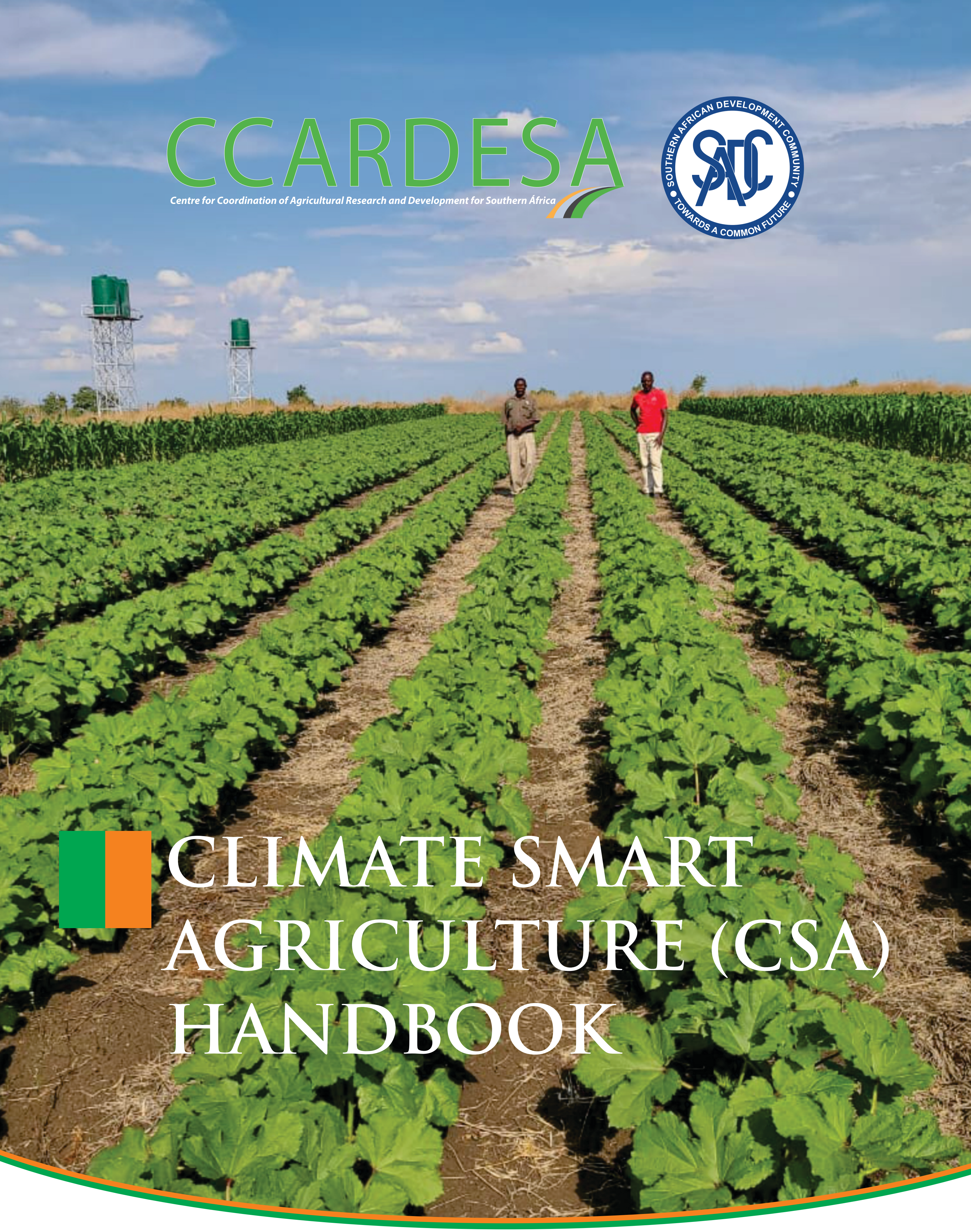

CCARDESA

Centre for Coordination of Agricultural Research and Development for Southern Africa

SOUTHERN AFRICAN DEVELOPMENT COMMUNITY
SADC
TOWARDS A COMMON FUTURE

# CLIMATE SMART AGRICULTURE (CSA) HANDBOOK

GCCA+ THE GLOBAL CLIMATE CHANGE ALLIANCE PLUS INITIATIVE
Funded by the European Union
CGIAR
AICCRA Accelerating Impacts of CGIAR Climate Research for Africa
bembani GROUP (PTY) LIMITED
SACREEE SADC CENTRE FOR RENEWABLE ENERGY & ENERGY EFFICIENCY

## FOREWORD

The realisation of the Southern African Development Community's (SADC) goals of regional integration, job and wealth creation, food and nutritional security and environmental well-being cannot be achieved in the absence of climate change adaptation and mitigation. SADC is one of the world's most vulnerable regions to climate change and has been referred to as a 'hotspot'. The SADC region is adversely affected by climate-change-related weather extremes, including unpredictable rainfall, drought, floods, heat waves and strong winds, which have impacted food and nutritional security, and livelihoods and driven people further into hunger and poverty. Considering the transboundary nature of resources and climate-change-related risks, SADC can be key in coordinating and supporting member states' responses to climate change and strengthening their capacities.

While agriculture is a key contributor to greenhouse gas (GHG) emissions, accounting for 19-29% of GHG emissions, it remains the region's major vehicle for achieving socio-economic transformation. However, it is also very sensitive to climate change. Most farmers in the SADC are smallholder farmers living in rural areas and depending on rainfed agriculture for their livelihoods and food security. In balancing the need to increase agricultural productivity and incomes under climate change with minimising trade-offs with environmental health and sustainability, adopting approaches that recognise the nexus between water, energy, food, and the environment is necessary.

Climate Smart Agriculture (CSA) aims to sustainably increase agricultural productivity and incomes without harming the environment and sustainability. The CSA approach also aims to enhance livelihoods and food and nutritional security, especially of smallholder farmers, by improving the management and use of natural resources and adopting appropriate technologies and practices for producing, processing and marketing agricultural goods. This makes CSA a strong, compelling business case, as CSA is as much about development as it is a viable business.

Key attributes of CSA include facilitating sustainable agricultural productivity and income increase under climate change through integrated landscape approaches that uphold sound environmental, land and water management principles. This is achieved through various methods and approaches, such as sustainable intensification, improved agricultural water and energy productivity, improved land and soil management practices, and diversification of farming systems. CSA, therefore, contributes to the economic, social and environmental dimensions of sustainable development, thereby promoting sustainable development (economic, social and environmental) by jointly addressing food and nutritional security and climate change.

This Climate Smart Agriculture (CSA) Handbook is an important resource for use by CSA practitioners in providing training, policy advocacy, and upscaling CSA technologies and practices for improving sustainable productivity and adapting to and mitigating climate change. It is informed by up-to-date climate change and CSA knowledge, experiences and lessons learnt across the region, making it relevant to the region's context and development agenda. It addresses productivity, adaptation/resilience, mitigation and clean energy sources and proposes best-bet solutions for supporting the SADC's food security and sustainable development ambitions. It is, therefore, a knowledge product for transforming agriculture production and fostering socio-economic and socio-ecological sustainability under climate change. Uptake, adoption and scaling of CSA technologies and practices will build the resilience of smallholder farmers in the SADC region, enhancing livelihoods and incomes, food and nutritional security and sustainable development of smallholder farmers under climate change.

Achieving the goals of CSA will require a transformational shift that considers its multi-objectives, intersectionality, and cross-sectorial nature and fosters novel, integrated and cross-scale solutions that are bespoke and respond to specific local conditions. This should be done within the context of promoting local solutions to global challenges. Coordination within agriculture (e.g. crops, livestock, forestry and fisheries) and other sectors, such as water, energy, environment and health, is essential to integrate CSA into existing planning frameworks, harness potential synergies, and minimise trade-offs and optimise the use of natural resources and ecosystem services. Therefore, this handbook is an important knowledge product for enabling the inherent potential of agriculture for sustainable and resilient livelihoods, value creation, biodiversity integrity and building climate change resilience that promotes the SADC region's developmental goals, green growth and investment ambition.

**H.E. Mr Elias M. Magosi**
**Executive Secretary**

## PREFACE

The CSA handbook was developed as a reference material for front-line extension agents, environmentalists, and researchers in providing the best bet CSA solutions to the communities. The handbook outlines the best bet CSA technologies. Innovations and management practices apply to the SADC region and are adaptable under varying agroecological conditions. The Center for Coordination of Agricultural Research and Development in Southern Africa (CCARDESA) led to the development of the manual in response to the demands from stakeholders responsible for enhancing agricultural productivity while mitigating and adapting to the effects of climate change. The manual avails CSA solutions applicable to the SADC region, where the effects of climate change significantly impact the GDPs of most member states.

National governments recognize the role of CCARDESA in coordinating agricultural research and development in the region. Technologies and good agricultural practices (GAPs) are generated and disseminated for farmers to adopt and improve their yield. National and international agricultural research centers have developed various promising CSA technologies. Farmers themselves have also developed production practices that can be accepted as GAP. However, there has been inadequate adoption and slow pace in upscaling the technologies for several reasons, including inadequate access to simplified reference CSA materials, high cost of agricultural inputs, and inadequate extension services. There is also inadequate coordination, cooperation, and commitment between and from the public as well as private sector stakeholders. This has resulted in the 'localized' use of the CSA practices and has not benefited many people as desired. CCARDESA felt the need to avail good agricultural practices not only under present circumstances but also robust enough to hold up under changing climatic conditions; as such, the CSA handbook was envisioned to be critical in addressing the impacts of Climate Change in agriculture. Promoting CSA includes getting existing technologies off the shelf and into the hands of farmers and developing new technologies, such as drought or flood-tolerant crops, to meet the demands of the changing climate. There are many technologies and practices "on the shelf," but the scale and speed of climate change require considerable investment in filling knowledge gaps and in research. This includes the development of decision-support tools to prioritize adaptation and mitigation actions and investments, and further work on institutions and incentives that work for farmers (e.g., payments for environmental services such as soil carbon sequestration).

CCARDESA facilitated the development of the handbook through the Global Climate Change Plus (GCCA+) project, funded by the European Union (EU), and through the Accelerating Impacts of CGIAR Climate Research for Africa (AICCRA) project, which the World Bank funded.

Specialists with diverse practical, research, and academic experience drafted different sections of the manual. The views expressed in this manual, therefore, are those of the contributors and do not necessarily imply the views or policies of CCARDESA. The designations employed and the presentation of material in this handbook do not imply the expression of any opinion whatsoever on the part of CCARDESA concerning the legal or development status of any country, territory, area, or boundaries. This work may be copied, redistributed, and adapted for non-commercial purposes, provided that the work is appropriately cited. CCARDESA welcomes comments and reviews through the Executive Director, Professor Cliff Dlamini (cdlamini@ccardesa.org). The comments will be addressed in the subsequent versions of the manual.

**Prof. Cliff Sibusiso Dlamini (Ph.D., MDevF., EMBA., CDFA)**
**Executive Director and Head of Mission**

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## PURPOSE AND TARGETED AUDIENCE

This Climate Smart Agriculture (CSA) handbook has been developed as **a resource material for use by CSA practitioners in providing training, policy advocacy, and upscaling CSA technologies and practices for improving sustainable productivity, adapting to the effects of climate change, and mitigating climate change**. The handbook is structured in a manner that covers key aspects of climate-smart agriculture, CSA working definition, including the effects of climate change, CSA technologies for increasing productivity, enhancing adaptation and resilience, mitigation, considerations for clean energy and the scaling up of CSA technologies have been. Respective chapters have covered issues of productivity, adaptation/resilience, mitigation and clean energy sources, and best bets suitable for supporting SADC countries' food and sustainable development ambition. The choice of best bets was based on observed evidence so far on how effective the CSA technologies and practices address the three pillars of CSA, given the experiences acquired from the countries of the SADC region over time.

The preparation of the handbook was thus informed by existing CSA knowledge, experiences and lessons learnt across the regions on CSA and the implication of climate change. It is envisaged that the handbook will serve as a knowledge asset that inspires the transformation of agriculture production and foster social-economic and environmental wellbeing. It is envisaged that the uptake of respective CSA approaches will impact smallholder farmers in the SADC region in a manner that unlocks the potential and value of the agriculture sector for food, nutrition, livelihoods and green growth. It will directly inspire improved livelihood, food and nutritional security, local community incomes and sustainable development of small holder farmers who face the impact of climate change.

The handbook serves as an important knowledge asset that builds on the existing knowledge on CSA and its use as an enabler for unlocking inherent worth in the agriculture sector for broad-based improved livelihood, value creation, biodiversity integrity and climate change resilience that rewards development and investment ambition.

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## GLOSSARY OF TERMS

***Adaptation:*** The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to the expected climate and its effects.

***Adaptive capacity***: The ability of systems, institutions, humans, and other organisms to adjust to potential damage, take advantage of opportunities or respond to consequences

***Adoption*** is the continued use of a new technology or practice that is beneficial to the targeted agricultural system.

***Approach*** is a way of implementing technologies and practices that address identified challenges.

***Climate (change) scenario:*** A plausible and often simplified representation of the future climate based on an internally consistent set of climatological relationships and assumptions of radiative forcing, typically constructed for explicit use as input to climate change impact models.

***Climate change***: Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forces such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or land use.

***Climate data***: Historical and real-time climate observations and direct model outputs covering historical and future periods.

***Climate extreme*** (extreme weather or climate event): The occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable. For simplicity, both extreme weather and climate events are collectively referred to as 'climate extremes.'

***Climate Information Services***: Refers to the packaging and disseminating of climate information to specific users. It will involve collecting and distributing climate data, including temperature, rainfall, wind, soil moisture, ocean conditions and extreme weather indicators. This will allow policymakers to make the most informed decisions, and governments to involve evidence-based information and climate policies in their planning. It will also allow users to plan and prepare the most suitable strategies for their particular endeavour and no longer have to be at the mercy of an erratic climate.

***Climate model:*** A numerical representation of the climate system based on the physical, chemical, and biological properties of its components, their interactions and feedback processes, and accounting for all or some of its known properties. The climate system can be represented by models of varying complexity (differing in such aspects as the number of spatial dimensions, the extent to which physical, chemical, or biological processes are represented etc.). Coupled Atmosphere-Ocean General Circulation Models (AOGCMs) provide a comprehensive representation of the climate system. More complex models include active chemistry and biology. Climate models are applied, as a research tool, to study and simulate the climate, but also for operational purposes, including monthly, seasonal, and interannual climate predictions.

***Climate projection:*** A climate projection is the simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases and aerosols, generally derived using climate models. Climate projections are distinguished from climate predictions by their dependence on the emission/concentration/radiative-forcing scenario used, which is, in turn, based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized.

***Climate service***: Providing climate information to assist individuals and organisations in decision-making. A service requires appropriate engagement and an effective access mechanism and must respond to user needs (WMO GFCS Implementation Plan).

***Climate Smart Agriculture (CSA)*** is a concept that aims at sustainably increasing agricultural productivity and incomes, adapting and building resilience to climate change, and reducing greenhouse gas emissions.

***Climate system:*** The climate system is a highly complex system consisting of five major components: the atmosphere, the hydrosphere, the cryosphere, the lithosphere, and the biosphere, and the interactions among them. The climate system evolves under the influence of its internal dynamics and because of external forces such as volcanic eruptions, solar variations, and anthropogenic forces such as the changing composition of the atmosphere and land-use change.

***Climate variability:*** Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability) or variations in natural or anthropogenic external forcing (external variability).

***Climate***: Climate, in a narrow sense, is usually defined as the average weather or, more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization.

***Conservation agriculture (CA)*** is a crop and land management system based on three principles – minimum soil disturbance, crop residue retention, and crop diversification – among other complimentary good agricultural practices needed to support its functioning.

***Crop rotation*** is a practice by which different crop species are alternated by fields or years.

***Disaster risk reduction:*** Mechanism for preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and achieving sustainable development.

***Disaster***: Severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions. These may lead to widespread adverse human, material, economic, or environmental effects requiring an immediate emergency response to satisfy critical human needs and external recovery support.

***Drought (meteorological)***: A period of abnormally dry weather long enough to cause a serious hydrological imbalance. Drought is a relative term; therefore, any discussion in terms of precipitation deficit must refer to the particular precipitation-related activity that is under discussion

***Early warning system***: An integrated system of hazard monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities, systems and processes that enable individuals, communities, governments, businesses and others to take timely action to reduce disaster risks in advance of hazardous events.

***El Niño Southern Oscillation (ENSO)***: El Niño, in its original sense, is a warm-water current that periodically flows along the coast of Ecuador and Peru, disrupting the local fishery. This oceanic event is associated with fluctuating the intertropical surface pressure pattern and circulation in the Indian and Pacific Oceans, called the Southern Oscillation. This coupled atmosphere-ocean phenomenon is called El Niño Southern Oscillation or ENSO. During an El Niño event, the prevailing trade winds weaken, and the equatorial counter current strengthens, causing warm surface waters in the Indonesian area to flow eastward to overlie the cold waters of the Peru current. This event greatly impacts the wind, sea surface temperature, and precipitation patterns in the tropical Pacific. It has climatic effects throughout the Pacific region and many other parts of the world. The opposite of an El Niño event is called La Niña.

***Exposure:*** The situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas. Measures of exposure can include the number of people or types of assets in an area. These can be combined with the specific vulnerability and capacity of the exposed elements to any particular hazard to estimate the quantitative risks associated with that hazard in the area of interest.

***Extreme weather event***: An extreme weather event is an event that is rare at a particular place and time of year. Definitions of rare vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of a probability density function estimated from observations. By definition, the characteristics of extreme weather may vary from place to place in an absolute sense.

***Good Agricultural Practices (GAPs)*** are practices that promote the sustainable production of quality and safe food and non-food agricultural products, while maintaining environmental, economic, and social sustainability.

***Hydrometeorological hazards***: These are those of atmospheric, hydrological or oceanographic origin. Examples are tropical cyclones (also known as typhoons and hurricanes); floods, including flash floods; drought; heatwaves and cold spells; and coastal storm surges. Hydrometeorological conditions may also be a factor in other hazards such as landslides, wildland fires, locust plagues, epidemics and the transport and dispersal of toxic substances and volcanic eruption material.

