# Empowering Smallholder Farmers Through Crop-Based CSA Approaches

## TRAINING AND IMPLEMENTATION GUIDE FOR THE FREE STATE, SOUTH AFRICA

TAGDev 2.0

UFS

RUFORUM

In partnership with

mastercard foundation

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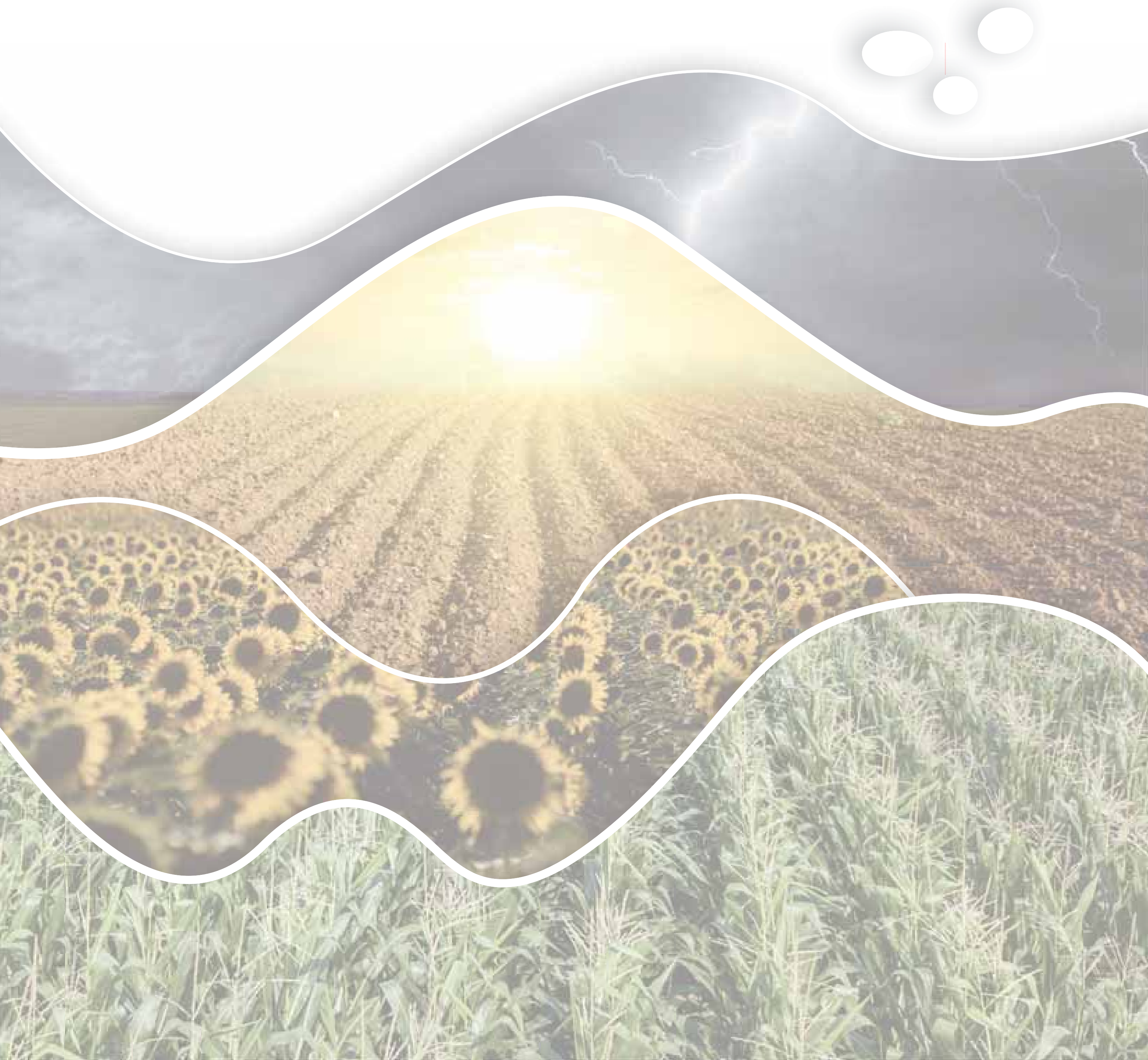

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TAGDev 2.0 (Transforming African Agricultural universities to Generate Development) is a significant $100 million, ten-year Mastercard Foundation-funded project led by RUFORUM and involving 12 core African universities.

TAGDev 2.0 aims to drive inclusive, equitable, and climate-resilient transformation in African agriculture by equipping young people with skills for work, wealth creation, and entrepreneurship. The project substantially enhances the capacity of universities and TVET institutions across the continent to combat youth unemployment and marginalization. The University of the Free State (UFS) is a proud core African university partner in this impactful programme.

This strategic project, led by the Department of Sustainable Food Systems and Development, adopts a comprehensive approach to empowering farmers. UFS provides the essential academic foundation and research expertise needed to deliver sustainable solutions for rural communities.

In partnership with

# Foreword

As the Research Chair on Impact Assessment of Climate-Smart Interventions and Vice Dean of the Faculty of Natural and Agricultural Sciences at the University of the Free State, my work focuses on understanding how innovative agricultural practices can strengthen resilience, improve productivity, and promote sustainable livelihoods in the face of a changing climate.

Through this position, I have the privilege of witnessing how information, when made accessible and practical, can transform the way smallholder farmers plan, adapt, and thrive.

Climate change continues to pose significant challenges to agriculture, especially among smallholder farmers who depend directly on natural systems for their daily survival. Irregular rainfall, prolonged droughts, and increasing temperatures are now part of our agricultural reality. However, with access to reliable data and tools, farmers can anticipate and manage these risks more effectively.

This guide, "Empowering Smallholder Farmers Through Crop-Based CSA Approaches: Training and Implementation Guide for the Free State, South Africa," is designed to bridge that gap. It translates research into practical, user-friendly information that farmers can use to guide day-to-day decisions. It provides a single entry, and reflects our ongoing commitment of the University of the Free State to ensure that climate-smart interventions are not only innovative but also impactful and inclusive. It reinforces the principle that building resilience begins with knowledge, knowledge that is local, accessible, and empowering.

I commend all the contributors and partner institutions who have worked to make this resource possible. It is my hope that this guide will serve as a practical companion for farmers, extension practitioners, and policymakers alike, inspiring informed action and strengthening our collective response to climate challenges.

Together, through collaboration and innovation, we can build an agricultural sector that is not only productive but truly climate-resilient.

**Prof Johan van Niekerk**
Vice-Dean: Agriculture
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# Executive SUMMARY

## Moving Forward Together

The journey through these pages will take us from understanding the climate challenges facing the Free State to exploring practical, proven solutions that can make a real difference on your land. Climate-Smart Agriculture is not a distant dream; it is a practical, accessible approach that starts with small, intentional changes to better soil management today, smarter water use tomorrow, and thoughtful crop choices for the season ahead. Each practice you adopt, no matter how modest it may seem, contributes to building a more resilient farming system that can withstand the uncertainties of our changing climate.

This guide and the TAGDEV 2.0 project are about making sure farmers who have that commitment, who have farming in their blood, get what they need to make it work. Because passion alone isn't enough. You need knowledge, markets, and community.

Our province has always been known as the breadbasket of South Africa, and this reputation was not built on ideal conditions alone

## The Free State Advantage

Our province has always been known as the breadbasket of South Africa, and this reputation was not built on ideal conditions alone. Free State farmers have thrived because of their determination, innovation, and willingness to adapt. The very challenges we face today, erratic rainfall, temperature swings, disease outbreaks, and soil degradation, are invitations to continue this legacy of adaptation and innovation.

The practices outlined in this guide are rooted in both scientific evidence and the lived experiences of farmers just like you. These are not theoretical concepts but practical tools that have been tested and refined in Free State conditions.

## Your Role in the Climate-Smart Movement

You are not alone in this journey. Across South Africa, and in this case, the Free State, farmers and extension officers are already implementing climate-smart practices and seeing results. These success stories remind us that change is possible, practical, and already happening. Your decision to implement even one climate-smart practice creates a ripple effect, inspiring neighbours, strengthening your community's food security, and contributing to the broader resilience of Free State agriculture.

We hope that this guide will inspire you to "Start Small, Start Now". Choose one practice from this handbook that resonates with your current needs and resources. Continue to learn by doing, pay attention to how your land responds. "Keep records. Adjust as needed". Your farm is your best teacher. Use the tools available in the guide to reach out to extension officers, join farmer groups, and connect with others on this journey. Lastly, "Share your Story": As you implement these practices and see results, share your experiences with fellow farmers. Your success story could be the encouragement someone else needs to take their first step toward climate-smart farming.

The Department of Sustainable Food Systems and Development at the University of the Free State, along with our partners at TAGDev, RUFORUM, and the Mastercard Foundation, remains committed to supporting you. We are not just researchers and institutions, we are your partners in building a climate-resilient agricultural future for the Free State.

To every smallholder farmer reading this: You are the backbone of our food system. Your resilience, innovation, and hard work feed communities and sustain livelihoods. The challenges ahead are real, but so is your capacity to meet them.

To every extension officer: Your role as a bridge between knowledge and practice has never been more critical. Thank you for your dedication to supporting farmers through these changing times. You are cultivating not just better farming practices, but stronger, more resilient communities.

To all stakeholders in Free State agriculture: Together, we have the knowledge, the tools, and the determination to transform climate challenges into opportunities for sustainable growth.

The future of Free State agriculture is being cultivated right now, in the decisions you make, the practices you adopt, and the knowledge you share.

Let us cultivate it together.

Let us cultivate it with wisdom.

Let us cultivate it with hope.

In every season, we cultivate resilience. In every harvest, we gather hope. In every challenge, we farm together.

**Prof Jan Willem Swanepoel**

Director: Centre for Sustainable Agriculture
Project Coordinator: TAGDEV 2.0
University of the Free State

# Glossary of KEY terms

**Adaptation:** *Actions that help agricultural systems adjust to actual or expected climate effects, minimizing harm and taking advantage of beneficial opportunities (e.g., drought-tolerant crops).*

**Agricultural extension officer/practitioner:** *An approach that applies ecological principles to agricultural systems, emphasizing biodiversity, natural processes, and reduced dependence on external inputs.*

**Agroecology:** *An approach that applies ecological principles to agricultural systems, emphasizing biodiversity, natural processes, and reduced dependence on external inputs.*

**Agroforestry:** *Integrating trees and shrubs into agricultural landscapes to improve soil fertility, biodiversity, and carbon storage.*

**Carbon markets:** *Systems where carbon emission reductions or sequestration can be traded, providing financial incentives for climate-smart practices.*

**Carbon sequestration:** *The process of capturing and storing atmospheric carbon dioxide in plants, soils, or other carbon pools.*

**Climate change:** *A large-scale, long-term shift in the planet's weather patterns or average temperatures.*

**Climate finance:** *Funding from public or private sources to support climate adaptation and mitigation projects, including those in agriculture.*

**Climate data:** *Statistical information, or a synthesis of weather variation focusing on a specific area for a specified interval. Climate is usually based on the weather in one locality, averaged for at least 30 years.*

**Climate variability:** *Refers to variations in the mean state and other climate statistics (standard deviations, the occurrence of extremes, etc.) on all temporal and spatial scales.*

**Climate-Smart Agriculture (CSA):** *An integrated approach to managing farms, livestock, forests, and fisheries that aims to increase productivity, enhance resilience to climate change, and reduce greenhouse gas emissions sustainably.*

**Climate-Smart Livestock:** *Animal production systems that enhance productivity and efficiency while minimizing emissions and enhancing animal welfare.*

**Conservation agriculture:** *A set of practices based on minimum soil disturbance (no-till), permanent soil cover (mulching), and crop rotations to improve soil health and reduce erosion.*

**Crop diversification:** *Growing a variety of crops to reduce risk, improve resilience, and enhance soil and ecosystem health.*

**Greenhouse gases (GHGs):** *Gases like carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$) trap heat in the atmosphere and contribute to global warming.*

**Integrated Pest Management (IPM):** *Combining biological, cultural, and mechanical methods with minimal pesticide use to manage pests sustainably.*

**Integrated Soil Fertility Management (ISFM):** *Combining organic and inorganic fertilizers with good agronomic practices to maintain soil health and productivity.*

**Manure management:** *Practices that capture and use livestock waste to reduce methane emissions and enhance soil fertility (e.g., biogas production).*

**Mitigation:** *Efforts to reduce greenhouse gas emissions or enhance carbon sinks (e.g., reforestation, reduced tillage).*

**Nationally determined contributions (NDCs):** *Climate action plans submitted by countries under the Paris Agreement, outlining commitments to reduce emissions and adapt to climate change, often include CSA measures.*

**Precision agriculture:** *Using technology (GPS, sensors, data analytics) to manage crops and resources efficiently, applying the right input at the right time and place.*

**Rainwater harvesting:** *Collecting and storing rainwater for use in irrigation or livestock watering.*

**Reewable energy in agriculture:** *Using solar, wind, or bioenergy to power farm operations, reducing reliance on fossil fuels.*

**Resilience:** *The ability of farming systems to absorb shocks and stresses (such as droughts or floods) while maintaining essential functions.*

**Soil Organic Matter (SOM):** *Decomposed plant and animal material that improves soil fertility, water retention, and carbon sequestration.*

**Sustainable agriculture:** *Farming that meets current food needs without compromising the ability of future generations to meet theirs, balancing environmental health, economic profitability, and social equity.*

**Water-Use Efficiency (WUE):** *Maximizing crop yield per unit of water used through improved irrigation, mulching, or drought-tolerant varieties.*

# Introduction

## Understanding Climate-Smart Agriculture (CSA)

South Africa's agricultural sector, such as in the Free State, is standing at the frontline of climate change. Across the region, farmers are increasingly confronted by prolonged droughts, heatwaves, erratic rainfall, and pest outbreaks that threaten both crop and livestock production. These changes have made farming far more unpredictable, undermining food security, rural livelihoods, and the stability of local economies.

Traditional farming systems, which once depended on predictable weather cycles, are now struggling to cope with these new realities. This has created an urgent need for farming approaches that are both adaptive and sustainable systems that allow farmers to continue producing food while protecting the environment on which agriculture depends.

One such approach is Climate-Smart Agriculture (CSA). CSA offers a transformative and practical pathway for farmers, particularly smallholders and emerging producers, to build resilience against the effects of climate change. It helps them to adapt production systems, improve productivity, and secure multiple benefits, economic, social, and environmental.

Importantly, CSA is not a single technology or practice; rather, it is a way of thinking about farming that helps farmers make informed, climate-conscious decisions. It combines the best of traditional knowledge with modern innovation, promoting the efficient use of natural resources such as soil, water, and biodiversity.

Through this integrated approach, CSA supports farmers in protecting their land while maintaining productivity and profitability. At its core, the CSA approach seeks to transform and reorient agricultural systems to ensure food security under changing climatic conditions.

The approach focuses on three key and interrelated goals often referred to as the three pillars of CSA:

1. **Productivity:** Sustainably increasing agricultural productivity and farm incomes to ensure food security and economic growth.
2. **Adaptation:** Building resilience and adaptive capacity to cope with climate variability and long-term change.
3. **Mitigation:** Reducing or removing greenhouse gas emissions wherever possible to limit agriculture's environmental footprint.

These three pillars work together to form the foundation of climate-resilient farming systems. In simple terms, CSA ensures that farmers can grow more, using efficient resources, while protecting the environment for future generations.

## Why CSA matters in the Free State

The Free State is one of South Africa's most productive agricultural regions, often described as the country's "grain basket." However, it is also among the most climate-vulnerable areas, characterized by semi-arid to temperate conditions, irregular rainfall, and rising temperatures.

Most farming here relies heavily on rainfed systems, which are increasingly affected by drought, floods, and shifting rainfall seasons. These challenges make CSA especially relevant. By adopting CSA practices, farmers in the Free State can better manage water and soil resources, choose more resilient crop varieties, and diversify their production systems. This, in turn, helps them withstand climate shocks while maintaining yields and protecting the environment.

CSA thus provides a balanced framework, one that meets immediate production needs while ensuring long-term sustainability. It enables the agricultural sector to remain productive, competitive, and resilient despite the growing pressures of a changing climate. In practical terms, CSA involves adopting proven, locally adapted techniques that enhance both productivity and resilience.

While many of these practices are not new, CSA brings them together into a coordinated, data-informed system, supported by farmer training, extension services, and research. This integrated approach ensures that smallholder farmers can make better decisions, reduce risks, and increase productivity under variable climatic conditions.

## Purpose of this training guide

The purpose of this Climate-Smart Agriculture training guide is to provide farmers, extension officers, and agricultural stakeholders with a practical understanding of CSA concepts, principles, and applications within the context of the Free State. The guide aims to build awareness and strengthen capacity for implementing climate-resilient agricultural practices that enhance productivity while safeguarding natural resources.

Specifically, the guide seeks to:

- Explain the principles and importance of CSA in addressing climate change impacts on farming systems.
- Equip smallholder farmers and extension officers with practical knowledge and tools to apply CSA approaches effectively in local cropping and livestock systems.
- Promote sustainable management of soil, water, and other natural resources to improve farm productivity and resilience.
- Support knowledge sharing, innovation, and collaboration among farmers, researchers, and policymakers to accelerate CSA adoption.
- Align training efforts with the province's diverse agroecological zones to ensure locally relevant and practical learning outcomes.

Ultimately, this guide serves as a foundation for building climate-resilient agriculture for smallholder farming communities in the Free State that can adapt, thrive, and contribute to sustainable food security under changing climatic conditions.

# Climate change and AGRICULTURE:
## National & provincial policy perspectives

This chapter explores how South Africa's climate change policy framework has evolved to support CSA.

Over the past couple of years, South Africa has built a comprehensive climate policy landscape. This policy evolution has created enabling conditions for CSA interventions in the country, even though gaps remain in scaling solutions at local level. Our response to climate change as a country has evolved significantly, creating an empowering environment for CSA, an approach that also seeks to sustainably increase productivity and incomes, adapt and build resilience to climate change, and reduce or remove greenhouse gases.

The country's climate policy journey can be traced through key milestones:

**Figure 1** **The National Climate Change Adaptation Policy development timeline.**

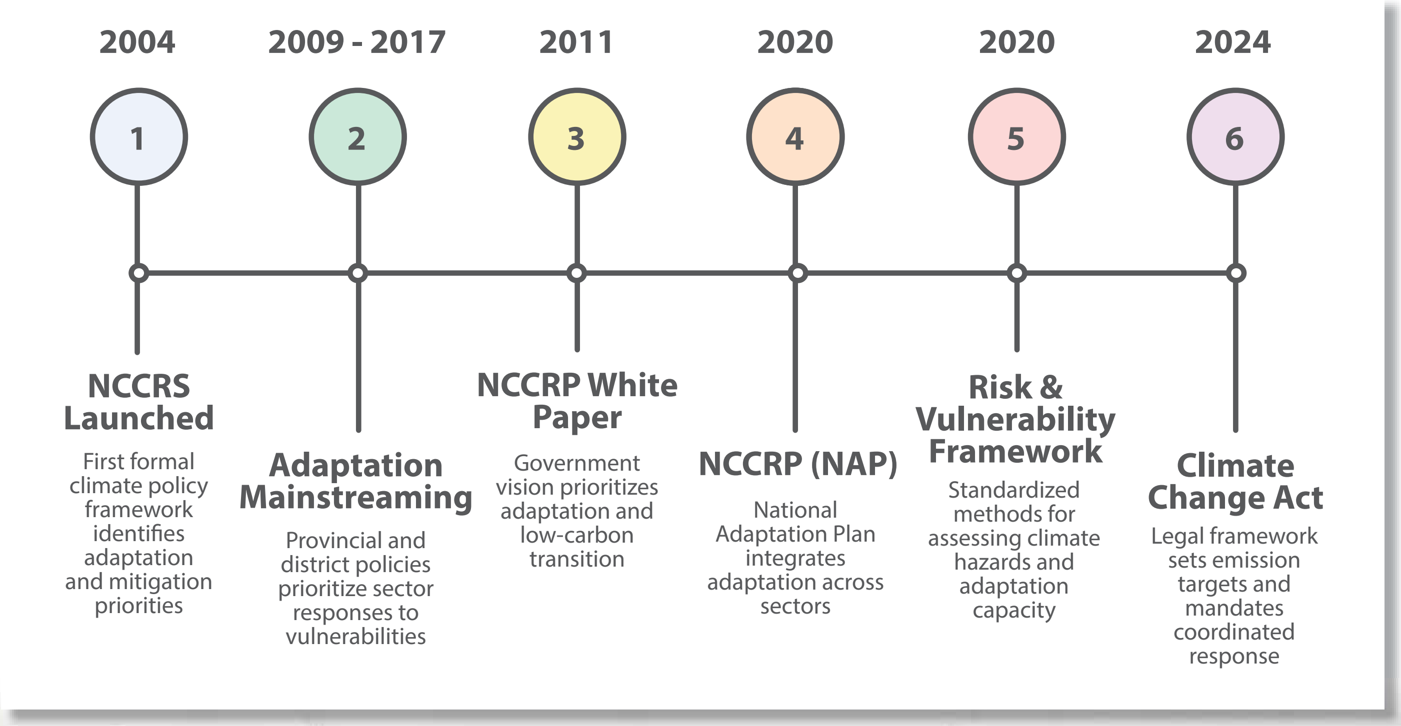



**Table 1** **The South African climate change policy framework evolution and its application.**

| Year | Policy/ Framework | Importance |
|---|---|---|
| 2004 | National Climate Change Response Strategy (NCCRS) | • South Africa's first formal climate policy framework. Early recognition of climate risks identified climate change adaptation and mitigation as national priorities. |
| 2011 | National Climate Change Response White Paper (NCCRP) | • This document marked the formal government vision, prioritizing a two-pronged approach: managing inevitable climate change impacts (adaptation) and making a transition to a lower-carbon, climate-resilient economy (mitigation). This laid the foundational mandate for adaptation strategies, including in the agricultural sector. |
| 2009 - 2017 | Provincial and District Adaptation Policy Development and Mainstreaming | • This laid the foundational mandate for adaptation strategies, including in the agricultural sector. |
| 2020 | National Climate Change Adaptation Strategy (NCCAS) | • Understanding provincial vulnerabilities and prioritizing sector responses. Understanding municipal vulnerabilities and prioritizing sector responses to advance service delivery. |
| 2020 | National Risk and Vulnerability Assessment Framework | • Provides standardized methodologies, tools, and a structured process for assessing a nation's exposure to climate change hazards, its sensitivity, and its capacity to adapt. |
| 2024 | Climate Change Act (2024) | • This Act establishes a clear legal framework and set mandatory emission reduction targets. Crucially for agriculture, it institutionalizes the climate change response across government, providing long-term certainty and greater motivation for a coordinated climate response in South Africa including CSA implementation. |

National climate change policy has enabled CSA in the following ways:

- **Prioritizing Adaptation Funding:** Policy has signalled the need for financial support, which has unlocked international funding streams like the Adaptation Fund and Green Climate Fund for projects that directly benefit smallholder farmers.
- **Driving Research and Development:** The policy environment directs research institutions like the Agricultural Research Council (ARC) to focus on climate-resilient crop varieties and local, context-specific CSA techniques relevant to production.
- **Mandating Cross-Sectoral Coordination:** Climate change impacts cut across many sectors such as water, energy, and land use. Policies promote better cooperation between the Department of Agriculture, Land Reform and Rural Development (DALRRD), Department of Forestry, Fisheries and the Environment (DFFE), and local governments, which is essential for effective management or accessing climate information.

