adaptation focuses on building robust systems for problem-solving. Efforts focus on climate change hazards and their impacts. Examples include:

- Developing communication systems and planning processes
- Improvement of hazard mapping and weather monitoring measures
- Natural resources management (NRM) such as:
    - Reduction of soil erosion and land degradation through improved soil management
    - Increase of water use efficiency and availability
    - Improve water uptake and reduce wind erosion
    - Conservation of genetic resources
    - Change of farming practices to conserve soil moisture, organic matter and nutrients
    - Adopt practices that improve forest resilience and promote healthier forests
    - Adopt livestock grazing practices that will enhance soil cover, increase water retention and encourage natural soil-forming processes
    - Implement co-management systems to enhance the governance of fisheries
    - Strengthen institutions to maximize responsiveness to change at all levels

2. Reduce agriculture's contribution to climate change (Mitigation)

Mitigation activities promote "efforts to reduce or limit GHG emissions or to enhance GHG sequestration", including "technological changes that reduce resource inputs and emissions per unit of output". There are three primary options to mitigate climate change:

- Reducing emissions
- Avoiding or displacing emissions
- Removing emissions

3. Reducing emissions

Cutting emissions means finding better ways to reduce carbon dioxide, methane or nitrogen dioxide fluxes by efficiently managing carbon and nitrogen in farming so that we release less carbon dioxide, nitrogen dioxide, and methane into the air, which are harmful greenhouse gases.

Examples include:

Minimal soil disturbance (e.g. minimum and zero tillage) and improved grazing management (stocking rate management, rotational grazing, and enclosure of grassland from livestock grazing) can reduce emissions from volatilization of organic soil carbon.

Integrated nutrient management can reduce emissions by reducing leaching and volatile losses, improving nitrogen use efficiency through precision farming and fertilizer application timing.

Improving livestock feeding practices can increase the efficiency of the digestive process, thus reducing emissions from enteric fermentation. Examples include:

- Use of specific agents or dietary additives

- Improvements in forage quality and quantity
- Seeding fodder grasses or legumes with higher productivity and deeper roots
- Reducing fuel load by vegetation management

Maintaining a shallower water table and avoiding deep ploughing and cropping row crops and tubers will prevent the draining of organic soils, leading to high GHG emissions.

Committing forests to reduce emissions from deforestation and forest degradation (REDD) and the sustainable management of existing forests will also support emission reduction goals.

The adoption of improved aquaculture management can also reduce emissions. This can be done by:

- Selection of suitable populations of aquatic species
- Improving energy efficiency
- Increasing feeding efficiency
- Switching to herbivorous or omnivorous aquaculture species to reduce emissions from input use

Avoiding or displacing emissions

Shift energy sources from fossil fuels to renewable options like solar, wind, and hydropower to reduce emissions associated with energy production.

Energy Efficiency: Enhance energy efficiency in buildings, transportation, and industries to reduce overall energy consumption and subsequently lower emissions.

Promote Sustainable Transportation: Encourage the use of public transportation, walking, cycling, and electric vehicles to minimize emissions from traditional combustion engine vehicles.

Adopt Sustainable Agricultural Practices: Implement eco-friendly farming methods, such as precision agriculture, agroforestry, and organic farming, to reduce emissions from agricultural activities.

Increase Afforestation and Reforestation: Plant more trees and restore forests to absorb carbon dioxide from the atmosphere, acting as a natural way to displace emissions and enhance carbon sequestration.

Avoiding or displacing emissions aims to improve the energy efficiency used in agriculture. In some cases, biofuels can replace fossil fuels used in agricultural production. Improved post-harvest handling and improved storage will also contribute to avoiding emissions.

Removing emissions

Greenhouse gases can be absorbed from the atmosphere through sinks. A sink is any process or activity that removes a greenhouse gas from the atmosphere.

Improved agronomic practices: such as using cover crops and incorporating crop residue into the soil can generate higher inputs of carbon residue and lead to increased soil carbon storage.

Improved soil and water management: The construction of soil or stone bunds, irrigation and drainage systems increase available water in the root zone, which can enhance biomass production, the amount of above-ground and root biomass returned to the soil, and thus improve the soil organic carbon concentration.

Agroforestry, afforestation/reforestation, forest restoration: Carbon storage can be further increased through:

- Combining crops with trees for timber and fodder
- Establishing shelter belts and riparian zones/buffer strips with woody species
- Conversion from non-forest to forest land use and from degraded forests to fully carbon-stocked forests

1. Sustainably increase agricultural productivity (Productivity)

CSA aims to sustainably increase agricultural productivity and incomes from crops, livestock, and fish without harming the environment. This, in turn, will raise food and nutritional security. A key concept of raising productivity is sustainable intensification by increasing food production from existing farmland while minimizing environmental pressure.

Session 4: Drought-Resilient Techniques

Purpose of this Session

To introduce the farmers to the key concepts in drought-resilient techniques.

Expected Learning Outcomes

By the end the session, the learner should be able to:

1. Outline the key concepts in drought-resilient techniques, encompassing sustainable water management, crop selection, soil health improvement, and technological innovations.
2. Discuss the relationship between resilience and sustainability.

Duration

One session of 1 hour 45 minutes with smaller breaks in between

Method

- Brainstorming
- Presentation
- Question and answer session

Material

PPT, white board and marker, audio-visual system.

Instructions for Trainer

This session will introduce participants on drought resilient techniques. Delivery of the session will involve face-to-face presentations, demonstrations and group discussion and a field visit on day 2.

Introduction

In the recent decades, drought has been recurring and intensifying which has posed a significant threat to global agriculture. The increasing frequency and severity of drought events as a result of climate change has necessitated the need for effective drought-resilient techniques during production.

Through sustainable water management, judicious crop selection and breeding, soil health improvement, agroecological approaches, and technological innovations, farmers can fortify their operations against the uncertainties of drought. This holistic approach not only ensures food security but also contributes to the broader narrative of building a resilient and sustainable agricultural landscape in the face of an evolving climate.

This session introduces key concepts in drought-resilient techniques. By understanding and implementing these concepts, farmers in Eastern Africa will not only adapt to changing climatic conditions but also contribute to building a more resilient and sustainable agricultural system.

Sustainable Water Management:

At the heart of drought resilience lies sustainable water management—an intricate dance between resource optimisation and conservation. Efficient irrigation systems, such as drip irrigation, minimizes water wastage. Rainwater harvesting using small ponds, tanks, or installing low-cost water storage containers to enable farmers to conserve water for use during droughts emerges as a crucial tool in water-stressed regions.

Crop Selection and Breeding:

Selection of the crops being cultivated in water scarce areas play a big role in drought resilience. Traditional drought-resistant varieties and the advancements in drought-tolerant crops through breeding programmes are essential components. These technologies enable the development of crops equipped with traits that enhance their capacity to withstand water stress. The promotion of diverse crop portfolios, including drought-tolerant cereals, legumes, and tubers, stands as a strategic move towards agricultural sustainability in water-scarce regions. This approach not only safeguards against crop failures but also contributes to broader food security initiatives.

Soil Health Improvement:

The health of the soil, a dynamic and living entity, plays a foundational role in a farm's resilience to drought. Practices such as cover cropping, conservation tillage, and the incorporation of organic amendments are integral components of soil health improvement. Cover crops act as protective shields, reducing soil erosion and enhancing water retention. Conservation tillage methods minimize soil disturbance, preserving structure and minimizing water runoff. Mycorrhizal fungi, known for enhancing nutrient and water uptake by plant roots, can be employed to establish symbiotic relationships in the rhizosphere. By fostering healthy soil microbial communities, farmers can create an environment that better supports plant growth during periods of water scarcity.

Agroecological Approaches:

Agroecology integrates ecological principles into agricultural systems, promoting biodiversity and enhancing ecosystem services thereby emerging as a beacon of resilience. The cultivation of diversified agroecosystems, such as agroforestry and intercropping, not only provides farmers with multiple revenue streams but also augments the overall resilience of the farming system. Agroforestry, by integrating trees into the agricultural landscape, contributes to microclimate regulation, reducing water evaporation and improving soil moisture retention. The synergy between different crops in intercropping systems creates mutually beneficial relationships, enhancing resource-use efficiency and fortifying the system against environmental stressors.

The ‘three key pillars’ of drought risk reduction

First key pillar: Implementing drought monitoring and early warning systems:

a) Monitor key indicators and indices of precipitation, temperature, soil moisture, vegetation condition, streamflow, snowpack and ground water
b) Develop reliable seasonal forecasts and develop appropriate decision-support tools for impacted sectors
c) Monitor the consequences of drought especially the impacts to vulnerable sectors such as agriculture
d) Communicate reliable warning messages and respond to the risks in a measured and timely fashion

Second key pillar: Addressing drought vulnerability and risk:

a) Identify drought impacts on vulnerable economic sectors including food and agriculture (cropping and livestock), biodiversity and ecosystems, and energy, tourism and health sectors
b) Assess physical, social, economic and environmental pressures on communities to identify who and what is at risk and why – before, during and shortly after drought

c) Assess conditions or situations that increase the resistance or susceptibility to drought and the
d) coping capacity of communities affected by drought
e) Assess the extent of potential damage or loss in the event of a drought

Third Key pillar

a) Implement structural or physical measures, and non-structural measures to limit the adverse impacts of drought, prioritized based on level of vulnerability (Key pillar #2)
b) Response includes all efforts, such as the provision of assistance or intervention during or immediately after a disaster to meet the life-saving and basic subsistence needs of the vulnerable and affected communities and sectors
c) Measures need to be relevant to sectors affected by drought based on their vulnerability – particularly agriculture, water and the environment, as well as transport and tourism
d) Measures can be long-, medium- or short-term, depending on implementation time
e) Biodiversity, land and ecosystem services play a vital role in reducing vulnerability and mitigating impacts of drought.

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Session 5: Drought-resistant inputs

Purpose of this Session

To equip the farmers to knowledge on drought resistant inputs to advance their resilience, including drought resistant and drought-tolerant plants and seeds, livestock breeds, fertilizer inputs etc.

Expected Learning Outcomes

By the end the session, the farmers should be able to:

1. Identify drought resistant inputs available in Eastern Africa
2. Apply alternative fertilizer to advance drought resilience

Duration

One session of 1 hour 45 minutes with smaller breaks in between

Method

- Brainstorming
- Presentation
- Question and answer session

Material

PPT, white board and marker, audio-visual system.

Instructions for Trainer

This session will introduce participants on drought resilient inputs. Delivery of the session will involve face-to-face presentations demonstrations and group discussion and field visits.

Drought-resistant plants

Drought-resistant plants and drought-tolerant plants are two types of plants that have adaptations that allow them to survive and thrive in dry environments. These plants can maintain their productivity during periods of limited water availability, while drought-tolerant plants can survive periods of severe water shortage but may experience reduced growth and productivity.

Drought resistance refers to a plant's ability to maintain its growth and productivity during periods of limited water availability. This can be achieved through various mechanisms, such as reducing water loss through transpiration or storing water in specialized tissues.

Drought tolerance, conversely, refers to a plant's ability to survive periods of severe water shortage, even if it experiences reduced growth and productivity.