***Impacts (of climate change)***: Effects on natural and human systems. In this report, the term impact refers primarily to the effects on natural and human systems of extreme weather, climate events, and climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure.

***Infrastructure:*** The basic equipment, utilities, productive enterprises, installations and services essential for the development, operation and growth of an organisation, city or nation.

***Integrated Pest Management*** is carefully considering all available pest control techniques (biological, chemical, physical, cultural) and the subsequent integration of appropriate measures that discourage the development of pest populations. It minimizes the use of pesticides, reducing or minimizing risks posed by pesticides to human health and the environment for sustainable pest management.

***Integrated Soil Fertility Management (ISFM)*** is a set of soil fertility management practices that combines mineral fertilizer, organic inputs and improved crop varieties.

***Intercropping*** is the practice of growing two or more crops simultaneously on the same piece of land.

***Intertropical Convergence Zone (ITCZ)***: This is the region that circles the Earth near the equator, where the trade winds of the Northern and Southern Hemispheres come together. The intense sun and warm water of the equator heat the air in the ITCZ, raising its humidity and making it ascent, expand and cool, releasing the accumulated moisture in an almost perpetual series of thunderstorms.

***Minimum tillage*** is a practice which decreases soil disturbance by reducing tillage and excessive mixing of soil horizons.

***Mitigation***: A human intervention to reduce the sources or enhance the sinks of greenhouse gases.

***Multi-hazard***: Refers to (1) the selection of multiple major hazards that the country faces; and (2) the specific contexts where hazardous events may occur simultaneously, cascadingly or cumulatively over time, and taking into account the potential interrelated effects. Hazards include (as mentioned in the Sendai Framework for Disaster Risk Reduction 2015-2030, and listed in alphabetical order) biological, environmental, geological, hydrometeorological and technological processes and phenomena.

***Nationally Determined Contribution:*** A climate action plan to cut emissions and adapt to climate impacts. Each Party to the Paris Agreement is required to establish an NDC and update it every five years.

***Practice*** is a collection of principles or methods applied to producing better agricultural products.

***Projection:*** A projection is a potential future evolution of a quantity or set of quantities, often computed with the aid of a model. Unlike predictions, projections are conditional on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized. Also, see Climate prediction and Climate projection.

***Reach*** refers to the exposure/access to an approach, practice or technology; it is a pre-requisite to adoption.

***Resilience*** to climate change is the ability to prepare for, respond to, and recover from the harmful impacts of climatic events.

***Resilience:*** The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.

***Risk:*** The potential of consequences where something of value is at stake, and the outcome is uncertain, recognising the diversity of values. Risk is often represented as the probability of the occurrence of hazardous events or trends multiplied by the impacts of these events or trends occurs.

***Scenario:*** A plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of technological change, prices) and relationships.

***Semi-arid regions:*** Ecosystems with more than 250 mm precipitation per year but are not highly productive; usually classified as rangelands.

***Soil and Water Conservation (SWC)*** is a practice that sustainably enhances land productivity, nutrition, and natural resources such as soil water and plant health and capacity.

***Stakeholders:*** Person or entity holding grants, concessions, or any other type of value that would be

***Technology*** is a method, system, or tool scientifically developed for practical purposes to address challenges in agriculture.

***Tropical cyclone is the general term for a strong, cyclonic-scale disturbance originating*** over tropical oceans. Distinguished from weaker systems (often named tropical disturbances or depressions) by exceeding a threshold wind speed. A tropical storm is a cyclone with one-minute average surface winds between 18 and 32 m/ s. Beyond 32 m/ s, a tropical cyclone is called a hurricane, typhoon, or cyclone, depending on geographic location.

***Vulnerability:*** The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.

***Water harvesting*** is collecting and storing rainwater and runoff for future use in crop and livestock production.

***Watershed*** is a land area that drains water into one common point

## CLIMATE SMART AGRICULTURE AND CLIMATE CHANGE NEXUS

This section discusses long-term climate change threats to the livelihoods' food security and sustainable development of people in the southern African region. It is important to appreciate the nexus of climate change and agriculture in southern Africa as the region is highly vulnerable to climate variability and change. This vulnerability is compounded by social, economic and environmental factors as well as the low adaptive capacity of the people in the region. Projections show temperature increases due to human-induced climate change of between 1°C and 3°C over the larger part of the region by 2060. Increased annual heat wave frequency and climate variability have also been detected.

According to the IPCCC assessment report, sub-Saharan Africa is a rapidly developing region with a population of about 900 million, characterised by wide ecological, climatic and cultural diversity. In the recent past, six (6) of the ten (10) fastest-growing economies in the world are in Africa. Although the growth in these economies started from a relatively low base, the current rate of economic development is on a growth trajectory. It has overcome the challenges of three decades of poor development performance, conflict and economic marginalisation. Nonetheless, it is critical to recognise that Africa's growth is fragile and requires a resilient green growth pathway. There is no doubt that real economic transformation is yet to take root. A significant aspect of Africa's vulnerability lies in the fact that recent development gains have been in climate-sensitive sectors, as highlighted in the IPCCC 5$^{th}$ assessment report.

Africa's growing population will increase the demand for water and food. On the other hand, prolonged droughts will put additional pressure on already scarce water resources and reduce crop yields. These risks could intensify under a changing climate without adequate adaptation measures. Consistent with IPCC observations, some of the major crops in Africa are highly sensitive to changes in temperature. They, thus, are likely to have reduced yields of major cereal crops across Africa.

Climate variability and change present long-term threats and negative impacts on people's livelihoods in southern Africa. This vulnerability is compounded by social, economic and environmental factors as well as the low adaptive capacity of the people in the region. Climate change increases risk and uncertainty in the region resulting from the impacts of changes in temperatures and rainfall patterns that have a bearing on increased water scarcity, pest infestations, and increased frequency and occurrence of drought and floods. Climate change-associated extreme weather events such as floods, droughts, and cyclones further exacerbate people's vulnerabilities in the region characterized by low adaptive capacity.

Climate Smart Agriculture (CSA) is an approach that supports identifying the most suitable strategies with national and local priorities and conditions by building on existing knowledge, technologies, and principles of sustainable agriculture. Climate-smart agriculture addresses climate change while systematically considering the synergies and trade-offs between productivity, adaptation and mitigation. Climate-smart agriculture also aims to capture new funding opportunities to close the deficit in government investments. Nevertheless, there is no such thing as an agricultural practice that is climate-smart per se. Whether or not a particular practice or production system is climate-smart depends upon the particular local climatic, biophysical, socio-economic and development context, which determines how far a particular practice or system can deliver on productivity increase, resilience building and mitigation benefits.

## CHAPTER 1: THE REGIONAL PERSPECTIVE OF CLIMATE-SMART AGRICULTURE

Africa's growing population, coupled with climate variability and change, puts immense pressure on the need for improved food productivity, security, and overall resilience of smallholder farming systems. According to Stockholm International Peace Research Institute (Solna, Sweden), southern Africa remains one of the world's most vulnerable regions to climate change. The impacts include; droughts, floods and tropical cyclones undermining development and reducing the availability of natural resources, which invariably impact most of the region's population. Although southern Africa can be considered as not a hotspot in respect of climate insecurity in comparison to other regions in Africa, it is evident that climate change has worsened the state of livelihood and food insecurity, displacement and migration, and heightened competition over land and water resources. Consequently, climate-related impacts are likely to instigate or exacerbate potential tensions and dynamics of ongoing conflicts and affect the region's peace efforts.

Considering the transnational and multidimensional nature of climate-related security risks, regional organizations such as the Southern African Development Community (SADC) can play a key role in assessing and coordinating responses to them in the region. With this growth, nearly 690 million people were reported to be hungry in 2020 in Africa, according to the 2023 World Economic Forum report. It is reiterated that due to the intensive impact of climate change, Southern Africa has been referred to as a 'hotspot' by the Intergovernmental Panel on Climate Change (IPCC). The SADC region is adversely affected by climate hazards that include, among others, unpredictable rainfall, frequent drought, extreme rainfall, heat waves and strong winds.

As the population grows, it is estimated that about 70% more food needs to be produced to feed the estimated 9 billion global population by 2050. Therefore, addressing agriculture and climate change (CC) constraints remains vital in achieving sustainable agricultural productivity, food security and economic growth, particularly in Africa. The intimate relationship between climate change and agriculture is thus increasingly well-recognized in expert and policy circles. *CCARDESA team led by Dr. Simon Mwale during the visit of AICCRA project in Magugu village in Chipata, Eastern Zambia.*Agriculture **remains one of the most significant contributors to climate change, accounting for 19-29% of the total greenhouse gas emissions.**[1] As a sector, it **predominantly comprises smallholder farmers** dependent on rain fed agriculture.

*CCARDESA team led by Dr. Simon Mwale during the visit of AICCRA project in Magugu village in Chipata, Eastern Zambia.*

[1] Vermeulen, S. J., Campbell, B. M., and Ingram, J. S. I. (2012). Climate change and food systems. Annu. Rev. Environ. Resour. 37, 195–222. doi: 10.1146/annurev-environ-020411-130608

The Sustainable Development Goals (SDGs) report of 2022 has documented the severity and magnitude of the challenges that, if not addressed, can potentially reverse the progress made in eradicating poverty and hunger, improving health and education, providing basic services, and much more. The confluence of disruptive crises, dominated by climate compounded by the COVID-19 pandemic and conflicts, directly affects the achievement of SDGs.

The delivery approach applied to SDGs has explicitly recognized the "*integrated and indivisible*" interconnections between sustainability goals and the nexus between food, water, energy and climate change in minimizing trade-offs between inter-related sustainability issues. Contribution of other pertinent policies, such as the Comprehensive Africa Agriculture Development Programme (CAADP) and Agenda 2063, constitute important Africa Union's flagship development and is important in fostering agricultural transformation and green growth ambition across the region.

The SADC countries remain highly vulnerable to the impacts of climate change because they have a lower adaptive capacity (Guillaumont and Simonet, 2011). It presents Africa's peculiar vulnerability to climate change due to low adaptation and mitigation capacities, limited finance, and other means of implementation. This has constrained the attainment of the '*Africa We Want*' as a Pan-African Ambition for Africa to assume a development position on the global stage.
Positioning Climate-smart agriculture as an approach to addressing the interlinked challenges of food security and accelerating climate change by simultaneously achieving **increased productivity**, **enhanced resilience, and reduced greenhouse gas emissions.** These three dimensions of sustainable development that CSA integrates are aimed at:

1) sustainably increasing agricultural productivity and incomes,
2) adapting and building resilience to climate change from the farm to national levels, and
3) developing opportunities to reduce greenhouse gas emissions from agriculture.

# CHAPTER 2: CLIMATE CHANGE IMPACTS ON AGRICULTURE IN SADC

## 2.1 Introduction

This chapter covers the impacts of extremes in climate variability (floods and droughts) and climate change on agriculture through impacts on germplasm (e.g., seed/starter material), land/soils/nutrients, water, energy, crops, livestock, fisheries, aquaculture, ecosystems and biodiversity, among others.

### Climate hazards and associated risks and vulnerabilities in the SADC Region

The SADC Region covers an area of 9.85 million $km^2$, with a climate regime ranging from arid to sub-humid conditions, hosting about 380 million people. The[2] major climate hazards in the region are temperature rise, rainfall pattern that shifts in space and time in the form of droughts and dry spells, especially in the arid sub-regions, and floods, typically from tropical cyclones. There are several risks that these hazards from climate change and associated climate variability pose to SADC's development goals. Figure 2.1 illustrates the prevailing vulnerabilities regarding food and livelihood insecurity per country.

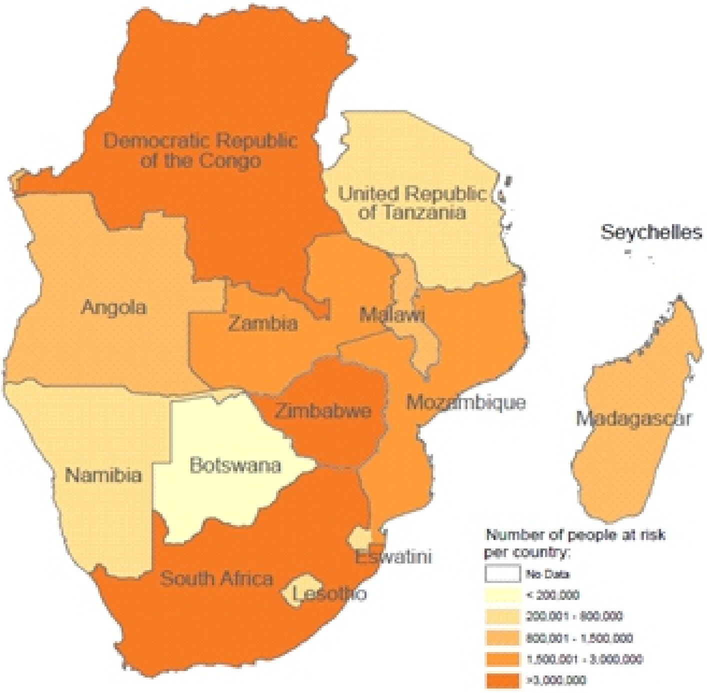



**Figure 2.1:** Population at risk of food and livelihood insecurity by country. *Source: SADC Regional Vulnerability Assessment & Analysis (RVAA) Report of 2019.*

[2] *Official website: https://www.sadc.int/*

### Climate Change Risks in the SADC Region

Some examples of the hazards and risks experienced in the SADC region are listed in Table 2.1 below. The most common ones are increased frequency of droughts, floods and cyclones.

**Table 2.1:** Climate Change Hazards and the risks they pose to agriculture in the SADC Region.

| Main Climate Hazards to which the SADC Region is vulnerable | Main Climate Risks Arising from the Hazards |
|---|---|
| 1. Temperature – rise | Risk of increased evapotranspiration, increased heat stress, frequent heat waves, increased frequency and severity of pests and disease incidences, causing depressed agricultural productivity, etc. |
| 2. Rainfall pattern shifts in amounts, space and time | Risk of less predictable timing of rainfall and intensity of weather events, more erratic rainfall regimes, ecosystem degradation, increased frequency and severity of pests and disease incidences, delayed onset and/or early cessation of rainy seasons, leading to reduced growing periods, price fluctuations, etc. |
| 3. Droughts and dry spells, especially in the arid sub-regions – with increased frequency and severity | Risk of water resources degradation/ water scarcity, crop failure, livestock deaths, ecosystem degradation, increased frequency and severity of pests and disease incidences, biodiversity loss, price fluctuations, disruption of livelihoods, etc. |
| 4. Floods, excessive rains and landslides following periods of drought – with increased frequency and severity | Risk of damage to infrastructure, land degradation, ecosystem degradation, increased frequency and severity of pests and disease incidences, loss of life, etc. |
| 5. Tropical cyclones and related storms – increased frequency and severity | Risk of loss of life and damage to infrastructure, damage to crops, destruction of fishing equipment and degradation of fish ponds, loss of life, etc. |

***Source:*** *Table constructed using information synthesized from the SADC Regional Vulnerability Assessment & Analysis (RVAA) Report of 2019.*

### Vulnerabilities to climate change in the SADC Region

Southern Africa is highly vulnerable to climate change, increased climate variability, extreme weather events, and severe weather events associated with climate change, which increases climate risks in the agriculture sector in the SADC region. This vulnerability to change (see Table 2.2) is compounded by the low adaptive capacity of the people and systems in the region, as manifested in the prevailing adverse biophysical and socioeconomic circumstances. Distinct differences in rainy season onset, cessation, and frequency of dry spells manifest evidence of Climate variability and climate change. This is projected to be exacerbated under a changing climate.

**Table 2.2:** Climate change vulnerabilities in the SADC region with respect to different resource domains.

| Resource domain | Vulnerability of the resource |
|---|---|
| 1. Germplasm (e.g., seed/ starter material) | Performance ranges of crop varieties and livestock breeds and being affected, where climate change is exceeding the optimum agronomic temperature and rainfall requirements |
| 2. Weather | Natural climate variability and Global Temperature rise affect rainfall and storm patterns both in space and time |
| 3. Land/soils/nutrients | Increased variability in temperature and rainfall are accelerating the degradation of land and soils, and affecting nutrient availability for crop growth, including forage growth. |
| 4. Water | Climate change affects water resources in the SADC Region through increased water column temperature, increased evaporation rates, and shorter rainy seasons. It decreases water quality in water bodies. The effect of all this is to reduce water supplies. |
| 5. Energy | Temperature rise and extreme rainfall variability affect energy production and delivery, tilting the balance of energy demand and supply. Climate change affects the infrastructure needed to collect, produce, distribute, store, and consume power. |
| 6. Crops | Crop production is mainly rainfed and hence affected by quantity across spatial and temporal changes in rainfall patterns |
| 7. Livestock | Similar to crop production, forage production for livestock production is mainly rainfed and hence affected by the changing rainfall patterns. Heat stress due to temperature rise also affects livestock productivity. |
| 8. Fisheries | Capture fisheries are largely dependent on weather conditions, especially rainfall and cyclones. Therefore, such extreme weather events are affected by the interruption of fishing time, destruction of fishing equipment, and loss of life. Rising temperatures of the water column in water bodies affect fish productivity. |
| 9. Aquaculture | Tropical cyclones, heavy rainfall and storms cause damage to aquaculture infrastructure, such as degradation of fish ponds, etc. |
| 10. Ecosystems | Climate change degrades ecosystems and forces species to relocate and migrate to more favourable ecological areas, becoming extinct. |
| 11. Biodiversity | Climate change increases the rate of biodiversity loss |

### Impacts of Climate Change in the SADC Region

**Temperature**: Temperatures in the SADC Region have increased by over an increase in temperature by 0.5°C in the last 100 years[3].

**Rainfall**: increasingly erratic rainfall events of high intensity, leading to floods and more frequent droughts and within-season dry spells.