**Figure 2** **Some of the pros and cons of national climate policy.**

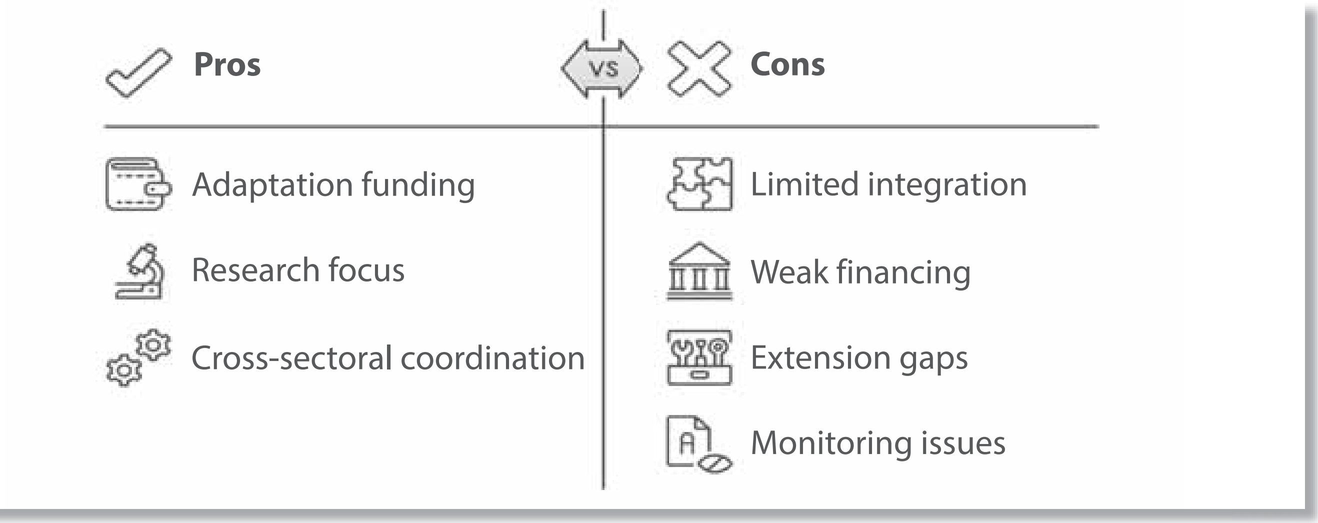
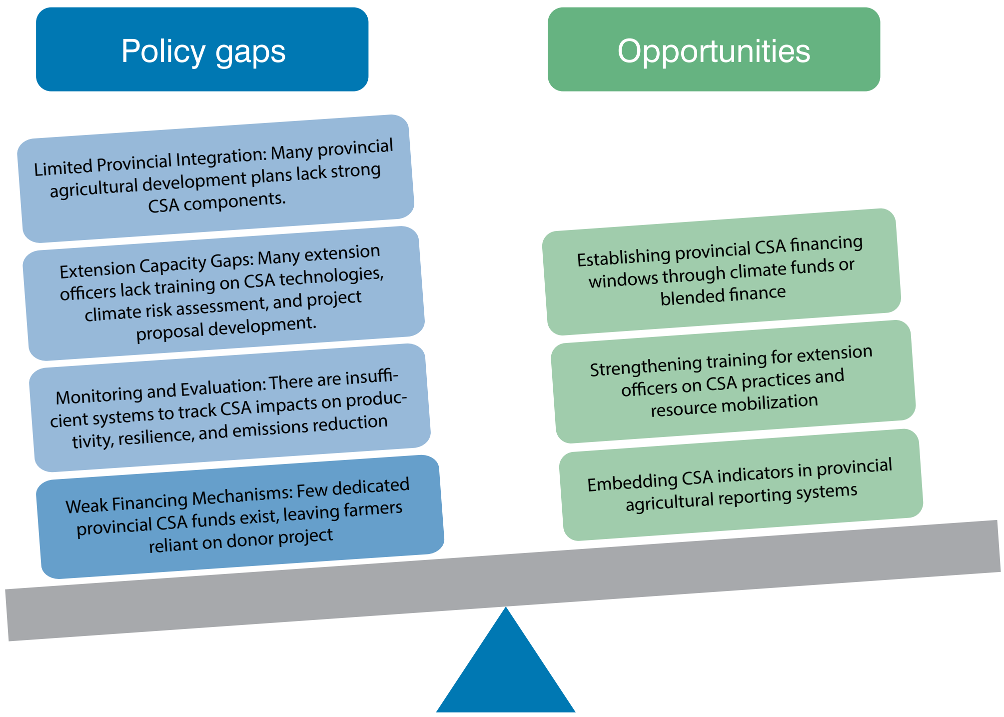


**Figure 3** **Identified national policy gaps and opportunities on Climate-Smart Agriculture (CSA) in South Africa.**




National policy directives have encouraged provinces, including the Free State, to integrate climate considerations into agricultural planning, research, and extension services. The policy environment provides a clear opportunity for the Free State to lead by example, demonstrating how a province can integrate CSA into development planning and extension delivery to strengthen the resilience of its food systems.

## Summary

South Africa's evolving climate policy framework has created an enabling environment for CSA. In the Free State, the strategies link climate action directly to agriculture by promoting sustainable land use, water-efficient irrigation, renewable energy, and farmer capacity building. Together, these policies strengthen agricultural resilience and support a transition to a low-carbon, climate-resilient food system.

**Table 2** **Free State climate change policies.**

| Year | Policy/Framework | Importance |
|---|---|---|
| 2018 | The Free State Province Climate Change Adaptation Response Strategy (2018) | • This strategy promotes sustainable economic growth through low-carbon, resource-efficient practices. It links directly to agriculture by encouraging climate-smart farming systems, such as water-efficient irrigation, conservation agriculture, and renewable energy use in production, thereby supporting the province's transition to a resilient and low-emission agricultural sector. |
| 2018 | The Free State Province Climate Change Adaptation Response Strategy (2018) | • The strategy aims to guide provincial and local responses to climate impacts by promoting adaptation planning across key sectors. The strategy directly supports agriculture by encouraging sustainable land management, water-use efficiency, and capacity building for farmers to strengthen resilience to droughts, floods, and temperature variability. |
| 2024 | Provincial and District Adaptation Policy Development and Mainstreaming | • This strategy promotes sustainable economic growth through low-carbon, resource-efficient practices. It links directly to agriculture by encouraging climate-smart farming systems, such as water-efficient irrigation, conservation agriculture, and renewable energy use in production, thereby supporting the province's transition to a resilient and low-emission agricultural sector. |

# Free State CLIMATE:
## Overview of local climate trends and risks

### Introduction

The Free State province is located in the midlands of South Africa. It is a unique province featuring diverse agro-ecological zones, particularly the Eastern Highveld, which is well known for its mountainous terrain and temperate climatic conditions. The Eastern Highveld is highly suitable for deciduous fruits, such as apples, peaches, and plums, as well as asparagus and cherries. The Central and Southern regions have a drier climate supporting extensive livestock farming and the growth of winter grains like wheat, and alongside summer crops such as maize, sunflowers, groundnuts, and dry beans. Nevertheless, the Free State Province faces significant risks associated with climate variability and change, including severe frost occurrences, heatwaves, rainfall irregularities, a shift in the planting season, increased rainfall variability, droughts, prolonged intraseasonal dry spells, noticeable occurrences of hailstorms, windstorms, veld fires, and disease and pest outbreaks. The occurrence of the aforementioned hazards poses a threat to agriculture, water resources, food security, livelihoods, and vulnerable communities in the province. In mitigating the devastating effects of weather and climate-related threats, the provincial government has developed a Climate Change Adaptation Strategy to address these challenges while promoting a sustainable and resilient agricultural sector (DESTEA, 2024).

South Africa faces a plethora of climate change hazards across sectors, and the agricultural fraternity is indifferently impacted within the agroecological zones. The Free State province is no different, since it has dynamic climatic conditions, which are described by its distinct east-west variations, from wetter to drier

**Figure 1** **Map of rainfall districts for the Free State Province of South Africa (SAWB, 1972) with named municipalities showing the average of the annual total rainfall 1980 - 2019.**

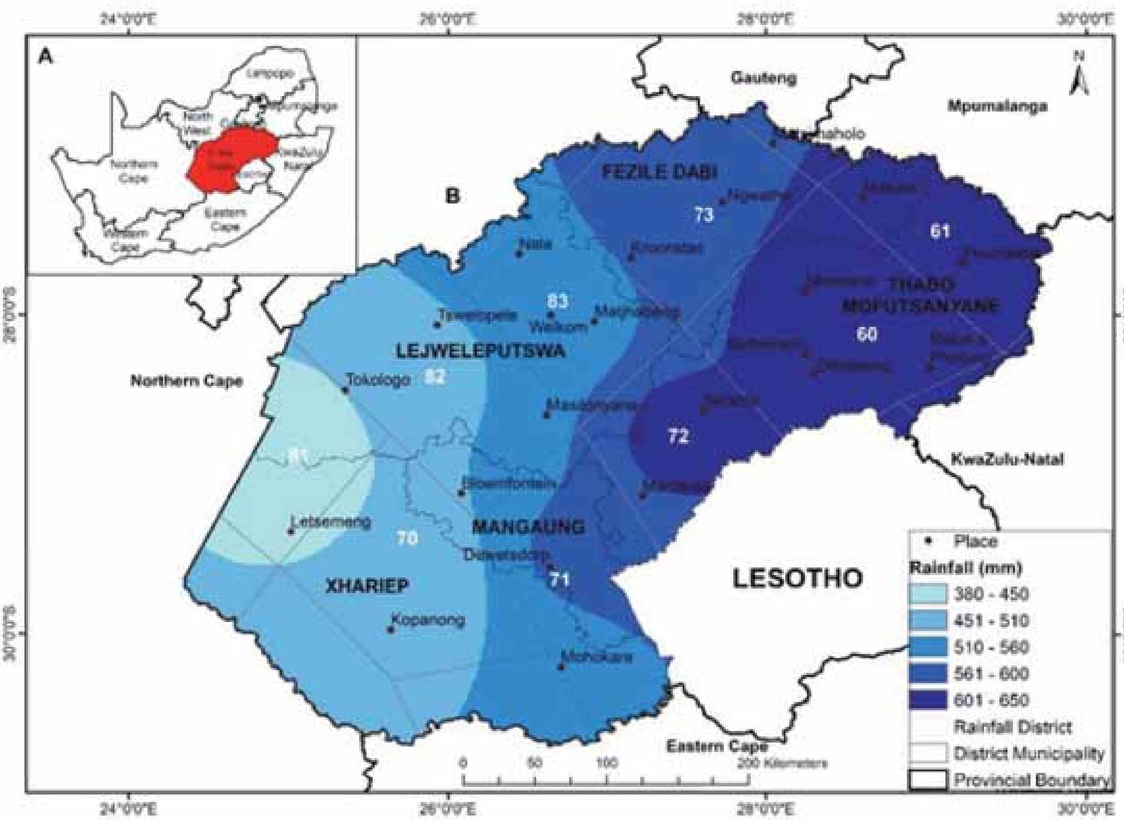


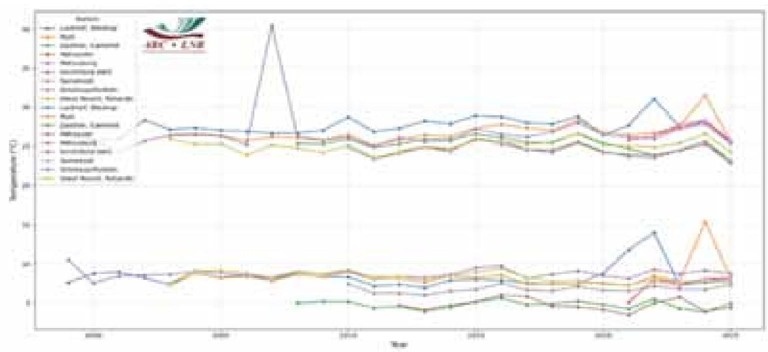
**Table 1** **Annual rainfall time series for selected Automatic Weather Stations at Various Districts in Free State, South Africa, with major climate risks and adaptation strategies indicators.**
(Source: ARC, Natural Resources and Engineering, Agrometeorology and Climate Services, Glen)

**Free State: Xhariep District**

| Agroecological Zones | Annual Rainfall (mm) | Primary Land Use | Major Climate Risks | Adaptation Strategies |
|---|---|---|---|---|
| Located in the South-Western part<br>Semi-arid to arid zone<br>Driest climatic area,<br>Low precipitation, high temperature, high evaporation<br>Annual rainfall ranges from 200 to 600 mm | Luckhof: (~350)<br>Rust: ~ (270)<br>Zastron: ~ (645)<br>Patrysvlei: ~ (390)<br>Petrusburg: ~ (518)<br>Smithfield: ~ (599)<br>Samekost: ~ (417)<br>Grootzuurfontein: ~ (504)<br>Alwal North:~( 553) | Extensive agriculture<br>~ extensive livestock<br>~ Intensive orange and olive orchards, grains, and vegetables | Water scarcity<br>Prolonged dry spells<br>High evaporation rate<br>Desertification (exacerbated by overgrazing)<br>Heatwave events increase<br>Increased frequency of extreme weather phenomenon | Adoption of mitigation techniques (renewable energy)<br>Soil moisture conservation<br>Rainwater harvesting<br>Climate-smart farming techniques<br>Rotational grazing and fodder storage |

Annual Rainfall Trends (mm)

Minimum and Maximum Temperature (ºC)

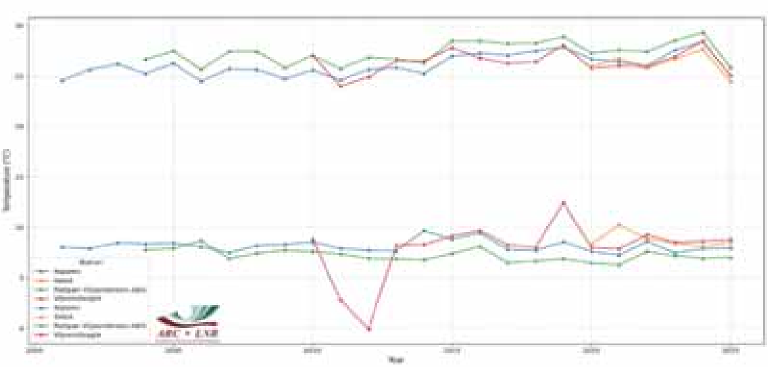


**Free State: Fezile Dabi District**

| Agroecological Zones | Annual Rainfall (mm) | Primary Land Use | Major Climate Risks | Adaptation Strategies |
|---|---|---|---|---|
| Located in the Northern part<br>Semi-arid zone<br>Prone to drought<br>Highly variable rainfall<br>Warmer temperatures,<br>High evaporation<br>Annual rainfall ranges from 250 to 600 mm | Koppies: (~692)<br>Geluk: ~ (620)<br>Viljoenskroon: Rietpan: ~ (475)<br>Viljoenlaagte:~(463) | Extensive agriculture<br>~ Grains, vegetables<br>~Livestock farming | Water scarcity<br>Prolonged dry spells<br>High evaporation rate<br>Desertification (exacerbated by overgrazing)<br>Heatwave events increase<br>Increased frequency of extreme weather phenomena | Sequential planting<br>Soil moisture conservation<br>Rainwater harvesting<br>Climate-smart farming techniques<br>Rotational grazing and fodder storage<br>Drought-tolerant cultivars |

Annual Rainfall Trends (mm)

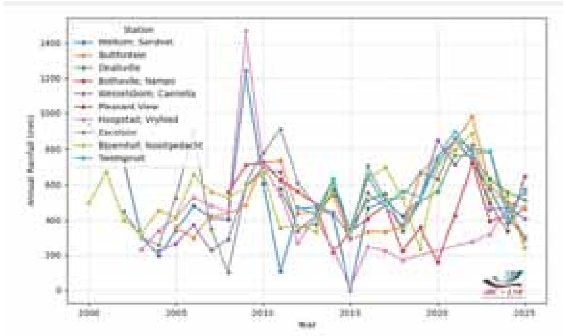
Minimum and Maximum Temperature (ºC)



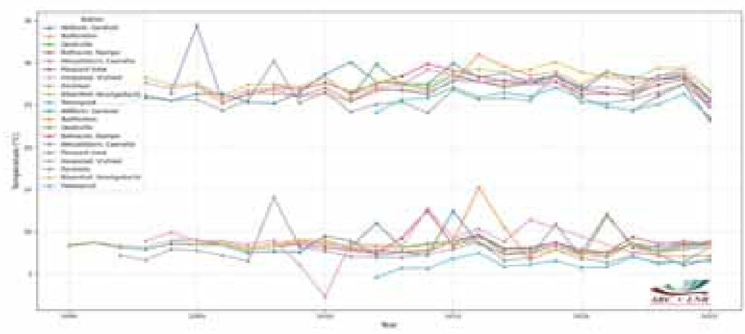
## Free State: Lejweleputswa District

| Agroecological Zones | Annual Rainfall (mm) | Primary Land Use | Major Climate Risks | Adaptation Strategies |
|---|---|---|---|---|
| Located in the Northwestern part<br>Semi-arid climate<br>Prone to drought<br>Highly variable rainfall<br>Warmer temperatures,<br>High evaporation<br>Annual rainfall ranges from 400 to 600 mm | Welkom: Sandvet: (~559)<br>Bultfontein: ~ (384)<br>Dealvile: ~ (317)<br>Bothavile: Nampo: ~ (646)<br>Wesselsbron: Caenelia: ~ (560)<br>Pleasant View: ~ (530)<br>Hoopstad: Vryheid: ~( 410)<br>Excelsior: ~ (510)<br>Bloemhof: Nooitgedacht: ~(534)<br>Tweespruit: ~ (582) | Extensive agriculture<br>~ Maize production, vegetables,<br>~Poultry<br>~ extensive dryland crop | Water scarcity<br>Prolonged dry spells<br>High evaporation rate<br>Increasing rainfall variability<br>Heatwave events increase<br>Increased frequency of extreme weather phenomena | Sequential planting<br>Soil moisture conservation<br>Rainwater harvesting<br>Climate-smart farming techniques<br>Rotational grazing and fodder storage<br>Drought-tolerant cultivars<br>Improved water use management |

Annual Rainfall Trends (mm)



Minimum and Maximum Temperature (ºC)

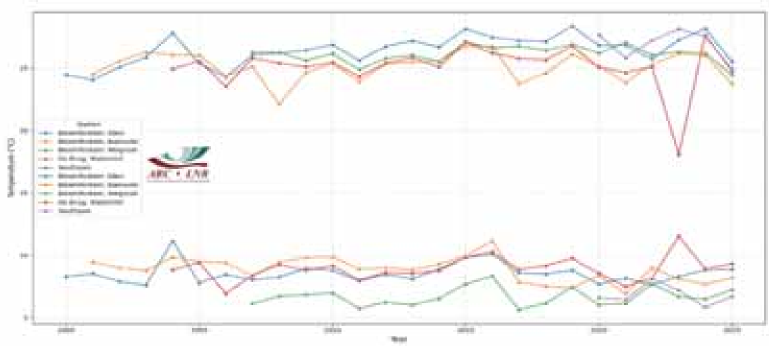


## Free State: Mangaung District

| Agroecological Zones | Annual Rainfall (mm) | Primary Land Use | Major Climate Risks | Adaptation Strategies |
|---|---|---|---|---|
| Located in the central interior of the province<br>Temperate climate conditions<br>Prone to drought,<br>Heatwaves, severe frost<br>Highly variable rainfall<br>Hot temperatures,<br>High evaporation<br>Annual rainfall ranges from 600 to 1000 mm | Bloemfontein: Glen: (~560)<br>Bloemfontein: Bainsvlei: ~ (571)<br>Bloemfontein: Wegsluit: ~ (540)<br>De Brug: Waterkloof: ~(545)<br>Soutpan: ~ (570) | Agro-industrial zone<br>Extensive agriculture<br>~ Maize production, vegetables,<br>~Large and small grains<br>~ extensive dryland crop production | Water scarcity<br>Prolonged dry spells<br>High evaporation rate<br>Increasing rainfall variability<br>Heatwave events increase<br>Increased frequency of extreme weather phenomena | Sequential planting<br>Soil moisture conservation<br>Rainwater harvesting<br>Climate-smart farming techniques<br>Rotational grazing and fodder storage<br>Drought-tolerant cultivars<br>Improved water use management<br>Improved stormwater management |

Annual Rainfall Trends (mm)

Minimum and Maximum Temperature (ºC)



| Free State: Thabo Mofutsanyane District | | | | |
|---|---|---|---|---|
| **Agroecological Zones** | **Annual Rainfall (mm)** | **Primary Land Use** | **Major Climate Risks** | **Adaptation Strategies** |
| Located in the eastern part of the province<br>Semi-arid to temperate climate<br>Prone to drought, Heatwaves, severe frost<br>Highly variable rainfall<br>Hot temperatures, High evaporation<br>Annual rainfall ranges from 500 to 600 mm | Senekal: Driepan: ~(432)<br>Reitz: Silos ~ (686)<br>Golden Gate: Clarens: ~ (750)<br>Verkykerskop: Van Koppe ~(710)<br>Bethlemhem: Khengraan-istituit: ~(868)<br>Marquad: Wilde-becslaagte: ~ (570)<br>Harrismith: Blokhuis: ~ (750)<br>Vlakbult: ~ (680)<br>Hobhouse: ~ (458)<br>Vrede-Kismet: ~ (620) | Temperate fruits<br>~ Asparagus<br>~Apples<br>~Berries, cherries<br>~Peaches<br>Livestock farming<br>Vegetables | Water scarcity<br>Prolonged dry spells<br>High evaporation rate<br>Desertification (exacerbated by overgrazing)<br>Increasing rainfall variability<br>Heatwave events increase<br>Increased frequency of extreme weather phenomena | Sequential planting<br>Soil moisture conservation<br>Rainwater harvesting<br>Climate-smart farming techniques<br>Rotational grazing and fodder storage<br>Drought-tolerant cultivars<br>Improved water use management<br>Improved stormwater management |

Annual Rainfall Trends (mm)

Minimum and Maximum Temperature (ºC)

conditions respectively. Additionally, the province is a summer rainfall area with hot summers and very cold winters, exclusively in the eastern highlands, where minimum temperatures can drop below the freezing point. In simple terms, the climate conditions are largely semi-arid to temperate, characterized by hot summers and cold, dry winters. The rainfall season occurs primarily during the summer months, commencing from November to March, averaging 350-700 mm annually, decreasing westwards (Archer *et al*., 2021). The winters are cold to severely cold, most especially in the eastern regions of the province. Temperatures can drop below freezing, with night-time lows sometimes reaching negative 10°C and/or even lower. The winter season, starting from April, and the occurrence of frost influence crop, pasture, horticulture, and livestock systems.