Drought-resistant plants are compared based on their ability to survive in dry conditions. They have different strategies to cope with drought. Some plants have deep root systems that can reach deep into the soil to find water. Other plants have waxy leaves that reduce water loss through transpiration. Some plants have succulent leaves and stems that store water. They can be compared based on their ability to tolerate heat, cold, and drought. The rate of water loss through leaf transpiration is reduced. However, it is broadly accepted that changes in the root system, including root size, density, length, proliferation, expansion, and growth rate, represent the primary strategy for drought-tolerant plants to cope with water deficits.

Smallholder farmers can employ various strategies to enhance the drought resistance of their crops. Here are some practices that can be beneficial:

1. **Drought-resistant crop varieties:** Choose crop varieties that are specifically bred or genetically modified to be drought-resistant. Look for seeds that have been developed to thrive in arid or semi-arid conditions.
2. **Improved soil management:** Implement conservation agriculture techniques, such as minimal tillage, cover cropping, and mulching, to improve soil structure and water retention. Use organic matter (compost or manure) to enhance soil fertility and moisture-holding capacity.
3. **Water management:** Implement efficient irrigation systems such as drip or sprinkler irrigation to optimize water use. Collect rainwater and use it for irrigation during dry periods.
4. **Crop rotation and diversification:** Rotate crops to break pest and disease cycles and improve soil health. Diversify crops to reduce the risk of complete crop failure during drought.
5. **Conservation of water resources:** Implement water conservation practices, such as rainwater harvesting, to ensure a sustainable water supply. Consider using water-saving technologies like moisture sensors to optimize irrigation.
6. **Agroforestry:** Integrate trees and shrubs into farming systems to provide shade, reduce evaporation, and improve soil fertility. Choose drought-resistant tree species that complement the chosen crops.
7. **Appropriate planting techniques:** Optimize planting times to take advantage of the rainy season. Use techniques like contour ploughing to reduce water runoff and erosion.
8. **Use of organic and green manures:** Incorporate organic and green manures to improve soil structure and water retention. These practices enhance the soil's ability to retain moisture during dry periods.
9. **Drought monitoring and early warning systems:** Stay informed about weather patterns and use early warning systems to anticipate drought conditions. Plan planting and harvesting schedules based on weather forecasts to minimize the impact of dry spells.
10. **Community-based approaches:** Collaborate with other farmers to share knowledge and resources. Participate in community-based initiatives for water management and drought preparedness.

Implementing a combination of these strategies can contribute to building resilience in smallholder farming systems, making them better equipped to withstand and recover from drought conditions. It's essential to consider the region's specific requirements and the crops being cultivated when selecting and implementing these practices.

Drought-resistant seeds

Drought-resistant seeds are crucial to CSA, particularly for smallholder farmers facing water scarcity and unpredictable rainfall. Several approaches are used to develop drought-resistant seeds, including traditional breeding, genetic modification, and biotechnology. Here are some characteristics and strategies associated with drought-resistant seeds:

1. **Deep Root Systems:** Plants with deep root systems can access water from deeper soil layers, making them more resilient to drought conditions.
2. **Water-Use Efficiency:** Drought-resistant seeds are often bred or engineered to use water more efficiently, optimizing water uptake

and minimizing water loss through transpiration.

3. **Early Maturity:** Varieties with shorter growing seasons or early maturity are better suited for regions with limited water availability.
4. **Tolerance to Osmotic Stress:** Plants that can tolerate osmotic stress, where water availability is low, and solute concentration is high, are more resilient to drought.
5. **Drought-Responsive Genes:** Genetic modifications or breeding programmes may focus on incorporating activated genes in response to drought stress, triggering mechanisms that help the plant cope with water scarcity.
6. **Breeding for Specific Environments:** Developing seeds adapted to a region's specific climatic and soil conditions enhances their resilience to drought.
7. **Hybrid Varieties:** Hybrid seeds may exhibit improved drought resistance, often by combining traits from different parent plants.
8. **Trait Stacking:** Incorporating multiple drought-resistant traits into a single plant, a practice known as trait stacking, can enhance overall resilience.
9. **Marker-Assisted Selection (MAS):** MAS involves using genetic markers to identify and select plants with desired traits more efficiently, accelerating the breeding process for drought resistance.
10. **Transgenic Approaches:** Genetic modification techniques can introduce genes from other organisms that confer drought resistance, such as genes coding for proteins that help the plant retain water.
11. **Screening and Selection:** Traditional breeding involves screening plants for desirable traits under drought conditions and selecting those with the best performance.
12. **Public-Private Partnerships:** Collaborations between public institutions, private companies, and research organizations can accelerate the development and distribution of drought-resistant seeds.

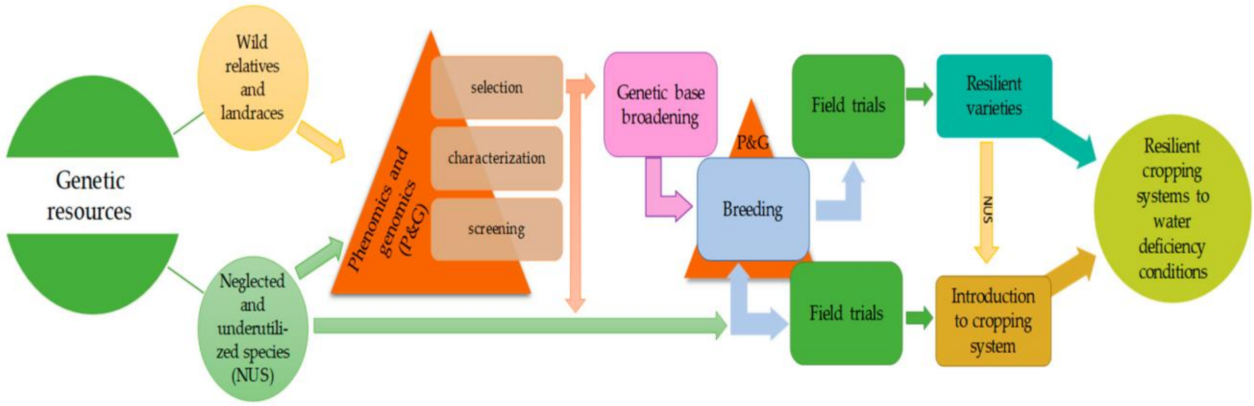

Figure 11 Dual strategy of breeding for drought tolerance (adopted from Rosero et al., 2020) [12]

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[12] Rosero A, Granda L, Berdugo-Cely JA, Šamajová O, Šamaj J, Cerkal R. A Dual Strategy of Breeding for Drought Tolerance and Introducing Drought-Tolerant, Underutilized Crops into Production Systems to Enhance Their Resilience to Water Deficiency. Plants. 2020; 9(10):1263.

It's essential to note that the acceptance and adoption of genetically modified seeds vary, and there are ongoing debates about their safety and environmental impact. Traditional breeding methods are often also influential in developing drought-resistant varieties.

Before adopting any specific seed variety, farmers should consider factors such as the local climate, soil conditions, and available resources. Additionally, engaging in community-based seed-saving initiatives can help ensure access to locally adapted seeds with drought-resistant traits.

Alternative Fertilizers in Drought Resilient Techniques

Drought-resilient agriculture focuses on improving water use efficiency in farming systems, and alternative fertilizers play a crucial role in this approach. Here are some alternative fertilizers and techniques that can contribute to drought resilience in agriculture:

1. **Organic Fertilizers:** these are natural substances derived from plant or animal sources, offering a sustainable alternative to synthetic fertilizers. Composed of organic matter like compost, manure, or bone meal, they enrich the soil with essential nutrients, fostering healthy plant growth. Unlike chemical fertilizers, organic options release nutrients slowly, promoting long-term soil fertility. Moreover, they improve soil structure, water retention, and microbial activity, contributing to overall soil health. By embracing organic fertilizers, farmers prioritize environmentally friendly practices, reduce the risk of nutrient runoff, and support a more balanced and sustainable approach to agriculture.
2. **Cover Crops:** is an agricultural technique which involves the planting of specific crops to cover and protect the soil during periods when primary crops are not growing. These cover crops, often legumes or grasses, offer a myriad of benefits such as preventing soil erosion, suppress weed growth, and enhance soil fertility by fixing nitrogen. Legumes, like clover and vetch, can fix nitrogen in the soil, reducing the need for synthetic nitrogen fertilizers.
3. **Biofertilizers:** these are natural substances containing beneficial microorganisms that enhance soil fertility and promote plant growth. Derived from nitrogen-fixing bacteria, phosphate-solubilizing bacteria, or mycorrhizal fungi, biofertilizers establish symbiotic relationships with plants, aiding nutrient absorption. Biofertilizers enhance soil structure, improve water retention, and stimulate microbial activity. This eco-friendly approach supports long-term soil health, mitigates nutrient runoff, and represents a viable strategy for environmentally conscious farming, aligning with the principles of sustainable and regenerative agriculture. Examples include:
    a. Rhizobium and Mycorrhizal Inoculants: examples of beneficial microorganisms that form symbiotic relationships with plant roots, aiding nutrient absorption and water uptake.
    b. Azotobacter and *Azospirillum*: examples of bacteria with the ability to fix atmospheric nitrogen and make it available to plants.

4. **Water-Soluble Fertilizers:** these are concentrated nutrients that easily dissolve in water, providing a quick and efficient means of nourishing plants. Comprising essential elements like nitrogen, phosphorus, and potassium, these fertilizers are readily absorbed by plant roots. Ideal for both soil and foliar application, they offer rapid nutrient uptake, promoting robust growth and development. Water-soluble fertilizers are versatile, allowing precise nutrient management and customization based on specific plant needs. Their use minimizes nutrient wastage, enhances plant resilience, and is a practical solution for both conventional and hydroponic farming systems, exemplifying a modern and efficient approach to nutrient supplementation in agriculture. They can improve nutrient absorption efficiency, particularly during periods of water scarcity.
5. **Polymer-coated fertilizers:** are fertilizers encapsulated in a polymer coating that gradually releases nutrients over an extended period. These fertilizers feature a protective polymer coating that controls the release of nutrients in response to environmental factors like temperature and moisture. This slow-release mechanism enhances nutrient efficiency, reducing the risk of leaching and runoff. Polymer-coated fertilizers provide a consistent and sustained supply of nutrients to plants, promoting balanced growth and minimizing the need for frequent applications. This technology contributes to more efficient nutrient management, increased crop yield, and reduced environmental impact, aligning with the principles of precision agriculture and sustainable farming practices. It also helps reduce nutrient leaching and ensures a steady nutrient supply to plants over an extended period.
6. **Seaweed Extracts:** derived from various seaweed species, these extracts are rich in essential nutrients, growth-promoting hormones, and beneficial compounds. As organic fertilizers, they enhance soil fertility, stimulate plant growth, and improve stress resistance. Seaweed extracts also contain natural chelating agents that enhance nutrient absorption. Their application fosters healthier plants, increased crop yields, and improved soil structure. Additionally, seaweed extracts contribute to sustainable agriculture by minimizing environmental impact and reducing dependence on synthetic inputs, offering a promising avenue for cultivating crops with minimal ecological footprint. Seaweed extracts contain various. They can enhance plant growth and help plants cope with stress, including drought.