**Tropical cyclones**: Tropical cyclones are increasing in frequency and the severity of the damage they cause, including loss of life and property.

## 2.2 Climate Change Impacts on Crop Yields

*Effects of Droughts on a maize field in Chilanga District, Zambia*Agriculture in Africa is largely rainfed, making climate a critical input in crop production. Extremes in climate variability and climate change lead to reduced yields for agricultural value chains in agro-ecological zones. However, there are projected increases in yields in some value chains in some agro-ecological zones of the Region. Climate change has an overall impact on reduced food availability and food stability.

*CCARDESA team led by Dr. Simon Mwale during the visit of AICCRA project in Magugu village in Chipata, Eastern Zambia.*

[3] https://www.sadc.int/file/2940/download?token=j-9s28Fc#:~:text=Temperatures%20in%20the%20region%20have,years%20are%20becoming%20more%20frequent.

*Cassava field in Mansa District, Northern Zambia*

## 2.3 Climate Change Impacts on Livestock Production

*Herd of cattle in Kazungula District, Southern Zambia*

*Herd of cattle in Kazungula District, Southern Zambia*

Most of the income from livestock in the SADC Region is from beef cattle, dairy cattle, goats, sheep, and chicken. In many rural communities in the Region, livestock is the only asset option for low-income people.

**Climate change impacts in the SADC Region**

1. Shifts in climate-sensitive diseases and disease vectors.

2. Heat-related mortality, morbidity, and the increasing incidence of climate-sensitive infectious diseases.

3. Water scarcity due to increased evaporation and evapotranspiration rates, even if rainfall rates do not change.

4. Increased and/or prolonged incidences of heat stress.

5. Shortages of feed and forages, grazing area and water.

6. Low milk and meat productivity for cattle, small ruminants (like goats and sheep), pigs, and poultry.

7. Changes in livestock feed-grain availability and price.

8. Increased frequency of livestock diseases and pests.
9. Spread of disease and parasites into new regions or increase the incidence to which a particular disease is already prevalent, leading to a decrease in animal productivity and an increase in animal mortality.
10. Reduced quality and amount of feed supply and reduced carrying capacity of pastureland.
11. Increased incidences of market price fluctuations.

## 2.4 Impacts of Climate Change on Agroforestry, Ecosystems and Biodiversity

Temperature increases, changes in rainfall and increases in carbon dioxide have affected the growth and productivity of agroforestry, ecosystems and biodiversity. Warming temperatures have shifted the habitats of some types of trees and animals. Increases in carbon dioxide in water bodies have caused acidification in the water bodies. A list of examples of the impacts is provided below:

**The impacts**

1. Increased disturbances such as insect outbreaks, invasive species, and wildfires.
2. Land degradation, biodiversity loss, bush encroachment, and the spread of pests and invasive species.
3. Local extinction of the Cape Fur Seals and large-bodied bird species.
4. Changes in wildfire regimes (behaviour, occurrence, and severity): In regions and/or seasons with severe drought, the fire season is longer than it was decades ago, and these regions experience many more large-scale fires.
5. Coral reefs, African penguins and Cape fur seals.
6. Habitat loss/ home range contraction/ increased mortality risk.
7. Increased mortality risk of sea fish, increased nest failure, reduced chick survival, compromised breeding effectiveness.
8. Reduced water flows.
9. Displacement or loss of many species.
10. Shifts in the timing of biological events affecting species and habitats.
11. Increased risk of local extinctions of species.
12. Spread of invasive species.
13. Reduced provisioning of timber supplies, increased release of carbon into the atmosphere, increased water scarcity, and increased soil erosion.
14. Reduced water availability due to dwindling water supplies, altered volume and quality of stream flows, and raised water column temperatures, harming aquatic organisms.
15. Severe and prolonged droughts interspersed with flooding resulting in the loss of arable land.
16. Reduced agricultural yields, increased crop failure and livestock deaths.
17. Reduced soil moisture conditions.
18. Altered active behaviour and duration of pests and disease vectors.

19. Ocean acidification, with detrimental impacts on aquatic life.
20. Increased frequency of ecological disturbances presents opportunities for invasive species to colonize areas outside their native habitats.
21. Geospatial shifts in ecological belts and geographical home range of animals, including crop pests and disease vectors.

*Faidhebia albida species commonly integrated with annual crops on farms.*

### Projected impacts of climate change

Climate change scenarios project that the impacts stated above will become more severe over the coming years.

# CHAPTER 3: JUSTIFICATION FOR CLIMATE SMART AGRICULTURE

## 3.1 The ABCs of Climate Smart Agriculture

Climate Smart Agriculture (CSA), as defined by FAO at The Hague Conference on Agriculture, Food Security and Climate Change in 2010, continues to contribute to achieving sustainable development (economic, social and environmental) by jointly addressing food security and climate change. Climate-smart agriculture is an integrated approach to managing landscapes. It helps to adapt agricultural methods, livestock, crops, forestry and fisheries while responding to the ongoing human-induced climate change by reducing greenhouse gas emissions and considering the growing population's food security.

Climate Smart Agriculture places emphasis not only on **sustainable agriculture** but **also on increasing agricultural productivity** and **resilience in farming systems**. The magnitude, immediacy and broad scope of the effects of climate change on agricultural systems create a compelling need to ensure the comprehensive integration of these effects into national agricultural planning, investments and programs. The CSA approach is designed to identify and operationalize sustainable agricultural development within the explicit parameters of climate change.

Climate-smart agriculture is composed of three main pillars that include:

1. Sustainably intensifying production systems to increase agricultural productivity and incomes - (**Productivity**).

2. Adapting and building the resilience of agricultural systems and rural livelihoods to the impacts of climate change (**Adaptation**).

3. Reducing or removing greenhouse gas emissions and increasing carbon sequestration - (**Mitigation**).

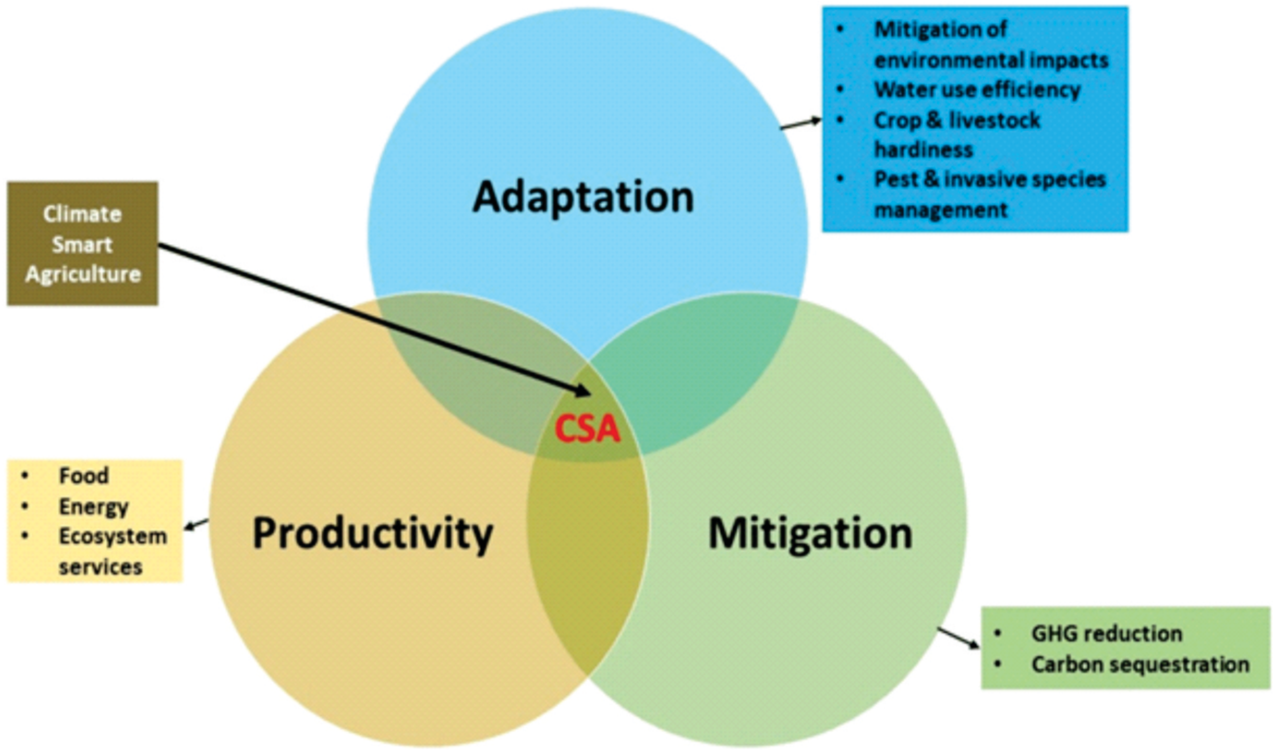



**Figure 3.1:** Interactivity of the three pillars of climate-smart agriculture.

The three goals of productivity, adaptation and mitigation described above address the impacts of climate change by contributing to environmental and social sustainability, strengthening farmers' resilience to climate change, and reducing agriculture's contribution to climate change by reducing greenhouse gas emissions while increasing carbon storage on farmland.

Achieving the goal of CSA requires a transformational shift that inspires multi-objectives and fosters an integrated approach as a way to respond to specific local conditions. Coordination across other agricultural sectors (e.g. crops, livestock, forestry and fisheries) and others, such as energy and water sector developments, is essential to harness potential synergies, minimize trade-offs and optimize the use of natural resources and ecosystem services. The CSA approach also aims to **enhance livelihoods and food security**, especially of **smallholder farmers**, by improving **the management and use of natural resources** and adopting **appropriate methods and technologies for producing, processing and marketing agricultural goods**. To maximize the benefits, CSA considers the social, economic, and environmental context in which it is applied. Implications on energy and local resources are also assessed. A key component of CSA is the integrated landscape approach that upholds ecosystem management principles and sustainable land and water use.

The first pillar of productivity is characterized by Sustainable Production Intensification (SPI) and refers to productive agriculture that conserves and enhances biodiversity resources. It uses an ecosystem-based approach that draws on nature's contribution to sustainable crop production, soil organic matter, water flow regulation, and natural predation of pests. It applies appropriate external inputs at the right time and amount to improve crop varieties' resilience to climate change. It also uses nutrients, water and external inputs more efficiently. Increased SPI is done through improved resource use efficiency by cutting down on fossil fuels contributing to better maintenance of the ecosystem.

The second pillar of building resilience can be achieved by reducing vulnerabilities and increasing adaptive capacity. This can act in each domain, either biophysical or economic and social. There are three ways to build resilience: **(a)** by reducing exposure to the risk of climatic shocks, and (**b)** by reducing the sensitivity of systems to shocks. Using drought-resistant varieties or keeping adequate hay stocks can, for instance, reduce sensitivity to drought and **(c)** increase adaptive capacity, which includes modifying a system and taking into account all the potential shocks and changes together to take into account compensating cumulative or exacerbating effects.

Mitigation effects can be achieved through many agricultural and land management systems and practices (e.g., sustainable land management, agroforestry and integrated food energy systems) that are climate smart. They increase the carbon content of the soils and above-ground biomass, enhance productivity and resilience, and mitigate co-benefits. These can be enhanced through integrated landscape management by seizing mitigation opportunities of any particular landscape through increased biomass production. Increasing or intensifying productivity sustainably offers important opportunities in mitigating climate change through enhanced carbon sink, rehabilitating degraded soils and reducing pressure on the surrounding natural ecosystem. Similarly, holistic management of grassland ecosystems will help to generate degraded areas and improve vegetative cover.  Grassland management can also be accompanied by introducing trees, which sequester carbon in the soil and biomass. Improved grazing management (management that increases production) can lead to an increase in soil carbon stocks.

The different actions encouraged by CSA characterize the technologies that apply to the three pillars. Generally, many more technologies address the first and second pillars, while only a few are interventions readily amenable for mitigation.  **Climate-smart agriculture is not a new agricultural system or a set of practices**. It is **not a specific technology or practice** that can be universally applied. Rather, it is **an approach that requires site-specific assessments to identify suitable agricultural production technologies and practices**. The approach guides the needed changes in agricultural systems, given the necessity to jointly address food security and climate change. Climate-smart agriculture brings together practices, policies and institutions that are not necessarily new but are used in the context of climatic changes. Climate-smart agriculture addresses multiple challenges faced by agriculture and food systems simultaneously and holistically, which helps avoid counterproductive policies, legislation or financing.

Climate-smart agriculture is an inclusive approach that supports **policy, technical and financial**

**means** to mainstream climate change considerations into agricultural sectors and provide a basis for operationalizing sustainable agricultural development under changing conditions. It provides an approach that enables the mobilization of innovative financing mechanisms that link and blend climate and agricultural financing from the **public and private sectors** as means for implementation.

Climate-smart agriculture is not a specific agricultural technology or practice that can be universally applied. It is an approach that requires assessments to identify suitable agricultural production technologies and practices. The approach takes care of the following:

1. Addresses the complex interrelated food security, development and climate change, and identifies integrated options that create synergies and benefits and reduce trade-offs;
2. Recognizes that specific country contexts and capacities will shape these options by the particular social, economic, and environmental situation where it will be applied;
3. Assesses the interactions between sectors and the needs of different stakeholders involved;
4. Identifies barriers to adoption, especially among farmers, and provides appropriate solutions in terms of policies, strategies, actions and incentives;
5. Seeks to create enabling environments through greater alignment of policies, financial investments and institutional arrangements;
6. Strives to achieve multiple objectives with the understanding that priorities must be set and collectives decisions made on different benefits or trade-offs.
7. Seeks to prioritize strengthening livelihoods, especially those of smallholders, by improving access to services, knowledge, resources (including genetic resources), financial products and markets.
8. Addresses adaptation and builds resilience to shocks, especially those related to climate variability and change, as the magnitude of the impacts of climate change has major implications for agricultural and rural development;
9. Considers climate change mitigation as a potential secondary co-benefit, especially in low-income, agricultural-based populations;
10. Seeks to identify opportunities to access climate-related financing and integrate it with traditional sources of agricultural investment finance.

# CHAPTER 4: CLIMATE SMART AGRICULTURE TECHNOLOGIES FOR INCREASED PRODUCTIVITY AND INCOMES

**Learning Objectives**

At the end of the module, the extension officer should be able to:

- Identify the key attributes of the Climate Smart Agriculture approach and its role in increasing productivity and incomes.
- List and differentiate how Climate Smart Agriculture approaches contribute to increased productivity and incomes
- Identify and relate how to differentiate climate smart agriculture approaches for productivity have been implemented through regional case studies.

## 4.1 Introduction

Climate Smart Agriculture aims to sustainably increase agricultural productivity and incomes from crops, livestock and fish without having a negative impact on the environment. This, in turn, will raise food and nutritional security. Sustainable intensification is key to raising productivity (FAO, 2016). This can be achieved through various methods and approaches, such as using less water for crop growth, decreasing tillage and retaining residues for soil fertility, and diversifying crop rotations. These methods can assist farmers in overcoming difficulties such as rising input prices, limited market access, lack of information, and inadequate infrastructure. (Brian, 2023).

One of the key attributes of a CSA approach is that it should facilitate a sustainable increase in agricultural productivity and income. This contributes to the economic, social and environmental dimensions of sustainable development. These three dimensions are all interlinked (Figure 4.1)

***a. The economic dimension***

Increasing agricultural productivity means producing more output with the minimum possible inputs with efficient labour. This is done by improving the efficiency of the farming systems by applying the right quantities and quality of agricultural inputs at the right time, using appropriate technologies, thereby reducing wastage. This will, in turn, improve the income from farming operations.

***b. The environmental dimension***

Sustainably increasing productivity means that productivity is improved while ensuring that natural resources and ecosystem services are preserved. The ecosystem must remain in a productive state to enable it to support the resources and processes necessary for the proper functioning of the crop, livestock, forest and aquatic production systems and rural livelihoods.

### c. *The social dimension*

Increasing productivity ensures food security for farming communities while increasing farm incomes to sustain their other livelihood needs. Food security and livelihoods depend on a functioning ecosystem that will provide the required services for all agricultural production and other requirements for rural livelihoods

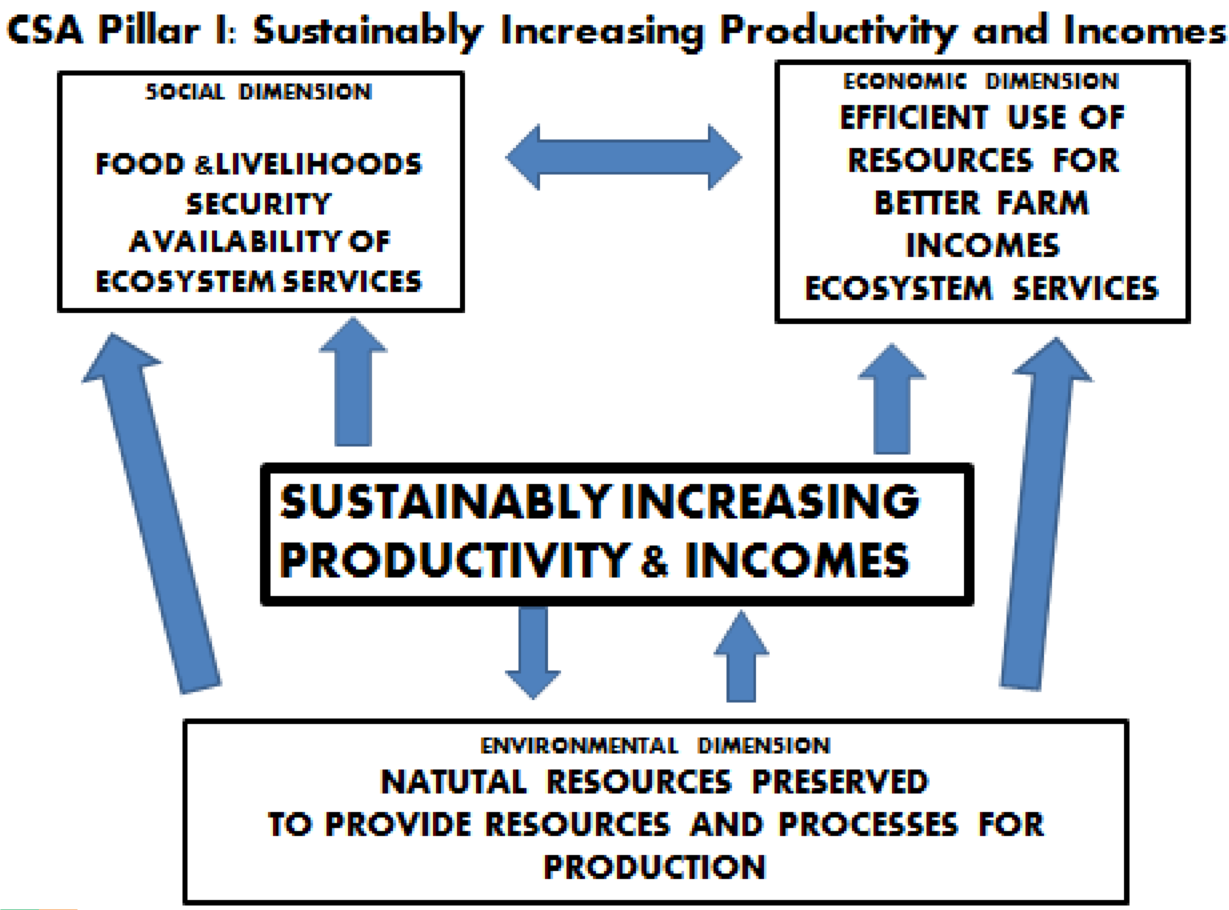



**Figure 4.1.** CSA Pillar I: Addressing the three inter-linked dimensions of Sustainable Development.

## 4.2 CSA contribution towards crop, livestock and fish productivity

Over many years, climate-smart agricultural practices targeting increased crop and livestock productivity have been developed after widespread testing and validation in the SADC countries. **Table 4.1** summaries the definitions, key characteristics and major benefits of CSA technologies and practices suitable for mixed farming systems of the SADC region..