Given the fact that the Free State is largely a rain-fed reliant province, this relates to the fact that its agricultural production depends on rainfed agricultural systems rather than irrigation. This further indicates that agrarian practices depend largely on seasonal precipitation, making it susceptible to weather extremes, drought, and climate variability. Rainfed cropping systems, particularly grains and small grain production, dominate the landscape, supported by extensive livestock farming adapted to the natural grasslands.

The change in climatic trends and patterns may severely affect the socio-economic well-being and food security of its populations.

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The farming population in the province is encapsulated by a myriad of farmer categories ranging from subsistence to large commercial farmers. These groups of farmers experience the impact of climate change in distinctly different ways due to their farming experiences, disproportions in resource access, production scale, and adaptive capacity. Smallholder farmers are more vulnerable to climate-related stress, which is highly exacerbated by limited access to water resources and irrigation infrastructure, a lack of access to financial capital, and a lack of access to climate information and knowledge, all of which constrain their ability to adopt climate-smart agricultural (CSA) practices.

Regardless of the status, all farmer categories are affected by climate change

On the other hand, commercial farmers classically operate at larger production scales, and possessing greater financial capacity, are enabled to invest and adopt climate-smart practices and technologies, such as irrigation systems, improved seed varieties, and even crop insurance. Regardless of the status, all farmer categories are affected by climate change; the magnitude of effect and the ability to respond differ significantly, reinforcing existing inequalities within the agricultural sector.

## Climate change hazards are expected to increase in frequency, severity, and range

- Extreme heat is expected to increase hot days, heat waves, and high nighttime temperatures
- Heat stress intensification affects mostly vulnerable communities and livestock.
- Seasonal shifting and precipitation patterns: some areas are experiencing delayed rainfall onset, heavy rains, intense storms, strong winds, and erratic rainfall.
- Intensification of weather extremes, such as the occurrence of frequent stronger storms and severe wind events.
- Expanded risks of agroecosystems and stressed agricultural systems: a decline in biodiversity for species that are unadaptable, and the occurrence of crop failure.
- Expanded spread of known and unknown pests and diseases affecting crop fields, pasture, livestock rearing, and farm workers.

## Climate change scenarios in the Free State

### TEMPERATURE

- By 2040 - 2060, in the region, the average temperatures are expected to rise by about 2°C relative to historical baselines, causing frequent and intense heat waves and warmer nights,
- The heat waves are expected to have longer duration and increased frequency, and the magnitude might become significantly greater later in the season, resulting in higher fire indices
- The projections indicate a decline in the frost window since fewer frost days will occur with a minimum temperature ≤ 0°C, mostly in the escarpment and eastern areas in the province

### PRECIPITATION/RAINFALL VARIABILITY

- Uncertainties on how the mean rainfall will change exist, as some models show a slight increase and others decrease, depending on scenarios.
- Projections suggest a shift in the rainy season, causing delays in rainfall onset and the rainy season becoming shorter with frequent occurrence of dry spells intraseasonal.
- Projection indicates the possible occurrence of intense rainfall events, such as heavy rainfall days and flooding, in some years.
- The number of consecutive dry days or prolonged dry spells is expected to increase under high warming scenarios.

### SPATIAL VARIATION WITHIN THE FREE STATE

- The western parts, which are predominantly drier, are likely to experience worse drought risk, frequent heatwave events, soil degradation, and severe dryness.
- The eastern part and escarpment regions are projected to experience increased rains under some scenarios, with high risks of heavy rains, snowfalls, hailstorms, but getting warmer with reduced frost window and frost days.

## Summary

Overall, Free State districts demonstrate a gradual warming trend with increased temperature variability over the past two decades. While Lejweleputswa is characterized by broader agricultural exposure to heat and drought stress, Mangaung faces compounded risks from urban heat effects and limited water resources. The regional climate trajectory for the Free State thus points toward higher mean temperatures, more frequent extreme heat events, and greater interannual variability. These conditions elevate the vulnerability of rainfed farming systems, challenge water management, and increase energy demands for cooling. Climate-resilient adaptation strategies such as crop diversification, improved irrigation technology, urban greening, and integrated heat-risk monitoring will be critical for sustaining agricultural and urban livelihoods in both Lejweleputswa and Mangaung districts in the coming decades.

## References


- DESTEA, 2024. Free State Province Climate Change Adaptation Strategy and Implementation Plan 2024-2029. International Institute for Sustainable Development Published. http://www.destea.gov.za/wp-content/uploads
- Archer, ERM., Landman, WA., Malherbe, J., Maluleke, P., and Weepener, H., 2021. Managing climate risk in livestock production in South Africa: How might improved tailored forecasting contribute? Climate Risk Management, 32. https://doi.org/10.1016/j.crm.2021.100312
- Januarie, D. B., Archer van Garderen, E.R.M. , Hetem, R.S. and Koelle, B., 2015: Heat stress and livestock farming in the Suid Bokkeveld: some emerging results. Presentation at the Arid Zone Ecology Forum, October 2015, South Africa

3

# Planning & SOIL management

## Principles of planning and soil preparation

The success of agricultural production systems is predicated on rigorous planning, which provides the foundation for sustainable soil management and crop performance. In the context of CSA, planning transcends operational scheduling to encompass strategic considerations of soil health, long-term productivity, greenhouse gas emissions (GHGs) reduction, and resilience against climatic variability.

Improving nutrient use efficiency in crops requires an integrated approach that considers soil health, water availability, topography, and management capacity. In the semi-arid regions of the Free State, effective soil fertility management combined with Climate-Smart and Conservation Agriculture (CA) practices enhances the uptake and utilization of nutrients by crops. Practices such as balanced fertilization, residue management, contour planting, and diversified rotations not only reduce nutrient losses through erosion and leaching but also build long-term soil resilience. By aligning labour, machinery, and knowledge systems, farmers can achieve sustainable productivity while maintaining soil fertility and environmental integrity (see **Figure 1**).

Soil preparation within CSA systems seeks to establish seedbeds that ensure rapid and uniform germination with minimal soil disturbance, reduce erosion and degradation while enhancing soil structural stability, increase water infiltration and storage, promote biological activity by maintaining organic matter inputs, and optimize nutrient cycling through integrated soil fertility management. These objectives highlight the paradigm shift from mechanical soil manipulation towards ecological soil stewardship.

## Conservation tillage

Conservation tillage constitutes a central pillar of CSA. Unlike conventional deep ploughing, which disrupts soil aggregates and exposes soil to erosion, conservation tillage emphasizes minimal disturbance, continuous soil cover, and diversified rotations. This approach aligns with global evidence that reduced tillage enhances soil organic carbon, improves water use efficiency, and stabilizes yields under climate variability (**Table 1**).

**Figure 1** **Integrated approach under CSA illustrating the synergy between soil fertility, moisture conservation, crop diversification, and resource-efficient management for improved resilience and nutrient use efficiency.**

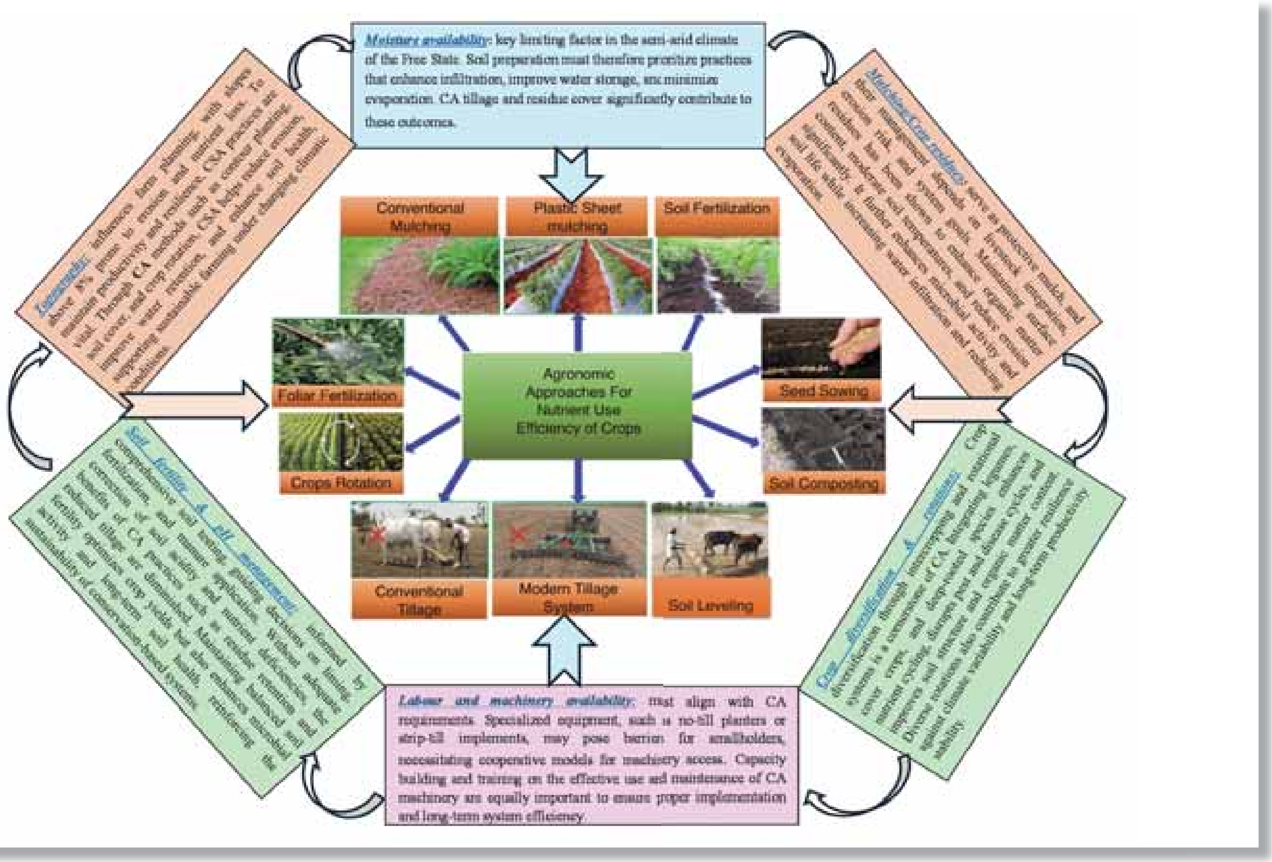


**Table 1** Identified conservation tillage methods practiced by Free State farmers.

| Method | Description | Best suited for | Equipment required | Benefits/Challenges |
|---|---|---|---|---|
| No-till | Seeds are directly planted into residue-covered soil | Areas with good soil fertility and weed control | No-till planter & synthetic herbicide sprayers | **Benefits:**<br>• Crop residues can reduce erosion by 50% - 80%.<br>• Improved moisture conservation.<br>• Reduces fuel costs by up to 40% due to fewer field operations.<br>• Lowers GHG emissions.<br>• Enhances carbon storage in the soil.<br>• Promotes microbial activity and organic matter content.<br>**Challenges:**<br>• Customized implements increase inputs costs.<br>• Farmer adoption process is slow.<br>• Potential soil compaction. |
| Strip-till | Combines the benefits of tillage and no-till by disturbing only narrow seed rows (strips), leaving inter-row areas undisturbed with residue cover | Heavy soils or where fertilizer placement is critical (fertiliser banding) | Strip-till implement & synthetic fertilizer applicators | |
| Mulch-till | Involves shallow tillage (e.g., disk harrow, chisel plough) that incorporates residues into the soil while leaving ≥30% residue cover on the surface | Farms transitioning from conventional to no-till | Chisel plough, harrows | |

**Table 2** Recommended cover crops for Free State conditions.

| Group | Cover crop | Role | Management practices |
|---|---|---|---|
| Grass | Oats<br>Rye | High biomass & cold-tolerance | • Plant after harvest or during fallow periods<br>• Terminate cover crops 3 - 4 weeks before planting cash crops (rolling, mowing, herbicide)<br>• Rotate cover crops to avoid pest carry-over<br>• Use mixtures (legumes + grasses) for multiple benefits<br>• Soil texture improvement |
| Legume | Cowpea<br>Vetch | Drought tolerance & high nitrogen contribution | |
| Brassica | Mustard | Bio-fumigant | |
| Root crops | Forage/radish | Improves soil structure | |

## Cover cropping

Cover crops are primarily grown to benefit the soil, rather than for direct sale. They are an essential part of CSA and are highly relevant for Free State farmers who experience seasonal fallow periods. Cover crops enhance soil function beyond the immediate cash crop cycle. Their role in nutrient cycling, erosion control, organic matter build-up, and biological pest suppression positions them as multifunctional components of resilient production systems. Different cover crops can perform different functions with regard to soil health, which needs to be considered, together with adaptability, in planning a cover crop strategy. Cover crops play a key role in improving soil health and farm productivity. Legumes fix nitrogen while grasses capture residual nutrients, enhancing nutrient cycling. Their dense canopy and roots help control erosion, stabilize the soil, and create channels that improve aeration and water infiltration. By adding biomass, cover crops increase organic matter and soil fertility. Additionally, they suppress weeds by shading the soil and reducing the germination of invasive species.

## Climate-Smart Agriculture practices for soil health

In the Free State, farmers manage a diverse range of soils from sandy, light-textured soils in the north-west (Bothaville) and west (Hoopstad, Boshoff, Hertzogville) to heavier clay soils in the central and southern regions (Botshabelo, Thaba Nchu, Zastron). While these soils differ in behavior and characteristics, they share a crucial trait: their health directly influences crop growth. Soil health refers to the soil's capacity to function effectively, supplying nutrients and water, supporting root development and soil life, and resisting erosion. In CSA, maintaining and improving soil health is central to achieving sustainable productivity and resilience. Soil health is shaped by two key types of properties:

- **Inherent (unchangeable):** Texture, depth, mineral composition.
- **Dynamic (manageable):** Organic matter, structure, nutrient status, and biological activity, which improve through CSA practices like cover crops, residue retention, and reduced tillage.

Climate-Smart Agriculture focuses on practices that maintain and enhance soil health. By minimizing soil disturbance, the natural structure of the soil is preserved, allowing roots to grow and water to infiltrate more effectively. Maintaining a permanent soil cover through crop residues and cover crops reduces erosion, conserves moisture, and gradually adds organic matter to the soil. Crop diversification, through rotations or intercropping, helps balance nutrients, improve fertility, and break cycles of pests and diseases.

For farmers, these practices offer tangible benefits. Yields become more stable even during dry periods, input costs for fertilizers and pesticides are reduced, and the land becomes more resilient to climate variability, supporting sustainable farming over the long term, however, challenges remain. Common issues in the Free State include erosion, soil compaction, declining organic matter, surface crusting, and, in irrigated areas, salinity and sodicity.To address these, practical CSA strategies are applied: adding organic matter through residues, cover crops, or compost; reducing soil disturbance with no-till or strip-till systems; protecting the soil surface with residues and contour planting; managing water efficiently through rainwater harvesting and careful irrigation; and maintaining fertility through soil testing, liming, and crop rotation.

Climate-Smart Agriculture focuses on practices that maintain and enhance soil health

To help farmers monitor progress, a Soil Health Score provides a simple, practical way to evaluate soil condition. This score combines key indicators, including organic matter, structure and aggregation, water infiltration, compaction, pH, nutrient balance, and biological activity, into a single number ranging from 0 to 100. Soils are classified as Poor (0 - 40), Moderate (41 - 70), or Good (71 - 100). By tracking this score over time, farmers can see improvements, make informed management decisions, and stay motivated to adopt CSA practices. Overall, focusing on soil health through CSA not only enhances productivity but also builds resilience and sustainability, providing a clear pathway for farmers to improve the long-term performance of their land.

## Recommendations for farmers transitioning to Climate-Smart Agriculture

- **Start gradually:** Begin with 1 to 2 fields before expanding across the farm.
- **Soil testing first:** Correct pH and fertility before adopting CSA practices.
- **Residue management:** Shred or bale crop residues for soil cover or livestock feed.
- **Combine practices:** Integrate conservation tillage, cover crops, and crop rotation for maximum benefits.
- **Collaborate:** Share equipment through cooperatives or hire contractors for costly machinery.
- **Monitor progress:** Keep records of soil health, yields, and improvements over time.

## Step-by-step guidelines:

- Conservation tillage: Assess soil, choose appropriate tillage (no-till for sandy, strip-till for clay), manage residues, monitor soil health, and manage weeds gradually.
- **Cover cropping:** Select suitable cover crops by soil type, plant after main crop harvest, manage growth carefully, terminate before cash crop planting, and retain residues for erosion control.
- **Seasonal focus:** Maintain soil cover year-round, summer for cash crops, autumn for cover crop planning, winter for cover crop growth, spring for seedbed preparation.
- **Transition calendar:**
  - o Year 1: Trial cover crops, shallow tillage ⇨ lower costs, reduced erosion.
  - o Year 2: Expand no-till/strip-till, retain residues ⇨ improved moisture retention, reduced fuel.
  - o Year 3: Scale no-till and integrate legumes ⇨ higher organic matter, reduced weeds.
  - o Year 4 - 5: Full CSA adoption ⇨ stabilized yields, improved soil health, long-term savings.

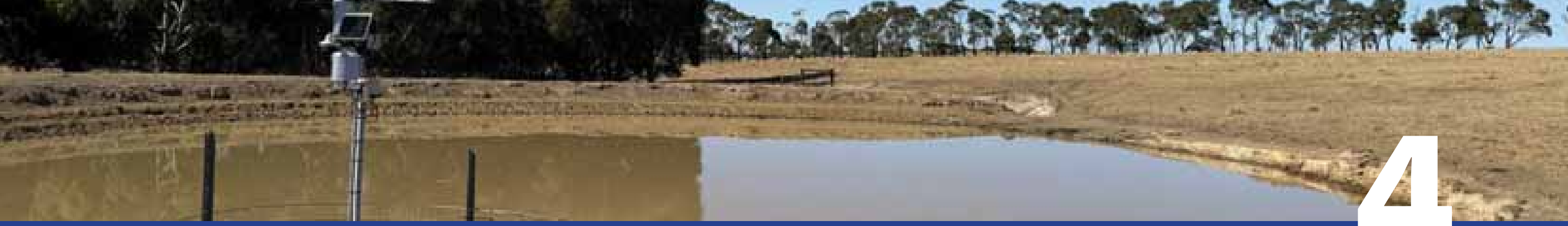
This approach ensures a practical, phased transition to sustainable, resilient farming in the Free State (see some practical case studies in the Free State, **Table 3**).