7. **Crop Rotation and Diversification:** Diverse cropping systems, including crop rotation, can improve soil health and reduce the dependence on specific nutrients. Crop rotation involves systematically changing the types of crops cultivated in a specific area over consecutive seasons. This method helps maintain soil fertility, manage pests, and prevent diseases. By alternating plant species, crop rotation balances soil nutrient levels, reducing the risk of depletion. It disrupts the life cycles of pests and pathogens, limiting their impact on crops. This practice promotes sustainable land management, improves soil structure, and enhances

water retention. Crop rotation is a time-honored technique that contributes to the long-term health and productivity of agricultural land, ensuring sustainable and resilient farming systems.

8. **Green Manure:** involves the incorporation of fresh, growing plant material into the soil to enhance fertility. Typically, cover crops like legumes or grasses are cultivated and later turned into the soil before flowering. As they decompose, green manures release nutrients, improve soil structure, and increase organic matter. This method prevents soil erosion, suppresses weeds, and promotes beneficial microbial activity. Green manure is a natural and cost-effective way to enrich the soil, providing a holistic approach to sustainable farming that benefits both the environment and agricultural productivity. Incorporating green manure crops into the rotation adds organic matter to the soil, improving its structure and water retention capacity.
9. **Mulching:** a layer of organic or inorganic material is applied to the soil surface around plants. This practice offers various benefits, such as conserving soil moisture, suppressing weed growth, and regulating soil temperature. Organic mulches, like straw or compost, decompose over time, enriching the soil with nutrients. Additionally, mulching protects against soil erosion, enhances microbial activity, and fosters a favorable environment for plant roots. This cost-effective and sustainable approach contributes to improved soil health, increased water efficiency, and overall resilience in farming systems, making mulching an invaluable practice in modern agriculture. Mulching with organic materials helps retain soil moisture, reducing the need for excessive irrigation and enhancing the efficiency of applied fertilizers.

When implementing these techniques, it's essential to consider the specific conditions of the region, the crop, and the existing agricultural practices. Integrated approaches that combine various strategies yield the best results in promoting drought resilience in agriculture.

Figure 3~~12~~ Dimensions of organic farming [13]

Organic farming is an agricultural approach rooted in sustainability and environmental stewardship. At its core, organic farming rejects synthetic pesticides, herbicides, and genetically modified organisms, opting instead for natural and holistic methods to cultivate crops. The emphasis is on maintaining soil health through practices like crop rotation, cover cropping, and the application of organic matter, fostering a biodiverse ecosystem that supports beneficial insects and microorganisms. By eschewing chemical inputs, organic farming aims to create a harmonious relationship between nature and agriculture, promoting healthier food and sustainable farming practices and prioritising the long-term health of the soil, water, and surrounding ecosystems.

Organic farming is guided by four fundamental principles that prioritise sustainability, environmental health, and ecological balance:

1. Health: Organic farming emphasizes the production of food that enhances the health and well-being of consumers. By avoiding synthetic pesticides, herbicides, and genetically modified organisms (GMOs), organic agriculture aims to provide wholesome and nutritious produce while

[13] https://agritech.tnau.ac.in/org_farm/orgfarm_introduction.html

minimizing the risks associated with chemical residues.

2. Ecology: The ecological principle of organic farming underscores the importance of maintaining and enhancing ecological balance. This involves cultivating crops in harmony with natural systems, preserving biodiversity, and promoting the health of the soil, water, and air. Practices such as crop rotation, cover cropping, and agroforestry contribute to a resilient and sustainable agroecosystem.
3. Fairness: Social responsibility is a key aspect of organic farming. Fair treatment of workers, respect for local communities, and support for social justice are integral components. Organic farmers strive to create equitable relationships throughout the supply chain, ensuring fair wages, safe working conditions, and community engagement.
4. Care: The principle of care in organic farming involves responsible and ethical stewardship of resources. This includes minimizing environmental impact, conserving water, and adopting practices that promote the long-term health of the land. By prioritizing care, organic farming seeks to leave a positive legacy for future generations and contribute to a more sustainable and regenerative agricultural model.

Benefits of Organic Farming: A Holistic Approach to Agriculture

Beyond the avoidance of synthetic chemicals, organic farming offers many benefits. It reduces environmental pollution, conserves water, and mitigates soil erosion by fostering a more resilient and naturally balanced ecosystem. Organic farming methods also prioritize animal welfare, prohibiting the routine use of antibiotics and growth hormones in livestock. The resulting organic produce is not only free from synthetic residues. Still, it is often noted for its enhanced flavour and nutritional content. Additionally, organic farming contributes to rural development by fostering local economies and promoting fair trade practices. As consumers increasingly seek sustainable and ethical choices, the principles of organic agriculture resonate as a model that nourishes individuals and nurtures the planet for generations to come.

Organic agriculture can enhance drought resilience through several key practices and principles:

1. Improved Soil Structure: Organic farming focuses on building and maintaining healthy soil through practices like cover cropping, composting, and reduced tillage. Well-structured soil with high organic matter content retains moisture more effectively, making it more resilient to drought conditions.
2. Water Conservation: Organic farming often involves water-conserving techniques such as mulching and efficient irrigation practices. Mulching reduces evaporation, while precision irrigation methods ensure that water is used more judiciously, contributing to better water management during dry periods.
3. Diverse Cropping Systems: Organic farming encourages diverse crop rotations and intercropping. This diversity can enhance the agroecosystem's ability to withstand stress, including drought. Different crops have varied water requirements, and a diverse system can adapt more

effectively to fluctuating water availability.

4. Enhanced Soil Microbial Activity: Organic practices promote beneficial microbial activity in the soil. These microorganisms contribute to improved soil structure and nutrient availability, enhancing the overall resilience of plants to environmental stress, including drought.
5. Cover Cropping: The use of cover crops in organic agriculture helps protect soil from moisture loss, reduces erosion, and contributes organic matter to the soil. These cover crops can act as a buffer during periods of water scarcity, improving overall resilience.
6. Regenerative Practices: Organic agriculture often incorporates regenerative practices that focus on restoring and maintaining ecological balance. This holistic approach can contribute to healthier ecosystems, which, in turn, are more adaptable to extreme weather events like drought.

Drought resilient Livestock

In Eastern Africa, drought is a common challenge, affecting both crop and livestock farming. Over the years, farmers have favored certain types of livestock that have shown resilience to drought conditions. These animals have adapted to survive in environments with scarce water and limited forage. These livestock species and breeds have been integral to the survival of pastoralist and agro-pastoralist communities in Eastern Africa. They provide essential resources such as meat, milk, and draught power, even under challenging environmental conditions marked by recurrent droughts.

Heat waves, which are projected to increase under climate change, could directly threaten livestock. Over time, heat stress can increase vulnerability to disease, reduce fertility, and reduce milk production.

Drought may threaten pasture and feed supplies. Drought reduces the amount of quality forage available to grazing livestock. Some areas could experience longer, more intense droughts, resulting from higher summer temperatures and reduced precipitation. For animals that rely on grain, changes in crop production due to drought could also become a problem.

Climate change may increase the prevalence of parasites and diseases that affect livestock. The earlier onset of seasons could allow some parasites and pathogens to survive more easily. In areas with increased rainfall, moisture-reliant pathogens could thrive.

Potential changes in veterinary practices, including an increase in the use of parasiticides and other animal health treatments, are likely to be adopted to maintain livestock health in response to climate-induced changes in pests, parasites, and microbes. This could increase the risk of pesticides entering the food chain or lead to evolution of pesticide resistance, with subsequent implications for the safety, distribution, and consumption of livestock and aquaculture products.

Increases in carbon dioxide (C02) may increase the productivity of pastures but may also decrease their quality. Increases in atmospheric CO2 can increase the productivity of plants on which livestock feed. However, the quality of some of the forage found in pasturelands decreases with higher CO2. As a result, cattle would need to eat more to get the same nutritional benefits.

Here are some drought-resistant livestock commonly found in Eastern Africa:

1. Goats: Goats, especially local breeds such as the Eastern African and Galla goats, are highly resilient to drought. They can survive on poor, dry vegetation that other livestock cannot consume and are efficient in converting this feed to meat and milk. Their ability to browse a wide variety of plants also makes them less susceptible to food shortages during droughts.
2. Camels: Camels are perhaps the most iconic drought-resistant livestock in Eastern Africa. They are superbly adapted to arid environments, capable of going for weeks without water and can drink up to 40 gallons in one go when water is available. Camels can eat dry, thorny vegetation that other animals cannot digest, making them invaluable assets during prolonged dry periods.
3. Sheep: Certain sheep breeds, such as the Red Maasai sheep, are known for their drought tolerance. These sheep are adapted to harsh environments and can survive on limited water and forage. They are also resistant to some of the parasites and diseases that can afflict livestock in dry conditions.
4. Cattle: While cattle generally require more water than goats or sheep, some breeds have adapted to the Eastern African climate. Breeds such as the Boran, Zebu, and Ankole are known for their tolerance to heat and drought. These breeds can survive on less water and are able to utilize poor-quality forages more effectively than non-adapted breeds.
5. Donkeys: Donkeys are often overlooked in discussions about livestock, but they are incredibly resilient animals that can survive in arid conditions. They are used primarily as beasts of burden but can subsist on sparse vegetation and require less water than horses and cattle, making them well-suited to dry climates.

Session 6: Integrated Pest Management (IPM)

Purpose of this Session

To equip farmers with the key concepts and application of Integrated Pest Management (IPM) in advancing resilience.

Expected Learning Outcomes

By the end the session, the learner should be able to:

1. Describe the fundamental principles in IPM
2. Discuss application of IPM in managing pests.

Duration

One session of 1 hour 45 minutes with smaller breaks in between

Method

- Brainstorming
- Presentation
- Question and answer session

Material

PPT, white board and marker, audio-visual system.

Instructions for Trainer

This session will introduce participants on IPM. Delivery of the session will involve face-to-face presentations, demonstrations and group discussion and field visits.

Integrated Pest Management (IPM): A Comprehensive Approach to Sustainable Agriculture

IPM is a holistic and sustainable approach to managing pests in agriculture. It combines biological, cultural, physical, and chemical control methods to minimize the impact of pests while promoting economic, ecological, and human health. IPM emphasizes a proactive and integrated strategy, moving away from over-reliance on chemical pesticides that can adversely affect the environment and non-target organisms. This comprehensive approach seeks to balance the need for pest control with the preservation of natural ecosystems and the long-term health of agricultural systems.

IPM represents a paradigm shift in agriculture, moving from reliance on chemical pesticides to a more sustainable and environmentally friendly approach. By incorporating biological, cultural, mechanical, and chemical controls, IPM provides a comprehensive strategy for managing pests while promoting long-term ecological balance. The benefits of reduced environmental impact, cost-effectiveness, and improved crop quality make IPM a crucial component of modern, sustainable agriculture. As the global agricultural community faces challenges such as climate change and increasing pressure on natural resources, the principles of IPM become even more relevant in building resilient and adaptive farming systems for the future.