**Table 4.1:** Crop, livestock and fish productivity enhancing CSA technologies for southern Africa.

| Thematic Area | Approaches | Definition and description of the approach | Key characteristics of the methodologies | Contributions and benefits to productivity | Where methodologies and approaches are in use |
|---|---|---|---|---|---|
| **Crop production** | Conservation agriculture | It is a way of farming that conserves, improves, and makes more efficient use of resources through the integrated use of available resources and external inputs.[4] | Minimum soil disturbance; Retention of organic soil cover; and Crop rotations and/or intercropping. | Improvement in water infiltration and conservation; Precision in fertilizer application; Improvement in nutrient use efficiency; and Reduction in cost of crop establishment when mechanized CA is used. | Various approaches used by SADC countries: Hand-hoe based options on small land holdings; Animal draft powered CA equipment for small and medium-scale farmers; and Motorized CA for medium and large-scale farmers in Eswatini, Lesotho, Malawi, Mozambique, South Africa, Zimbabwe and Zambia. |
| | Multiple cropping | Growing two or more different crops together on the same piece of land in the same cropping season. | **Intercropping**: crops grown at the same time in a deliberate pattern. **Relay cropping**: The second crop is planted 3-5 weeks after the first crop. **Companion cropping**: two crops sown together for benefits in terms of revenue, soil fertility, yield, and crop protection | Benefits from output and income from two or more crops instead of one; Reduction in cost of production from crop protection benefits and shared management practices; Spreading the risk of total crop failure in the event of a major drought. | Intercropping cereals with legumes used in traditional farming systems across the region; Increasingly becoming important for farming households with small land units; Improvement in access to and capacity in low cost-efficient irrigation technologies can enable farmers to grow crops 3-4 crops per year and increase their output and income generation. |

[4] *Conservation_Agriculture_Tanzania.pdf (oaklandinstitute.org)*

| Thematic Area | Approaches | Definition and description of the approach | Key characteristics of the methodologies | Contributions and benefits to productivity | Where methodologies and approaches are in use |
|---|---|---|---|---|---|
| **Crop production** | Water management practices | These water management practices promote efficient water utilisation at the field level to optimize productivity and income generation by farmers[4]. | **Water management options:** variety and crop selection that suits the rainfall in the target area; use of solar-powered irrigation; deficit irrigation; use of efficient irrigation technologies; in-field water harvesting and conservation; Rainwater harvesting and storage for future use in crop production. | The selection of crops and varieties adapted to low water requirements, the precise application of water through drip irrigation, and deficit irrigation that targets the critical stages of growth improve water use efficiency; this can, in turn, improve nutrient use efficiency and crop yield. | While breeding and selecting heat and drought-tolerant crops is supported by governments in SADC and partners in the region, efficient irrigation technology still needs more capacity in the end-user and the supply chain stakeholders involved in the distribution and maintenance of related equipment and infrastructure. |
| | Irrigation Management | The act of timing and regulating irrigation water application in a way that will satisfy the water requirement of the crop grown. | Growing crops with artificially supplied water as opposed to rainfall<br>water harvesting to improve soil moisture supply to crops. | Efficient utilization of water; two or more crop cycles per year; stabilization of crop yields. | Suitable for farming systems across all SADC countries. Efficient and climate-smart irrigation systems include drip Irrigation and solar-powered irrigation water pumping. |
| | New and improved crop varieties | Crop types that have been developed to address a given objective, for example, drought and heat tolerance. | Drought and heat tolerance; water use efficient varieties; increase in nutritional food value, such as an increase in iron and zinc. | Stable crop growth and yield performance under CC stress. | Suitable for farming systems across SADC in humid, sub-humid and dryland. |

| Thematic Area | Approaches | Definition and description of the approach | Key characteristics of the methodologies | Contributions and benefits to productivity | Where methodologies and approaches are in use |
|---|---|---|---|---|---|
| **Crop production** | Crop diversification | Adding new crops to agricultural production systems on a particular farm considers the different returns from the added crops with complementary marketing opportunities. | Mixing of crop species; introducing new cultivated species; growing fodder crops together with food crops; biofuel crops; agroforestry and timber tree/shrub species. | Diversity of crops leads to break in pests and diseases; Increased incomes arising from new markets; Spread of risks associated with failure of one crop; Diversity of food in the community is increased. | Crop diversification is a common practice in traditional farming systems in the SADC region, with cereals, legumes, and cash crops done where land is available. |
| | Integrated pest and disease management | Integrated Pest Management (IPM) is an effective and environmentally sensitive approach to pest management that relies on a combination of common practices, with chemicals usually the last option. It uses information on the life cycles of pests and their interaction with the environment | IPM focuses on the following stages: **Identification:** correct identification of the pest. **Prevention:** Use preventative measures, e.g., cultural practices (disease-resistant planting material; keeping the plants healthy). | Helps to reduce pest management costs, thus, in the long term, reducing production costs and improving the profitability of the farming enterprise. Reducing chemical use will also minimize environmental pollution, thereby encouraging biota thriving, which is beneficial for soil fertility. | Climate variability and change have resulted in changes in pest populations, demanding more integrated approaches to pest management. Smallholder citrus farms in the Eastern Cape (SA) are increasingly becoming interested in IPM due to the increasing cost of chemicals. |

| Thematic Area | Approaches | Definition and description of the approach | Key characteristics of the methodologies | Contributions and benefits to productivity | Where methodologies and approaches are in use |
|---|---|---|---|---|---|
| **Crop production** | | [4] | **Monitoring:** Regular and effective monitoring allows early identification of pests and diseases for timely and appropriate action. **Control**: involves appropriate removal by either removal of pests or diseased plants as well as application of pesticides. | | |
| | Improved post-harvest handling and storage. | This is properly handling harvested produce to maintain quality and add value where possible. | Correct and timely harvesting, standard and adequate storage facility (e.g., metal silos, traditional granaries); Improved market linkages, harvesting and processing technologies. | Efficient post-harvest processing will reduce post-harvest losses while maintaining high-quality produce – this will facilitate access to more profitable markets, while value addition will ensure higher income from the value-added produce. | Improved grain storage systems are needed in the whole SADC region. Case studies on storage in Tanzania for using hermetic bags improved and extended period. The quality of the resulting grain also improved in some cases reducing aflatoxin levels in stored products. |
| **Livestock Manage ment systems**[5] | New and tolerant breeds | Breeds that are drought-tolerant, heat-tolerant, and efficient in the utilization of feed. | Crossing of different breeds of cattle or other livestock for productivity. | Crossing breeds that are hardy to CC and have higher feed conversion rates create permanent germplasm/ breeds. Survival under harsh conditions means increased livestock assets. | Suitable for farming systems across all SADC countries in h umid, sub-humid and dry lands. |

[5]Livestock Production in SADC [Available at https://www.sadc.int/pillars/livestock-production]

| Thematic Area | Approaches | Definition and description of the approach | Key characteristics of the methodologies | Contributions and benefits to productivity | Where methodologies and approaches are in use |
|---|---|---|---|---|---|
| | Livestock Diversification | Addition of new livestock breeds and types and livestock rearing systems t o agricultural production on a particular farm, taking into account the d ifferent returns from the value-added livestock p roducts with complementary m arketing opportunities. | Different cattle breeds, such as the hardy types<br>Small livestock such as goats and sheep that are resilient.<br>Increase in productivity per unit area for small livestock systems and hardy breeds. | Small ruminant animals such as Boer goats and Merino sheep have reduced demand for food. Poultry types are cheaper to procure and sell. | Practiced in mixed farming systems across all SADC countries in humid, sub-humid and dry lands. |
| **Livestock Manage ment systems** | Forage/fodder production and conservation. | Feed for domesticated livestock that can be either hay, silage, stover or pasture. | Fodder trees/shrubs grown in the field alongside crops or between crop fields; Over sowing with specific species that increase digestibility and feed conversion; Use of cut and carry to feed livestock at homestead; harvest and store systems, e.g., store as bales. | Increased feed conversion allows for fast growth, higher egg and milk production, earliness to first birthing, and increased incomes. | Production of forage crops such as legumes is practised in SADC, especially drylands; cereal stalks/stover for dry season use. |
| | Improved pasture management | This involves planting new pasture varieties (e.g., *Stylolanthes*) and rotational grazing of livestock to minimize land degradation. | Planting selected high-yield pastures.<br>Planning grazing schedules of fields. | Increased pasture diversity<br>Increases yield of pasture hence growth<br>Reduced pressure on fields. | Case studies of Zambian com-mercial farms using adaptive rotational grazing (fast grazing for a few hours followed by fallow for a season or two); a case study in Botswana Ghanzi district research on continuous versus rotational grazing with latter showing positive results. |

| Thematic Area | Approaches | Definition and description of the approach | Key characteristics of the methodologies | Contributions and benefits to productivity | Where methodologies and approaches are in use |
|---|---|---|---|---|---|
| **Livestock Manage ment systems** | Grassland restoration. | The regeneration of grassland ecosystems as a means of supplying natural feed. | Increases biomass production, which increases feed available to livestock. | Reduction in erosion; reduction in distances covered by livestock for feeding. | Case studies in Zimbabwe mainly focused on improving communal grazing land by participatory planning rotational grazing. |
| | Improved animal manure t reatment. | Manure is a product from livestock waste and urine mixed with water that needs to be treated to reduce losses and GHG emissions is the optimal, site-specific handling of livestock manure from the collection, through treatment and storage, up to the application to crops (and aquaculture) | When well handled, manure increases the soil's fertility status; Improves structure, water retention and yields of crops. It also reduces the demand for external inputs and increases income gains from sales of commodities | Wet handling and fast collection and decomposition Aids in nutrient cycling. Non-exposure of manure to the sun and rain using roofed housing and tarpaulin covers. | Using manure in increasing organic content by direct application is a common practice in SADC; adding manures to inorganic fertilizer in formulation blended fertilizers. |
| | Improved housing for small ruminant livestock. | Housing designed to keep livestock to meet CC standards. | Improves feed utilization. | Reduce pest and disease exposure. | A common practice in all SADC countries. |
| **Soil mana-gement** | Contour planting in mountainous or ordinary farming areas. | Planting of crops or agroforestry trees/shrubs across the slope of the land. | Rows of crops or agroforestry trees/shrubs are established across the slope. | Reduces soil erosion, harvests rainwater, and conserves soil moisture. | A common practice in all SADC countries. Particularly important in the hilly parts of Eswatini, Lesotho, Madagascar, Malawi, South Africa, and Zimbabwe. |

| Thematic Area | Approaches | Definition and description of the approach | Key characteristics of the methodologies | Contributions and benefits to productivity | Where methodologies and approaches are in use |
|---|---|---|---|---|---|
| **Soil mana-gement** | Terracing | Levelling of land in areas with slopes that are greater than 15 degrees' slope. | Terracing and bunding across the slope of the land. | Reduce soil erosion and soil movement; promotes water infiltration and moisture retention. | Case of Fanya juu terraces in Tanzania that helps in reducing erosion. Important in the hilly parts of Eswatini, Lesotho, Madagascar, Malawi, South Africa, and Zimbabwe. |
| | Soil pH testing | Testing the soil to determine the acidity or alkalinity of the soil that influences plant nutrient availability. | Optimal pH range aids in the efficient extraction of nutrients hence higher yields and less wastage of inorganic fertilizer. | Reduced application of inorganic fertilizers. | Important practice for all SADC countries. Actual rapid field testing by Solidaridado and Agricares in Zambia, Mozambique and other countries in southern Africa. |
| | Liming | Addition of agricultural lime or wood ash to increase the soil pH. | Lime is added in liquid or powdered form to raise the soil's pH. | The availability of more nutrients; reduces toxicity to plants. | A standard practice in conservation agriculture systems in SADC countries. |
| | Biochar Application | Addition of charred organic material to the soil | Charring of crop residue such as maize husks.<br>Kiln setup for the process of charring | Infiltration improved Soil Physical structure improved and sustained | Eastern Province in Zambia under pilot study and Malawi. |
| | Organic and I norganic fertilizer addition | Complementary application of organic manures and mineral fertilizer. | Reduction in the amount of inorganic fertilizer added; increased soil moisture retention. | Improves fertilizer utilization. | A standard practice in conservation agriculture systems in all SADC countries. |

| Thematic Area | Approaches | Definition and description of the approach | Key characteristics of the methodologies | Contributions and benefits to productivity | Where methodologies and approaches are in use |
|---|---|---|---|---|---|
| **Soil mana-gement** | Integrated Soil fertility Management. | A holistic approach to s oil fertility management includes seed selection, cultivation practices, cropping systems and soil amendments. | Seed selection; using No-till, Conservation tillage, Soil amendments such as biochar, organic matter, compost and liming; use of different cropping systems. | Improves soil fertility hence yields; Increases soil structure hence water retention. | A standard practice in conservation agriculture systems in all SADC countries. |
| **Agrofores try** | Nitrogen-fixing trees. | Incorporating trees/shrubs into the farming system – a dynamic and ecological method of land management involving the simultaneous cultivation of farm crops and trees. | Trees such as *Faidherbia, Leucaena, Sesbania, and Tephrosia Gliricidia* are grown together with crops in different spatial arrangements in the same field. | Nutrient cycling; Increase in organic matter content; reduction in soil erosion and runoff, and increased crop yields. | Common in some SADC countries, e.g., Malawi, Zambia, and Zimbabwe. |
| | Intercropping crops with Trees - Alley cropping. | Alley cropping is a production system in which trees and shrubs (preferably fast-growing leguminous species) are established in hedgerows on arable cropland, with crops cultivated in the alleys between the hedgerows. | Planting trees at a given distance; Integrating livestock feeding; Planting crops in alleys; and feeding livestock. | Increased fertilization from leaf/litter fall, improved soil erosion control; weed suppression; increases yield as low input improves incomes. | Common in some SADC countries, e.g., Malawi, Zambia, and Zimbabwe. |

| Thematic Area | Approaches | Definition and description of the approach | Key characteristics of the methodologies | Contributions and benefits to productivity | Where methodologies and approaches are in use |
|---|---|---|---|---|---|
| **Agroforestry** | Intercropping with Leguminous trees and shrubs | Use of leguminous plant species in place of herbaceous plants in the farming system. | Intercropping of woody trees with crops<br>Pruning the trees to provide manure | Reduced erosion; Soil moisture retention; Soil nutrient increase as the pruned material rots. | Extensive practice in the eastern province of Zambia and Malawi. |
| **Fisheries** | Integrated fish farming systems | Integrating capture and successful aquaculture species by either restocking or breeding and rearing. | Capture fisheries - restocking of those at risk.<br>Breeding and rearing in ponds and other structures.<br>Appropriate development of fishing gear and fish harvesting equipment. | Assisted reproduction and rearing result in big catches; Increased incomes; Sustainable catches, and right-sized fishes. | Zambia – Lake Kariba, Chirundu, Bangweulu.<br>Malawi – Lake Malawi.<br>Zimbabwe – Lake Kariba.<br>Mozambique – marine and fresh water fisheries both include aquaculture.<br>Mozambique, Namibia, South Africa, and Tanzania - Marine fisheries are crucial. |
| | Feed Manufacturing | Replacing fish meal and oil in new feeds. | Formulation of new feeds using other ingredients. | Increased growth rates; Less expenditure on fish meal oil-based feeds and production costs. | Done by Novatek-Zambia, but it can also be done in other SADC countries. |
| | Improving stocks and fingerlings; Production and other nursery materials for abalone, oyster, seaweed and others | Breeding and screening of local fish types or introduction of exotic ones.<br>Production of fingerlings in hatcheries. | Breeding work to increase size;<br>Selecting and screening adapted breeds;<br>Increasing the diversity of fish stocks. | Fast growth which reduces costs of production, hence increasing incomes;<br>Increased volumes of production. | Western cape abalone, Namibia oyster, Malawi, Zambia. Zimbabwe produces Tilapia on lake Kariba, Mozambique and Tanzania marine species and seaweeds. |