## References

- FAO, n.d. Conservation Agriculture. *http://www.fao.org/ag/ca/1a.html* [Accessed 06 October 2025]
- Maritz Nel Family Trust, 2025. Regenerative Agriculture in the Free State: From Concept to Practice. *https://maritznel.co.za/regenerative-agriculture-in-the-free-state/* [Accessed 30 September 2025]
- Land Type Survey Staff, 2002. Land Types of South Africa: Digital Map (1:250 000 scale) and Soil Inventory Databases. ARC-Institute for Soil, Climate and Water, Pretoria
- Soil Classification Working Group (SCWG), 2018. *Soil Classification: A Natural and Anthropogenic System for South Africa* (2nd ed.). Pretoria: Agricultural Research Council – Institute for Soil, Climate and Water
- Van Coller, C. 2024. The Development of Conservation Agriculture Systems on a farm in the arid, sandy north-western Free State, South Africa. 9th World Congress on Conservation Agriculture, 2024. Proceedings of the 9th World Congress on Conservation Agriculture, Cape Town, South Africa, 22-24 July 2024. Cape Town


**Table 3** Some of the conservation tillage available and practiced by farmers in the Free State.

| Case studies description/Summary | Conservation Agriculture journey and implementation processes |
|---|---|
| **Case Study 1: The Conservation Agriculture Journey at Libanon Farm (Viljoenskroon)** located in the Viljoenskroon area of the north-western Free State, with summer rainfall averaging around 550 mm annually.<br>• **Soil type:** The soils are mainly sandy loam with 4 - 12% clay in the topsoil, characterized as freely drained, apedal, and poorly structured, with red to yellow-brown profiles up to 1.4 m deep. Dominant soil forms include Avalon, Bainsvlei, Tukulu, and Westleigh.<br>• **Farming system:** The farm follows a commercial mixed farming system that integrates grain crops (maize, soybean, sunflower), cover crops, natural and planted pastures, livestock (cattle and sheep), backgrounding operations, and a feedlot.<br>**Summary of Benefits of Conservation Agriculture at Libanon Farm**<br>• Reduced erosion through permanent soil cover.<br>• Improved water retention and drought resilience.<br>• Better soil structure and lower compaction.<br>• Reduced fertilizer needs via nutrient cycling from cover crops.<br>• More flexible planting window for variable seasons.<br>**Impact**<br>After 25 years, Conservation Agriculture has greatly improved soil health, water efficiency, and farm resilience, proving essential for sustainable and profitable farming in the Free State's dryland areas. | **Initial Farming Practices (2000 - 2005)**<br>• Conventional tillage was the primary land preparation method.<br>• The crop rotation was limited to maize and sunflower.<br>• Livestock integration was minimal, with only occasional post-harvest grazing.<br>**Transition to Minimum Tillage (2006 - 2015)**<br>• In 2006, the farmer adopted a minimum-tillage system using a planter equipped with a 24 cm tine.<br>• A chemical burndown (glyphosate/Roundup) was used for weeding and residue management.<br>• Crop rotation was broadened to include maize, soybean, and sunflower.<br>• Limited livestock grazing continued, mostly on crop residues after harvesting.<br>**Integration of Summer Cover Crops (2016)**<br>• The Farmer introduced multi-species summer cover crops.<br>• These cover crops were lightly grazed by livestock and subsequently terminated with glyphosate in April.<br>• Mechanical rolling was used to flatten the residues, leaving a protective mulch layer on the soil surface.<br>• Expansion to Winter Cover Crops (2018)<br>• Multi-species winter cover crops were added to the system.<br>• These were utilized for high-density grazing by sheep and backgrounding weaner calves.<br>• The system followed a rotation of cash crops ⇨ winter cover crops ⇨ summer cover crops ⇨ cash crops, which improved soil cover and year-round biological activity.<br>**Intercropping Innovation (2024 onwards)**<br>• Farmer implemented multi-species intercropping of maize and sunflower.<br>• Aimed to optimize resource use, diversify cropping systems, and enhance ecological resilience.<br>• Partnered in on-farm CA research trials coordinated by ASSET Research and funded by the Maize Trust, contributing to farmer-led scientific knowledge generation. |
| **Case study 2: Regenerative Agriculture Maritz Nel Family Trust – Hennenman, Free State**, a key grain-producing area of FS<br>• The farm previously relied on CON, intensive ploughing, mono-cropping, & heavy fertilizer use, which led to declining yields and degraded soils.<br>• In 2019, the farm began transitioning to regenerative agriculture, focusing on ecosystem restoration rather than just soil conservation.<br>• Practical steps, measurable results, and lessons from this shift toward soil health, biodiversity, and sustainability.<br>**Challenges and Lessons Learned**<br>• **Mindset change:** Initial skepticism from older generations.<br>• **Weed pressure:** Early no-till years required careful weed control.<br>• **Investment costs:** New equipment, fencing, and training demanded upfront capital. Despite these hurdles, the transition led to greater profitability, resilience, and sustainability.<br>**Impact**<br>The Maritz Nel Family Trust's journey in Hennenman demonstrates that integrating cover crops, reduced tillage, and livestock can restore soil health, boost water efficiency, and improve profitability. What began as a response to soil decline has evolved into a successful model of regenerative and sustainable farming for the Free State and beyond. | **Step 1:** Soil Testing and Baseline Mapping (a regenerative roadmap tailored to the farm's local conditions).<br>**Organic Matter** is very low, averaging below 2%. Imbalanced pH and nutrient availability, with deficiencies in N & Zn. CA dense plough pan at 10 - 15 cm, restricting root growth and water infiltration.<br>**Step 2:** Winter cover crop trial after maize harvest, using a mix of oats, radish, and vetch: aimed at Radish breaking compacted soil layers; Vetch: Fixed nitrogen, reducing fertilizer needs; and Oats: Provided quick biomass and soil cover. Outcomes: Improved soil friability, greater biological activity, and better surface moisture retention.<br>**Step 3:** Reduced Tillage Practices: Recognizing the negative effects of repeated ploughing, the farmer transitioned from conventional full inversion tillage to minimal soil disturbance. This involved ripping only in compacted areas and using no-till planters to establish summer crops directly into cover crop residues.<br>**Outcomes:** The shift led to reduced diesel use and labour needs, better soil structure with less crusting, and more consistent crop emergence under variable rainfall conditions.<br>**Step 4:** Livestock Integration: Livestock were integrated into cropping systems using adaptive multi-paddock grazing with high-density, short-duration rotations, supported by electric fencing. Crop residues and cover crops provided valuable forage. Such as More diverse and resilient pastures; Improved cattle condition with less supplementary feed, enhanced nutrient cycling from dung and trampling.<br>**Benefits:**<br>• Soil Health & Fertility: Organic matter increased from 1.7% to 2.9% in 3 years; Earthworm counts tripled, showing soil recovery; Less crusting and better water infiltration after rain.<br>• Water Efficiency: Improved water retention and reduced runoff, even on slopes.<br>• Animal Performance: Lower winter feed needs and better body condition.<br>• Economic Resilience: Lower fertilizer, diesel, and input costs and Stable yields despite erratic rainfall. |



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# Agricultural WATER management

Agricultural water management is a critical concern for smallholder farmers in the Free State Province of South Africa, where climatic constraints and rainfall variability strongly influence agricultural productivity. The Free State lies on South Africa's central plateau, spanning the transitional zone between the Grassland and Nama-Karoo biomes, a landscape shaped by dryland conditions and high interannual rainfall variability (Mucina and Rutherford, 2006). According to the Köppen–Geiger classification, the region is characterized as cold semi-arid (BSk), typified by hot summers, cool to cold dry winters, and short, intense summer convective storms (Kottek *et al*., 2006; Peel, Finlayson and McMahon, 2007; Moeletsi and Walker, 2012).

Often referred to as South Africa's "grain basket," the Free State plays a vital role in national food security, producing significant shares of the country's maize, wheat, sunflower, and livestock. However, most farming in the province remains rain-fed, making agricultural productivity highly dependent on seasonal rainfall and vulnerable to the impacts of climate variability and drought. Annual rainfall across the province ranges from approximately 400 mm in the arid west to about 700 mm in the more humid east, presenting a pronounced west-east gradient in water availability and production potential.

In Bloemfontein, the provincial capital and a representative site for semi-arid central South Africa, mean annual rainfall (~514 mm) contrasts sharply with high potential evaporation (~1,676 mm) (Ololade *et al*., 2019; Makhadi *et al*., 2020). This climatic water deficit, expressed by a low Aridity Index (AI = P/PET) of 0.2 - 0.5, reflects the characteristic imbalance between precipitation and atmospheric water demand typical of semi-arid climates (Zomer, Xu and Trabucco, 2022). Long-term meteorological observations highlight strong seasonal rainfall concentration, short rainy periods, and frequent intra-seasonal dry spells, compounding the drought risk for dryland agriculture (Moeletsi and Walker, 2012; Botai *et al*., 2016; Free State DESTEA, 2024).

These climatic and environmental challenges place smallholder and subsistence farmers, who form an important but vulnerable segment of the agricultural economy, under increasing stress. Their reliance on rain-fed production, limited access to irrigation infrastructure, and constraints in input, machinery, and financial resources amplify exposure to drought and land degradation. Consequently, the promotion of sustainable and adaptive water management strategies is crucial for long-term agricultural resilience. Practices such as conservation and regenerative agriculture (e.g., minimum tillage, crop diversification, mulching, and cover cropping) are increasingly recognized for enhancing soil moisture retention, fertility, and drought resilience.

To ensure the sustainability of smallholder farming systems in this semi-arid context, there is a growing need for integrated water management, climate-smart agricultural practices, and stronger institutional support. Strengthening extension services, farmer training, and cooperative resource sharing, including access to machinery, inputs, and market networks, can significantly improve adaptive capacity. Moreover, with studies indicating an eastward expansion of semi-arid conditions across South Africa (Jury, 2021), proactive water management and policy support in the Free State are essential to safeguard livelihoods, stabilize yields, and sustain the province's role as the nation's agricultural heartland. To keep crops and soil healthy under these semi-arid and variable rainfall conditions, farmers can use simple, low-cost practices that conserve water, protect the soil, and improve yields over time.

By adopting simple, affordable practices, farmers can protect their soil, make better use of rainfall, and strengthen their farms against drought

### Summary

Smallholder farmers in the Free State face many challenges from low and unpredictable rainfall, high evaporation, and limited resources. Yet, by adopting simple, affordable practices, farmers can protect their soil, make better use of rainfall, and strengthen their farms against drought. Practices such as rainwater harvesting, mulching, using compost or manure, growing drought-tolerant crops, and sharing tools and knowledge help improve productivity and resilience. Working together and thinking long-term can make a big difference. Through healthy soils, smart water management, and strong community collaboration, smallholders can turn the challenges of climate change and unpredictable weather into opportunities for resilience and lasting food security.

**Table 1** **Climate-Smart Agricultural practices and techniques for water conservation and soil management.**

<table>
<tr><th>Practices & techniques</th><th>Illustrations and key messages</th></tr>
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**Harvest and store rainwater:** Make the most of every drop of rain.

- Contour bunds or ridges: Build small ridges along the slope to slow water and let it soak into the soil.
- Farm ponds or small dams: Collect runoff from fields or roofs for later use.
- Roof water harvesting: Catch rain from roofs into tanks or drums for garden irrigation.
- Sandbags or stone lines: Trap runoff in gullies and prevent soil loss.

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Line ponds or tanks with clay or plastic to reduce water loss from seepage.

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**Use water wisely:** Even small savings can make a big difference.

- Clay pot irrigation*:* Bury clay pots between plants and fill them with water – it seeps slowly into the soil.
- Bottle drip irrigation*:* Use small holes in plastic bottles to drip water to plant roots.
- Alternate furrow watering*:* Water every second furrow to save water without reducing yield.
- Water early in the morning or late afternoon to reduce evaporation.

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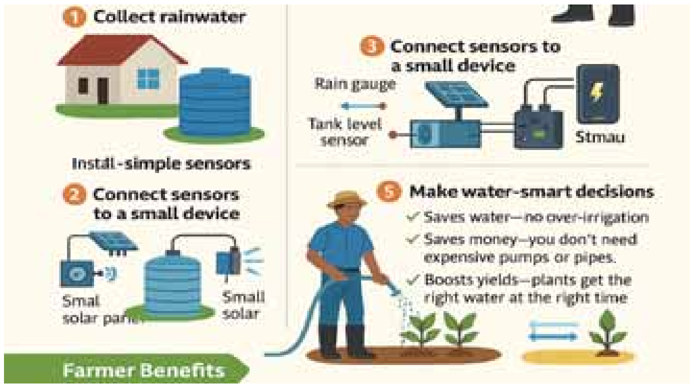


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**Keep the soil covered and healthy:** Healthy soil holds more water and resists drought.

- Mulching: Cover the soil with crop residues, grass, or leaves to keep moisture and reduce weeds.
- Minimum tillage: Disturb the soil as little as possible to maintain structure and organic matter.
- Add compost or manure: Improves soil fertility and water-holding capacity.
- Plant cover crops: Use legumes (like cowpeas, lablab, or clover) to protect soil between main crops and fix nitrogen.

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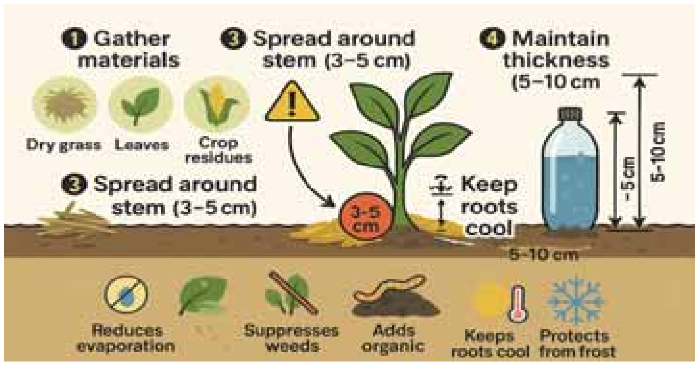


Never leave the soil bare due to soil loses water quickly and erodes easily.

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**Choose the right crops and planting method:** Adapt to rainfall and soil conditions for better survival.

- Use drought-tolerant crops such as sorghum, millet, cowpeas, or sunflowers.
- Choose early-maturing varieties to beat late-season dry spells.
- Plant across slopes (on the contour) to reduce runoff and erosion.
- Intercrop (e.g., maize with beans or cowpeas) to make better use of moisture and land.

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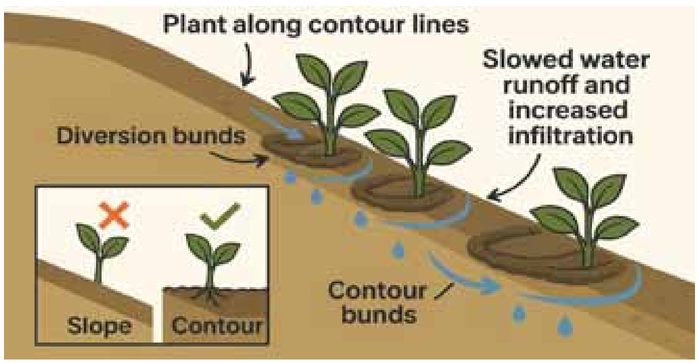


Plant as soon as the first good rain falls and stagger planting dates to spread risk.

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5

# Pest and disease MANAGEMENT

## The disease triangle

To understand how plant diseases develop and how to protect our crops, we first need to look at the basic relationship that makes any disease possible. Every plant disease arises from an interaction between a susceptible host, a pathogen, and a conducive environment. This is called the disease triangle. Let's look at each part of this triangle:

- **A susceptible host:** All plants are able to get "sick" too. In the case of agriculture, we focus on crops. However, a plant must be susceptible to a pathogen for it to be infected and cause disease. Some varieties are naturally more resistant, while others are more vulnerable.
- **A virulent pathogen:** These are microscopic living organisms, such as fungi, bacteria, viruses, or nematodes that can cause disease. Some pathogens are less virulent, causing less extreme reactions in the host, while others are highly virulent, meaning they can cause serious damage in a short time.
- **A conducive environment:** These are environmental and agronomic conditions which play a role in whether a disease can develop and to what extent. It is important to note that we have an influence over our environments through manipulating the agronomic practices on the farm.

When these three factors come together at the same time and interact, disease occurs. If one side of the triangle is missing, for example, if the plant is resistant, or the weather is too dry for the pathogen to grow, then disease cannot develop. Understanding this triangle is the foundation for managing plant diseases wisely. It helps us see that climate change, through shifts in rainfall patterns, cooler/warmer temperatures depending on the regions, and unpredictable seasons, affects each corner of the triangle. It can make the environment more favourable for some diseases, stress crops so that they become more susceptible, or even change which pathogens are found in our fields.

Recognising this relationship will help us understand why integrating CSA into our production systems is essential to plant health. Practices such as good soil preparation, crop rotation, use of resistant varieties, and improved water management are not just good farming practices; they are key tools within integrated disease management (IDM) strategies and used as interventions to protect our crop yield and quality in a changing climate.

## Recognising symptoms and signs in the field

Symptoms are the plant's visible response to infection, or how the host reacts to being attacked. These can include yellowing (chlorosis) of the leaves, wilting, water-soaked lesions, dark spots or halos, leaf curling, stunting, or other abnormal growth patterns. These changes signal that the plant is under stress and help us detect early stages of disease (for example see **Figure 1**).

Signs, on the other hand, are the physical evidence of the pathogen itself, what we can actually see of the pathogenic organism. Examples include the white, cottony mycelium of stem rot (caused by *Sclerotinia sclerotiorum*), black microsclerotia of charcoal rot (caused by *Macrophomina phaseolina*), the smut sori on sorghum grain (caused by *Sorghum smut*), or the orange-brown pustules of rusts (caused by a variety of *Puccinia spp*. and other fungal species).

**Figure 1 Mature smut sori rupture and release black fungal spores that spread the disease.**

Recognising both symptoms and signs gives us important clues about which pathogen may be responsible. Some are distinctive and make diagnosis easier (like the black microsclerotia of charcoal rot or the pustules of rust), while others are more general, such as wilting, chlorosis, or dead tissue lesions, which can result from several different causes.

These symptoms and signs also reveal the impact of the disease on the crop, for instance, reducing the leaf area available for photosynthesis, limiting water and nutrient uptake through root damage, or affecting flower and seed development. All of these can ultimately reduce yield and quality. Recognising these symptoms and signs is the first step; once we know what disease we are dealing with, the next step is to determine how much of it is present in the field, so we can decide when and how to act.

Diagnostic support is available through several institutions, including the Agricultural Research Council (ARC) diagnostic clinics, the University of Pretoria's FABI Diagnostic Clinic, which serves the National Grain Research Programme (NGRP), and Stellenbosch University: Plant Disease Clinic. In short, the more we observe, the earlier we act, and the healthier our fields remain.

## Integrated disease management

When we think about CSA, it's not about changing everything we do; it's about reorienting what already works and understanding how these practices influence plant diseases. Many of the good agricultural practices we already use have built-in benefits for disease management; we just need to make these connections visible.

**Figure 2** **Soybean stem rot.**

When we start looking at disease management, there are also certain things we need to consider. Firstly, we need to be realistic about the fact that we cannot be absolute in saying that we will have zero disease. That is not practical and realistically most likely not even possible. The aim is not to eliminate all disease but to reduce disease progress and keep disease development below an acceptable level, which is determined by the economics of the disease and its impact on yield and quality.

The first step to any disease management strategy is monitoring. This means observing what's happening in your fields, noting disease symptoms early, and being aware of what pathogens are present. Early detection allows for timely and informed action.

Disease management begins with the decisions we make about where and what to plant

The first step in any disease management strategy is active monitoring. By regularly scouting fields, recording symptoms, and linking what we observe to weather and soil conditions, we can identify when disease levels approach the threshold for action, the point at which intervention becomes necessary to prevent noticeable yield or quality losses. This kind of proactive monitoring allows us to manage disease development early and more effectively, rather than reacting once damage has already occurred.

Disease management begins with the decisions we make about where and what to plant. Careful site selection helps prevent problems before they start. Avoid planting high-value crops in fields known to be prone to specific diseases, for example, waterlogged areas increase the risk of soybean stem rot caused by S. sclerotiorum, while extremely dry soils can encourage charcoal rot caused by M. phaseolina in maize.

Adjusting planting dates is another important consideration, and it links directly back to the principles of the disease triangle. A disease can only develop when a susceptible host, a virulent pathogen, and a conducive environment coincide. By shifting planting dates, farmers can reduce the overlap between these three factors; in other words, we can avoid having susceptible plant tissue at the same time that weather conditions favour infection and the pathogen is present in the air. Adjusting planting time, therefore, helps shorten the window of infection, lowering overall disease risk without additional inputs.

In the same way, intercropping and crop rotation help to interrupt the disease cycle and reduce the buildup of pathogen inoculum, since fewer susceptible hosts are present over time. They can also encourage natural enemies, ultimately lowering disease pressure. However, it's also important to remember that some pathogens have a wide host range, so crop choices should be made carefully.

Now that we move to choosing which crops and where to plant them, it becomes important to consider varieties that carry disease-resistance genes and those that are more tolerant to drought or local environmental stress. Disease-resistance genes are specific sequences within the DNA of the crop that help the plant recognise a

pathogen and defend itself. They don't necessarily prevent infection completely, but they reduce how severe the disease becomes. The plant may still show some symptoms, but the severity is moderated by the number and strength of resistance genes it carries.

Not only do varieties differ, but entire crops can perform better in certain areas depending on soil type, rainfall patterns, and historical disease pressure. Selecting disease-resistant and drought-tolerant varieties strengthens the overall resilience of the production system. Using different cultivars with diverse resistance genes within or across fields also helps slow down pathogen spread and development, especially for polycyclic diseases, those that complete several infection cycles and produce multiple inoculum types within one growing season. In contrast, monocyclic diseases produce only one generation of inoculum per season, so they progress more slowly. Crop and cultivar diversity, therefore, acts as a natural buffer, helping to prolong the effectiveness of resistance and stabilise yield over time.

Seed treatments, though long established, are receiving greater attention for their role in IDM. These products, often containing fungicides, protect the seed from soilborne pathogens right from germination, helping establish healthier seedlings. Because they are applied directly to the seed and not sprayed across the field, they use smaller quantities of active ingredients and reduce the risk of chemicals entering the air or water. This makes them a more efficient and environmentally considerate option.

When considering biocontrol options, it's important to make sure that the products are registered, tested, and supported by independent research

Up to this point, we've looked at the proactive measures, the things we plan and put in place before or at planting to prevent disease from taking hold. But sometimes, despite these efforts, disease still appears in the field. In these cases, we need to take reactive measures to contain and manage the problem before it spreads further.