Fundamental Principles of Integrated Pest Management

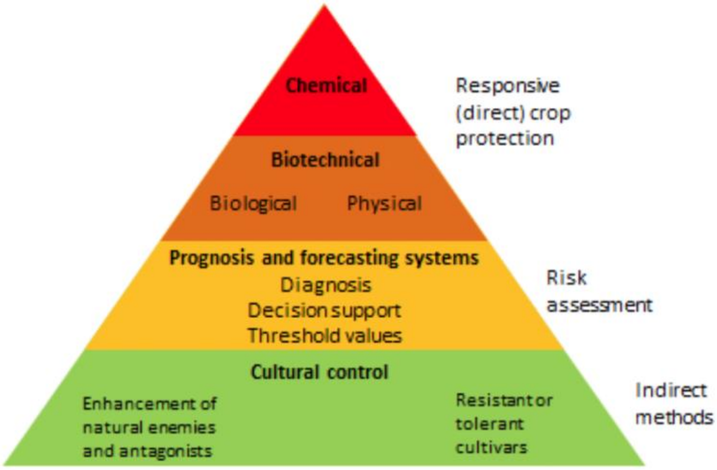


Figure 13 Principles of IPM [14]

1. **Biological Control:**

   Natural Enemies: Encourage the presence of natural predators and parasites that feed on pests. This can include beneficial insects, birds, and microorganisms that help regulate pest populations.

2. **Cultural Controls:**

   Crop Rotation: Altering the types of crops grown in a particular area from season to season disrupts the life cycles of many pests and reduces the risk of infestations.

   Polyculture: Growing various crops in proximity can confuse and deter pests, making it more difficult for them to locate and infest specific plants.

3. **Mechanical and Physical Controls:**

   Traps and Barriers: Use physical barriers, like nets or traps, to prevent pests from reaching crops. This method is particularly effective for specific pests, such as flying insects.

   Mulching: Applying mulch to the soil can suppress weeds and create an environment less favourable to certain pests while conserving soil moisture.

4. **Chemical Controls:**

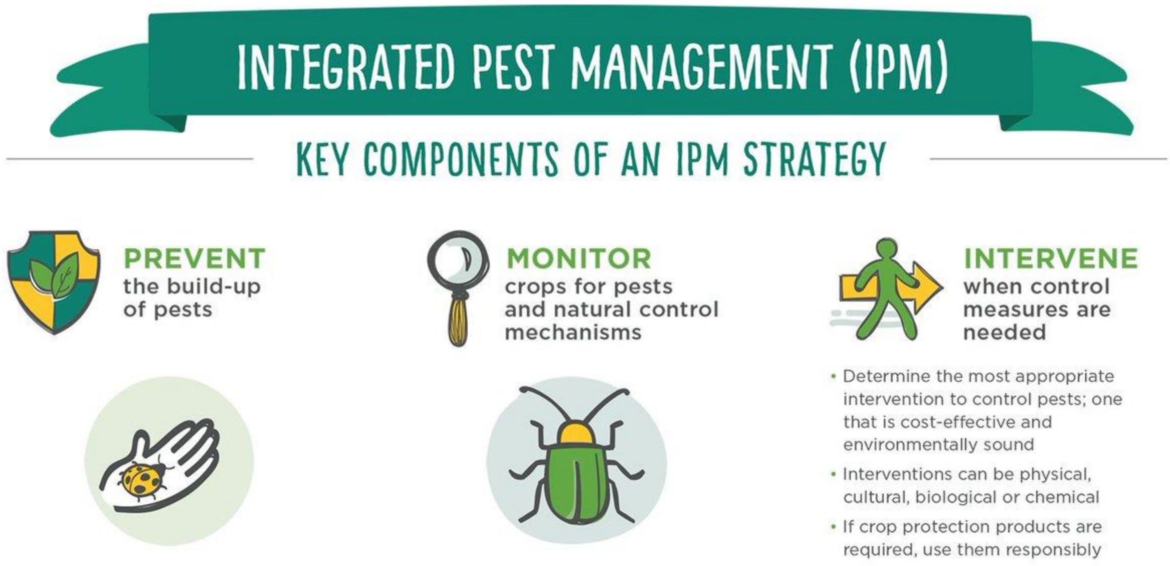
   Selective Pesticides: If chemical control is necessary, choose pesticides specific to the target pest and have minimal impact on non-target organisms.

   Threshold Levels: Implement pest control measures only when pest populations reach economically or environmentally significant levels, avoiding unnecessary pesticide use.

5. **Monitoring and Early Detection:** Regularly monitor crops to detect pest populations before they reach damaging levels. Early intervention is often more effective and reduces the need for extensive pest control measures.

[14] https://sendthewholebattalion.wordpress.com/2016/03/15/an-introduction-integrated-pest-management-ipm/

Components of Integrated Pest Management



1. **Identification of Pests:** Accurate identification is crucial for effective pest management. This includes understanding the pest's life cycle, behaviour, and vulnerabilities.
2. **Monitoring Systems:** Implementing monitoring systems involves regular surveillance of crops to assess pest populations and determine if intervention is necessary. This may include traps, visual inspections, and technology such as remote sensing.
3. **Establishing Action Thresholds:** Action thresholds are predetermined levels of pest infestation that trigger the need for control measures. Setting appropriate thresholds helps prevent unnecessary pesticide applications.
4. **Preventive Measures:** Implementing preventive measures, such as selecting pest-resistant crop varieties and using good agricultural practices, reduces the likelihood of pest problems.
5. **Biological Controls:** Introduce or enhance natural enemies of pests, such as predatory insects, parasitoids, or pathogens. This can involve releasing beneficial organisms into the environment or creating conditions that favour their presence.
6. **Cultural Controls:** Practices like crop rotation, intercropping, and adjusting planting dates disrupt pest life cycles and make the environment less favourable for pests.
7. **Mechanical and Physical Controls:** Implement physical barriers, traps, and other mechanical methods to prevent or reduce pest infestations.
8. **Chemical Controls:** If chemical control is necessary, choose effective pesticides against the target pest while minimizing harm to non-target organisms. Apply pesticides judiciously and consider alternatives such as biopesticides.
9. **Post-Treatment Evaluation:** After implementing control measures, assess their effectiveness and adjust strategies if needed. This step allows for continuous improvement and refinement of pest management practices.

Benefits of Integrated Pest Management

1. **Reduced Environmental Impact:** By minimizing the reliance on chemical

pesticides, IPM reduces the negative impact on the environment, including water and air quality, as well as non-target organisms.

2. **Cost-Effectiveness:** While the initial implementation of IPM may require an investment, the long-term cost-effectiveness is often higher than conventional pest management. IPM reduces the need for expensive chemical inputs and can enhance farm profitability.
3. **Preservation of Beneficial Organisms:** IPM allows natural predators and parasites to thrive, contributing to a balanced ecosystem. This, in turn, helps control pest populations naturally.
4. **Resistance Management:** Using various control methods, including biological and cultural controls, IPM reduces the risk of pests developing resistance to pesticides. This is a significant advantage in the face of increasing pesticide resistance.
5. **Improved Crop Quality:** IPM often leads to better overall crop quality due to reduced plant stress and less chemical residue. This can result in enhanced marketability and consumer acceptance.
6. **Sustainable Agriculture:** IPM aligns with sustainable agriculture principles by promoting long-term resilience and minimizing the negative impacts of farming practices on the environment.
7. **Human Health and Safety:** Minimizing pesticide use reduces the risk of exposure to harmful chemicals for farmers, farmworkers, and nearby communities.

Challenges and Considerations

1. **Knowledge and Education:** Successfully implementing IPM requires knowledge and education. Farmers need training and access to information on the principles and practices of IPM.
2. **Initial Investment:** Transitioning to IPM may require an initial investment in training, monitoring equipment, and alternative pest control methods. However, the long-term benefits often outweigh these costs.
3. **Adoption and Behavioral Change:** Convincing farmers to adopt new practices and change traditional methods can be challenging. Extension services and community engagement are essential to overcoming this barrier.
4. **Monitoring and Decision-Making:** Accurate monitoring and timely decision-making are critical for effective IPM. Farmers need support in developing the skills to assess pest populations and make informed decisions.
5. **Market Access:** Some markets have strict quality standards regarding pest damage. Farmers practicing IPM need assurance that their produce will meet these standards to maintain market access.

Session 7: Sustainable management of scarce resources

Purpose of this Session

To introduce the farmers to the basic concepts in sustainable management of scarce resources, such as fresh water, arable land, biodiversity etc.

Expected Learning Outcomes

By the end the session, the learner should be able to:

1. Identify the scarce resources available for agricultural production in their area.
2. Demonstrate the knowledge on key principles in sustainable resource management

Duration

One session of 1 hour 45 minutes with smaller breaks in between

Method

- Brainstorming
- Presentation
- Question and answer session

Material

PPT, white board and marker, audio-visual system.

Instructions for Trainer

This session will introduce participants on sustainable resource use. Delivery of the session will involve face-to-face presentations, demonstrations and group discussion and field visits.

Introduction

As the global and African population continues to rise and climate change amplifies agriculture's challenges, the sustainable use of scarce resources has become a critical imperative. Among these resources, fresh water for irrigation and post-harvest activities and soil quality and moisture retention mechanisms are paramount. As the global demand for resources intensifies, the imperative to strike a delicate balance between consumption and conservation has never been more crucial. In this module, we will delve into the strategies and technologies that promote the sustainable management of these resources. From innovative irrigation practices to soil-enhancing additives, the goal is to outline a holistic approach that optimizes agricultural productivity and preserves the delicate balance of our ecosystems for future generations. The session will delve into the dimensions of the multifaceted challenges of managing finite resources sustainably, exploring key concepts, strategies, and case studies that illuminate pathways toward a more resilient and equitable future.

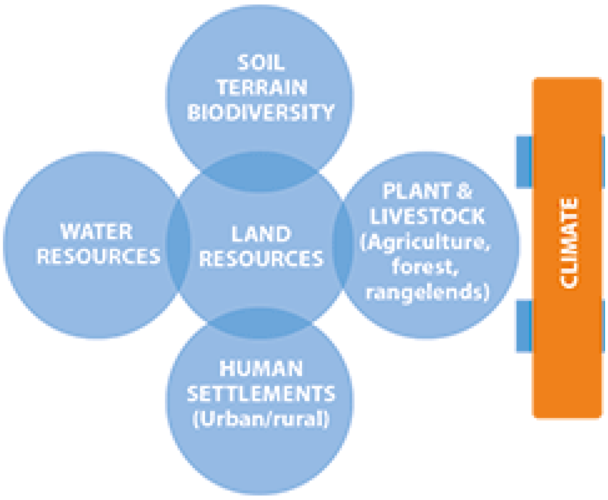


Figure 14 Favorable scarce resource use for sustainability

Understanding Scarce Resources:

Scarce resources encompass a spectrum of natural elements, from water and arable land to minerals and energy sources. The recognition of their finite nature underscores the urgency of adopting sustainable practices. Population growth, coupled with increasing urbanization, exerts pressure on resources, demanding innovative solutions to ensure their availability for current and future generations.