## 4.3 Best-Bet Productivity Technologies

***Best-bet 1:*** *Conservation Agriculture with Trees (CAWT)*

Although CA addresses food sufficiency by increasing productivity, combining it with agroforestry enhances increased crop productivity and improves sustainability in farming systems by minimizing the impact of food production on the environment and making the production systems more resilient to climate change impacts. In Zambia, intercropping *Gliricidia sepium* with maize has shown improved soil quality and increased yields and protein content in maize grain

*Faidherbia albida trees in a cropped field in Kasisi Agricultural Training Centre, Lusaka province, Zambia.*

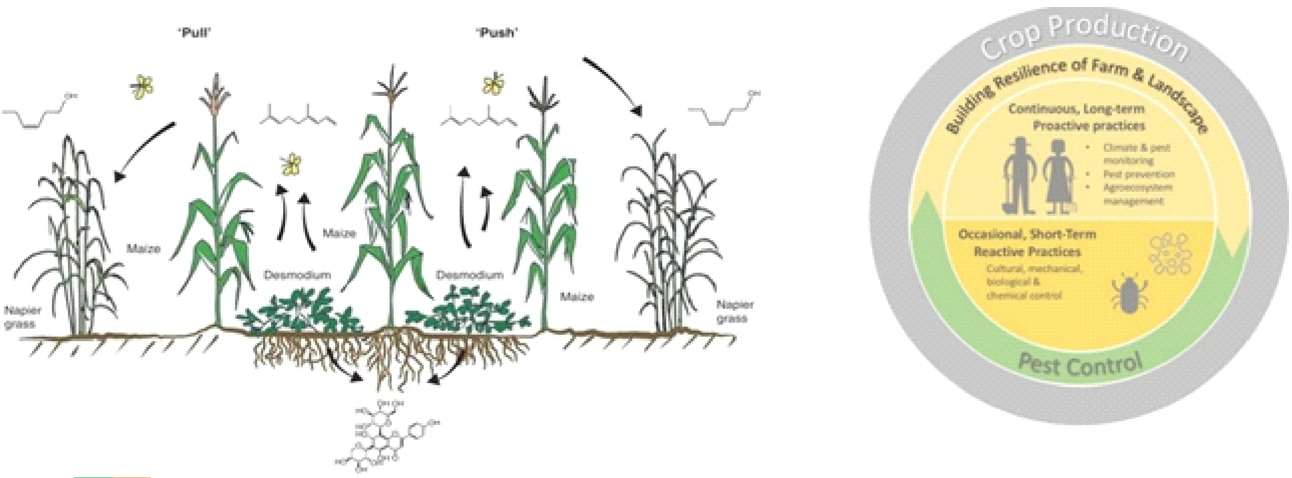
***Best-bet 2:*** *Fodder Production and Conservation*

In Zimbabwe's Murewa district, lablab and velvet beans growing as cover crops in CA fields provided a cheap option for enriching the degraded soil and the much-needed livestock feed. Drying and making hay bales from lablab, velvet beans, and maize residues has provided a protein-rich source for pen-fattening projects for local farmers in the district, trebling their earnings from livestock sales, as pen-fattened livestock fetched more money. The dried hay bales also provide a much-needed fodder source for the livestock during the dry months of the year *(*https://www.cimmyt.org/news/fodder-for-thought/*)*. Due to insufficient rainfall, most livestock production systems in southern Africa are affected by low fodder productivity (nutritional and quantities). Raising fodder and forage crops and their subsequent storage for later use at all production levels is insurance for feeding sustenance and productivity. Additionally, forage and fodder production and storage could aid in limiting land degradation but also provide a domestic and regional market for trade in forages and fodder crops..


*Dried hay bales from mucuna and groundnut residue in Murewa district, Zimbabwe (left) and mucuna growing at Chitedze Research Station, Lilongwe, Malawi (right).*

***Best-bet 3:*** *Pull and Push in Cereal Farming Systems*

It is important as it increases biodiversity and suppresses weeds. Pilot studies are ongoing before the technology is up scaled. Cereals that can be grown in push-pull systems in southern Africa are maize, sorghum and pearl millet. These cereals can be grown in intercropping or strip systems with pigeon pea, *desmodium*, sunhemp and cowpea. Grasses such as *Bracharia* can also be grown in strips alongside main crops such as maize and sorghum.




*Spatial arrangement of cereal and legume crops in a push-pull focused cropping system. (Source: KP14 CCARDESSA, 2022).*

***Case study 4:*** *Mixed crop, livestock and aquaculture production in Zambia*

Kazungula Zambia has been implementing a mixed farming system to increase productivity by keeping livestock and growing indigenous vegetables and field crops. Mixing farm enterprises such as crops, livestock and aquaculture or two of these helps increase the business' or households' productivity.

*Crop-livestock-fish integration in smallholder farming in Zambia.*

***Case study 5:*** *Increased access to new and improved crop varieties*

The SADC Seed Variety catalogue, where high-quality seeds that are high yielding are traded across the sub-region to increase yield within the region. Timely access to improved seed by smallholder farmers in the SADC region is cost-effective. It can facilitate increased crop productivity due to timely planting and good agronomic practices on the smallholder farmers' fields.


*https://www.usaid.gov/southern-africa-regional/news/largest-single-jump-improved-seed-varieties-regional-catalog.*

# CHAPTER 5: CLIMATE SMART AGRICULTURE TECHNOLOGIES FOR INCREASED ADAPTATION

**Learning Objectives**

At the end of the Module, the extension officer should be able to:

- Identify the key attributes of the CSA approach and its role in increased adaptation.
- List and differentiate how CSA approaches contribute to increased adaptation to climate change
- Identify and relate how differentiate CSA approaches for increased adaptation have been implemented through regional case studies.

## 5.1. Introduction

Climate smart agriculture technologies for increased adaptation mainly focuses on adjusting to actual and expected future climate change scenarios. Recurrent droughts and floods mainly drive these changes, temperature increases and reduced rainfall in season rainfall. The goal is to reduce our risks from the harmful effects of climate change (like sea-level rise, more intense extreme weather events, or food insecurity). It also includes making the most of any potential beneficial opportunities associated with climate change (for example, longer growing seasons or increased yields in some regions).

This includes increasing adaptive capacity in the short-term, where there is more uncertainty over climate extremes, and in the medium-long term, as permanent changes in climate patterns become more apparent (Cooper et al., 2013).

Adaptation actions aim to reduce the vulnerability of natural and human systems to climate change. They can include actions to reduce exposure and sensitivity to climate change effects and increase adaptive capacity. Examples in agriculture and forestry can include:

- Changes in farming and land management practices to build long-term resilience,
- Strengthening disaster preparedness and recovery,
- Increased access to useful and usable tools and technology, and
- Outreach and education to build adaptive capacity.

CSA technologies and practices present opportunities for addressing climate change challenges and economic growth and development of the agriculture sector.

## 5.2. CSA technologies with adaptation potential

**BOX 1** provides an inventory of some of the adaptation measures/responses currently being used in some farming systems of the SADC region and have proven successful.

- Shifting to drought and heat-tolerant crop varieties and livestock breeds.
- Shifting to crop varieties and livestock breeds with greater pest and disease resistance.
- Diversifying enterprises towards planting higher value crops, keeping higher value livestock, engaging in beekeeping, engaging in integrated crop-livestock-fish farming, engaging in value addition (processing), and engaging in off-farm employment and marketing infrastructure.
- Using improved grain storage practices by minimizing post-harvest losses and ensuring access to surpluses all year round.
- Using climate forecast advice from extension services to inform farm management decision-making when implementing farm activities.
- Implementing forecast-based actions at the farm level, such as purchasing drought-tolerant seeds based on the anticipated weather forecasts.
- Buying weather-related crop and livestock insurance (when available and affordable) to mitigate against risks of total crop or livestock losses/failures due to climate change.
- Intensifying food production through the use of improved inputs, including improved seed, organic compost and organic fertilisers, and integrated pest management (IPM).
- Complementing rain-fed agriculture with the use of improved on-farm water and energy use efficient technologies, including affordable irrigation systems, water harvesting technologies, sustainable extraction of groundwater, and other underground water resources.
- Changing from conventional agriculture practices to CSA practices such as conservation agriculture and agroforestry.

**Table 5.1:** Crop, livestock and fish adaptation technologies and approaches for enhancing CSA in southern Africa.

| Thematic Area | Approaches | Definition and description of the approach | Key characteristics of the methodologies | Contributions and benefits to productivity | Where methodologies and approaches are in use |
|---|---|---|---|---|---|
| **Crop production** | Conservation agriculture | It is a way of farming that conserves, improves, and makes more efficient use of resources through the integrated use of available resources and external inputs. | The three main principles of conservation agriculture (minimum soil disturbance, crop diversification (rotations), and permanent soil cover) help to protect the environment and to reduce the impacts of climate change on agricultural systems (adaptation) through sustainable land management. | Conserves soil structure and In-situ moisture. Minimizes erosion and nutrient losses through leaching, preserve soil moisture, avoid compaction, contain pest and diseases, and increase biodiversity in the agro-ecosystem. Higher profits due to increased crop yields and reduced production costs. | Various approaches used by SADC countries: Hand-hoe based options on small land holdings; Animal draft powered CA equipment for small and medium-scale farmers; Motorized CA for medium and large-scale farmers in Eswatini, Lesotho, Malawi, Mozambique, South Africa, Zimbabwe, Zambia. |
| | Multiple cropping | One crop is the main, and the other is a minor crop. Ensure proper seed rate and plant population for the two crops for good yields. The main crop should be established 2 to 3 weeks earlier to allow their establishment before the minor crop. Crops of different families should be planted. Crops of different rooting depths should be used | Intercropping includes:<br>**Strip intercropping:** growing two or more crops in strips wide enough to allow independent cultivation and yet narrow enough to induce crop interaction.<br>**Row intercropping:** growing two or more crops in a well-defined row arrangement.<br>**Relay intercropping:** planting one or more crops within an established crop so that the first crop's final stage coincides with the next crop's initial stage.<br>**Companion cropping:** two crops sown together for benefits in terms of revenue, soil fertility, yield, and crop protection. | Intercropping reduces the risk of crop failure and spreads the risk for the farmer if another crop is more susceptible to heat or drought stresses. Intercropping systems also create a micro-environment that conserves soil moisture and hence benefits crops against drought and heat stress periods during the growing season | Intercropping cereals with legumes used in traditional farming systems across the region; Increasingly becoming important for farming households with small land units; Improvement in access to and capacity in low cost-efficient irrigation technologies can enable farmers to grow crops 3-4 crops per year and increase their output and income generation. |

| Thematic Area | Approaches | Definition and description of the approach | Key characteristics of the methodologies | Contributions and benefits to productivity | Where methodologies and approaches are in use |
|---|---|---|---|---|---|
| **Crop production** | Crop rotations | Crop rotation is growing different crops on the same piece of land periodically. Good crop rotation is a systematic succession of the three general classes of farm crops: cultivated, grain, and grass. | It should be adaptable to the existing soil, climatic and economic factors. The sequence cropping adopted for any specific area should be based on proper land utilization, or it should be so arranged concerning fields that crop yields can be maintained and also build up the organic matter content of the soil. Rotation should contain sufficient area under soil improving crops (legumes) to maintain and build the soil's organic matter content. It should help control pests, diseases, and weeds and provide maximum area under the most profitable crops adapted to the area. | Prevent the proliferation of pests encouraged by repeated plantings of the same crop by breaking disease cycles and resurgence and build-up of pests: decreases the amount of inputs needed to control similar pests and diseases, potentially increasing profit by decreasing the variable cost of production. Reduces fertiliser use, diversifies farm incomes, and improves resilience by promoting moisture retention and conservation. Contributes to soil health by improving physical, chemical, and biological characteristics. Crop rotation can reduce soil water evaporation from the planting system, and reduce surface water runoff, thereby ensuring high crop water use efficiency | Common practise in conservation agriculture sites in southern Africa |

| Thematic Area | Approaches | Definition and description of the approach | Key characteristics of the methodologies | Contributions and benefits to productivity | Where methodologies and approaches are in use |
|---|---|---|---|---|---|
| **Crop production** | Drought and heat-tolerant crop varieties | Drought tolerance is the ability of a plant to maintain its biomass production in drought/ arid conditions. Drought-tolerant varieties are essential for ensuring household food security, particularly in years when soil water conditions are sub-optimal during the growing season. | These are varieties bred to escape drought conditions but still give high yields. Early, medium and late-maturing varieties capable of withstanding different levels of drought conditions are available in Zimbabwe. Drought-tolerant varieties minimize yield losses during drought but maximize yields under optimum soil moisture conditions | • Reasonable yields are achieved even under drought/insufficient rainfall conditions.<br>• Reasonable yields are achieved even under increasing heat stress/ heat shocks during the growing season that are being experienced.<br>• Increase resource use efficiency, e.g., available rainfall and fertiliser inputs under unfavourable conditions.<br>• Minimize chances of crop failure. | Various approaches used by SADC countries: Hand-hoe based options on small land holdings; Animal draft powered CA equipment for small and medium-scale farmers; Motorized CA for medium and large-scale farmers in Eswatini, Lesotho, Malawi, Mozambique, South Africa, Zimbabwe, Zambia. |
| | Community Seed Banks | Community seed banks are collective (community) and focused on saving and distributing seeds (banking). | Seed banks are mainly established to conserve local/farmer varieties and/or rare varieties as a response to the loss of diversity due to societal forces or due to recurring natural disasters, most notably droughts and floods caused by climate change | Farmers can use inter-crop diversity by switching to more resilient crops, for example, from maize to millets in rain-stressed areas, or use better-adapted varieties developed through local on-farm selection, a formal sector crop improvement programme, or a collaborative effort such as participatory plant breeding | Across Southern Africa, plant breeders have bred field crop varieties for drought tolerance with various degrees of success. National crop breeding institutes and CGIAR institutions such as ICRISAT and CIMMYT are currently spearheading drought-tolerant se |

| Thematic Area | Approaches | Definition and description of the approach | Key characteristics of the methodologies | Contributions and benefits to productivity | Where methodologies and approaches are in use |
|---|---|---|---|---|---|
| **Crop production** | Water management practices | These water management practices promote efficient water utilisation at the field level to optimize productivity and income generation by farmers. Water harvesting as a climate adaptation practice is harnessing rainwater or groundwater for crop and livestock production and aquaculture. Rainwater harvesting can be classified into two major categories: in-situ (infield), including small basins, pits, bunds/ridges and ex-situ practices, and runoff-based catchment and/or storage systems. The storage system is usually used in supplementary irrigation and involves either direct tapping of rainwater or diversion of water from storage works and seasonal | Water management options: variety and crop selection that suits the rainfall in the target area; use of solar-powered irrigation; deficit irrigation; use of efficient irrigation technologies; in-field water harvesting and conservation; Rainwater harvesting and storage for future use in crop production. | Water harvesting is important to keep water in the soil during drought or extended within-season dry spells. Optimization of crop yields. Soil nutrients are also conserved, and it complements the performance of drought-tolerant crops under drought conditions. | While breeding and selecting heat and drought-tolerant crops is supported by governments in SADC and partners in the region, efficient irrigation technology still needs more capacity in the end-user and the supply chain stakeholders involved in the distribution and maintenance of related equipment and infrastructure. CGIAR institutions such as IWMI are spearheading solar-based irrigation and improved land and water management practices. |

| Thematic Area | Approaches | Definition and description of the approach | Key characteristics of the methodologies | Contributions and benefits to productivity | Where methodologies and approaches are in use |
|---|---|---|---|---|---|
| **Crop production** | Integrated Soil Fertility Management Practices | Integrated soil fertility management (ISFM) is an approach to improve crop yields while preserving sustainable and long-term soil fertility through the combined judicious use of fertilizers, recycled organic resources, responsive crop varieties, and improved agronomic practices, which minimize nutrient losses and improve the nutrient-use efficiency of crops. | ISFM aims to reduce external inputs in crop production systems on smallholder farms. The improved crop species for ISFM include cereals and legumes; legumes are critical for fixing nitrogen in the cropping system. Good agronomic practices are a key component of ISFM to increase the efficient utilization of crop production resources such as nutrients, soil water and labour invested in producing crops by smallholder farmers. | Increases crop yields, ensuring household food and nutrition security; Increases farm profits through more crop products for sale generated by improved yields.; Improves soil quality through the application of organic soil fertility amendments. Organic materials improve organic matter, reduce soil acidity, and increase water-holding capacity through improved soil structure.; Increases efficient utilization of plant nutrients applied to the cropping system; Precise timing and placement of nutrients minimize losses and promote better utilization by crop plants. Farm profits are increased by combining organic and inorganic nutrient sources in the cropping system. | Suitable for farming systems across all SADC countries. |

| Thematic Area | Approaches | Definition and description of the approach | Key characteristics of the methodologies | Contributions and benefits to productivity | Where methodologies and approaches are in use |
|---|---|---|---|---|---|
| **Crop production** | Irrigation Management | The act of timing and regulating irrigation water application in a way that will satisfy the water requirement of the crop grown. | Growing crops with artificially supplied water as opposed to rainfall water harvesting to improve soil moisture supply to crops. | Reasonable yields are achieved even under drought/insufficient rainfall conditions. Reasonable yields are achieved even under increasing heat stress/ heat shocks during the growing season that are being experienced; Increase resource use efficiency, e.g., available rainfall, inputs such as fertilizer under unfavourable conditions; Minimize chances of crop failure | Suitable for farming systems across all SADC countries. Efficient and climate-smart irrigation systems include drip Irrigation and solar-powered irrigation water pumping. |
| | Crop diversification | Addition of new crops to agricultural production systems on a particular farm, taking into account the different returns from the added crops with complementary marketing opportunities. | Mixing of crop species; introducing new cultivated species; growing fodder crops together with food crops; biofuel crops; agroforestry and timber tree/shrub species. | Reduces the risk of crop failure caused by increased droughts and dry spells. Optimises biodiversity and conserves soil moisture when combined with appropriate cover crops such as mucuna. The multiple benefits of intercropping crops with livestock cover crops such as velvet bean, enhancing soil fertility. | Crop diversification is a common practice in traditional mixed farming systems in the SADC region, with growing both cereals, legume and cash crops done where land is available. |