Eradication practices include removing visibly diseased plants or residues, but these must be handled with great care. Infected material should never be left on the soil surface or piled at the field edge, as this allows pathogens to persist and spread. Although composting is sometimes an option, it is not recommended for most plant diseases, since many pathogen structures, such as sclerotia or thick-walled spores, can survive for long periods, even under high composting temperatures. The safest approach is to completely remove and destroy infected material by burning under controlled conditions or burying it deeply, well away from production areas. This reduces the risk of reintroducing the pathogen into healthy fields.

Still, foliar fungicides sometimes remain necessary, and when their use is unavoidable, responsible stewardship becomes essential. This means following the label carefully, using the product only on the registered crop, at the recommended dosage, and applying it correctly and safely. Stewardship isn't only about using the product properly, but also about protecting yourself while using it. Always wear the correct personal protective equipment, wash your hands afterwards, and avoid touching your face or eyes. These are still chemicals, and we need to handle them with care and mindfulness.

Overusing fungicides or repeatedly applying the same active ingredient can cause pathogen resistance, meaning the fungus adapts and the chemical stops working effectively. In simple terms, resistance develops when the disease "learns" how to survive the treatment. Rotating products with different modes of action and combining chemical, biological, and cultural measures (discussed above) helps prevent this problem and supports long-term disease management.

Biological control, or biocontrol, is another valuable tool that fits within IDM. Biological control agents are usually other beneficial organisms, such as fungi, bacteria, or yeast, that, when used correctly, can help manage disease in different ways. They can act directly by attacking the pathogen and reducing its inoculum potential, which means lowering its ability to establish disease. They can also act indirectly, by stimulating the plant's own defences (this is called induced resistance) or by improving soil health, which strengthens the plant and makes it less susceptible to infection.

When considering biocontrol options, it's important to make sure that the products are registered, tested, and supported by independent research. Farmers should be cautious of so-called "miracle" biocontrol products that make big promises without scientific proof of efficacy. Always check that a product is approved for use, that you understand how and when to apply it, and that you follow the instructions carefully, because these are living organisms, or products derived from them, and they need the right conditions to work effectively.

Ultimately, disease management must be integrated and coordinated across scales. No single practice should stand alone; all of the practices above interact and have a ripple effect on our agro ecosystems. If one measure fails, another should support it. But integration doesn't stop at the farm level. Farms do not exist in isolation; what happens on one field, whether it's residue management, irrigation, or chemical intervention, can influence neighbouring fields and the surrounding environment. Effective disease management, therefore, depends on communication, shared planning, and collaboration between farmers, extension officers, researchers and industry. When practices are aligned and knowledge is shared, we move from isolated farm management

## Table 1 Case study Smart seed selection for healthier uChokwane (tepary bean) production.

### Case studies description/summary

uChokwane, a tepary bean landrace, is managed wisely by many producers who remove unhealthy seed before planting. This simple step protects the crop because diseased grain often has poor germination and carries more fungal pathogens.

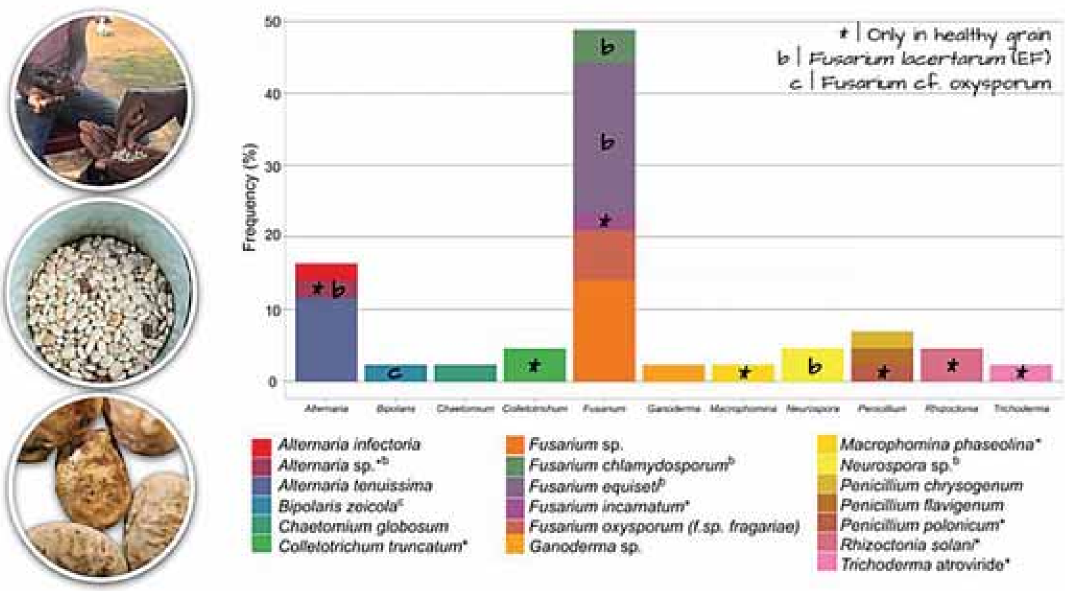
During fieldwork in KwaZulu-Natal and Limpopo, we asked producers whether they could distinguish healthy grain from mouldy grain. Their knowledge sparked our research. Laboratory testing confirmed what they are already doing right: healthy seed had much higher germination (75.5%) and a lower fungal load (47.8%) than diseased grain (germination = 25.6% and fungal load = 90%).

Fusarium species were the most frequent fungi detected in both healthy and diseased seed, and several were found internally in the seed. This highlights that even when grain looks healthy, fungi can still be present inside. Many producers are already protecting future harvests by removing shrivelled, discoloured or mould-infected beans, which lowers the spread of inoculum when saving seed.

Some fungi, including Alternaria, Fusarium and Penicillium, are known to produce mycotoxins, i.e., harmful toxins produced by some fungi that can reduce grain quality and may pose health risks to humans and livestock if present and consumed in high amounts. Their presence does not automatically mean high toxin levels, only that the potential exists. Awareness and good seed hygiene are important to minimise risks.

uChokwane is valued for its tolerance to heat and drought. By protecting seed health, producers are helping maintain this climate-resilient landrace and safeguarding important genetic diversity for future generations.

A gentle reminder: Some improved varieties are protected by Plant Breeders' Rights and cannot be retained without permission.




Frequency of fungi isolated from healthy and diseased uChokwane (tepary bean) seed collected from small-scale farms in KwaZulu-Natal. Asterisks (*) indicate fungi detected only on healthy grain. Fungal identification was confirmed using DNA sequencing.

toward a connected, landscape-level approach that strengthens both productivity and ecosystem health.

## Summary


Pest and disease management in crops is based on understanding the disease triangle, the interaction between a susceptible host, a virulent pathogen, and a conducive environment. Recognizing symptoms (the plant's response) and signs (visible evidence of the pathogen) enables early detection and diagnosis, which are essential for effective management. Integrated Disease Management (IDM) combines proactive and reactive strategies such as crop rotation, resistant varieties, seed treatments, biological control, and responsible chemical use to reduce disease pressure and safeguard yields.


## References


- Del Ponte, E. M. (2023). R for Plant Disease Epidemiology (R4PDE). Author. https://r4pde.net
- Francl, Leonard J. "The disease triangle: a plant pathological paradigm revisited." The Plant Health Instructor 10 (2001)
- Maloy, O.C. 2005. Plant Disease Management. The Plant Health Instructor. DOI: 10.1094/PHI-I-2005-0202-01
- Oliver, Richard, ed. Agrios' plant pathology. Elsevier, 2024
- Pal, K. K. and B. McSpadden Gardener, 2011. Biological Control of Plant Pathogens The Plant Health Instructor. DOI: 10.1094/PHI-A-2006-1117-02
- Riley, M.B., M.R. Williamson, and O. Maloy. 2002. Plant disease diagnosis. The Plant Health Instructor. DOI: 10.1094/PHI-I-2002-1021-01
- Schumann, Gail L., and Cleora J. D'Arcy. "Essential plant pathology." Plant Dis 10 (2010): 90PLO3
- Zadoks, J. C., & Schein, R. D. (1980). Epidemiology and plant disease management, the known and the needed. Comparative Epidemiology, 1-17

6

# Practical approaches for SUSTAINABLE dryland crop/vegetable farming

## Section I: Field crop management strategies

Agriculture forms the backbone of the Free State Province's economy and landscape, with approximately 32,000 km² under cultivation and a further 87,000 km² comprising natural veld and grazing land. The province's vast open plains and fertile soils make it one of South Africa's most important agricultural regions (**Figure 1**). Field crops dominate production, accounting for nearly two-thirds of the province's gross agricultural income, while animal products contribute around 30%, and horticulture makes up the remainder.

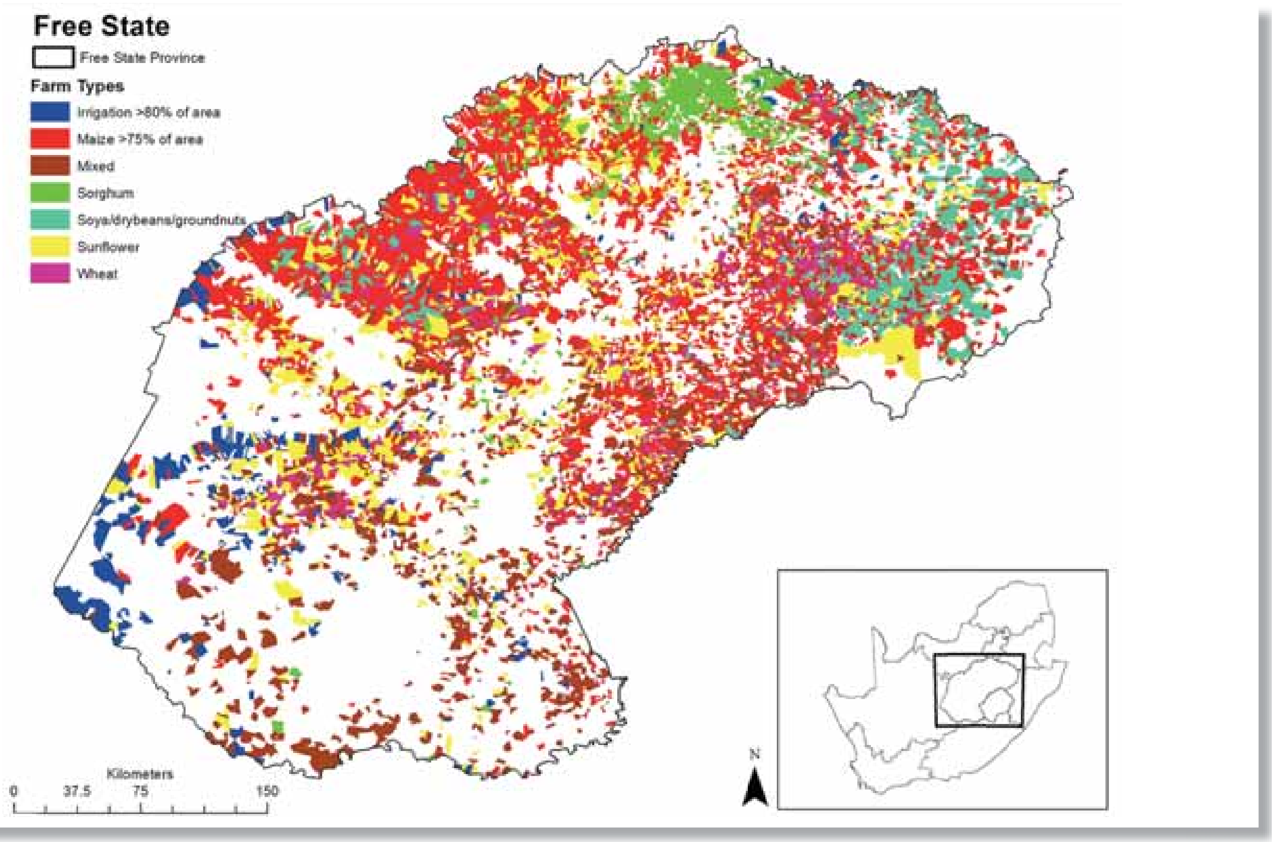
The Free State is South Africa's leading producer of maize, contributing about 40% of national white maize (for human consumption) and 38% of yellow maize (for animal feed). The province also supports extensive cultivation of soybean, sorghum, sunflower, and wheat, particularly in the eastern highlands, where seed production is an important specialization. Furthermore, the Free State produces about 40% of South Africa's potato crop, especially in its cooler, high-lying areas. This strong agricultural base makes the province a key contributor to national food security and a significant source of employment.

In 2010, agriculture contributed 3.8% to the provincial Gross Domestic Product (GDP), 19.2% of formal employment, and approximately 8% of South Africa's total agricultural output. Beyond its economic role, the sector supports rural livelihoods, agribusiness development, and sustainable land management across the province.

### Management practices

Conservation agriculture is a proven system for improving soil health, which in turn leads to better crop yields. It's a nature-based approach that is proven to improve soil potential, soil health, and resilience. Soil conservation prevents erosion and soil degradation using techniques such as contour farming and cover cropping.

**Figure 1** **Stratification of seven different farming types in the Free State based on the crop planted.** (Source: *https://agmip-ie.wenr.wur.nl/free-state-s.-africa*).



Focus on building soil health by enriching it with natural techniques like composting and mulching. Compost is made by recycling organic matter, such as crop residues and animal manure, into nutrient-rich soil amendments. Also referred to as no-tillage, this approach reduces soil disturbance, which can decrease erosion and help maintain soil moisture. It may also reduce expenses related to fuel and labour.

The effects of no-tillage vary according to soil type, so it is recommended to identify the soil characteristics beforehand. Keep the soil covered at all times. This can be done by leaving crop residues, such as stalks and leaves, on the field after harvest, or by planting cover crops, like certain grasses or legumes, between your main crops. This protective layer reduces evaporation, controls weeds, and adds organic matter to the soil.

## Crop rotation and diversification

Don't plant the same crop in the same field every year. Crop diversity is a simple and cost-effective method to increase your farm's resilience, as it breaks pest and disease cycles and improves soil fertility naturally. It also requires less external irrigation and pesticides and provides you with a more varied food source. The practice of mixed cropping, where you grow two or more crops together, can also help to naturally repel pests.

## Water and nutrient management

In addition to soil, water and nutrients constitute essential resources. Their efficient management is integral not only to operational profitability but also to the advancement of environmental sustainability. With unpredictable rains, efficient water use is critical.

If farmers irrigate, consider using methods like drip irrigation, which delivers water directly to the plant's roots and significantly reduces water consumption. Rainwater harvesting, where you collect and store water in tanks or small dams, provides a crucial buffer for dry periods.

Healthy soil grows healthy crops. Instead of relying solely on expensive and sometimes harmful chemical fertilizers, use natural alternatives like compost and animal manure. Organic materials enhance soil structure and gradually provide nutrients; however, they may not fully meet the crop's complete nutritional requirements. When you do use fertilizers, make sure you are applying the right amount at the right time. Over-application wastes money and contributes to environmental damage by polluting our rivers and streams.

## The power of information: Guide to data collection for dryland smallholder farming

In dryland smallholder farming, information is more than just records or figures; "it is a tool for survival and resilience". The ability to collect, understand, and use data effectively determines how farmers adapt to changing weather patterns, manage scarce resources, and improve productivity.

This guide provides practical steps for collecting reliable data in dryland systems, demonstrating how accurate information can turn uncertainty into informed action. By mastering data collection, smallholder farmers and researchers can identify trends, assess risks, and make better decisions that strengthen livelihoods and ensure the sustainable use of land and water resources.

## Pre-season planning: The foundation of your farm

The first step to a successful season happens long before you plant a single seed. It is about understanding the production potential of your land, which is the natural yield of a crop based on the climate, soil, crop cultivar, agronomy and management practices.

- **Climate data:** Before selecting your crop, gather information on the local climate. This includes rainfall, temperature fluctuations, and the risk of frost. The South African Weather Service, along with many online platforms and apps, provides valuable

**Figure 2** **Mobile app interface and weather station variables for monitoring and data collection in dryland smallholder farming systems.** (Source: Adapted from field observations, 2025, and Pessl Instruments GmbH, iMETOS 3.3).

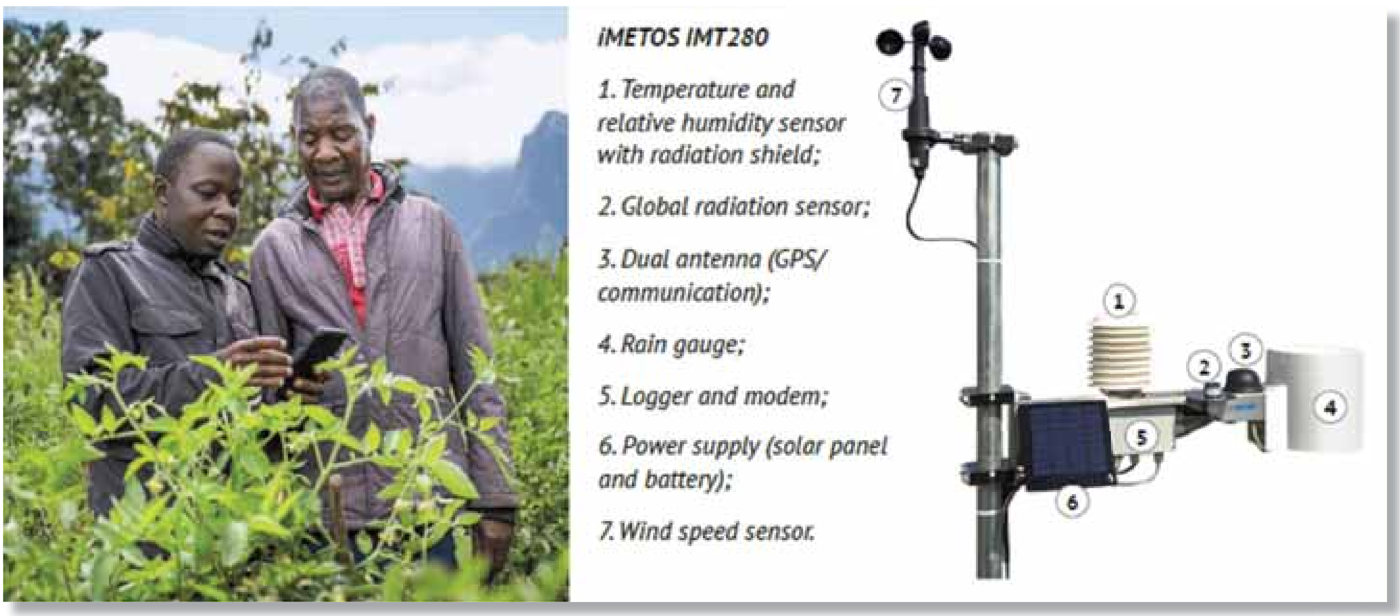
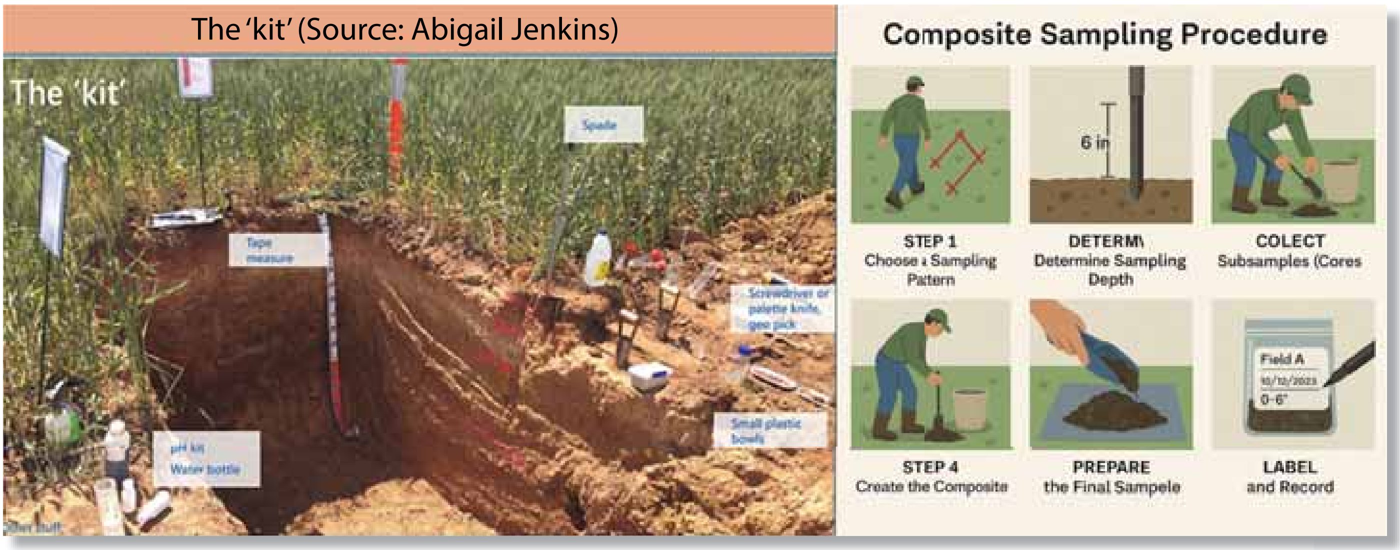


**Figure 3** **Field illustration of soil profile pit, soil auger, soil chemical and biological analysis (left), and a simple composite sampling procedure (right).**

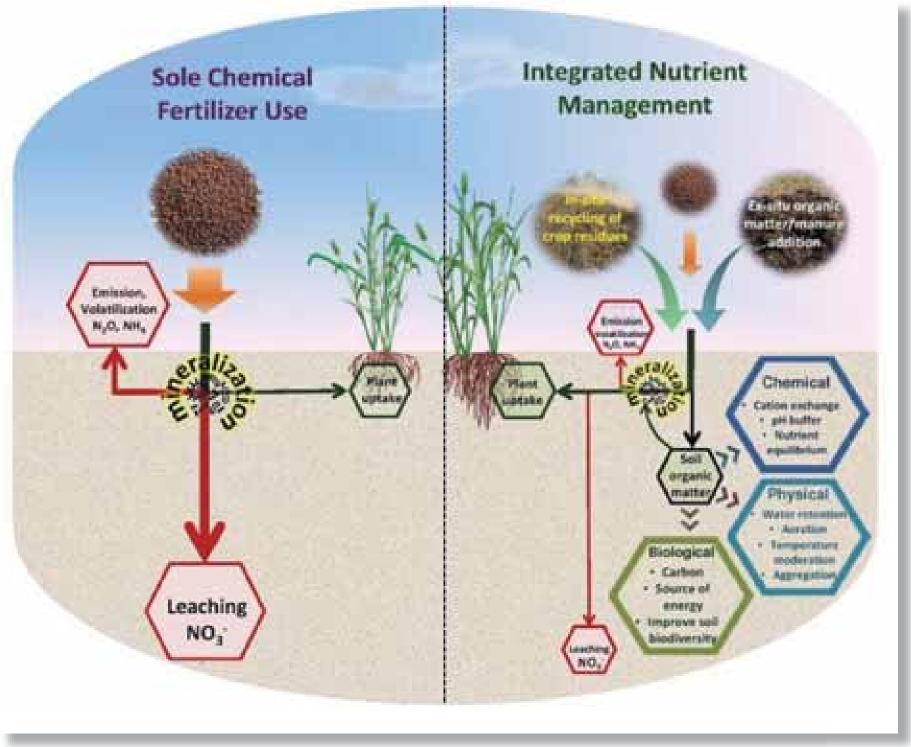



historical data. For example, a mobile application and a weather station are used to monitor key environmental variables such as temperature, rainfall, humidity, radiation, and wind. These tools help smallholder farmers make timely and informed decisions. For example, the iMETOS 3.3 weather station and mobile app display real-time environmental data for agricultural monitoring and decision support in dryland smallholder systems (**Figure 2**).