Water as a Precious Resource:

Water scarcity stands as a prominent illustration of the challenges associated with managing finite resources sustainably. Case studies from regions grappling with chronic water shortages shed light on the complex interplay between population demands, climate variability, and mismanagement. Innovative solutions, such as decentralised water harvesting, efficient irrigation technologies, and water recycling, showcase the transformative potential of sustainable water management practices.

Land Use and Agriculture:

Agriculture, a cornerstone of human sustenance, often drives deforestation and land degradation. Sustainable land management practices, including agroforestry, organic farming, and precision agriculture, present viable alternatives. Case studies from around the globe illustrate how adopting these practices not only preserves soil health but also enhances agricultural productivity and resilience.

Mineral Resources and Circular Economy:

Minerals, vital for industrial processes and technological advancements, face depletion and environmental degradation. The concept of a circular economy, where products are designed for reuse and recycling, emerges as a transformative approach. Case studies from countries championing circular economy principles reveal how rethinking resource consumption patterns can lead to reduced waste, increased resource efficiency, and minimized environmental impact.

Energy Transition and Renewable Resources:

The transition from fossil fuels to renewable energy sources represents a critical paradigm shift in resource management. There are many countries globally and in Africa aggressively pursuing renewable energy initiatives, which demonstrate the economic, social, and environmental benefits of such transitions. The integration of solar, wind, and hydropower into national energy grids not only mitigates climate change but also ensures a more sustainable energy future. Biodiversity is crucial in timber-rich forests, where the variety of plant and animal species supports a healthy ecosystem. Diverse forests not only provide timber but also contribute to climate regulation, water purification, and habitat for countless species. Sustainable timber harvesting practices are vital to preserving these essential biodiversity hotspots. The use of cookstoves, briquettes, increased cloned trees like the South African eucalyptus, goes a long way in addressing deforestation (especially in sectors like tea curing) hence limiting devastation on forest cover, which indirectly impacts climate change.

Social Equity and Resource Management:

Sustainable resource management is inseparable from considerations of social equity. Many countries are now pursuing community-driven conservation efforts and participatory resource governance models that underscore the importance of meaningfully including local communities in decision-making processes and in the implementation of projects to follow. By empowering marginalized populations and respecting indigenous knowledge, resource management becomes not only sustainable but also socially just.

Session 8: Post-harvest water management

Purpose of this Session

To equip the farmers with skills in sustainable use of harvested water.

Expected Learning Outcomes

By the end the session, the learner should be able to:

1. Outline the options available in harnessing rainwater for use in subsequent seasons.
2. Design post-harvest water management plans for ones specific region.

Duration

One session of 1 hour 45 minutes with smaller breaks in between

Method

- Brainstorming
- Presentation
- Question and answer session

Material

PPT, white board and marker, audio-visual system.

Instructions for Trainer

This session will introduce participants on post-harvest water management. Delivery of the session will involve face-to-face presentations, demonstrations and group discussion and field visits.

Fresh water for agriculture: Nurturing crops in a water-scarce system

Freshwater scarcity, particularly in Africa, poses a formidable challenge to smallholder farmers, demanding a paradigm shift in irrigation practices. Traditional methods of irrigation such as furrow or basin are characterised by excessive water use and inefficient delivery systems, contribute to water wastage and environmental degradation. Sustainable agriculture, however, advocates for drip, sprinkler, or subsurface irrigation techniques to optimise water use[15]. These technologies minimise water loss through evaporation and runoff, ensuring that each droplet serves its purpose in nurturing crops. Additionally, the adoption of rainwater harvesting systems provides a supplementary water source, reducing the dependence on conventional water supplies and contributing to the resilience of agricultural systems in the face of erratic rainfall patterns.

Most of the smallholder farmers in EA rely on traditional ways of soil moisture determination, using rudimentary methods like soil "feel" approach, observation of the soil surface 'water appearance'. Advancing to modern and more precise systems like intelligent irrigation technologies that integrate sensors and data analytics would enable farmers to tailor irrigation schedules to the specific needs of crops. This precision approach prevents overwatering and allows for the efficient use of water resources. Beyond technological advancements, sustainable water

[15] Nakawuka, P., Langan, S., Schmitter, P. and Barron, J. (2018) A review of trends, constraints and opportunities of smallholder irrigation in East Africa, *Global Food Security*, 17, 196-212,

management in agriculture involves adopting agroecological practices that promote soil health and water retention. Cover cropping, agroforestry, and contour ploughing enhance soil structure, mitigating water runoff and erosion while optimizing water infiltration.

Post-harvest activities also play a pivotal role in sustainable water use. Efficient water recycling systems in processing units and adopting water-saving technologies in cleaning and packaging contribute to minimizing water waste. The integration of circular economy principles in agricultural supply chains ensures that water resources are conserved throughout the entire agricultural lifecycle.

Water scarcity is a pressing issue globally, and agriculture is a major consumer of this precious resource. Sustainable water management in agriculture involves strategies to optimize water use efficiency, reduce waste, and promote the conservation of freshwater resources.

i. **Precision Irrigation Systems:** Precision irrigation technologies, such as drip irrigation and subsurface systems would revolutionize how water is applied to crops. These systems minimize water wastage through evaporation and runoff by delivering water directly to the root zone. Moreover, they enable precise control over the timing and amount of water applied, ensuring that crops receive the required moisture without excess.
ii. **Rainwater Harvesting:** Rainwater harvesting is a sustainable practice involving collecting and storing rainwater for agriculture. This method provides an additional water source and reduces reliance on groundwater and surface water, promoting long-term water sustainability.
iii. **Water Recycling and Reuse:** Implementing systems for the recycling and reusing of water in agriculture can significantly contribute to sustainable water management. When safely processed, treated wastewater from various sources can be used for irrigation, reducing the demand for freshwater supplies.
iv. **Cover Crops and Mulching:** Cover crops and mulching are crucial in reducing water evaporation from the soil surface, enhancing water retention, and preventing soil erosion. These practices not only conserve water but also contribute to improved soil health.

The sustainable use of water in agriculture extends beyond the field to post-harvest activities. Efficient water management in processing, cleaning, and storage is essential for reducing waste and environmental impact.

i. **Water-Efficient Processing Technologies:** Using technologies that save water in food and farming industries after harvesting can help use less water. Things like closed-loop water systems and recycling water in food processing plants are examples of innovations that make sure we use water in a way that is better for the environment.
ii. **Smart Packaging and Storage:** Innovative packaging and storage solutions that prolong the shelf life of agricultural products can indirectly reduce water waste.

Less water is required to produce replacement goods by minimising food losses due to spoilage.

iii. **Efficient Cleaning Practices:** Adopting water-efficient cleaning practices in post-harvest operations is crucial. This includes using high-pressure, low-volume cleaning systems and implementing cleaning schedules that minimize water consumption.

Session 9: Nurturing crops in a water-scarce system: Water enhancing additives, moisture retention mechanisms and organic conditioners

Purpose of this Session

To equip the farmers with knowledge on available options in nurturing crops in a water scarce system.

Expected Learning Outcomes

By the end the session, the learner should be able to:

1. Outline the various options available to enhance moisture retention at the farm.
2. Understand the moisture retention mechanisms.
3. Discuss water enhancing additives, conditioners.

Duration

One session of 1 hour 45 minutes with smaller breaks in between

Method

- Brainstorming
- Presentation
- Question and answer session

Material

PPT, white board and marker, audio-visual system.

Instructions for Trainer

This session will introduce participants on nurturing crops in a water-scarce system. Delivery of the session will involve face-to-face presentation, demonstrations, group discussion and field visits.

Introduction

Soil, often called the "living skin of the Earth," is a fundamental component of sustainable agriculture. The depletion of soil fertility and degradation resulting from intensive farming practices necessitates re-evaluating soil management strategies. Incorporating soil-enhancing additives and moisture retention mechanisms is a cornerstone of sustainable soil stewardship. Often overlooked and underestimated, soil is a cornerstone of global food production and ecosystem health. Integrating soil-enhancing additives and moisture retention mechanisms becomes increasingly crucial as agricultural practices evolve to meet the demands of a growing population and changing climate. Understanding the multifaceted dimensions of these additives and mechanisms is imperative, as unravelling their significance in nurturing soil health, improving agricultural productivity, and fostering sustainability.

One essential approach is the integration of organic soil conditioners. These natural amendments, such as compost and manure, replenish soil nutrients and enhance its structure and water-holding capacity. Compost, for instance, acts as a reservoir for moisture, reducing the required frequency and volume of irrigation. Harnessing the power of organic matter in the form of cover crops also contributes to soil fertility. Through nitrogen fixation, leguminous cover crops enrich the soil with this essential nutrient, reducing the need for synthetic fertilizers and fostering a more sustainable nutrient cycle.

In the pursuit of soil sustainability, soil moisture retention mechanisms become imperative, especially in regions prone to drought. Hydrogels, or water-absorbing polymers, represent an innovative solution. When incorporated into the soil, these substances can absorb and release water as needed, ensuring a more consistent plant moisture supply. This not only enhances the resilience of crops to water stress but also reduces the overall water demand for irrigation. Furthermore, the exploration of seaweed products as soil amendments has gained traction. Seaweeds, rich in minerals and growth-promoting compounds, contribute to soil health and water retention. Their natural biostimulant properties enhance plant resilience to environmental stressors, fostering sustainable and robust agricultural ecosystems.

Additionally, agroforestry practices, integrating trees and woody perennials into agricultural landscapes, are pivotal in enhancing soil structure and moisture retention. The canopy cover provided by trees mitigates soil erosion, while their deep root systems improve water infiltration and storage. This synergistic approach promotes biodiversity and contributes to the sustainable management of scarce water resources in agriculture.

Soil health is the bedrock of sustainable agriculture. It encompasses a dynamic and intricate web of physical, chemical, and biological processes supporting plant growth. Unfortunately, conventional farming practices, marked by intensive tillage, heavy chemical inputs, and monoculture, often lead to soil degradation, erosion, and nutrient depletion. In response to these challenges, a paradigm shift toward holistic soil management has gained momentum, emphasizing the importance of soil health in achieving long-term agricultural sustainability.

Organic Soil Conditioners: Nurturing the Living Soil

Organic soil conditioners represent a fundamental component of soil enhancement strategies. Comprising materials such as compost, manure, and cover crops, these additives contribute organic matter to the soil, fostering a thriving microbial community. Microbial activity, in turn, plays a pivotal role in nutrient cycling, soil structure improvement, and disease suppression.

Compost, often called "black gold," is a rich source of organic matter from decomposing plant and animal residues. When incorporated into the soil, compost enhances water-holding capacity, reduces erosion, and promotes nutrient availability. Beyond its immediate benefits, compost acts as a carbon sink, mitigating the impacts of climate change by sequestering carbon in the soil.

Manure, derived from animal waste, is another potent organic soil conditioner. Rich in nutrients, manure replenishes soil fertility and enhances microbial diversity. However, its application requires careful management to prevent nutrient runoff and water pollution.

Cover crops, strategically planted between cash crops, contribute to soil health by preventing erosion, suppressing weeds, and adding organic matter. Through nitrogen fixation, leguminous cover crops further enrich the soil with this essential nutrient, reducing the need for synthetic fertilizers.