| Thematic Area | Approaches | Definition and description of the approach | Key characteristics of the methodologies | Contributions and benefits to productivity | Where methodologies and approaches are in use |
|---|---|---|---|---|---|
| Crop production | Integrated pest and disease management | Integrated Pest Management (IPM) is an effective and environmentally sensitive approach to pest management that relies on a combination of common practices, with the use of chemicals usually the last option. It uses information on the life cycles of pests and their interaction with the environment | IPM focuses on the following stages: Identification: and correct pest identification. Prevention: Use of preventative measures, e.g., cultural practices (disease-resistant planting material; keeping the plants healthy). Monitoring: Regular and effective monitoring allows early identification of pests and diseases for timely and appropriate action | Reduces crop losses from pests and diseases even when cops are under water stress. Improves food security. | Climate change has resulted in changes in pest populations, demanding more integrated approaches to pest management. Smallholder citrus farms in the Eastern Cape (SA) are increasingly becoming interested in IPM due to the increasing cost of chemicals. |
| | Improved post-harvest handling and storage. | This is the proper handling of harvested produce to maintain quality and value add where possible. | Correct and timely harvesting. Standard and adequate storage facility (e.g., metal silos, traditional granaries); Improved market linkages, harvesting and processing technologies. | Safeguarding harvest in the context of reduced yields by climate-induced droughts. | Improved grain storage systems are needed in the whole SADC region. Case studies on storage in Tanzania for use of hermetic bags improved and extended period. The quality of the resulting grain also improved in some cases reducing aflatoxin levels in stored products. |
| Livestock Manage ment systems | New and drought-t olerant breeds | Breeds that are drought tolerant, heat hardy, and efficient in utilization of feed. | Crossing of different breeds of c attle or other livestock for productivity. Livestock diversification, including small stock, | increased productivity in livestock systems, Reduced overgrazing and soil erosion | Suitable for farming systems across all SADC countries in humid, sub-humid and dry lands. Practised in mixed farming systems across all SADC countries in humid, sub-humid and dry lands. |

| Thematic Area | Approaches | Definition and description of the approach | Key characteristics of the methodologies | Contributions and benefits to productivity | Where methodologies and approaches are in use |
|---|---|---|---|---|---|
| **Livestock Manage ment systems** | Livestock Diversification | Addition of new livestock breeds and types and livestock rearing systems to agricultural production on a particular farm, taking into account the different returns from the value-added livestock products with complementary marketing opportunities. | Different cattle breeds, such as the hardy types. Small livestock such as goats and sheep that are resilient. Increase in productivity per unit area for small livestock systems and hardy breeds | Reduced overgrazing and soil erosion | Practised in mixed farming systems across all SADC countries in humid, sub-humid and dry lands. |
| | Forage/fodder production and conservation. | Feed for domesticated livestock that can be either hay, silage, stover or pasture. | Fodder trees/shrubs grown in the field alongside crops or between crop fields; Over sowing with specific species that increase digestibility and feed conversion; | Water use by growing fodder crops varies from 3 to 9.9 mm/day with an average of 5.4 mm/day in dryland cropping systems. | Production of forage crops such as legumes is practised in SADC, especially drylands; cereal stalks/ stover for dry season use. |
| | Improved pasture management | This involves planting new pasture varieties (e.g., *Stylolanthes*) and rotational grazing of livestock to minimize land degradation. | Planting selected high-yield pastures. Planning grazing schedules of fields | Reduction in overgrazing and soil erosion associated with high demand for forage and pastures on the same land. It allows the regeneration of pastures during rotational grazing. Pasture can be bailed for livestock feeding in the drier season. | Case studies of Zambian com mercial farms using adaptive rotational grazing (fast grazing for a few hours followed by fallow for a season or two); a case study in Botswana Ghanzi district research on continuous versus rotational grazing with latter showing positive results. |
| | Grassland restoration. | The regeneration of grassland ecosystems as a means of supplying natural feed. | Increases biomass production, which increases feed available to livestock. | Increased livestock productivity and reduced animal deaths due to drought. | Case studies in Zimbabwe mainly focused on improving communal grazing land by participatory planning rotational grazing. |

| Thematic Area | Approaches | Definition and description of the approach | Key characteristics of the methodologies | Contributions and benefits to productivity | Where methodologies and approaches are in use |
|---|---|---|---|---|---|
| **Livestock Manage ment systems** | Improved animal manure treatment. | Manure is a product from livestock waste and urine mixed with water that needs to be treated to reduce losses and GHG emissions. I mproved animal manure treatment is the optimal, site-specific handling of livestock manure from the c ollection, through treatment and storage, up to the application to crops (and aquaculture) | Different cattle breeds, such as the hardy types. Small livestock such as goats and sheep that are resilient. Increase in productivity per unit area for small livestock systems and hardy breeds | Reduced overgrazing and soil erosion | Practised in mixed farming systems across all SADC countries in humid, sub-humid and dry lands. |
| | Improved housing for small ruminant livestock. | Housing designed to keep livestock to meet CC standards. | Improves feed utilization. | Optimised productivity and protection against extreme weather events. | A common practice in all SADC countries. |
| **Soil management** | Contour planting in mountainous or ordinary farming areas. | Planting of crops or agroforestry trees/shrubs across the slope of the land. | Rows of crops or agroforestry trees/shrubs are established across the slope. | Reduces run-off, increases water infiltration, soil fertility improvement through leguminous trees and enhances organic matter | A common practice in all SADC countries. Particularly important in the hilly parts of Eswatini, Lesotho, Madagascar, Malawi, South Africa, and Zimbabwe. |
| | Terracing | Levelling of land in areas with slopes that are greater than 15 degrees' slope. | Terracing and bunding across the slope of the land. | Slows water runoff and increases infiltration into the soil. There is reduced soil erosion and nutrient preservation. | Case of *Fanya juu* terraces in Tanzania that helps in reducing erosion. Important in the hilly parts of Eswatini, Lesotho, Madagascar, Malawi, South Africa, and Zimbabwe. |

| Thematic Area | Approaches | Definition and description of the approach | Key characteristics of the methodologies | Contributions and benefits to productivity | Where methodologies and approaches are in use |
|---|---|---|---|---|---|
| **Soil management** | Soil pH testing | Testing the soil to determine the acidity or alkalinity of the soil that influences plant nutrient availability. | Optimal pH range aids in the efficient extraction of nutrients hence higher yield s and less wastage of inorganic fertilizer. | Aid in a proper soil amendment to increase nutrient use efficiency and update the soil. | Important practice for all SADC countries. Actual rapid field testing by *Solidaridado* and *Agricares* in Zambia, Mozambique and other countries in southern Africa. |
| | Liming | Addition of agricultural lime or wood ash to increase the soil pH. | Lime added in liquid or powdered form to raise the soil pH. | Increased nutrient update by the plant roots leading to decreased nitrogenous fertilizers | A standard practice in conservation agriculture s ystems in SADC countries. |
| | Biochar Application | Addition of charred organic material to the soil | Charring of crop residue such as maize husks. | | Eastern Province in Zambia under pilot study and Malawi. |
| | Organic and inorganic fertilizer addition | Complementary application of organic manures and mineral fertilizer. | Reduction in the amount of inorganic fertilizer added; increased soil moisture retention. | Reduced fertilizer use also reduces greenhouse gas. Reduced inorganic fertilizer will lead to more organic nutrient use, which is more adaptable | A standard practice in conservation agriculture systems in all SADC countries. |
| | Integrated Soil Fertility Management. | A holistic approach to soil fertility management includes seed selection, cultivation practices, cropping systems and soil amendments. | Seed selection; using No-till, Conservation tillage, Soil amendments such as biochar, organic matter, compost and liming; use of different cropping systems. | Significant yields are achieved as the soil becomes less reliant on inorganic fertility. Farmers are able to access other fertility options from nature, organic matter and specialised trees | A standard practice in conservation agriculture systems in all SADC countries. |
| **Agroforestry** | Nitrogen fixing trees. | Incorporating trees/shrubs into the farming system – a dynamic and ecological method of land management involving the simultaneous cultivation of farm crops and trees. | Trees such as *Faidherbia, Leucaena, Sesbania, Tephrosia Gliricidia* are grown together with crops in different spatial arrangements in the same field. | Multiple benefits of trees to conserve moisture and enhance soil fertility leading to improved harvest. Perennial trees can offer food at a household level all year round. | Common in some SADC countries, e.g., Malawi, Zambia, and Zimbabwe. |

| Thematic Area | Approaches | Definition and description of the approach | Key characteristics of the methodologies | Contributions and benefits to productivity | Where methodologies and approaches are in use |
|---|---|---|---|---|---|
| **Agroforestry** | Intercropping crops with Trees - Alley cropping. | Alley cropping is a production system in which trees and shrubs (preferably fast-growing leguminous species) are established in hedgerows on arable cropland, with crops cultivated in the alleys between the hedgerows. | Planting trees at a given distance; Integrating livestock feeding; Planting crops in alleys; and feeding livestock. | Offers alternative livestock feed and facilitates reducing overgrazing and soil erosion in pastures. | Common in some SADC countries, e.g., Malawi, Zambia, and Zimbabwe. |
| | Intercropping with Leguminous trees and shrubs | Use of leguminous plant species in place of herbaceous plants in the farming system. | Intercropping of woody trees with crops | Facilitates soil nutrient improvement and moisture conservation through the cover crops | Extensive practice in the eastern province of Zambia and Malawi. |
| **Fisheries** | Integrated fish farming systems | Integrating capture and successful aquaculture species by either restocking or breeding and rearing. | Capture fisheries - restocking of those at risk. | Alternative to increased livestock systems and considerable reduction in methane gas | Zambia – Lake Kariba, Chirundu, Bangweulu. |
| | Improving stocks and fingerlings; Production and other nursery materials for abalone, oyster, seaweed and others | Breeding and screening of l ocal fish types or introduction of exotic ones. Production of fingerlings in hatcheries | Breeding work to increase s ize; Selecting and screening adapted breeds; Increased the diversity of fish stocks | Increased productivity of livestock systems and reducing pressure on grazing l ands on limited pasture lands | Western cape abalone, Namibia oyster, Malawi, Z ambia. Zimbabwe produces Tilapia on lake Kariba, Mozambique and Tanzania marine species and seaweed. |

**Watershed management for climate change adaptation**

- Watershed management is the process of formulating and carrying out the course of action involving the manipulation of a watershed's natural, agricultural and human resources to provide resources that are desired by and suitable to the watershed community.
- Watershed management is also understood as any human action aimed at ensuring the sustainable use of natural resources in a watershed and attempts to provide solutions to these threats.
- Watershed management, therefore, aims to preserve the range of environmental services, particularly hydrological services provided by a watershed. Therefore, watershed management is supposed to be an integrated and multidisciplinary approach.

**Key principles of watershed management**

Watersheds are envisioned as dynamic systems characterized by diverse interactions and spatial relations between humans and the environment that manifest as mosaics of different land-use systems. The socio-economic, cultural and environmental relationships, flows and conflicts between the upper and lower parts of a watershed are referred to as upstream-downstream linkages. The consideration of these linkages forms integral principles of watershed management.

- The other principles of climate-smart watershed management include;
    - o Addressing the root causes and drivers of environmental degradation (instead of treating symptoms)
    - o Planning in an iterative process involving cycles of analysis
    - o Plan formulation, implementation and evaluation that allows for continuous learning and adjustments
    - o Working across sectors, with all stakeholder groups and administrative levels, thereby integrating bottom-up and top-down aspects
    - o Combining local and scientific knowledge. (FAO, 2013).

**Climate smartness of watershed management**

Watershed management as a climate-smart practice can therefore be applied to;

- Adapting to climate change, particularly in larger watersheds that have high forest cover or high potential for afforestation and reforestation.
- Identifying areas for carbon storage and sequestration by forests and trees
- Reducing deforestation and forest degradation by limiting agricultural expansion and the conversion of forests to pasture lands.

### Agroforestry management approaches

- Agroforestry is the use of trees and shrubs in agricultural farming systems: Agroforestry is appreciated in most farming systems because the trees, shrubs and palms integrated into a farm can provide year-round vegetative cover that reduces soil disturbance and provides habitats for beneficial species such as pollinators and natural enemies of crop pests.
- The adaptation practices associated with agroforestry in Southern Africa include the use of some tree species as improved fallows, growing multipurpose trees and shrubs, boundary planting, farm woodlots, plantation/crop combinations, shelterbelts, windbreaks, conservation hedges, fodder banks, live fences, trees on pasture and tree apiculture.
- Agroforestry, therefore, includes both the integration of trees on farmland and the use of agricultural crops and livestock in woodlands.

**Table 5.2.** Some Agroforestry Tree species currently being used by farmers in Southern Africa.

| Name of Agroforestry tree species | Description and agronomic use | Physical Morphology |
|---|---|---|
| *Azadirachta indica (neem):* | A fast-growing, large tree that grows well in low altitudes in some parts of southern Africa, such as the Shire valley. Its leaves are commonly used to protect stored grains against insect pests. Neem seed extracts are also effective against a wide range of pests in the field and storage. The leaves can also be used as green manure. Neem trees can be planted as boundary tress around gardens and homesteads or as woodlots |  |
| *Cajanus cajan (Pigeon Pea)* | A small-sized shrub that grows well in a wide r ange of altitudes in Malawi. Its seeds are a highly nutritious, high-protein food that is utilised in Malawi. Apart from its importance as a food crop, pigeon pea improves soil structure and fertility through its deep root system that has nitrogen-f ixing nodules and through green manure from abundant leaf fall. Pigeon pea can be used in alley cropping, under-sowing crop systems, f allows and in contour vegetation strips. |  |

| Name of Agroforestry tree species | Description and agronomic use | Physical Morphology |
|---|---|---|
| *Faidherbia albida (Winter thorn) (Msangu in Chichewa* | An ideal agroforestry tree species that is widely appreciated by farmers in some parts of Southern Africa. It is an indigenous species tree that grows well in a wide range of altitudes of the region. F. albida is a deciduous tree that losses nutrition-rich leaves during the rainy season. The leaves improve soil fertility, while the open canopy allows sufficient light to reach crops cultivated under the tree, resulting in good growth and increased crop yield. In times of famine, people eat the seeds after repeated boiling. Pods and leaves of F. albida are excellent fodder for livestock. Msangu can be grown in intercrops with crops as boundary trees around homesteads and farms. It can be used in fallows and also be planted along banks of streams. |  |
| *Gliricidia sepium (Mexican lilac):* | A species that grows well in a wide range of altitudes in Malawi. G. sepium enriches soils by fixing nitrogen in its root nodules. It can be cultivated as fodder and green manure banks, in alley cropping systems, as contour vegetation strips, and in fallows. |  |
| *Leuceana diversifolia (Luceana):* | A very fast-growing, drought-resistant agroforestry species that is well adapted to most parts of Malawi. It improves soil fertility by fixing nitrogen in its root nodules. In Malawi, Leuceana is used extensively as green manure, livestock feed, and for soil conservation. It can be grown in alley cropping practices, fodder/green manure banks, or planted along banks of streams. |  |
| *Leuceana diversifolia (Luceana):* | A fast-growing agroforestry tree that originated from India and Arabia but is naturalised in many tropical areas, including Malawi. M. oleifera grows well in low to medium altitudes, such as along the rift valley. It is a multipurpose tree whose leaves and flowers can be cooked after pounding and used as a relish. Moringa leaves are good fodder for livestock, while powder from ground seeds can be used to purify water. Moringa also has many medicinal properties that can benefit farmers. |  |

| Name of Agroforestry tree species | Description and agronomic use | Physical Morphology |
|---|---|---|
| *Sesbania sesban ( River bean)* | A very fast-growing agroforestry species that grows well on a wide range of soils in Malawi. It is good fodder and green manure species and also improves soil fertility through nitrogen-f ixing. S. sesban can be used in fallows, fodder and green manure banks in under-sowing systems, as contour vegetation strips, or for planting along banks of streams. |  |
| *Tephrosia vogelii* (Fish Bean) | A fast-growing shrub that grows well at medium to high altitudes in a wide range of soils in Malawi. It improves soil fertility through heavy leaf fall and nitrogen fixation in its root nodules. T. vogelii can be used in alley cropping, planted in boundaries around homesteads and/or farms, used in fallows, and as contour vegetation strips and also in under-sowing planting systems. T. vogelii is particularly important to agriculture because of its insecticidal properties against a wide range of pests, including maize stem borers. |  |

## 5.3 Best-Bet Climate Smart Agriculture Technologies for Adaptation to Climate Change.

Among the Climate Smart Agriculture Practices cited in the CSA Country profiles for Southern Africa (compiled by FAO) over the years, Conservation Agriculture, Agroforestry, Integrated Pest and Disease Management (IPDM) practices and the use of drought tolerant crop varieties and the use of solar-powered drip irrigation in smallholder vegetable production were reviewed and were considered as some of the best bet technologies for adaptation in the region. The factors that guided their choice as best bet technologies are discussed as follows:

### Best bet 1: Conservation agriculture with cover crop mixtures

Conservation Agriculture (CA) is acknowledged to be a practice that has been instrumental in climate change resilience building for farmers that are currently facing the risks of climate change in southern Africa. Increasing temperatures and changes in precipitation are expected to adversely affect biodiversity, amplify existing stress on water supplies, exacerbate the vulnerability of agricultural systems, and increase the burden of a range of climate-related health outcomes (IPCC 2014).[6]

[6] IPCC 2014. Intergovernmental Panel on Climate Change (IPCC) (2014) Climate change 2014: impacts, adaptation, and vulnerability. Part B: regional aspects. Contribution of working group II to the fifth Assessment Report

Whilst minimum tillage practices, including crop rotations, are probably the two most practiced forms of CA by farmers. However, cover crops—which are supposed to be added to a crop rotation mix are in most cases not considered by smallholder farmers, yet the benefits of drought-proofing activities of the cover crops have been acknowledged by farmers the world all over, especially in situations where farmers have the liberty of choosing the type and mix of cover crops of their own.