- **Soil data:** The most important step you can take for your farm's long-term health is to understand your soil's potential. This involves assessing its physical, chemical, and biological properties.
- **Physical properties:** Assess your soil's effective depth, drainage, and water retention. While some physical properties can't be changed, they can be managed with great success. For instance, knowing you have easily compacted sandy soil can lead you to adopt controlled traffic farming, conservation tillage, or conventional tillage. Request a connection to a soil scientist and lab from your extensionist.
- **Chemical properties:** Collect representative samples from a consistent depth (200 mm) and submit them to an accredited laboratory for analysis. The laboratory will report on nutrient levels (including phosphorus, potassium, calcium, magnesium, and other micro-nutrients), acidity (pH), and clay content. When interpreted by a specialist, this data provides insight into the nutrient profile of the soil and informs the development of an appropriate fertilization program. Ask your fertilizer supplier for crop-specific recommendations.
- **Biological properties:** Pay attention to the living organisms in your soil, which are crucial for soil health. Talk to experts in this field, like agronomists and microbiologists, to learn how to enhance your soil's living ecosystem.

As shown in **Figure 3**, the field illustration depicts key steps in soil sampling and analysis. On the left, a soil profile pit and soil auger are used to examine soil horizons and collect samples for chemical and biological analysis. On the right, a simple composite sampling procedure is demonstrated, showing how multiple subsamples are combined to obtain a representative soil sample for laboratory testing.

**Figure 4** **Effects of sole chemical fertilization versus integrated nutrient management on nitrogen pools, mineralization, leaching, and volatilization fluxes** (Source: Ajay Kumar *et al.*, 2023).



## Data capture/Record during the growth season

"A successful farmer is a keen observer. During the growing season, you must constantly monitor your crops for signs of stress or problems".

- **Monitoring plant nutrients:** Keep a watchful eye on your crops for signs of nutrient deficiencies, such as yellowing leaves or stunted growth. A simple leaf sample can be sent to a lab for confirmation. This data allows you to make timely corrections with fertilizer or a foliar spray, if needed. Please consult your agronomist or crop specialist for expert guidance.
- **Crop protection:** Regularly scout your fields for pests, diseases, and weeds. This is a crucial and sensitive stage for data collection. You need to not only spot a problem but also correctly identify it. For example, a fungal disease requires a different treatment than a bacterial one. Pests need to be accurately identified, too. This simple act of observation and data collection saves you from applying the wrong chemical, which is a waste of money and can harm the environment. Remember, failure to control weeds during the first five weeks of the crop cycle can lead to a 50% yield reduction. At this stage, agronomists, entomologists, and plant pathologists are consulted for their expertise.

## Harvesting and post-harvest planning

Harvesting is when all your hard work comes together. The yield per hectare is the most important piece of data.

- **Yield data:** Whether you hand-harvest and weigh your bags or use a harvester with a built-in monitor, this information is invaluable. Yield maps can be generated to show which parts of your field performed well and which didn't. This data, when combined with your records on soil properties and in-season treatments, becomes the foundation for your next planting season.
- **The post-harvest stage:** This is the most crucial, yet often overlooked, part of the cycle. It is time for analysis and planning. Gather all the data you collected from soil samples and planting records to pest sightings and yield maps. Analyse this information to determine trends and consequences. This is where you connect the dots between your actions and your results, allowing you to make sustainable and responsible recommendations for the future. Ask for help from your extensionist and agronomist.

## Data, technology, and advisory services: A support system

In dryland systems, subsistence farmers can gain significant benefits from information, even with limited technology and small plots of land. For smallholder farmers working in dryland areas, data can be a vital tool for improving resilience and productivity.

By using simple, accessible tools such as rainfall gauges, soil moisture indicators, or mobile-based record-keeping, farmers can gather valuable insights about their fields and environment. When this information is combined with appropriate technologies and expert advisory services, it empowers farmers to make informed decisions about planting, irrigation, fertilizer use, and risk management.

Data collection and advisory support help farmers identify changing weather patterns, anticipate droughts, and manage scarce resources more efficiently. Together, these elements form a support system that transforms traditional practices into knowledge-driven farming, strengthening livelihoods, enhancing productivity, and ensuring sustainable growth even under the tough conditions of dryland agriculture.

For smallholder farmers working in dryland areas, data can be a vital tool for improving resilience and productivity

## Tools for data collection

- **The farm journal:** This is your most important tool. A simple notebook and pen are all you need to get started. Use it to record everything: planting dates, rainfall, fertilizer applications, pest and disease sightings, and harvest yields for each field. This record is your farm's memory, helping you learn from past seasons.
- **Low-tech tools:** A rain gauge can help you record daily rainfall, and a ruler can ensure proper planting depth. These simple tools provide you with the critical information you need to make informed decisions. A soil auger or spade is an economical tool that can significantly enhance the efficiency and accuracy of soil sampling activities.
- **Hi-tech tools:** Technology has made data collection easier and more precise. These tools include automated weather stations, soil sensors, and mobile apps for recording field observations. Even without expensive equipment, you can take advantage of satellite imagery and other online platforms to gather valuable data.

## The role of the expert

Studies have found that the synergy between farmers' indigenous knowledge and expert advice was key to their success. You are not expected to be an expert on everything, but you must know who to ask.

- **Agricultural extension services:** The government and NGOs provide invaluable services. They offer specialized advice and training on everything from using climate forecast services to adopting new farming techniques.
- **Connect with experts:** Surround yourself with experts in the fields you need. Agronomists can help you with crop-specific issues, soil scientists can help you understand your soil, and entomologists can help you identify and manage pests. These specialists are available through universities, the ARC, and fertilizer companies.
- **Supply companies:** Most suppliers have experts to assist farmers in the correct application of their products.
- **Research institutes:** These organizations employ researchers and technicians with expertise in various fields who can assist in identifying and addressing specific problems. Extensionists should be familiar with appropriate points of referral.

By leveraging technology and advisory services, farmers can build a more resilient and sustainable agricultural system that secures their livelihood and contributes to a more robust food system for all.

## Section II: Vegetable management strategies

The effects of climate change have necessitated the need for and adoption of climate-smart agricultural practices and technologies. These effects are manifested through increased climate variability, prolonged droughts, soil degradation, and water scarcity, among others. Collectively, they have negatively impacted the production of vegetables, resulting in low yields that threaten food security and sustainability (Adeogun *et al*., 2025). Climate-smart agricultural practices play a crucial role in enhancing resilience, reducing greenhouse gas emissions, and increasing productivity, thereby ensuring food security (Muthama *et al*., 2024). Climate-Smart Agriculture (CSA) practices and technologies mitigate the effects of climate change, which are detrimental to the livelihoods of subsistence and smallholder farmers.

Both subsistence and smallholder farmers are some of the worst affected by the effects of climate change, even though they are probably the least contributors. They also have limited capacity to deal with their impacts due to a host of factors that include financial constraints and a lack of machinery. However, they need to find ways of coping and/or mitigating its effects. There are a variety of CSA practices and technologies that smallholder farmers can implement in order to minimize the impacts of climate change. Their adoption would largely depend on the affordability of those practices and technologies, and their potential economic benefits.

Mitigation strategies against the effects of climate should first start with production decisions that farmers must make

Mitigation strategies against the effects of climate should first start with production decisions that farmers must make. These decisions, to a great extent, inform some of the CSA innovations. These technologies that subsistence and smallholder farmers may employ include, among others, use of improved crop varieties, mulching, water harvesting and irrigation, shade nets and hydroponics/greenhouses, cover crops and crop rotation (Khatri-Chhetri *et al*., 2016; Adeogun *et al*., 2025).

Production decisions: Climate-smart agricultural practices can start with production decisions that farmers have to make regarding their enterprise(s). Vegetable farmers need to make informed decisions concerning what/when/how to plant, and so on. These should be based on climatic factors, weather forecast information, market demand in terms of the produce, soil needs, available resources use, profitability of the envisaged enterprise, etc.

Use of weather forecast information: Production decisions should not only be based, among others, on profitability and/or market demand for a particular crop or crops. They must also take into account the weather forecast for the short, medium, and long-term. This forecast talks to the amount of expected rain or lack thereof, i.e., drought, expected adverse weather such as cold fronts and snow, etc, and recommended actions to be undertaken by the farmers.

Improved crop varieties/cultivar choice: Cultivar choice plays an important role in the fight against the effects of climate change and variability. It is the potent way that is within the reach of everybody to fight the effects of climate change without paying extra money. Through cultivar choice, a farmer can both achieve his/her economic goals while at the same time counteracting the effects of climate change. For example, changing planting dates based on climate conditions and selecting drought-resistant crop varieties can improve water efficiency and safeguard yields (Patle *et al*., 2020; Frimpong *et al*., 2023).

Furthermore, a farmer needs to know, among other things, the common pests and diseases in his/her area to choose a suitable cultivar. This knowledge will assist farmers in choosing resistant cultivars to those pests and diseases. Factors to consider when choosing a cultivar: Planting and maturity date; Pests and diseases resistance; Hybrid or open-pollinated; Drought resistance; Adaptability; Yield potential; Plant characteristics; Horticultural qualities of a crop, etc.

Diversification: Diversification involves growing a range of different crops within a single farming system or across multiple growing systems (Mihrete and Mihretu 2025). There are different forms of diversification namely, intercropping and/or mixed cropping (concurrent cultivation of two or more crop species on the same piece of land), crop rotation (involves changing the types of crops grown on a particular piece of land each season or year), agroforestry (farming with trees and crops), traditional composting and cover crops (these are crops that are grown to cover the ground for the purpose of reducing soil erosion and nutrient loss (Singh and Singh, 2017). Cover crops are also referred to as green manure. When planted as legumes, they mainly assist in fixing nitrogen to the ecosystem, thereby reducing the cost of fertilizers. The key principles of diversification include:

- **Ecological resilience:** This emphasizes the importance of biodiversity in maintaining stable and functional ecosystems. Multiple plant species support a range of organisms, including natural predators, which help control pest populations and reduce the need for chemical pesticides.
- **Economic risk management:** This helps minimize potential financial losses due to the failure of any one crop.
- **Resource optimization:** By leveraging the varying nutrient requirements and growth patterns of different crops, farmers can maintain a balanced nutrient profile in the soil and minimize competition for resources.
- **Productivity and yield stability:** Diversified crops tend to be more resilient to environmental stresses and this can lead to higher, consistent yields over time than monoculture systems (Mihrete and Mihretu 2025).

### Moisture retention strategies and climate-smart practises

Climate change is characterized by, among others, erratic rainfall patterns, floods and droughts. It is therefore imperative that farmers mitigate against the impacts of these. According to Sikka *et al* (2016), challenges of water scarcity could effectively be addressed through the adoption of smart water management interventions and modern irrigation technologies. These include rainwater harvesting, use of irrigation technologies and practices that save water and moisture retention strategies. The following moisture retention strategies are discussed below, namely, mulching, shade netting and cover crops.

**Mulching:** Mulching refers to the practice of covering the topsoil with materials such as leaves, grass, twigs, crop residues, straw, etc (IFOAM - Organics International, 2020). Stones and plastics can also be used as mulch; however, these have to be removed after they have served their purpose. Mulch has the following benefits:

- Protects the soil from wind and water erosion
- Improves the infiltration of rain and irrigation water
- Keeps the soil moist by reducing evaporation
- Feeds and protects soil organisms
- Suppresses weeds
- Ensures the continued supply of nutrients through decaying biomass. Gradual organic matter mineralization releases essential nutrients into the soil, which are made available for plant absorption (FAO, 2020; Muthama *et al.*, 2024).

**Plastic mulch:** Since plastic mulch is easily accessible, easy to use, and as opposed to other forms of mulch materials, is found in abundance, it therefore deserves a special mention. It is a technique used to cover the soil around the root zone using a plastic film, leaving the plant from the stem upwards outside, while the entire area around it is covered with the plastic.

Benefits of plastic mulch:

- Prevent the growth of weeds
- Minimize evaporation and escape of fertilizer
- Manipulate soil temperature
- Disinfecting the soil by energy (solarisation) (Patle *et al.*, 2020).

As mentioned earlier, the plastic used for mulching has to be removed after harvesting in order to prepare for the next crop. This, however, can be done with ease. Its benefits far outweigh its disadvantages.

**Shade netting:** Shade netting is a technique used to protect vegetables against undesirable environmental conditions such as weather extremes, water shortages, pests and diseases (Ilic *et al.*, 2022). Nets of different colours and shade percentages are used. It is always advisable to seek expert advice before erecting a shade net.

Some of the benefits of shade nets are as follows:

- Reduces yield loss from insects, diseases, heavy rains and radiation
- Improves productivity and produces quality
- Protects crops from birds and animals (Baliyan, 2014; Ilic *et al.*, 2022).

Compared to hydroponics/greenhouse shade nets are easy to construct and also less expensive, and under normal circumstances, they have a longer lifespan.

**Hydroponics/greenhouse:** This type of farming does not use conventional open-air farming, where vegetables are grown in the soil. Instead, it uses other growth mediums such as sawdust and peat moss. Another system uses the nutrient film technique (NFT), where the liquid nutrient medium is provided to the plants. The main advantage of this system is its efficiency in water usage, and that the water may be recycled.

## Benefits of hydroponics/greenhouse:

- Less growing time
- Minimal disease
- Minimizes the use of fertilizer
- Higher yields
- In some areas all all-year production may be possible (Patle *et al.*, 2020).

It must be noted that this technology requires a high level of management. Again, given its high establishment costs, high-value crops should be grown in the greenhouse so as to get a return on investment.

## Summary

Effects of climate change are felt the world over and across different industries; the agricultural industry, especially subsistence and smallholder farmers, have not been spared. The only way for them is to adapt to the new reality and adopt climate-smart agricultural practices and technologies to survive.

All the above-mentioned practices and technologies are not new to the farmers, and they are within their purview. All that is needed is a change of mindset. Farmers should not only consider economic factors when making production decisions but should also factor in mitigation strategies against climate change effects.

## References


- Adeogun, S.O., Adebayo, O.A., Akintunde, M.A., Likoetla, P. Letela, R. Sethabthaba, A. Morie, M.P. and Shea, N.G. (2025). Adoption and impact of climate-smart agriculture practices among vegetable farmers in Maseru District, Lesotho. *Visegrad Journal on Bioeconomy and Sustainable Development* Vol. 14, 2025, no. 1 pp. 13-17 DOI: 10.2478/vjbsd-2025-0003
- Baliyan, S.P. (2014). Improving sustainable vegetable production and income through net shading: A case study of Botswana. *Journal of Agriculture and Sustainability*. Volume 5, Number 1, 2014, 70-103
- Erick, S.B., Mbwambo, J.S. and Salanga, R.J. (2025). Adoption of climate-smart agricultural practices among smallholder leafy vegetable agripreneurs in Semi-arid regions. A bibliometric review. *ELSEVIER* Social Sciences & Humanities Open
- Frimpong, F.A., Asante, M.D, Peprah, C.O., Amankwaa-Yeboah, D., Danquah, E.O., Riberio, P.F., Aidoo, A.K., Agyeman, K., Asante, M.O.O., Keteku, A. and Botey, H.M. (2023). (ed) Bhaduri, A. Water-smart farming: review of strategies, technologies, and practices for sustainable agricultural water management in a changing climate in West Africa. *Frontiers of Sustainable Food Systems*. DOI 10.3389/fsufs.. 2023.1110179
- Ilic, Z.S., Milenkovic, L., Šunić, L. and Fallik, E. (2022). Shading net and grafting reduce losses be environmental stresses during vegetable production and storage. Presented at the 1st International Electronic Conference Horticulturae, 16-30 April 2022
- *https:///sciforum.net/event/IECHo2022*
- Khatri-Chhetri, A., Aryal, J.P., Sapkota, T.B. and Khurana, R. (2016). Economic benefits of climate-smart agricultural practices to smallholder farmers in the Indo-Gangetic Plains of India. Current Science, Vol. 110, No. 7, 10 April 2016
- Mihrete, T.B. and Mihretu, F.B. (2025). Crop diversification for ensuring sustainable agriculture,, risk management and food security. Review. Global Challenges, 2025, 9. 2400267 DOI: 10.1002/gch2.202400267
- Muthama, E., Dharani, N., Namikoye, S. and Karanja, R. (2024). Impacts of selected climate-smart agricultural practices on African indigenous vegetables in Kenyan drylands. African Phytosanitary Journal. Volume 4, Issue 1, 2024. DOI: 10.52855/UWBW9156 *http://www.africanphytosanitaryjournal.go.ke*
- National Department of Agriculture, Döhne Agriculture Development Institute and ARC- Roodeplaat Vegetable and Ornamental Plant Institute, (N.d). Info Pak Resource Centre
- Patle, G.T., Kumar, M. and Khanna, M. (2020). Climate-smart water technologies for sustainable agriculture: a review. Journal of Water and Climate Change 11.4 2020 DOI: 10.2166/wcc 2019257
- Sikka, A., Islam, A. and Rao, K.V. (2016). Climate-smart land and water management for sustainable agriculture. 2nd World Irrigation Forum (WIF2) 6-8 November 2016, Chiang Mai, Thailand W.3.1.04
- Singh, R. and Singh, G.S. (2017). Traditional agriculture: a climate-smart approach for sustainable food production. Energ. Ecol. Environ. (2017) 2 (5):296-316. DOI 10.1007/s40974-017-0074-7. Springer
- The International Federation of Organic Agriculture Movements (IFOAM-Organics International), Food and Agriculture Organization of the United Nations (FAO TECA, 2020)

7

# Water harvesting as a PATHWAY to Climate-Smart Agriculture

## Abstract

Small-holder farmers in semi-arid areas face many challenges, especially with changing weather patterns and limited support. To make better farming decisions, farmers need clear and reliable information on alternative techniques. But without regular visits from extension officers, it's not always easy to learn or trust new methods. This work focused on bringing farmers and extension officers together through on-farm demonstration trials and farmers' information days. These gatherings provided an opportunity to observe and compare innovative practices, such as in-field rainwater harvesting (IRWH), with conventional tillage methods, the potential nutritional benefits of cereal-legume intercropping systems as an alternative to sole cropping.

Farmers appreciated seeing real results in real fields right in their communities, and many showed strong interest in trying IRWH on their own farms. It also helped open communication between farmers and extension officers, making it easier to share knowledge and support with each other. This approach shows that hands-on learning, farmer participation, and strong extension support are key to building resilience and adapting to climate risks.

**Keywords:** Farmers' information day; Smallholder farmers; Extension services; Farmer engagement; Infield Rainwater Harvesting (IRWH); Intercropping legume-cereal system

## Introduction

Agricultural extension is a vital component of the agricultural sector, playing a key role in facilitating knowledge transfer and improving farm productivity through enhanced management practices. However, improving smallholder farmers' access to extension services, particularly in rural and semi-arid regions where water is scarce and food insecurity is a major challenge, remains a significant issue for many governments (Bell, 2013).

Agricultural extension is a vital component of the agricultural sector, playing a key role in facilitating knowledge transfer and improving farm productivity through enhanced management practices

One effective way to bridge the gap between farmers and extension officers is through farmers' information days and regular workshops, which offer opportunities for both groups to engage with the technical aspects of on-farm trials. Traditional agricultural extension approaches, such as the Training and Visit (T&V) model, often follow a top-down structure, focusing primarily on the demonstration of recommended practices (Waddington *et al*., 2014).

In contrast, bottom-up approaches place more emphasis on farmer participation, encouraging the adoption of alternative and sustainable techniques by involving farmers directly in on-farm trials, field days, and routine visits (Kondylis *et al*., 2017). During these information-sharing events, communication must be tailored to local contexts, including the use of local languages and practical teaching methods that address pressing issues such as drought, pests, weeds, and climate variability. For instance, during the Farmers' Information Day held in Thaba Nchu on 8 March 2018, drought conditions emerged as a key topic of concern among participants (WRC Report No: K5 /2821//4).

As Asiedu-Darko (2013) highlights, both extension officers and farmers benefit greatly from regular in-service training and workshops to stay current with evolving agricultural technologies. The farmers' information approach should promote active interaction between farmers, extension personnel, and researchers.