Examples of additives and their moisture retention mechanisms

Maintaining soil health is fundamental to sustainable agriculture. Various additives and moisture retention mechanisms contribute to soil fertility, structure, and water-holding capacity, reducing the need for excessive water and chemical inputs.

i. **Organic Soil Conditioners:** Organic soil conditioners, such as compost and well-rotted manure, are valuable additions to improve soil structure and water retention. These materials enhance the soil's ability to hold water, reducing the frequency and quantity of irrigation needed.

ii. **Seaweed Products:** Seaweed extracts contain natural growth-promoting substances, including trace elements, hormones, and beneficial microorganisms. When applied to the soil, seaweed products can enhance plant growth, improve soil structure, and increase the soil's water-holding capacity. Seaweed products derived from marine algae have gained prominence as effective soil enhancers. Rich in minerals, growth-promoting hormones, and bioactive compounds, seaweeds contribute to soil health and plant vitality. The use of seaweed extracts or direct incorporation of seaweed residues into the soil offers a myriad of benefits. First, seaweed products enhance soil structure, improving porosity and water infiltration capacity. This facilitates better root development and nutrient uptake by plants. Secondly, the natural biostimulant properties of seaweeds promote plant growth and resilience to environmental stressors, including pests and diseases. Additionally, the high content of trace elements and minerals in seaweed contributes to the nutritional quality of crops. Beyond their direct impact on soil and plant health, seaweed products also hold promise in mitigating the effects of climate change. Marine algae play a role in carbon sequestration, so using seaweed in agriculture contributes to a more sustainable carbon cycle.

iii. **Hydrogels/ Water-absorbing Polymers:** Polymer absorbents, also known as hydrogels, are water-absorbing materials that can be incorporated into the soil. These polymers absorb and retain water, releasing it gradually to the plant's roots. When incorporated into the soil, these substances absorb water during periods of abundance and release it gradually during dry spells. The application of hydrogels offers several advantages, particularly in arid and semi-arid regions. Hydrogels contribute to water conservation and improve water use efficiency by reducing irrigation frequency and water loss through evaporation. Moreover, they enhance crop resilience to drought, ensuring a more consistent moisture supply for plant growth. Hydrogels' potential in mitigating climate change impacts, including erratic precipitation patterns and prolonged dry spells, underscores their significance in fostering agricultural sustainability.

iv. **Cover Cropping:** Cover crops, such as legumes and grasses, contribute to soil health by preventing erosion, suppressing weeds, and adding organic matter. Their extensive root systems also enhance the soil's ability to retain moisture, reducing the need for irrigation.

v. **Mulching:** Mulching involves covering the soil with organic or inorganic materials, such as straw or plastic, to reduce water evaporation, suppress weeds, and regulate soil temperature. This practice enhances moisture retention and contributes to overall soil health.

Session 10: Agroecology and regenerative Agriculture

Purpose of this Session

To equip the farmers with knowledge on agroecology and regenerative agricultural methods and practices.

Expected Learning Outcomes

By the end the session, the learner should be able to:

1. Outline the core concepts in agroecology and regenerative agriculture
2. Discuss available options in agroecology and regenerative agriculture.

Duration

Introduction

One session of 1 hour 45 minutes with smaller breaks in between

Method

- Brainstorming
- Presentation
- Question and answer session

Material

PPT, white board and marker, audio-visual system.

Instructions for Trainer

This session will introduce participants on agroecology and regenerative agriculture. Delivery of the session will involve face-to-face presentation, demonstrations, group discussion and field visits.

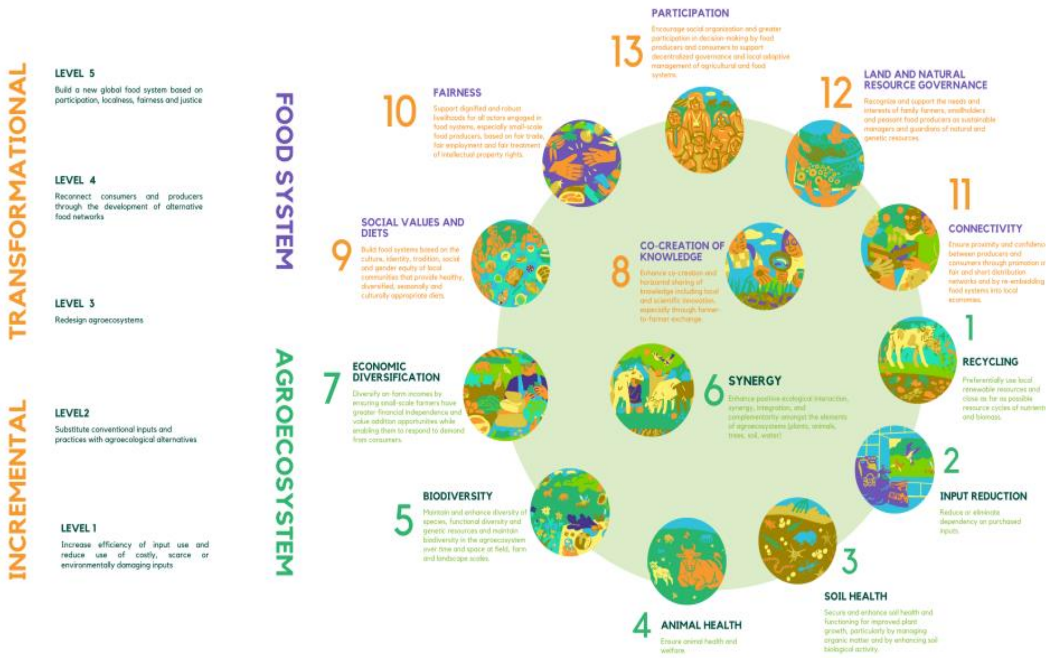


Figure 15 The 13 principles of agroecology [16]

Agroecology is sustainable farming that works with nature. Ecology is the study of relationships between plants, animals, people, and their environment - and the balance between these relationships. Agroecology represents a holistic and sustainable approach to agriculture, intertwining ecological principles with agricultural practices. It strives to enhance the resilience of farming systems, promote biodiversity, and minimize environmental impacts. Unlike conventional agriculture, which relies heavily on synthetic inputs and monoculture, agroecology embraces diversity in crops and integrates natural processes to foster soil fertility and pest control. By emphasizing local knowledge and traditional farming methods, agroecology seeks to empower farmers and communities, promoting self-sufficiency and reducing dependence on external inputs. Agroecology places a strong emphasis on the interconnectedness of ecological, social, and economic factors within a farming system. Agroecology recognizes the importance of preserving natural resources, mitigating climate change, and ensuring food security for present and future generations. As a paradigm shift in agricultural thinking, agroecology aligns with the broader goal of creating a more sustainable and resilient food system, where the well-being of the environment, farmers, and consumers are all prioritized.

Agroecology is a dynamic concept that has gained prominence in scientific, agricultural, and political discourse in recent years. It is increasingly promoted as being able to contribute to transforming food systems by applying

[16] https://www.agroecology-europe.org/the-13-principles-of-agroecology/

ecological principles to agriculture and ensuring a regenerative use of natural resources and ecosystem services while also addressing the need for socially equitable food systems within which people can exercise choice over what they eat and how and where it is produced. Agroecology embraces a science, a set of practices and a social movement and has evolved over recent decades to expand in scope from a focus on fields and farms to encompass whole agriculture and food systems. It now represents a transdisciplinary field that includes all the ecological, sociocultural, technological, economic, and political dimensions of food systems, from production to consumption.

Agroecology is the application of ecological concepts and principals in farming. Following 10 elements of agroecology are interlinked and interdependent:

1. Diversity;
2. Synergies;
3. Efficiency;
4. Resilience;
5. Recycling;
6. Co-creation and sharing of knowledge;
7. Human and social values;
8. Culture and food traditions;
9. Responsible governance;
10. Circular and solidarity economy.

describing common characteristics of agroecological systems, foundational practices and innovation

context features

enabling environment

Regenerative agriculture is an outcome-based food production system that nurtures and restores soil health, protects the climate and water resources and biodiversity, and enhances farms' productivity and profitability. Regenerative agriculture is an evolution of conventional agriculture, reducing the use of water and other inputs, and preventing Regenerative Agriculture is quite simple: it is any form of farming, ie the production of food or fibre, which at the same time improves the environment. This primarily means regenerating the soil. It’s a direction of travel, not an absolute.

For millennia, farmers have taken healthy soils and ploughed them and planted into the clean, exposed surface. For some years, their crops would grow well as there would be little competition from weeds and there would be plenty of freely available nutrients, but after a few years of this, the soil would lose health; crop yields would plummet so that the farmers were forced to rest and/or feed their land. The ancient farmers ever since have had to do this but nonetheless, over time, poor farming has resulted in soils becoming so unhealthy that they’ve eventually been blown or washed away.

A healthy soil is a fabulously complex ecosystem, comprising countless billions of microscopic organisms all working away in their own little niches, feasting on each other and sugars exuded from the roots of growing plants. The whole system is ultimately fuelled by growing plants, whilst at the same time the system helps the plants grow.

This gives us five principles to follow:

1. Don’t disturb the soil.

Soil supports a complex network of worm-holes, fungal hyphae and a labyrinth of microscopic air pockets surrounded by aggregates of soil particles. Disturbing this, by ploughing or heavy doses of fertiliser or sprays will set the system back.

2. Minimizing Soil Disturbance; Keep the soil surface covered.

The impact of rain drops or burning rays of sun or frost can all harm the soil. A duvet of growing crops, or stubble residues, will protect it.

3. Keep living roots in the soil.

In an arable rotation there will be times when this is hard to do but living roots in the soil are vital for feeding the creatures at the base of the soil food web; the bacteria and fungi that provide food for the protozoa, arthropods and higher creatures further up the chain. They also keep mycorrhizal fungi alive and thriving and these symbionts are vital for nourishing most plants and will thus provide a free fertilising and watering service for crops.

4. Adding Planting Diversity; Grow a diverse range of crops.

Ideally at the same time, like in a meadow. Monocultures do not happen in nature and our soil creatures thrive on variety. Companion cropping (two crops are grown at once and separated after harvest) can be successful. Cover cropping, (growing a crop which is not taken to harvest but helps protect and feed the soil) will also have the happy effect of capturing sunlight and feeding that energy to the subterranean world, at a time when traditionally the land would have been bare.

5. Integrating Livestock; Bring grazing animals back to the land.

This is more than a nod to the permanent pasture analogy, it allows arable farmers to rest their land for one, two or more years and then graze multispecies leys. These leys are great in themselves for feeding the soil and when you add the benefit of mob-grazed livestock, it supercharges the impact on the soil.