Cover crops, by definition, are plants that are planted to cover the soil rather than for the purpose of being harvested for food per se, to reduce soil erosion, weeds, pests, and diseases and increase soil fertility. Growing a cover crop between main crops imitates natural ecosystems where the soil is continuously covered with vegetation. This is an important management practice in preserving soil nutrient resources and reducing nitrogen (N) losses to waters. Cover crops also provide other functions that are important for the resilience and long-term stability of cropping systems, such as reduced erosion, increased soil fertility, carbon sequestration, increased soil phosphorus (P) availability, and suppression of weeds and pathogens.


*Farmers are at liberty to choose the cover crop combinations suitable and beneficial in their farming systems.*

The positive impact of cover crops as a conservation agriculture practice on the distribution of labour during the production cycle and, even more importantly, the reduction in labour requirement are probably the main reasons why farmers should adopt conservation agriculture based on a mix of cover crops, especially for farmers who rely fully on family labour. The aspects of labour requirements are important to consider in the farming systems of the smallholder farmers in the region because climate change affects men and women differently. Rural women farmers tend to be more susceptible to drought and the additional labor associated with household tasks. As such, building resilience against climate change is critical. In the sense of using a mix of cover crops. The constant addition of crop residues by cover crops leads to an increase in the organic matter content of the soil. In the beginning, this is limited to the top layer of the soil, but with time this will extend to deeper soil layers.
On the basis of labour considerations and the important role of adding organic matter to the soil, therefore, cover crops could be scaled up in the farming systems of smallholder farmers in the region to take advantage of the fact that most farmers in the region are already practicing CA. The suppression of weeds and pathogens by cover crops, in particular fulfills two more other requirements of CSA practices that are normally promoted separately as integrated pest management practices and

weed control measures to improve the crop outlook and yield.

**Best bet 2: Drought-tolerant crop varieties**

Drought is a huge limiting factor in crop (especially maize) production, mainly in the rain-fed agriculture of sub-Saharan Africa. In response to this threat, drought-tolerant (DT) crop varieties have been developed with the aim of ensuring production under mild drought conditions. A review of the literature on the use of drought-tolerant crop varieties indicates that the strategy is increasingly being used and adopted by smallholder farmers in southern Africa to manage drought events in their farming systems.

A study conducted in two districts of Chiredzi and Chipinge in south-eastern Zimbabwe to assess the impact of smallholder farmers' adoption of DT maize varieties on total maize production in a drought year, for instance, showed that total maize yield was 436.5 kg/ha for a household that did not grow DT maize varieties and 680.5 kg/ha for households that grew DT maize varieties.  The results show that households that grew DT maize varieties had 617 kg/ha more maize than households that did not grow the DT maize varieties.

Given that almost all farmers buy their seeds in the market, a change in varieties to DT maize seeds gives an extra income of US$240/ha or more than nine months of food at no additional cost. This has huge implications for curbing food insecurity and simultaneously saving huge amounts of resources at the household and national levels, which are used to buy extra food during the lean season. In a similar circumstance, a wide variety of DT crop varieties for different crops exist but may not have been fully shared to inform decision-making.

*Drought tolerant maize variety being tested by the Drought-tolerant yielding plants project in Botswana*

To reduce vulnerability and improve food security, the Drought Tolerant Maize for Africa (DTMA) project has facilitated the release of 160 drought-tolerant (DT) maize varieties between 2007 and 2013. These have been tested in experimental and farmers' fields and disseminated to farmers in 13 African countries through national agricultural research systems and private seed companies. Yields of the new varieties are superior to those of currently available commercial maize varieties under both stress and optimum growing conditions. Although the benefits of DT maize for African farmers have been repeatedly predicted, realization of those benefits depends on farmer uptake, which has received limited empirical study.

**Best bet 3: A Solar-powered water pump Drip Irrigation System for off season Vegetable Production**

*Even in situations where crop failure is reported as a result of drought, some farmers will still realize a slight additional harvest than others.*

The impacts of climate change in sub-Saharan Africa are severe and have far-reaching consequences for millions of smallholder farmers. Rising temperatures, destructive locust swarms, and increasingly erratic rainfall make it difficult for farmers to grow food and meet basic needs. However, expanding small-scale irrigation is emerging as part of the solution. When farmers take irrigation into their own hands, they can increase production, both by supplementing their rain-fed crops with irrigation and by growing an additional harvest during the dry season. Small-scale irrigation brings immense benefits, including better nutrition, higher incomes, and greater climate resilience.

*A Solar Pump being used to pump water from a shallow well to a reservoir for irrigation as an exhibition at the Provincial Agricultural Show in Livingstone District of Zambia.*

Experiences from other developing countries indicate that coupling low-cost irrigation technologies with water conservation and harvesting technologies allows better control and management of limited water resources and results in much higher returns to smallholder farmers. Small-scale, low-cost irrigation systems that can easily be established and managed by poor smallholder farmers have the potential to contribute significantly to the endeavors of ensuring food self-sufficiency at the household level.

Some of the advantages associated with solar-powered drip Irrigation systems are as follows:

- Solar irrigation can increase incomes dramatically, particularly for remote producers with inconsistent access to electricity or fuel.
- Pump irrigation reduces labour for water delivery.
- By targeting water at a crop's roots, drip irrigation can reduce weed and disease pressures and increase the efficiency of chemical applications.
- Drip irrigation significantly increases water use efficiency

- Return on investment, unlike paying utility bills
- Virtually no maintenance as solar panels last over 30 years
- With drip irrigation, water sources previously considered too small for irrigation can now be utilized.
- Water from existing sources like canals can be extended to irrigate twice as much land as is possible under flooding.

Due to the promise and benefits, the solar-powered irrigation system technology is able to offer, governments and NGOs in developing countries are now eager to invest in the operationalization of such farming technologies. Though the GCCA+ project is funded by the European Union, CCARDESA is one subsidiary organization of the SADC region that is currently demonstrating the efficacy of this type of technology through its project of harnessing climate-smart agriculture practices to mitigate the impact of climate change on farming systems. In addition, Research organizations and rural development service providers are now demonstrating the efficacy of solar-powered irrigation systems in some areas of the region.

In order to support the development and operationalization of solar-powered drip irrigation systems, governments in the region could probably consider subsidies, investments and technological backup with private partnership arrangements. The solar-powered Drip Irrigation System for off-season Vegetable Production is, therefore, an innovation that qualifies as both a new knowledge product as well as a best-bet technology.

# CHAPTER 6: CLIMATE SMART AGRICULTURE MITIGATION TECHNOLOGIES

**Learning Objectives**

At the end of the module, an extension officer should be able to:

- Describe the role of the climate smart agriculture approach in climate change mitigation.
- Identify climate smart agriculture approaches for climate change mitigation through regional case studies.

## 6.1 Description of Mitigation

The UN's Intergovernmental Panel on Climate Change (IPCC) advocates for the implementation of strategies that limit or prevent greenhouse gas (GHG) emissions and enhances the removal of these gases from the atmosphere. Climate change mitigation through agriculture entails reducing greenhouse gas emissions from farming systems and extracting GHGs such as carbon dioxide from the atmosphere through increased carbon sinks. Carbon dioxide, methane and nitrous oxide are the primary GHGs in the atmosphere. Mitigation of climate change requires human intervention to reduce GHG emissions and enhance the sinks of greenhouse gases. Consequently, mitigation may require the use of new technologies and clean energy sources, change people's behavior, or increase energy use efficiency when using older technologies. Where possible, it is envisaged that CSA should help reduce GHG emissions and remove some of the GHGs from the atmosphere. This implies that we reduce GHG emissions per unit of food, fiber and fuel produced. In addition, we produce as well as avoid deforestation from agriculture and be able to manage soils and vegetation in ways that maximize their potential to act as carbon sinks and absorb carbon dioxide from the atmosphere.

## 6.2 Key CSA technologies for mitigating climate change

Climate-smart agriculture is an approach that guides actions that transform agri-food systems towards green and climate-resilient practices leading to increased mitigation against climate change. Mitigation against climate change is combined with enhanced productivity and adaptation, is important for achieving national food security and development goals. Climate smart agriculture technologies and practices fall into seven categories namely crop management, livestock management, soil management, water management, forestry, fisheries and aquaculture, and energy management (Table 6.1). These practices are summarized below:

### a. Soil management

Soil management help mitigates climate change through several interventions and are an important 'carbon sink' through sequestration as organic matter. Management interventions harness the ability of soil as a carbon sink through organic matter additions under practices such as conservation agriculture, crop-tree integration of farms, and improved management of natural pastures which increase the degree of carbon sequestration. Emissions of nitrous oxide from inorganic fertilizer can be reduced through integrated approaches that improve the management and utilization of inorganic nitrogen fertilizer. Additionally, paddy systems of rice production promote the accumulation of soil carbon. Good soil management, particularly soil fertility improvement, ensures increased crop growth, and high plant biomass increases the use of carbon dioxide, hence increasing extraction of the GHG from the atmosphere during photosynthesis.

### b. Crop management

In the SADC region, crop production is practiced within a very diverse range of farming systems adapted to the different agro-ecological conditions of the region. Each crop production system is subject to widely variable climatic, soil and socio-economic conditions under either rainfed or irrigated agriculture or both. There is increasingly more attention placed on crop production practices that are climate-smart in terms of their mitigation potential. These climate-smart interventions include soil and water management, forestry/agroforestry practices and technologies, and integrating crops with shrubs/trees in appropriate cropping systems.

The mitigation potential of crop production is largely attributed to soil and water management or the agroforestry system under which crops are grown. However, perennial crops sequester more significant amounts of carbon below ground than annual crops. In addition, crop management technologies and practices that increase plant biomass production increase the carbon sink for extraction of carbon dioxide from the atmosphere and further reduce continued carbon dioxide fertilization of the atmosphere. Practices that promote mitigation through crop growth can integrate soil and crop management technologies, maximizing the synergies of the two in cropping/farming systems.

### c. Water Management

The SADC region annually accumulates approximately 2,300 km$^3$ of renewable water, with only 14% retained in the main reservoirs of the Zambezi basin (FAO, 2012). Storage and transmission infrastructure is needed to supply water for irrigated agriculture, but also for urban and industrial use. Surface water resources in the region contribute towards hydropower generation, a practice that minimizes the use of fossils such as coal for power generation. Burning of coal and other fossil fuels generates carbon dioxide, methane and nitrous oxide, the most common GHGs contributing to global warming and climate change.

Rice production in paddy systems emits substantial amounts of methane and nitrous oxide. Alternate wetting and drying cycles in such systems result in reduced methane emissions. In addition, irrigation strategies that reduce the amount of water required can reduce energy consumption for pumping, thereby reducing GHG emissions. Additionally, increased water use efficiency combined with good agronomic practices promotes increased growth and plant biomass accumulation in farming systems. Plant biomass is a sink as plants use atmospheric carbon dioxide during photosynthesis.

### d. Livestock management

Climate change has considerable impacts on livestock production, but mitigation opportunities exist and these are mainly related to the provision of high-quality feed that minimize the emission of GHGs. Improving livestock feeding practices and the use of legume-derived feeds can increase the efficiency of the digestive process, thus reducing methane emissions from the internal fermentation of ruminants. Improved grazing land management increases soil carbon sequestration and increases the mitigation potential in livestock systems. Emissions can be reduced through compacting and covering livestock manure, as well as appropriate timing of manure application to crops reduces methane and nitrous oxide emissions. Feed additives which are used to modify the methane production in ruminants are another way to reduce GHG emissions in livestock systems.

### e. Forestry and agroforestry management

Carbon storage can be increased through combining crops with trees for timber and fodder, afforestation and reforestation, and conversion from non-forest to forest land use and from degraded forests to fully carbon-stocked forests. Forests support a much bigger population by providing ecosystem services (carbon sequestration, food, fuel, water, and biodiversity). Climate change threatens the delivery of ecosystem services and consequently impacts on rural livelihoods. The potential of trees and shrubs on farms as a carbon sink can be increased through afforestation efforts and reduced deforestation. Mitigation activities that increase tree cover (agroforestry, afforestation, and reforestation) and reduce degradation and deforestation increase carbon sequestration through increased above and below-ground plant biomass.

### f. Fisheries

Capture fisheries and aquaculture support many people's livelihoods worldwide. Changes in ocean acidity and temperature cause major disruptions in migration patterns and food chains. Marine species' biological cycles lead to decreased fish populations and global changes in fish locations. Loss of biodiversity is also attributed to the extinction of specialized or endemic fish species due to extremes in climate variation and climate change. Frequent extreme weather events threaten fisheries and aquaculture installations along coastal shorelines with a slow sea level rise and increasing salinity.

*Maanda Sianga, Kafue based fish farmer sampling her fish from one of the ponds.*

***Maanda Sianga, Kafue based fish farmer sampling her fish from one of the ponds.***

Annual emissions estimated at 30% are sequestrated in aquatic environments, primarily in mangroves, sea grasses, floodplain forests, and coastal sediments. The promotion of carbon sequestration in these fish habitats is a key objective in climate change mitigation in fishery systems. In addition, sequestration can be enhanced through increased planted areas of mangroves and floodplain forests. Reduced greenhouse gas (GHG) emissions are also achievable by regulating the fuel use of fishing fleets through flexible quota allocations. Additionally, GHG emissions from fisheries can also be reduced through improved fish feeds and growing improved breeds that are more efficient in using the fish feed. In addition, the use of clean energy in fish storage facilities reduces GHG emissions, hence minimizing global warming and climate change.

### *g. Clean Energy sources for CSA in southern Africa*

Clean energy is produced from renewable natural resources that minimize the emission of GHGs into the atmosphere. Solar and wind generate electricity and there is minimal production of GHGs during electricity generation. Biogas is generated through fermentation in anaerobic digesters, and carbon dioxide and methane are retained as part of the gas mixture and are not emitted into the atmosphere, contrary to when manure and waste decompose under aerobic conditions. Generation of bio-energy through anaerobic conditions reduces methane production, contrary to the decomposition of plant biomass/residues under aerobic conditions. Hydro-energy is generated by water which is a renewable natural resource, and there is no generation of GHGs during the production of electricity. Clean energy sources suitable for CSA in SADC include:

***(I)*** *Solar energy*

***Installation of Solar Panels for irrigation purpose at SOS School in Chipata, Eastern Zambia.***

This is renewable and carbon-free energy generated from the sun and results in limited GHG emissions. Through photovoltaic panels, solar radiation is converted directly into electricity which is then used for powering agricultural machinery and farming operations such as water pumping for irrigation.

*Installation of Solar Panels for irrigation purpose at SOS School in Chipata, Eastern Zambia.*

***(ii)*** *Wind energy*

Wind energy is also a carbon-free and renewable natural resource and is generated by turbines driven by air currents. The power output from the turbines depends on the wind speed, and power generation increases with increased wind speed.

***(iii)*** *Hydro-energy*

Hydro-energy is generated from the natural flow of water from a higher elevation to a lower elevation in its flow. As the water falls, it drives turbines and this, in turn, generates electricity which can be used to power agricultural machinery and provide lighting on farms. Energy for pumping irrigation water is critical in food production in SADC.

***(iv)*** *Bio-energy*

Bio-energy is generated from food waste, animal manure and slurry, and crop biomass/residues. Energy is generated through biochemical, thermochemical and transesterification processes. The biochemical process involves anaerobic digestion and fermentation procedures to generate gases such as methane and carbon dioxide. The gases are used for generating heat energy which can be used for heating different systems such as poultry production on the farm.

## 6.3 Best-bet Practices for Climate Change Mitigation

Transformation of the agricultural sector to address climate change requires the identification of climate-smart, context-specific and investment-ready opportunities for farmers, investors and policy makers. Although promising CSA practices exist and much has been learned in recent years that can support decision-making, many decision-makers still struggle to identify the best-bet CSA interventions in their own context. To achieve the multiple objectives of productivity and food security, enhanced farmer resilience and reduced greenhouse gas emissions, CSA must adopt various systems perspectives. The agricultural sector emits not only carbon dioxide but also nitrous oxide mostly by soils and through the application of nitrogenous fertilizers, and methane essentially from livestock and rice cultivation. On the other hand, agriculture is a key sector that, along with the forestry sector, can lead to biological carbon capture and storage in biomass and soil, acting as "sinks". There are two ways by which agricultural production can contribute to climate change mitigation, namely by (i) improving the efficiency of decoupling production growth from emissions growth (i.*e. producing more of a given output using less of a given input*) directly driven by the use of resources, and (ii) enhancing soil carbon sinks through increasing soil organic matter accumulation.