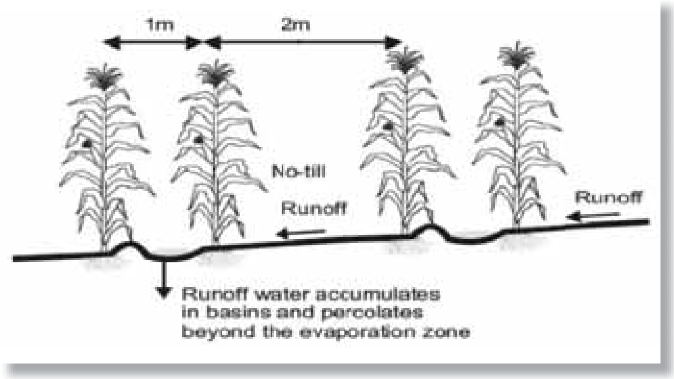
To enhance the effectiveness of such events, a variety of learning tools, including posters, illustrations, oral presentations, and field visits, should be used to support knowledge transfer. However, selecting the appropriate teaching method is essential to ensure that the content is delivered effectively and resonates with the audience. In this study, continuous farmer engagement was prioritized, and a farmers' information day was used as a practical platform to clearly demonstrate the benefits of alternative management practices, particularly in-field rainwater harvesting (IRWH), compared to conventional tillage systems.

## Research studies on in-field rainwater harvesting (IRWH)

The IRWH technique, as described by Hensley *et al*. (2000), showed potential in a semi-arid area of South Africa (**Figure 1**). Often referred to as "mini-catchment runoff farming" (Owies *et al*., 1999; Mo *et al*., 2018), IRWH is considered a simplified yet impactful technique for increasing water-use efficiency and supporting crop production in water-scarce environments. In-field rainwater harvesting incorporates the advantages of 'no-till', 'basin tillage', and 'mulching' on high drought-risk clay soils for water harvesting (Hensley *et al*., 2000). Basin tillage is also known as tied ridging, furrow disking, furrow blocking, micro-basin or reservoir tillage (Araya *et al*., 2012). Basin tillage practice was verified by earlier researchers as suitable for small-scale adoption (Rockstrom, 2000).

The reduction of runoff to zero through IRWH represents an opportunity for a sustainable alternative tillage system, as traditional

**Figure 1** **Diagrammatic layout of the IRWH technique, showing the 2 m width runoff strips and 1 m width basin strip (collection area) modified as micro basins.** (Hensley *et al*., 2000)




tillage (conventional tillage, CON) increases the risk of drought effects (Hensley *et al*., 2000). Long-term research studies demonstrated that IRWH produced significantly higher grain yield and rainwater productivity than CON (Botha *et al*., 2003). Yield improvements under IRWH are affected through higher infiltration rates, increased soil moisture and reduction in runoff (Anderson, 2007; Mzezewa and van Rensburg, 2011; Bothma *et al*., 2012).

Improved on-farm management through the integration of RWH and other cultural practices, such as intercropping, can prove to be an opportunity to upgrade current farming practices in the arid and semi-arid regions. The success of RWH systems in dryland agriculture has already been documented by several researchers (Araya *et al*., 2012; Makurira *et al*., 2011; Mo *et al*., 2018), but they identified large gaps in knowledge on the influence of cropping systems in facilitating efficient utilization of resources.

Crop intensification and diversification through intercropping and crop rotation systems are high-yielding with efficient use of water resources, and thus reduce water stress risk in arid and semi-arid climates (Guilpart *et al*., 2017). Thus, less risk of crop failure due to crop water deficits may improve farmers' willingness and ability to adopt IRWH, residue management, and cropping systems. However, there is a need to find optimal ways to ensure sustainable crop production through soil and water conservation practices with efficient use of limited water.

Diversifying the cropping systems through intercropping, cover cropping, mulching and utilization of livestock manure can present an opportunity for maintaining soil cover, fertility, reducing evaporation, and conserving the harvested soil moisture (Botha *et al*., 2003; Mzezewa *et al*., 2011; Tesfuhuney, 2012).

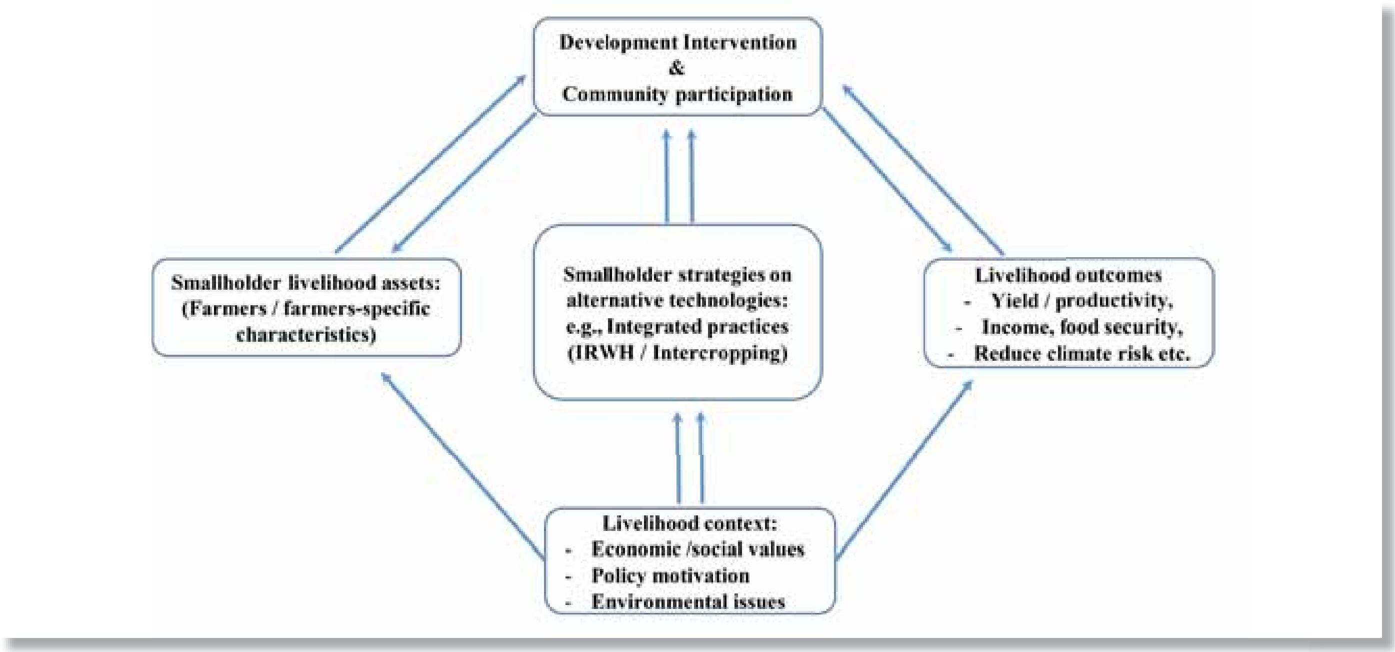
## Sustainable livelihood framework

The sustainable livelihood framework explains how smallholder farmers' livelihoods benefit from the available resources by engaging them in certain farming activities. The research focuses on including smallholder farmers in the project to undertake livelihood strategies using the assets that they own to transform their lives.

In this study, assets owned by smallholder farmers were key in implementing livelihood strategies such as crop farming (including homestead gardens), livestock rearing, and implements for cultivation. These were necessary to realize the desired livelihood outcomes and to minimize climate risk and vulnerability impacts. The sustainable livelihood framework illustrated in Figure 1 shows the relationships within the context of smallholder farmers' assets (different forms of capital), technology transfer, livelihood strategies, and livelihood outcomes.

Given the assets, households make decisions regarding improved technology uptake and intensification to generate positive social

**Figure 2** **Linkage between alternative techniques and livelihood outcomes as a sustainable livelihood framework for smallholder farmers in rural communities.**



and economic outcomes. As illustrated in **Figure 2**, the system is characterized by forward and backward linkages in response to changes in farm and farmer-specific variables. This becomes evident if farmers adopt alternative technologies or improved practices such as IRWH techniques and effective mixed cropping to enhance land productivity and ultimately improve their livelihoods.

Therefore, the expected positive benefits from these practices influence farmers' choice about technology uptake. The alternative techniques of IRWH or cereal-legume/cereal-vegetable intercropping are intervention mechanisms through which rural communities in Thaba Nchu, given their farming potential and socio-economic characteristics, can transform poor resource farming.

## Community-based natural resources management

Community-based natural resource management (CBNRM) is a major global strategy for enhancing conservation outcomes while also improving rural livelihoods; however, little evidence of socioeconomic outcomes exists (Brain, 2004; Anderson and Mehta, 2013). CBNRM has been widely promoted as a strategy to conserve biodiversity, while simultaneously enhancing rural livelihoods (Lund, 2007). The underlying theory indicates devolving control of natural resources to local communities, in particular the smallholder farmers.

Improvements are needed in natural resources management in order to take advantage of adopting improved and alternative techniques among small-holder farmers. Efforts are required to achieve efficient use of available resources, such as water for agriculture. This pooling of research and extension resources aids in developing strategies to increase the productivity of poor resource farming communities in rural areas (such as Thaba Nchu; **Figure 3**). In other words, a coordinated approach is required to raise the productivity of smallholder farmers in arid and semi-arid areas, where water for agriculture is scarce and fertile land for agricultural use has deteriorated.

To combat rural poverty and to conserve the deteriorated natural resources requires community-based research and to integration of resource management strategies (Anderson and Mehta, 2013). Focused attention to the linkages between agriculture and natural resource management will help greatly to solve the challenges of poverty, food insecurity, and environmental degradation in the rural communities around Thaba Nchu (Figure 3a - e). To benefit the rural poor, research should operate on a "bottom-up" approach, using and building upon the resources already available. This includes local people (smallholder farmers), their indigenous knowledge and the natural resources around their homeland (Figure 3c). It must also be implemented through participatory approaches. Nevertheless, achieving demonstrable benefits to rural communities will be crucial for CBNRM, future success in Thaba Nchu rural areas (Figure 3a).

Many governmental programmes seek to improve agricultural productivity, including the use of effective soil and water conservation techniques. Promising research areas for evaluation and promotion of alternative technologies (Figure 3a & b include rainwater harvesting, intercropping suitability, green and dry mulch application, use of manure, cover crops, crop-livestock mixed systems (Figure 3d & e), and integrated pest management (IPM) interventions. The expected results of the project could initiate more research and contribute to achieving food or nutrition security in rural communities, but the potential and further adoption depend on the knowledge uptake of the technology. The majority of the rural poor live in areas that are resource-poor, highly heterogeneous, and risk-prone environments.

**Figure 3** **Representation for community-based natural resources management at Thaba Nchu, including the introduction of alternative techniques, demonstration of natural resources use and mixed crop and livestock production.**


> Many governmental programmes seek to improve agricultural productivity, including the use of effective soil and water conservation techniques

## Farmers' information day setup

A farmers' information day was held on 8 March 2019 in Thaba Nchu as part of a stakeholder engagement workshop. The event aimed to share project progress and gather local perspectives on adopting in-field rainwater harvesting (IRWH) and maize-legume cropping strategies suited to the water-scarce, semi-arid conditions of the region. The theme for the day was: "Innovative Ways to Combat Drought and Nutrition Insecurity". This message addressed the ongoing drought challenges in the area and introduced practical solutions such as rainwater harvesting techniques and maize-legume intercropping, which can improve both soil fertility and household nutrition for resource-limited farmers.

Farmers from nine nearby villages were invited, ensuring broad representation and gender inclusivity. Participants included: Experienced farmers familiar with water harvesting, small-scale vegetable growers (mostly women), marginal rainfed farmers, and landless and vulnerable households. Other stakeholders included:

Extension officers, village leaders/headmen, agricultural students, and researchers.

The format of the day encouraged active participation, including open discussions on current challenges (e.g., drought, soil degradation), a guided tour of the on-farm IRWH demonstration plot, comparison of conventional tillage vs IRWH practices under sole and intercropping systems, and visual presentations and posters explaining the nutrient benefits of legume crops. This interactive setup allowed farmers to see, question, and evaluate the practices being promoted in their own local context. Participants expressed strong interest, particularly in the potential of IRWH to address water shortages and improve crop reliability under dryland conditions.

## Lessons learned from farmers' information day and stakeholder engagement

The stakeholder engagement and farmers' information day held in Thaba Nchu provided valuable insights into both the technical and social dimensions of implementing in-field rainwater harvesting (IRWH) and improved cropping systems in semi-arid smallholder farming contexts. The structured sessions and active participation from farmers, extension officers, agricultural students, and researchers helped generate practical lessons across several themes:

Bridging scientific research with local knowledge strengthens relevance and increases farmers' confidence in research outcomes

### Community engagement builds ownership and interest

- The inclusive nature of the event, which involved farmers, traditional leaders, extension officers, and students, created a strong platform for open dialogue and mutual learning.
- Opening discussions and speeches by local leaders (such as the Morago village headman) enhanced community trust and reinforced the relevance of the IRWH technique in local contexts.
- Farmers responded positively to the participatory setup, showing high levels of engagement and interest, especially where visual tools, demonstrations, and local languages were used.

### Local knowledge and history must inform current interventions

- Farmers shared that IRWH was previously promoted (2001 - 2006), but its adoption declined due to implementation challenges and lack of follow-up support.
- The revival of interest in IRWH must therefore build on existing knowledge while addressing past limitations through sustained extension services and tailored support mechanisms.

### Practical demonstrations foster better understanding and motivation

- On-site demonstrations and visual comparisons between IRWH and conventional (CON) tillage systems were particularly effective.
- Farmers appreciated observing IRWH structures in real backyard settings and relating them to their own experiences.
- Many participants expressed interest in adapting the techniques, with some suggesting the inclusion of vegetables or forage crops in intercropping systems.

### Drought/Climate variability undermines adoption without timely information

- The 2018/2019 growing season was marked by a late onset of rainfall and prolonged dry spells, which negatively affected crop germination and seedling establishment.
- These challenges discouraged planting and reduced participation in field trials, reinforcing the need for farmers to receive seasonal forecasts and climate advisories to guide timely planting decisions.
- Extension officers recommended improved communication channels to relay such information to smallholder farmers.

### Scientific measurements and farmer participation can be integrated

- Farmers actively participated in data collection activities, including rainfall recording, soil sampling, and assisting with instrument installations.
- Scientific demonstrations (e.g., soil moisture probes, runoff measurement, and radiation interception tools) were made accessible and meaningful through farmer collaboration.
- Bridging scientific research with local knowledge strengthens relevance and increases farmers' confidence in research outcomes.

### Conservation tillage and soil management need continued promotion

- Presentations highlighted the benefits of IRWH and conservation tillage, including reduced runoff, improved soil moisture, and protection of soil quality.
- Innovations such as mulching, winter cover cropping, and kraal manure application were introduced as potential enhancements for improving germination and reducing erosion.
- Despite challenges, some committed farmers maintained clean plots and showed better crop performance, demonstrating that proper management improves outcomes even under harsh conditions.

### Communication and continuous engagement are critical

- Early and ongoing communication is essential for the success of community-based agricultural projects.
- Farmers need clear, consistent information, especially under uncertain conditions (e.g., drought, seed failure, weed pressure).
- Engagement should go beyond information days, incorporating routine visits, accessible learning materials, and feedback loops with extension officers and researchers.

### Demonstration plots serve as learning hubs

- Visiting demonstration plots allowed farmers to directly observe and discuss implementation challenges and successes with peers.

- The visual comparison of basin construction and runoff control under IRWH versus CON tillage helped reinforce theoretical knowledge with practice.
- Farmers were able to ask detailed questions and share feedback, enriching the learning process for all stakeholders.

## Concluding remarks

The farmers' information day proved to be a highly effective platform for knowledge exchange, learning, and dialogue between farmers, extension officers, researchers, and other stakeholders. It highlighted the value of participatory approaches and hands-on demonstrations in promoting the adoption of sustainable agricultural practices, especially in climate-vulnerable, semi-arid areas like Thaba Nchu.

The event reinforced the need for sustained engagement, locally relevant solutions, and the integration of scientific innovation with farmers' indigenous knowledge. While farmers are eager to adopt improved techniques, they require timely, accessible, and practical information, something that traditional extension services often struggle to provide consistently. Farmers left the event feeling informed, motivated, and optimistic. Many expressed appreciation for the opportunity to learn directly through demonstrations and peer interaction, and strongly encouraged the expansion of such initiatives to reach more communities.

Special attention must be given to empowering female-headed households and youth, who represent a vital force for future agricultural resilience. Going forward, scaling up this model of engagement where farmers are active participants, not just recipients, will be critical in building adaptive capacity, strengthening food security, and fostering long-term sustainability in the face of climate change.

## References


- Anderson, J. and Mehta, S. (2013). *Community-based Natural Resource Management: addressing the critical challenges of the rural sector*. United States Agency for International Development, The United States Government (USAID Report), pp.12-45
- Anderson, JJ. (2007). *Rainfall-runoff relationships and yield responses of maize and dry beans on the Glen/Bonheim ecotope using conventional tillage and in-field rainwater harvesting*. Ph.D. University of the Free State, South Africa
- Araya, T., Cornelis, WM., Nyssen, J., Govaerts, B., Getnet, F., Bauer, H., Amare, K., Raes, D., Haile, M. and Deckers, J. (2012). Medium-term effects of conservation agriculture-based cropping systems for sustainable soil and water management and crop productivity in the Ethiopian highlands. *Field Crops Research*, 132: 53-62
- Asiedu-Darko, E. (2013). Agricultural extension delivery in Ghana: A case study of factors affecting it in Ashanti, Eastern and Northern regions of Ghana. *J. Agric. Ext. Rural Dev*., 5(2):37-41
- Bell, M. (2013). *Tips and Facts Sheets: Test Strips for On-Farm Demonstrations*. Modernizing Extension and Advisory Services ands UC Davis College of Agricultural and Environmental Science
- Botha, JJ., Van Rensburg, LD., Anderson, JJ., Hensley, M., Macheli, MS., Van Staden, PP., Kundhlande, G., Groenewald, DG. and Baiphethi, MN. (2003). Water conservation techniques on small plots in semi-arid areas to enhance rainfall use efficiency, food security, and sustainable crop production. *Water Research Commission Report*, 1176(1), pp.3-10
- Bothma, CB., Van Rensburg, LD. and Le Roux, PAL. (2012). Rainfall intensity and soil physical properties influence on infiltration and runoff under in-field rainwater harvesting conditions. *Irrigation Drainage*, 61: 41-49
- Brian, TBJ. (2004). *CBNRM, poverty reduction and sustainable livelihoods: Developing criteria for evaluating the contribution of CBNRM to poverty reduction and alleviation in southern Africa*. Center for Applied Social Sciences and Programme for Land and Agrarian Studies, Cape Town. No.7: pp.18-32
- Guilpart, N., Grassini, P., Sadras, VO., Timsina, J. and Cassman, KG. (2017). Estimating yield gaps at the cropping system level. *Field crops research*, 206: 21-32
- Hensley, M., Botha, JJ., Anderson, JJ., van Staden, PP. and du Toit, A. (2000). Optimising rainfall use efficiency for developing farmers with limited access to irrigation water. *Water Research Commission Report* 878/1/00, Pretoria, South Africa
- Kondylis, F., Valerie M. and Jessica ZHU. (2017). Seeing Is Believing? Evidence from an Extension Network Experiment. *Journal of Development Economics*, 125: 1 - 23
- Lund, JF. (2007). Is small beautiful? Village-level taxation of natural resources in Tanzania. *Public Adm Dev*., 27: 307–318. doi: 10.1002/pad.467
- Makurira, H., Savenije, HHG., Uhlenbrook, S., Rockström, J. and Senzanje, A. (2011). The effect of system innovations on water productivity in subsistence rainfed agricultural systems in semi-arid Tanzania. *Agricultural Water Management*, 98(11): 1696-1703
- Mo, F., Wang, JY., Ren, HX., Sun, GJ., Kavagi, L., Zhou, H., Nguluu, SN., Gicheru, P., Cheruiyot, KW., and Xiong, YC. (2018). Environmental and economic benefits of micro–field rain–harvesting farming system at maize (*Zea mays* L.) field scale in semiarid east African Plateau. *Agricultural Water Management*, 206: 102-112
- Mzezewa, J. and Van Rensburg, LD. (2011). Effects of tillage on runoff from a bare clayey soil on a semi-arid ecotope in the Limpopo Province of South Africa. Water SA, 37(2)
- Oweis, T., Hachum A, Kijne J. (1999). *Water harvesting and supplementary irrigation for improved water use efficiency in dry areas*. IWMI contribution (No. 7) to System-Wide Initiative on Water Management (SWIM)
- Oweis, T., Prinz D, Hachum A. (2001). *Water harvesting: Indigenous knowledge for the future of the drier environments*. International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria
- Oweis, TY. and Taimeh, AY. (1996). Evaluation of a small basin water-harvesting system in the arid region of Jordan. *Water Resources Management*, 10(1): 21-34
- Rockström, J. (2000). Water resources management in smallholder farms in Eastern and Southern Africa: an overview. *Physics and Chemistry of the Earth, Part B: Hydrology, Oceans and Atmosphere*, 25(3): 275-283
- Tesfuhuney, WA. (2012). *Optimizing Runoff to Basin Area Ratios for Maize Production with in Field Rainwater Harvesting*. Ph.D. University of the Free State, Bloemfontein, South Africa
- Tesfuhuney, WA., Van Rensburg, LD. and Walker, S. (2013). In-field runoff as affected by runoff strip length and mulch cover. In: *Soil and Tillage Research*, 131: 47-54
- Tesfuhuney, WA., Walker S., and Fourie, A. (2020). WRC Report No: K5 /2821//4
- Van Rensburg, LD., Botha, JJ., Anderson, JJ. and Joseph, LF. (2005). *A review on the technical aspects of rainwater harvesting for crop production*. Paper presented at the Combined Congress of the Soil Science Society of South Africa, 10-13 January 2005, Potchefstroom, South Africa. Unpublished
- Waddington, H., and Howard W. (2014). *Farmer Field Schools: From Agricultural Extension to Adult Education*. 3ie Systematic Review Summary 1. London: International Initiative for Impact Evaluation.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# Agricultural FINANCIAL support

Financing CSA for smallholder farmers in South Africa plays a vital role in strengthening agricultural resilience to climate change and promoting food security. A diverse range of actors and funding sources contribute to this financing ecosystem, which is increasingly acknowledged as essential for advancing sustainable agricultural development. Despite this acknowledgement, financing options specifically targeting CSA are still limited at international, regional, and national levels. For many smallholder farmers in the Free State, limited finance is a barrier to adopting CSA.