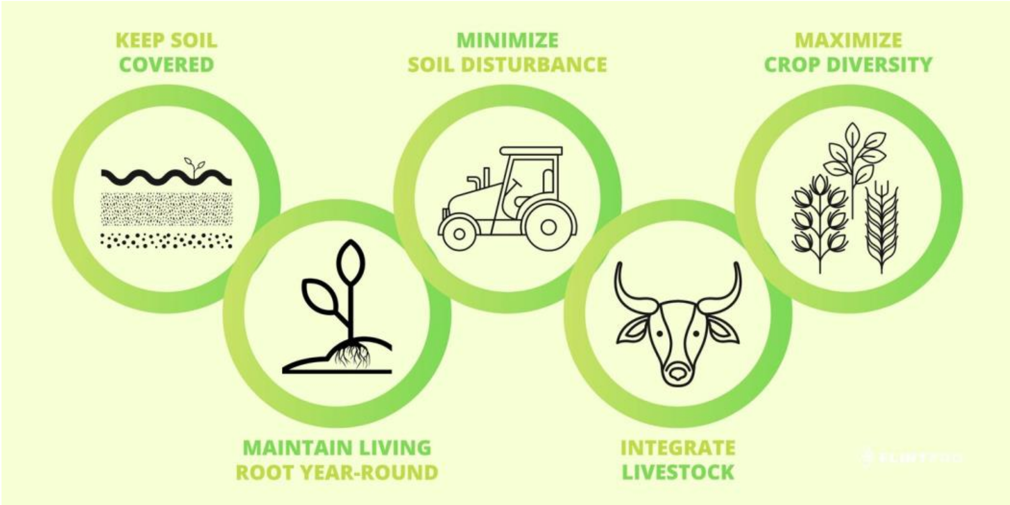


Figure 16 Regenerative agriculture average climate adaptation benefits [17]

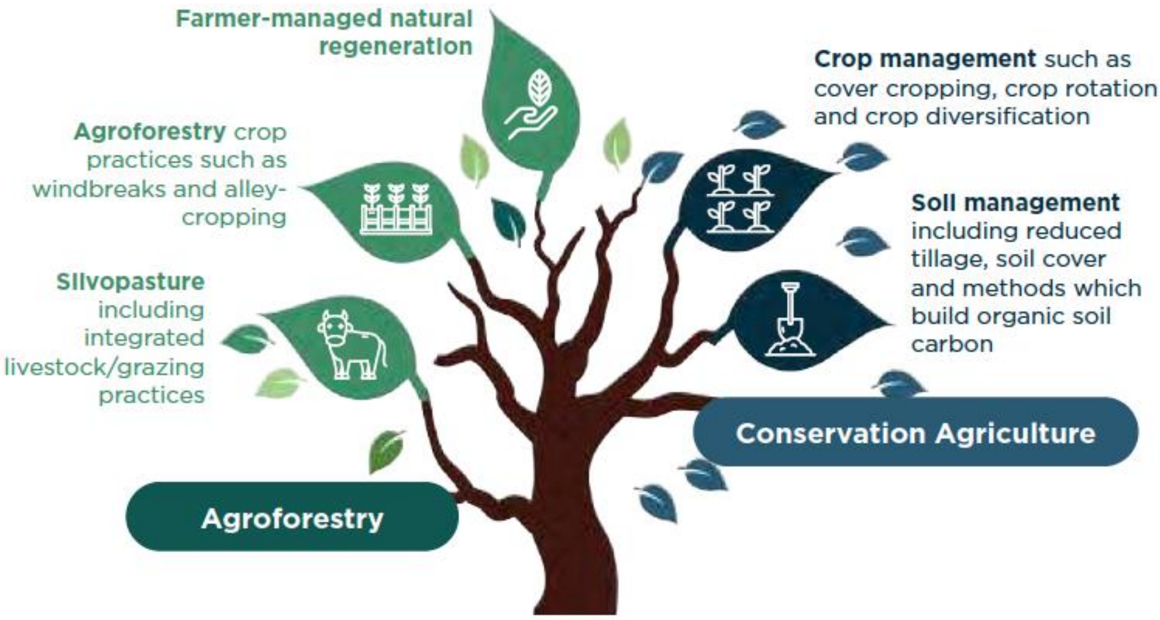


Figure 17 Regenerative agriculture average climate adaptation benefits [18]

It comprises a range of techniques, supported by innovative technologies, which can combat the challenges cause by climate change by restoring the health of soil and protecting the land's ecosystem. Some of the approaches to regenerative agriculture include:

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[17] https://learnlifescience.com/regenerative-food-production-a-sustainable-food-production-method/

[18] https://www.iucn.org/news/nature-based-solutions/202110/regenerative-agriculture-works-new-research-and-african-businesses-show-how

1. **Cover Cropping:** it involves the deliberate planting of specific crops during non-growing seasons. Cover crops prevent erosion, suppress weeds, and enhance soil fertility by fixing nitrogen and adding organic matter. The roots of cover crops contribute to soil structure, reducing compaction and promoting water retention. Beyond these soil benefits, cover cropping supports biodiversity and provides habitat for beneficial insects. This practice exemplifies a proactive approach to sustainable farming, fostering resilient ecosystems and contributing to the overall health and productivity of agricultural landscapes.
2. **Crop Rotation:** it involves systematically changing the types of crops grown in a specific area over time thereby maintaining soil fertility, managing pests, and preventing diseases. By alternating plant species, the nutritional needs of the soil are balanced, reducing the risk of nutrient depletion. Crop rotation disrupts the life cycles of pests and pathogens, limiting their impact. Additionally, diverse crops contribute to a healthier ecosystem, promoting biodiversity and reducing the need for chemical inputs. This time-tested technique enhances soil structure, fosters sustainable agriculture, and supports the long-term productivity of farmland. Rotating crops diversities helps break pest and disease cycles, improves soil structure, and enhances nutrient cycling. Diverse crop rotations contribute to a more resilient and sustainable agricultural system.
3. **No-Till or minimum tillage:** these are environmentally conscious agricultural practice that minimizes soil disturbance during planting. Unlike traditional plowing, which disrupts the soil structure, no-till preserves the natural composition as it involves planting seeds directly into untilled soil, reducing erosion, conserving moisture, and promoting soil health. By leaving crop residues on the field, no-till enhances organic matter, fosters microbial activity, and sequesters carbon. This method not only conserves energy and reduces greenhouse gas emissions but also contributes to sustainable farming practices, ensuring long-term soil fertility and resilience in the face of changing environmental conditions.
4. **Agroforestry:** this is an innovative land-use system that combines the cultivation of trees or shrubs with traditional agricultural crops or livestock. This sustainable approach maximizes the benefits of a diverse ecosystem, offering multiple outputs such as timber, fruits, and forage. The integration of trees provides shade, reduces soil erosion, and enhances biodiversity. Agroforestry systems contribute to climate resilience by sequestering carbon and improving soil fertility. This practice promotes sustainable land management, fostering a balance between agricultural productivity and environmental conservation. Agroforestry stands as a tangible solution, exemplifying the coexistence of agriculture and forestry for a more sustainable and resilient future.
5. **Holistic Grazing Management/ Regenerative Grazing:** By mimicking natural grazing patterns, regenerative grazing promotes soil fertility, biodiversity, and carbon sequestration. Livestock are rotated strategically, allowing pastures to recover, and prevent overgrazing. This

method fosters resilient landscapes, improves water retention, and reduces the need for external inputs. Regenerative grazing not only supports the well-being of animals but also contributes to sustainable land management, mitigating environmental degradation and fostering a harmonious balance between agriculture and the ecosystems it relies upon. Implementing holistic and planned grazing practices for livestock can improve soil health, increase carbon sequestration, and enhance the overall sustainability of animal agriculture.

6. **Composting, mulching, and organic amendments:** Composting, mulching, and organic amendments are cornerstones of sustainable agriculture, fostering soil health and productivity. Composting involves the decomposition of organic matter into nutrient-rich humus, enhancing soil structure and fertility. Mulching involves the application of organic materials on the soil surface, conserves moisture, suppresses weeds, and moderate temperature fluctuations. Organic amendments such as manure or composted materials enrich soil with essential nutrients. Together, these practices promote water retention, reduce erosion, and create a thriving ecosystem in which beneficial microorganisms flourish. These techniques also promotes microbial activity and helps sequester carbon in the form of stable organic compounds.
7. **Water Conservation Techniques:** Implementing water-saving techniques, such as rainwater harvesting, drip irrigation, and soil moisture management, can help build resilience to changing climate conditions and reduce the environmental impact of agriculture. Rainwater harvesting, a key strategy, involves collecting and storing rain runoff for later use in irrigation. Drip irrigation systems precisely deliver water to plants, minimizing wastage. Cover cropping and mulching reduce evaporation, retaining soil moisture. Soil moisture sensors aid in optimizing irrigation schedules, preventing overuse. Agroforestry, incorporating trees into farming, helps create a microclimate conducive to water retention. These techniques collectively enhance water efficiency, enabling agricultural systems to withstand periods of drought and contribute to building resilience in the face of changing climate patterns.
8. **Integrated Pest Management (IPM):** Instead of relying solely on chemical pesticides, IPM incorporates a combination of biological, cultural, and mechanical strategies to control pests and diseases. By utilizing natural predators, optimizing planting schedules, and employing preventive measures, IPM minimizes the need for harmful chemicals. This integrated approach enhances crop health, reduces environmental impact, and preserves beneficial organisms. IPM emphasizes long-term solutions, aiming for a balanced ecosystem where pest populations are managed without compromising the health of the environment, crops, or the overall agricultural system. This approach supports biodiversity and maintains a balance in the ecosystem.
9. **Polyculture and Diversification:** Polyculture involves cultivating multiple plant species in the same field, promoting biodiversity and

ecological balance. In contrast to monoculture, where a single crop dominates, polyculture mimics natural ecosystems, reducing susceptibility to pests and diseases. This method enhances soil fertility, as different crops complement each other, utilizing resources more efficiently. Polyculture mitigates environmental impacts, encourages natural pest control, and fosters resilient agricultural systems. Farmers benefit from diversified yields, reduced risk of crop failure, and increased economic stability. Embracing the principles of harmony and diversity, polyculture exemplifies a holistic and environmentally conscious approach to farming. Planting a variety of crops in the same area promotes biodiversity, reduces the risk of crop failure, and enhances ecosystem services. Polyculture also supports a more complex food web, including beneficial insects and microorganisms.

10. **Biochar Application:** Biochar is a carbon-rich material produced by heating biomass in a low-oxygen environment, a process known as pyrolysis. When incorporated into soil, biochar enhances fertility, water retention, and nutrient availability. It acts as a carbon sink, sequestering carbon and mitigating climate change. Moreover, biochar contributes to soil health by promoting microbial activity and reducing the need for synthetic fertilizers. Its porous structure provides a habitat for beneficial microorganisms, fostering a resilient and sustainable approach to agriculture while addressing environmental challenges such as carbon emissions and soil degradation. Integrate biochar, a stable form of carbon produced from organic materials, into the soil to enhance fertility and sequester carbon for the long term.
11. **Integrated Crop-Livestock Systems:** Combine crop and livestock farming to create synergies, optimize resource use, and improve overall sustainability of agricultural systems.