**Table 6.1:** Mitigation enhancing CSA technologies for southern Africa.

| Thematic Area | Approaches | Definition/Description of approach | Characteristics/ Methodologies | Contributions/ benefits to mitigation | Where the approaches are in use in SADC |
|---|---|---|---|---|---|
| Soil management | Conservation Agriculture | Application of operations, practices, and treatments to protect soil and enhance its performance. | Multipurpose trees on farms, improved residue management, Organic matter additions, minimum soil disturbance. | Increased degree of carbon sequestration. | Agroforestry approaches: Malawi, Zambia, Tanzania, Zimbabwe. |
| | Conservation Agriculture | Conserves, improves, and makes more efficient use of production resources through the integrated use of available resources and external inputs. | Minimum soil disturbance, retention of organic soil cover, Crop Rotations & intercropping. | Improving the efficiency of decoupling production growth from emissions growth. | Various approaches used by SADC countries: Hand-hoe based options on small land holdings; Animal draft powered CA equipment for small and medium-scale farmers; Motorized CA for medium and large-scale farmers in South Africa, Zimbabwe, Zimbabwe, Malawi, Lesotho, Swaziland. |
| Water Management | Conservation Agriculture | The approach collects and conserves water. The activity of planning, developing, distributing, and managing the optimum use of water resources. | Water harvesting, alternate wetting and drying cycles r educe methane emissions. | Use water more efficiently in agriculture; co-benefit of r educing soil erosion, improving water infiltration, increasing nutrient cycling, decreasing money spent on inputs like f ertilizer, building more resilient soils over time, and serving as a climate solution. | A common practice in all SADC countries. Particularly important in the hilly parts of Eswatini, Lesotho, Madagascar, Malawi, South Africa, and Zimbabwe. |
| Livestock production | Good Agricultural Practice (GAP) | Involves managing farm animals and operations. | Improving animal and herd efficiency, improved breeding and animal health interventions, improved animal feed, and manure management. | Reducing the amount of greenhouse gases emitted, or indirectly through the improvement of production efficiency. | All SADC countries. |

| Thematic Area | Approaches | Definition/Description of approach | Characteristics/ Methodologies | Contributions/ benefits to mitigation | Where the approaches are in use in SADC |
|---|---|---|---|---|---|
| Forestry and agroforestry | Conservation Agriculture | The deliberate combination of woody perennials on the same piece of land with agricultural crops and/or animals. | Contain substantial carbon in the soil, trees and other vegetation, and globally they are hugely important to the carbon, water and energy cycles. | (1) Sequestering carbon in biomass and soils, (2) reducing greenhouse gas emissions, and (3) avoiding emissions through reduced fossil fuel and energy usage on farms.<br>Involve feed additives used to modify the methane production in ruminants.<br>Co-benefits: phytoremediation, watershed protection and biodiversity conservation. | Agroforestry and afforestation in SADC countries. |
| Capture fisheries and aquaculture | GAP | Wild fish catches for all commercial, industrial, recreational and subsistence purposes/farming of aquatic organisms, including fish, mollusks, crustaceans and aquatic plants. | Physical impacts of climate change on marine and freshwater systems and then connects these changes with observed effects on fish production processes. | Increased planted areas of mangroves and floodplain forests<br>Regulate fuel use of fishing fleets through flexible quota allocations. | Innovate fishing methods and fishing gear to cope with climate change impacts. |
| Energy management | GAP | Use of energy on every stage of the agri-food systems/ value chain. | Improving energy efficiency and reducing losses, increasing energy diversification using renewable energy sources, and opening up access to energy sources through efficient and affordable small-scale systems. | Energy plays a crucial role in the pre-production stages of inputs; in the crop, fish, livestock production and forestry products and by-products; in post-harvest production and post-harvest operations; in food storage and processing; in food transport and distribution; and in food preparation. | Agroforestry, Energy saving Stoves. |

***Best-bet 1:*** *Agroforestry intervention*

*Farmer Managed Natural Regeneration in Malawi. Source: Evergreenagriculture.net.*

GHG inventories indicate that forests, urban trees, and harvested wood account for the majority of natural carbon dioxide sinks through **(1)** Sequestering carbon in biomass and soils, **(2)** reducing GHG emissions, and **(3)** avoiding emissions through reduced fossil fuel usage on farms. All these components contribute towards climate change mitigation that can come from adding agroforestry practices to agricultural and forested landscapes.

***Best-bet 2:*** *Biochar intervention in farming systems*

In South Africa, the recently published Mitigation Potential Analysis (MPA) and the National Terrestrial Carbon Sinks Assessment (NTCSA) identified biochar as one of the land-based mitigation opportunities that can contribute to a transition to a lower carbon economy. With just one application of bio-char products, one can increase the organic matter in the soil and help nutrients and water availability to the plants. Biochar contributes to the reduction of GHGs in the atmosphere by returning carbon to the soil. Biochar can be used in agriculture to improve and maintain soil fertility and to increase soil carbon sequestration.


*Use of Biochar in Cropping Systems.*

***Best-bet 3:*** *Residue retention for soil cover in farming systems*

*Soil cover crop residues. (Photo Credit: Total Land Care).*

Crop residue retention and minimum tillage are common conservation tillage practices that have been extensively applied for improving soil health and reducing the negative environmental impact caused by intensive farming. Retention of surface crop residue aid in erosion control and suppression of annual weeds while allowing tillage to facilitate planting, loosen the soil for improved root growth, and destroy perennial weeds. Residue retention enhances the resistance of soil organic carbon turnover to agricultural and environmental factors. Over time, residue retention supports the accumulation of organic matter in the soil.

***Best-bet 4***: *Cover crops in farming systems*

Cover crops are known for their ability to reduce erosion, fix atmospheric nitrogen, reduce nitrogen leaching, and improve soil health. Recently, there has been a resurgence in cover crop adoption with a heightened awareness of climate change. Climate change mitigation may be an additional, important ecosystem service provided by cover crops, though it currently lies outside of the traditional list of cover cropping benefits. Recent review boosts three key outcomes **(1)** cover crop effects on greenhouse gas fluxes typically mitigate warming by ~100 to 150 g $CO_2$ e/$m^2$ /year (FAO, 2012), which is higher than mitigation from transitioning to no-till; **(2)** the surface albedo change due to cover cropping, may mitigate 12 to 46 g $CO_2$ e/$m^2$ /year over a 100-year time horizon (FAO, 2012); and **(3)** cover crop management can also enable climate Change adaptation, through reduced vulnerability to erosion from extreme rain events, increased soil water management options during droughts or periods of soil saturation, and retention of nitrogen mineralized due to warming. Few tradeoffs were found between cover cropping and climate change mitigation, suggesting that ecosystem services that are traditionally expected from cover cropping can be promoted alongside with services related to climate change.

# CHAPTER 7: CONSIDERATIONS FOR SCALING UP

## 7.1 Fit for Purpose

National governments recognize the importance of agricultural research in generating technologies, technology dissemination and promoting Good Agricultural Practices (GAPs) for smallholder farmers to adopt and improve their yields. Over the years, national and international agricultural research centers have developed a range of promising technologies. As part of experiential learning, farmers themselves have also developed production practices that are relevant to GAPs. Climate Smart Agriculture-related technologies are a component of GAPs that are critical in addressing the impacts of climate change in agriculture.

Agenda 2063, as Africa's development blueprint, has acknowledged the threat and also resolves to address the effects of climate change by building the adaptive capacity and resilience of economies and local communities. The Malabo Declaration makes a further specific commitment to increase the number of farming households practicing CSA to 25 million by 2025. Despite numerous national, regional and continental programs supporting the adoption of CSA, progress towards the stated targets has however remained slow and fragmented. Accelerating the transition to CSA by farmers calls for a heightened sense of urgency by all key stakeholders. Foremost among the potential drivers of this shift in pace and intensity is a strong, coherent and sustained political voice at all levels.

According to the CIMMYT report (https://www.cimmyt.org), climate-smart agriculture (CSA) is considered a good method of mitigating the effects of climate change, especially for both farmers and the planet. Further, it denotes that the practices increase soil moisture levels and soil biodiversity, which have been observed to decrease soil erosion by up to 64%. Scaling up the adoption of technologies is considered effective when it leads to "bringing more quality and effective benefits to more people over a wider geographical area, more quickly, more equitably and more lastingly." For the successful adoption and scaling up of CSA technologies to be achieved, the indicator of effectiveness will constitute an increased number of male and female farmers consistently using CSA technologies and participating in functional networks with skills and knowledge to scale up the adoption of CSA technologies. The main compelling reasons for the clarion call to scale up CSA technologies are to broaden the impact of CSA on poverty, food security and the environment and facilitate local innovation development, building capacity of natural resources, human and social capital.

Scaling up focuses on people, and community development and not on technical change alone. Key to achieving scale and also to ensure sustainability in technological enhancement is the strengthening of local capacities to innovate. This is often just as or even more important than the technologies themselves. Due to the complexities of factors that affect scaling up, unlocking scale requires vertical and horizontal processes. The vertical process represents efforts to influence policymakers and donors and is generally institutional in nature. The horizontal process (***also referred to as scaling out***) refers to the spread across communities and institutions, and geographic boundaries. Both processes are needed for effective adoption. Ultimately what is required is the process of institutionalizing CSA in the research, extension, development and education arenas of the countries in order to get policymakers, researchers, extension workers, development practitioners, educationalists and farmers to forge joint efforts in addressing the factors that influence achieving scale for impact.

The major factors that have informed the low pace of uptake and scale include: **the high cost of agricultural inputs, and insufficient access to technology, equipment and markets. The farmers are also hampered by weak bargaining power and also being offered low producer prices for agricultural commodities and limited access to credit lines**. There is also no clear coordination, cooperation and commitment between and from the public as well as private stakeholders. This has resulted in the 'localised' use of these practices and has not benefitted as many people as would have been desired. It is, therefore, paramount that agricultural practices are not only good under present circumstances but are also robust enough to hold up under changing climatic conditions.

In this pursuit, access to resources supports technological innovation through the Climate Technology Centre and Network (CTCN) as the implementation arm of the Technology Mechanism of the United Nations Framework Convention on Climate Change, that is hosted by the UN Environment Programme. The Centre is relevant in the promotion of accelerated transfer of environmentally sound technologies for low carbon and climate resilient development at the request of developing countries.

There are a large number of CSA technologies and practices that have remained on the shelf. , The emergence of scale and speed of climate change, requires that considerable investment in addressing knowledge while fostering the uptake of innovation is vital to instigating transformational shifts. This includes the development of decision-support tools to prioritize adaptation and mitigation actions and investments and further work on institutions and incentives that work for farmers (e.g., payments for environmental services such as soil carbon sequestration). Continued research attention is needed to produce more with less, i.e., increasing productivity while reducing the ecological footprint of agriculture.

The more diverse the range of CSA options available to farmers in respective countries, the higher the chances of increased adoption. Offering a range of options is important as the needs and preferences of farmers differ and most farmers prefer to diversify in order to minimize production costs and risks. Recognizing that CSA is not a single specific agricultural technology or practice that can be universally applied but rather an approach that requires site-specific assessments to identify suitable agricultural production technologies and practices, this approach requires that the following five key elements are taken into consideration as success factors for accelerating wide-scale adoption of CSA:

***a) Supportive policy and legislative reform***

Attaining meaningful and sustainable development is built on the bedrock of an enabling policy environment and accompanying legislation. It is an important first step towards ensuring large-scale adoption of CSA anchored on an enabling policy position as the highest level of government commitment. CSA supportive policy creates a rallying point around which the energies of diverse stakeholder groups converge.

To ensure success, a supportive CSA policy constituted of an inclusive multi-stakeholder and multi-sectoral process of planning, prioritization and validation is important. In most African countries, the Ministry of Agriculture holds the policy mandate; however, it is important to secure the buy-in of various concerned ministries to include various interlinking aspects. Alignment and coherence of policies and strategies at the global, continental, regional, national and sub-nation levels are also vital for an effective response to climate change.

***b) Strong partnerships for implementation***

Multi-stakeholder partnerships between public, private, and development sector partners and farmers are a prerequisite for sustained adoption of CSA. Such partnerships are needed to overcome systemic constraints such as the lack of quality farmer advisory services, limited access to finance and poor linkages with offtake markets. Innovative partnerships should promote mutual interests and address shared climate risks between key value chain actors. To this end, the adoption of CSA by farmers provides an opportunity to deepening of partnerships and collaboration between different partners, including governments, civil society, farmer groups, development partners and the private sector.

The horizontal sectoral links are equally important in fostering CSA across other sectors, given the multi-sectoral dimensions of climate change and its impacts. To address current and future challenges, it requires close cooperation between state and non-state actors that include farmers, agribusiness and development partners. Many identified actions require sustained effort and investment over many years. Other strategic considerations in addressing the key aspects of development include; water, education, HIV and AIDS and other pandemics (e.g. Covid-19), gender and access to credit.

***c) Adequate frontline capacity for quality support to farmers***

Transforming farmer advisory services across Africa requires attention to both the quality of extension personnel and the modalities used in delivering advisory support to farmers. Farmer-centered research and participatory extension processes and local institutional capacity building are required to achieve effective adoption. The involvement of farmers in participatory technology development characterized by farmer-centered research and extension approaches has considerably improved farmers' skills and knowledge in the past. This is evidenced by farmers' innovative ideas in the utilization of various technologies, including those that are CSA related. The nature of challenges posed by climate change call for system-wide changes in agricultural training, including a revamp of the curricula to integrate CSA in all aspects of farming. Recent innovations in ICT also provide opportunities for more efficient, real-time, two-way information flow between service providers and large numbers of farmers. Tapping into these tools will also broaden the scope for farmer-to-farmer exchange and peer learning. Through training efforts, a substantial capacity for community self-monitoring can be established among farmer trainers. Local capacity building for the use of CSA should incorporate training on other important development aspects such as gender, pandemics, such as Covid-19, HIV and AIDS, facilitation skills, and processing and marketing, building a strong foundation for establishing strong CBOs for more consolidated development efforts.

### *d) Favourable conditions for long-term viability of smallholder agriculture*

Creating conditions for the long-term viability of smallholder agriculture is a key driver of the sustained adoption of CSA. Viable production systems give farmers both the capacity and incentive to adopt new practices and technologies that help them better cope with a changing climate. Five inter-connected and often mutually reinforcing key conditions are central to the long-term viability of smallholder agriculture within the African context, namely;

(i) improved market linkages;
(ii) improved access to appropriate finance;
(iii) increased participation in competitive value chains;
(iv) ensured sustainable management of environmental resources such as water and rangelands;
(v) capacitation in application of CIS and,
(vi) provision of quality farmer support services.

These conditions need to be addressed as a package. Opportunities for income generation through the existence of viable markets and processing opportunities for the various agricultural products are a great incentive for the adoption of CSA technologies that increase production and productivity. Where opportunities exist for contract production, it is easier to also get farmers organized into groups to ensure a consistent supply of the required quantity and quality of agricultural produce.

Factors to be considered in the provision of quality farmer support services is the establishment of viable community-based seed systems. A viable seed system that is characterized by quality seed, seedling production and distribution can be achieved through the collaboration of local actors and stakeholders (including farmers, governmental organizations, NGOs, CBOs, and research organizations). Developing sustainable systems should also seek to involve the private sector to help maintain a focus on germplasm quality.

### *e) Quality information and knowledge-sharing systems*

The necessary investment is needed to ensure access to quality information, including improving (and/or installing new) hardware such as research facilities, weather stations, ICT systems, and human capital development. This is vital in improving analytical and communication skills and providing the required operational resources for day-to-day functionality. Investments in the bundling of CSA and the capacitation of producers and users of CIS (Climate Information Systems) provide an opportunity for promoting the adoption of CSA and should be considered where possible.

Key elements of an information and knowledge sharing system for accelerati CSA ensures regular sharing of various experiences dissemination of knowledge and information gained from the scaling up processes is another important element in improving the uptake of CSA technologies. This ensures that partners make effective decisions in their dissemination activities. Information can be generated through formal and informal monitoring and evaluation systems. Regular community appraisals provide an excellent opportunity to monitor farmer needs and priorities for CSA options as well as to elicit farmers' views of the different training approaches.

***f) Monitoring and Evaluation***

To support the process of scaling up and tracking the progress made in adopting CSA, there is a need to develop a comprehensive framework for monitoring and evaluation of the dissemination work. To effectively achieve this, there is a need to establish clear definitions for the "reach" and "adoption" of CSA technologies by farmers, which is critical for systematic data collection and consistency in tracing and monitoring impact. CSA programs ought to set clear indicators of adoption and targets in their implementation plan which should be aligned to the M&E framework for the continent to assess the contribution to the continental targets, such as the **Malabo commitment that has set a target of increased number of farming households practicing CSA to 25 million by 2025**. There is a need to establish effective institutional frameworks for all institutions involved with linkage to the Implementation, Monitoring and Evaluation and Reporting systems across the member states and regional and continental levels.

## 7.2 The Call

From the discussion in this chapter, it has been confirmed that there is no single recipe for scaling up and that different approaches can be successful depending on the innovation, the environment, and the resources at hand. Further, it unlocks the important contribution of the five key success factors necessary for scaling and achieving impact. The role of enabling policy and legislative provisions is important in strengthening implementation partnerships, the improved business environment for smallholder agriculture, improving capacity for providing high-quality farmer support services, as well as improved information and knowledge systems.

It is important for continued support by partners in the region to facilitate the implementation of the CSA options as elaborated in the CSA handbook. The starting point is action and reaction at the level of development policies, development financing, as well as political and policy champions in driving awareness and practicing climate-smart farming.

The following five issues would be valuable in building sustained capacity to drive the necessary change for the adaptation of farming systems to ones that will remain effective and efficient while at the same time embracing "climate smartness":

1. **Rally and build networks or movements of like-minded persons and institutions:** These provide advocacy support as well as platforms for socio-political support (social capital) as well as peer learning and encouragement for each other. The more informed and self-regulating they are, the more effective such networks tend to be.
2. **Ensure empirically based priority setting and justification for CSA with a strong, compelling business sense:** CSA is a development just as much as it is a viable business. It is a concern for the public sector and civil society in as much as it is a concern for the private sector.
3. **Integrate CSA into existing planning frameworks:** Catalyse the advancement of CSA – from research through to policy and investment decisions – within existing strategies, plans and policies as well as within existing institutions. Setting up institutional structures specifically for CSA promotion and implementation will be futile. As a multi-sectoral issue, for most countries, this also implies connecting (coherence, alignment and collaboration) across more than two ministries and departments.
4. **CSA practices are novel and context-specific:** CSA differs from '*business-as-usual*' approaches by emphasizing the capacity to implement flexible, context-specific solutions supported by innovative policy and financing actions, as well as a frontline environment that allows experimentation and self/peer learning.
5. **Context is everything:** Success towards a transition to agriculture that is climate-smart needs holistic, cross-scale and inter-sectoral solutions. Local context - from weather and ecosystem environment, socio-economic factors as well as cultural and traditional norms and values – are critical features in "making it happen." This is especially so when talking about success that is sustainable and able to go to scale. The principles would be ***GLOBAL***, but the application is and will have to be ***LOCALISED***. This is why the promotion of Climate Smart Agriculture should take a bottom-up approach, thereby putting emphasis on scaling up indigenous knowledge and practices through multi-stakeholder cooperation.

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CCARDESA

Centre for Coordination of Agricultural Research and Development for Southern Africa


Ground Floor, Red Brick building
Plot 4701 Mmaraka Road
Private Bag 00357
Gaborone, Botswana
Telephone: +267 391 4997
Fax: +267 316 7211
Email: registry@ccardesa.org
Website: http://www.ccardesa.org



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