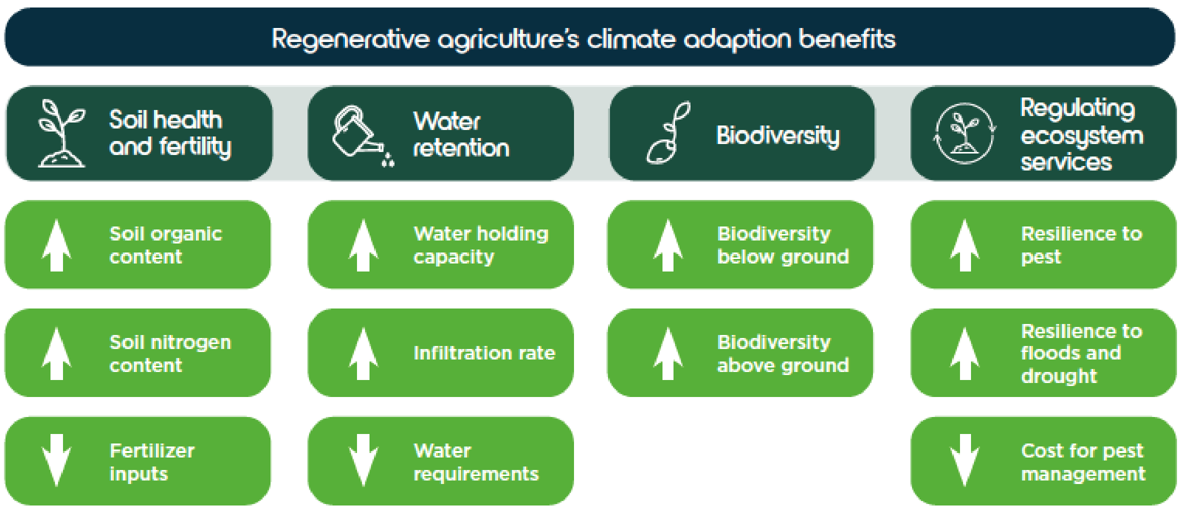

Figure 418: Regenerative agriculture average climate adaptation benefits

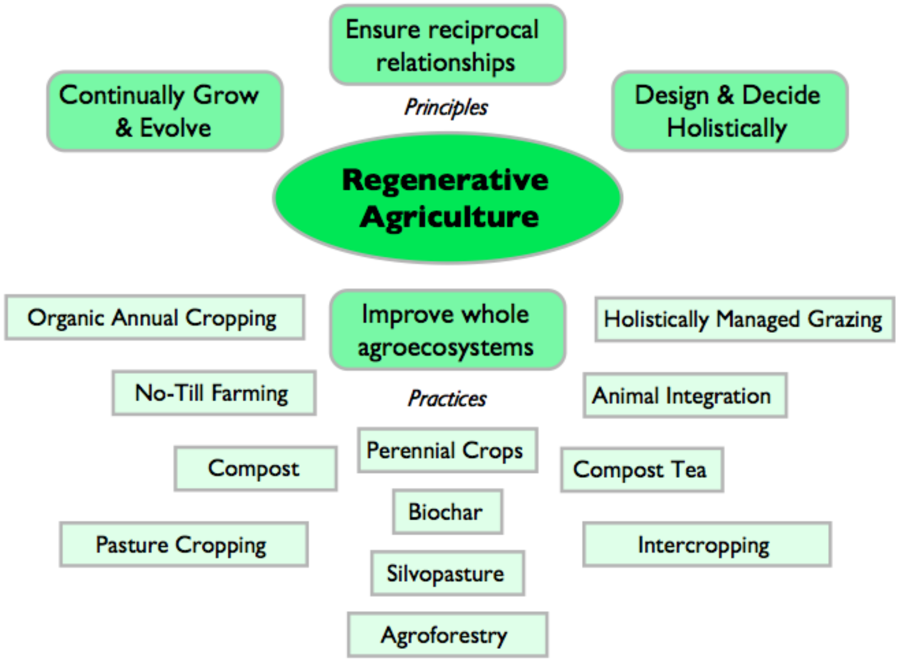

Figure 19 Regenerative agriculture average climate adaptation benefits [19]

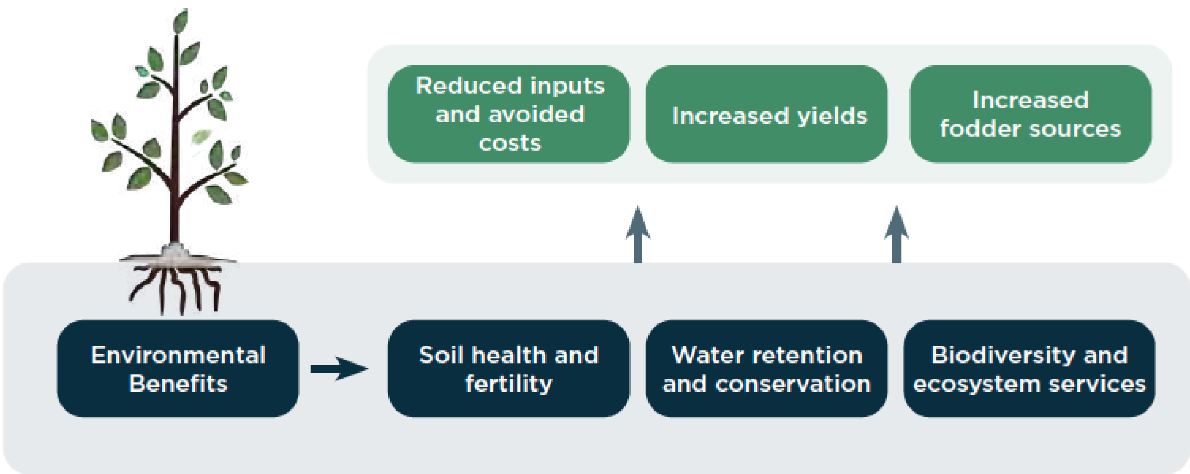

Figure 520: Benefits of regenerative agriculture at the farmer level

[19] https://learnlifescience.com/regenerative-food-production-a-sustainable-food-production-method/

Link between regenerative agriculture and agroecology

Agroecology and regenerative agriculture share a symbiotic relationship, both championing practices that prioritise ecological health and sustainability. Agroecology aligns seamlessly with the principles of regenerative agriculture. Agroecology integrates ecological principles into agriculture, emphasizing biodiversity and natural processes while regenerative agriculture takes this a step further by focusing on restoring and enhancing the health of the entire ecosystem. Both approaches emphasize soil health, biodiversity, and minimizing external inputs. Through agroecological practices, such as cover cropping and crop rotation, regenerative agriculture seeks to restore and enhance soil fertility, sequester carbon, and promote resilience in the face of climate change. Together, agroecology and regenerative agriculture form a harmonious alliance that contributes to building a more sustainable and regenerative future for agriculture.

Some of the similarities between agroecology and regenerative agriculture

1. Holistic Approach: Both agroecology and regenerative agriculture adopt holistic approaches, considering the entire ecosystem and its interconnected components rather than focusing solely on individual crops or livestock.
2. Biodiversity Emphasis: Both systems prioritize the importance of biodiversity in agricultural landscapes, recognizing that diverse ecosystems are more resilient and productive.
3. Soil Health Focus: Agroecology and regenerative agriculture share a common emphasis on improving and maintaining soil health through practices such as cover cropping, minimal tillage, and the use of organic matter.
4. Reduced Chemical Inputs: Both approaches advocate for minimizing the use of synthetic chemicals, pesticides, and fertilizers, promoting natural and sustainable alternatives.
5. Local Knowledge Integration: Agroecology and regenerative agriculture value local knowledge and traditional farming practices, emphasizing the importance of community involvement and understanding regional ecosystems.
6. Water Conservation: Both systems recognize the importance of responsible water management, seeking to conserve water resources through practices like rainwater harvesting, efficient irrigation methods, and soil conservation.
7. Climate Resilience: Agroecology and regenerative agriculture aim to build climate-resilient farming systems, adapting to and mitigating the impacts of climate change through sustainable practices.
8. Community Empowerment: Both approaches promote the empowerment of local communities, encouraging farmer participation and decision-making in agricultural processes.
9. Economic Viability: Agroecology and regenerative agriculture consider the economic sustainability of farming practices, aiming to create viable and profitable agricultural systems that benefit farmers and local economies.
10. Long-Term Sustainability: Both systems share a commitment to long-term sustainability, seeking to balance ecological, social, and economic factors to ensure the continued health

and productivity of agricultural systems.

While agroecology and regenerative agriculture share common principles, there are distinctions in their focus and implementation. Here are 10 differences between the two:

1. Scope of Focus:

   Agroecology: Emphasizes the integration of ecological principles into agriculture, considering the social and economic aspects of farming systems.

   Regenerative Agriculture: Specifically focuses on practices that actively regenerate and restore the health of the entire ecosystem, with a strong emphasis on soil health.

2. Philosophical **background**:

   Agroecology: Rooted in agroecological science, which studies the interactions between ecological processes and agricultural systems.

   Regenerative Agriculture: Primarily grounded in the goal of actively improving and regenerating the land, often drawing inspiration from holistic management principles.

3. Scale of **application**:

   Agroecology: Can be applied at various scales, from small-scale subsistence farming to large industrial agriculture, with a focus on adapting to local contexts.

   Regenerative Agriculture: Often associated with smaller-scale, holistic farming systems that prioritize direct land management practices for regeneration.

4. Management Practices:

   Agroecology: Encompasses a broad range of practices, including diverse cropping systems, integrated pest management, and agroforestry.

   Regenerative Agriculture: Places a strong emphasis on specific practices such as cover cropping, rotational grazing, and minimal tillage as means to actively regenerate the land.

5. Timeframe of Implementation:

   Agroecology: Generally, considers both short-term and long-term strategies for sustainable farming practices.

   Regenerative Agriculture: Often focuses on immediate and visible improvements to the land while maintaining a long-term perspective.

6. Economic **emphasis**:

   Agroecology: Considers economic viability within a broader context, including social and ecological dimensions.

   Regenerative Agriculture: While also concerned with economic viability, places a particular emphasis on the economic benefits derived from regenerating the land.

7. Adaptation to Climate Change:

   Agroecology: Adapts farming systems to climate change through diverse and resilient agricultural practices.

Regenerative Agriculture: Often framed as a response to climate change, with an explicit focus on carbon sequestration and mitigation.

8. Perception of Technology:

   Agroecology: May incorporate modern technology where appropriate but tends to prioritize traditional and indigenous knowledge.

   Regenerative Agriculture: Often embraces a mix of traditional and modern technologies, focusing on practices that actively restore ecological balance.

9. Certification and **standardization**:

   Agroecology: Has a diverse range of practices and lacks a standardized certification system.

   Regenerative Agriculture: Some systems have developed specific certification standards, providing guidelines for farmers practicing regenerative methods.

10. Global vs. Local Emphasis:

    Agroecology: Emphasizes adaptability to local contexts, with practices tailored to specific ecosystems and communities.

    Regenerative Agriculture: While also adaptable, has gained attention as a global movement with shared principles and practices promoted across various regions.

Five reasons why farmers have to change to regenerative farming:

1. We are putting carbon into the atmosphere rather than storing it in the soil (carbon sequestering)
2. We are losing 0.3% of our soil per year. That amounts to 30% in the last 100 years
3. We are producing nutrient-poor food
4. Our health is suffering
5. We are using ten times more energy to produce our food than the energy the food contains