## Classifications of CSA finance in South Africa

**Table 1** highlights the key agents contributing to climate finance in agriculture in South Africa that smallholder farmers in the Free State province can access. Gaining insight into the roles and operations of these actors, such as government institutions, international agencies, private sector entities, and non-governmental organisations, is crucial for improving and aligning CSA investment strategies.

### I) GOVERNMENT GRANTS AND SUBSIDY PROGRAMMES

Emerging and current government support programmes have been deemed crucial for assisting smallholder farmers to leverage the different Climate-Smart Agriculture opportunities in agriculture. The support provided includes financial and credit, extension and advisory services, technical, training, entrepreneurship, marketing, infrastructure and physical resources support.

The government programmes summarised in **Table 2** do not specifically focus on financing CSA, but they support CSA initiatives and are accessible to small-scale farmers. Typical application process flow (eligibility, documentation, evaluation) is applicable to benefit from these programmes available on national, provincial, municipal, and parastatal levels. Agri-parks.

## Summary

Financing CSA in South Africa supports smallholder farmers in adopting sustainable and resilient farming practices. Funding is available from government programmes, private banks, microfinance institutions, NGOs, and impact investors. Support includes grants, loans, credit guarantees, training, technical assistance, and infrastructure, helping farmers, cooperatives, and agribusinesses implement CSA practices effectively.

**Table 1** **Classifications for Climate-Smart Agriculture finance.**

| Finance providers/Actors | Type of finance/Finance instrument | Finance/Support beneficiaries |
|---|---|---|
| **Government agencies**<br>• National<br>• Provincial<br>• Municipal<br>• Parastatals<br>**Private sector**<br>• Commercial banks<br>• Multilateral development banks<br>• Microfinance institutions<br>• International development agencies<br>• Impact investors<br>• Agribusinesses<br>**Others**<br>• NGOs<br>• Foundations<br>• Donors<br>• Crowdfunding and peer-to-peer lending | • Grants<br>• Subsidies<br>• Loans and credit<br>• Blended finance<br>• Value-chain finance<br>• Guarantees and insurance<br>• In-kind support<br>• Input support<br>• Voucher schemes<br>• Extension services<br>• Infrastructure and physical assets | • Individual farmers<br>• Cooperatives<br>• Agribusinesses<br>• Government<br>• SMMEs |

**Table 2 Government CSA finance initiatives (Landscape).**

| Programme | Who can apply | Focus | Where to apply |
|---|---|---|---|
| Comprehensive Agricultural Support Programme (CASP) | • Smallholder<br>• Emerging farmers | • Inputs<br>• Infrastructure<br>• Training,<br>• Skills development<br>• Capacity building<br>• Marketing<br>• Business development<br>• Technical support<br>• Grants | Free State Department of Agriculture & Rural Development (FS-DARD) |
| Ilima/Letsema | • Individual farmers<br>• Groups | • Production inputs<br>• Equipment<br>• Technical support | FS-DARD |
| Land Care Programme | • Smallholder farmers | • Grants for land and water degradation challenges<br>• Capacity building | FS-DARD |
| Green Fund | • Community based organisations<br>• Small medium enterprises | • Sustainable farming support | Department of Environmental Affairs (DEA) implemented through Development Bank of Southern Africa (DBSA) |
| Green Outcome Fund | • SMMEs | • Blended finance | Jobs Fund and Green Cape |
| Blended Finance | • Smallholder<br>• Medium scale farmers | • Loan with a portion of grant | Land Bank |

**Table 3 Key financial and institutional support programmes enabling.**

| | Programme | Who can apply | Focus | Where to apply |
|---|---|---|---|---|
| Commercial financial institutions | Standard Bank Agribusiness Finance | Commercial and emerging farmers | • Loans for CSA-aligned infrastructure such as efficient irrigation systems, renewable energy, and water management technologies | Standard Bank Cultivating Africa's Future |
| | Absa climate adaptation finance partnerships | Smallholder and commercial farmers | • Financing for CSA adoption, including soil management, crop diversification, and water conservation | ABSA Supporting Climate Adaptation |
| | Land Bank (Agricultural Bank of South Africa) | Developing and commercial farmers | • Development finance for sustainable, inclusive agribusiness models aligned with CSA principles | Land Bank |
| | Khula Enterprise Finance | Agricultural SMMEs | • Credit guarantee schemes to improve access to finance for CSA technologies | Khula Enterprise Finance |
| Agribusinesses & support agencies | AgriLiving Farmer Development Programme | Small-scale and emerging farmers | • Cluster-based farming support, training, and mentorship on CSA practices | AgriLiving |
| | Grain SA Conservation Agriculture Innovation Programme | Grain producers | • Promotes farmer-led CSA innovation through conservation agriculture training and peer learning | Grain SA |

**Table 3 Key financial and institutional support programmes enabling (continued).**

| | Programme | Who can apply | Focus | Where to apply |
|---|---|---|---|---|
| Microfinance institutions | Capital Harvest Agricultural Loans | Smallholder farmers | • Competitive credit facilities supporting CSA adoption (e.g. irrigation, soil improvement) | Capital Harvest |
| | Small Enterprise Foundation (SEF) | Rural women farmers | • Microloans and training for women-led sustainable farming projects | Small Enterprise Foundation |
| | WDB microfinance | Rural women and small enterprises | • Financing for small-scale, water-efficient and climate-resilient agricultural activities | WDB Holdings |
| | Phakamani Foundation Microcredit | Low-income rural entrepreneurs | • Group-based microloans supporting diversified and sustainable farming | Phakamani Foundation |
| | Finmark Trust & Khula Credit Guarantee | Smallholder farmers and agribusinesses | • Financial inclusion and risk-sharing for CSA investments (drip irrigation, renewable energy) | FinMark Trust |
| | Grofin Agribusiness Investment | Small and medium agribusinesses | • Provides patient capital and advisory support for CSA-aligned ventures | GroFin |
| | Siyakhula Rural Finance Programme | Smallholder farmers | • Loans and technical support for climate-resilient production systems | Siyakhula |
| | Letshego Inclusive Finance | Small enterprises and farmers | • CSA-related investment loans (irrigation, renewable energy systems) | Letshego |
| | Maize Trust Development Fund | Maize producers | • Supports research and farmer development for climate-smart maize production | Maize Trust |
| Impact investors | GIZ – CSA Development Cooperation | Smallholders and cooperatives | • Implements CSA projects (training, drip irrigation, water storage) in partnership with DALRRD | GIZ Agriculture & Food |
| | GreenCape Green Economy Programme | Agritech innovators and SMMEs | • Promotes green innovation and CSA-aligned partnerships | GreenCape |
| | Root Capital | Agribusinesses integrating smallholders | • Impact financing for value-chain businesses using CSA approaches | Root Capital |
| | Acumen Resilient Agriculture Fund (ARAF) | Early-stage agri-business ventures | • Investment in technologies and ventures that promote CSA and resilience | Acumen ARAF |
| | Climate Fund Managers (CFM) | Private and public agribusiness projects | • Blended climate finance for CSA-linked infrastructure (renewable energy, water systems) | Climate Fund Managers |
| | Aavishkaar Capital | Rural agribusinesses | • Venture investment for scalable regenerative and CSA-focused enterprises | Aavishkaar Capital |
| | Nedbank Green Investments | Agribusinesses and SMEs | • Funds CSA infrastructure, renewable energy, and water efficiency aligned with the Just Transition | Nedbank |

**Table 4 The Community Adaptation Small Grants Facility (CA-SGF): Lessons from Climate-Smart Agriculture in Vuhehli Village**

| Case studies description/Summary |
|---|
| **Case Study: The Community Adaptation Small Grants Facility (CA-SGF): Lessons from Climate-Smart Agriculture in Vuhehli Village.** |
| International climate finance mechanisms (multilateral and bilateral) such as the GCF, AF and the German Agency for International Cooperation (GIZ) are already enabling tangible CSA interventions in South Africa. The project below was piloted in another province, however the lessons learned, and the technical approaches are highly relevant and transferable to Free State Province crop and livestock producers. |
| The South African National Biodiversity Institute (SANBI), in partnership with the Department of Forestry, Fisheries and the Environment (DFFE), secured US$2,442,682 from the Adaptation Fund to implement "Taking Adaptation to the Ground: A Small Grants Facility for Enabling Local Level Responses to Climate Change" – known as the Community Adaptation Small Grants Facility (CA-SGF) project. Approved in 2014 as a four-year pilot, the project aimed to increase resilience and reduce vulnerability of rural communities most affected by climate change. It focused on empowering communities to identify and implement locally appropriate adaptation measures, integrating climate adaptation into everyday practices to safeguard livelihoods from droughts, dry spells, and storm-related disasters. |
| The project targeted Namakwa District (Northern Cape) and Mopani District (Limpopo), offering grants of approximately US$100,000 to community. This case study focuses on Climate-Smart Agriculture, using the Vuhehli project in Limpopo as an example of successful local adaptation, Vuhehli Climate-Smart Agriculture Vegetable and Nursery Project: |
| The Vuhehli Village in Mopani District faced high rates of malnutrition and limited access to resources, making it highly vulnerable to climate change. Shifting rainfall patterns, soil erosion, and rising temperatures threatened agricultural productivity and food security. |
| In response, a local Non-Governmental Organisation (NGO) partnered with a farming and processing organisation to establish the Vuhehli Climate-Smart Agriculture Vegetable and Nursery Project. The initiative sought to improve food security, create income opportunities, and build community resilience by developing a sustainable food garden and nursery at the local community centre. These interventions collectively enhanced food production and strengthened the community's adaptive capacity. The garden provided nutritious vegetables, reduced food costs, and generated income from surplus sales. Improved access to healthy food contributed to lower malnutrition rates and better overall wellbeing in the community. |
| Through hands-on training and mentorship, participants gained skills in agroecology, composting, liquid fertiliser production, seed saving, and tree propagation, enabling them to maintain and expand the garden beyond the project's lifespan. |

**Figure 1 An image showing the outcomes of the CA-SGF.**

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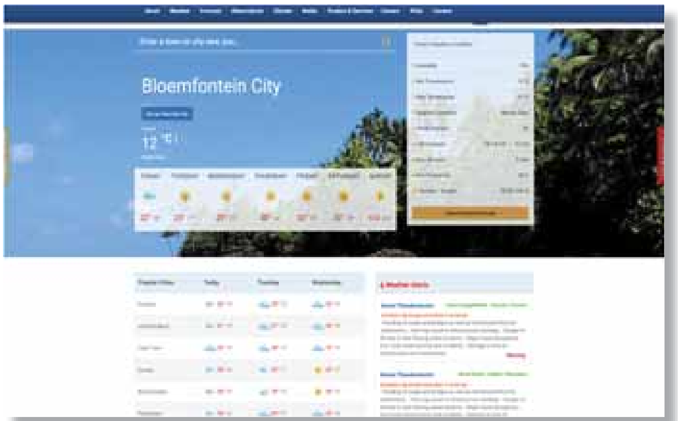
# Knowledge TOOLS

Access to reliable climate and weather information is one of the most important tools for farmers to plan ahead, protect their crops, and reduce losses. Climate-smart decisions begin with knowing what the weather and climate are expected to do, both in the short and long term (Maka *et al*.,2019). This section introduces key South African institutions and tools that smallholder farmers can use to stay informed, prepare for risks, and plan agricultural activities such as planting, irrigation, and pest management.

Each tool includes a short description and a QR code for quick access using a mobile phone.

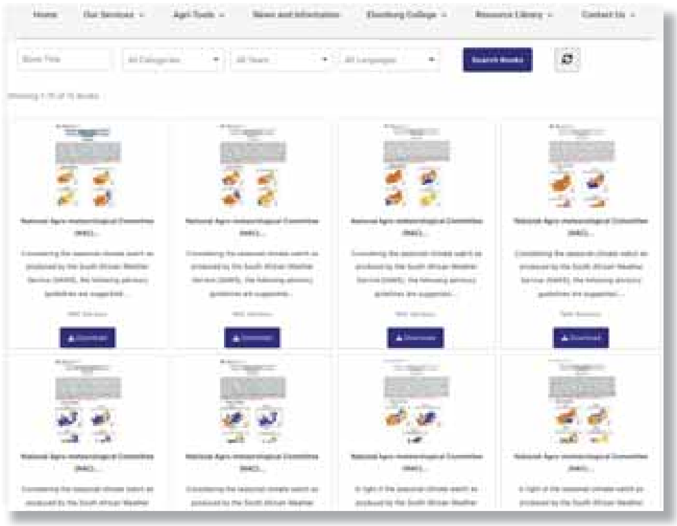
## 1. South African Weather Service (SAWS) used for Seasonal Climate Watch & Forecasts

National meteorological service providing daily forecasts, short-term (7-day) forecasts, and seasonal outlooks (Seasonal Climate Watch). These updates help farmers understand expected rainfall and temperature patterns for the coming months, allowing them to plan planting dates and prepare for possible dry or wet conditions.




## 2. Department of Agriculture, Land Reform and Rural Development (DALRRD) – National Agro-meteorological Committee (NAC) Advisory

The National Agro-Meteorological Committee (NAC), led by the DALRRD issues seasonal advisories that translate meteorology into agricultural guidance (planting windows, drought/flood notes). Farmers can use these advisories to align agricultural decisions with seasonal risks.



## 3. National/Provincial/District Disaster Management Centres (NDMC)

The Disaster Management Centres at national and sub-national disaster centres coordinate early warnings and emergency response (floods, fires, drought declarations). Farmers can use them for warnings, relief info, and official emergency procedures.

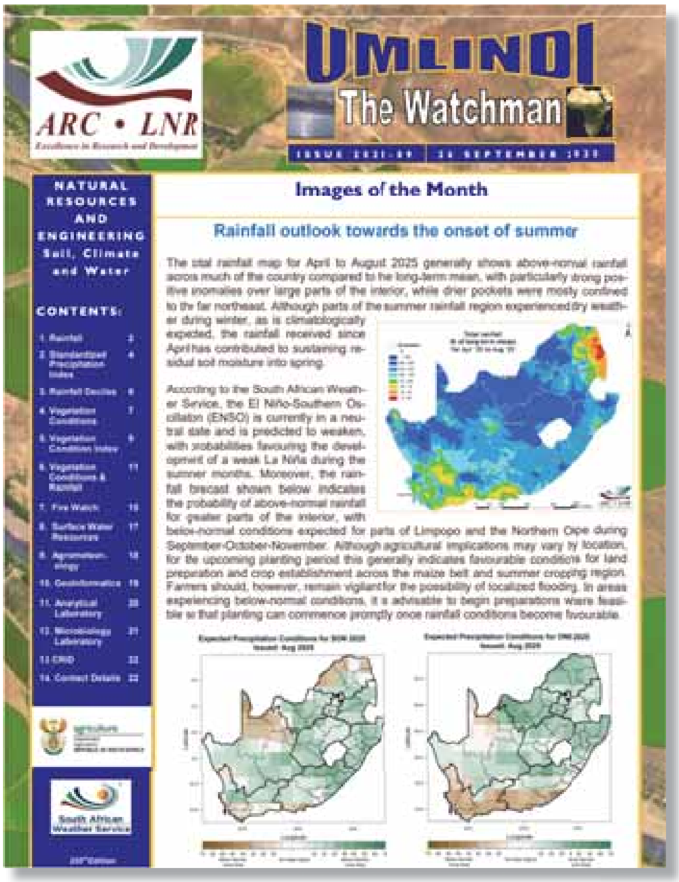
**Contact details, Free State:**
7th Floor, OR Tambo Building, Corner Markgraaff & St. Andrew Street
Bloemfontein 9300, Free State, South Africa

NATIONAL DISASTER MANAGEMENT CENTRE

## 4. Agricultural Research Council (ARC) Umlindi (ARC Soil, Climate & Water/ Umlindi newsletter)

ARC's Umlindi newsletter and advisory products provide agriculturally translated climate and vegetation summaries (NDVI, VCI, rainfall deciles) and practical tips for farmers (planting advice, pests).

Farmers are encouraged to subscribe to monthly bulletins.



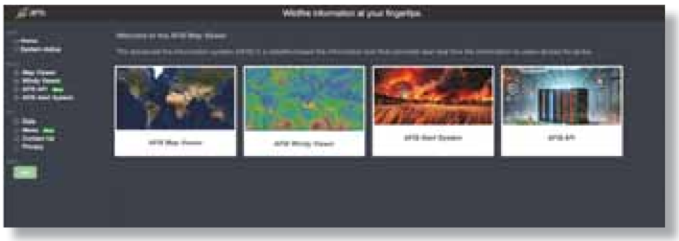

## 5. AgriSA (Agri South Africa)/AgriSA Relief resources

AgriSA is a farmer organisation that disseminates policy updates, practical alerts, and coordinates farmer relief (disaster funds). It is useful for networking, advocacy, and district-level practical bulletins.

Through its relief initiatives, AgriSA provides on-the-ground support to farming communities affected by droughts, floods, and other natural disasters, helping them to rebuild and sustain their livelihoods


## 6. Advanced Fire Information System (AFIS)

The Advanced Fire Information System (AFIS) is a tool that farmers can use to monitor active fires and wind/vegetation indices to mitigate wildfire risk. The system enhances preparedness by providing early warning alerts and situational awareness to help coordinate timely responses. It is a valuable decision-support tool for managing natural resources and reducing losses associated with veld fires in agricultural areas.



## 7. South African Risk & Vulnerability Atlas (SARVA)

SARVA is a spatial risk and vulnerability atlas that provides climate projections, exposure maps, and vulnerability data to support informed planning and decision-making. It helps farmers, planners, and policymakers understand local hazard profiles and long-term climate change impacts. The platform also promotes evidence-based adaptation strategies by integrating scientific data with community-level insights for resilience planning.


## 8. The Council for Scientific and Industrial Research (CSIR) – GreenBook (Municipal Risk Profile Tool)

The CSIR GreenBook is an interactive planning tool that provides municipal-level risk profiles, highlighting climate hazards, exposure, and adaptive capacity. It supports evidence-based climate adaptation and resilience planning by offering localized data and practical adaptation actions. The tool assists municipalities and practitioners in integrating climate risk into spatial and development planning for sustainable, climate-resilient communities.

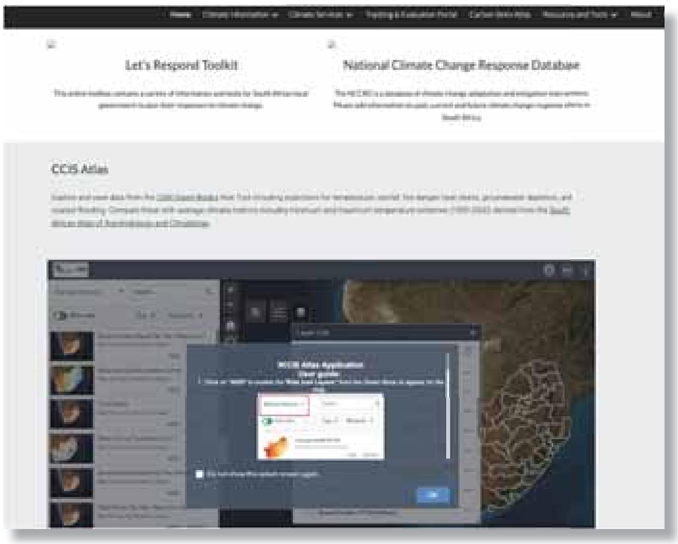


### Reference

- Maka, L., Ngotho, T., Walker, S. R., Ngcamphalala, S., and Maboa, L. (2021). An assessment of climate-smart agriculture (csa) practices skills amongst extension practitioners in south africa. *South African Journal of Agricultural Extension (SAJAE)*, 49(2), 70-83. https://doi.org/10.17159/2413-3221/2021/v49n2a12802


## 9. Department of Environment, Forestry and Fisheries (DEFF) – National Climate Change Information System (NCCIS)

The NCCIS is a national web-based platform developed by DEFF to centralize climate change data, adaptation actions, and policy resources. It provides decision-support tools for planners and policymakers, enabling tracking of national climate responses and alignment with South Africa's climate commitments. The system enhances coordination, transparency, and evidence-based decision-making across sectors.

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# Recommendations and way FORWARD

To strengthen the adoption of CSA and ensure sustainable agricultural productivity among smallholder farmers in the Free State and beyond, it is essential to implement focused and continuous training programs for both farmers and extension officers. The increasing challenges posed by climate variability, soil degradation, and limited access to resources highlight the need for a structured and well-coordinated approach to knowledge transfer that is both practical and locally relevant.

This chapter presents a set of strategic recommendations and a way forward aimed at enhancing capacity development and the practical implementation of CSA crop-based farming or cropping systems. It emphasizes the importance of equipping smallholder farmers and extension personnel with the technical, financial, and adaptive skills necessary to strengthen resilience, improve productivity, and ensure long-term sustainability in the agricultural sector.

**Capacity building and knowledge transfer:** A coordinated and inclusive training framework is recommended to enhance both technical and adaptive capacity.

- Develop comprehensive, locally contextualized training modules covering climate adaptation, soil and water management, pest and disease control, and financial literacy.
- Expand the use of *Farmer Field Schools (FFS)*, *on-farm demonstration plots*, and *farmers' information days* as platforms for experiential learning and peer exchange.
- Conduct regular in-service training for extension personnel to keep them informed on new CSA technologies, digital tools, and climate forecasting applications.
- Training materials should be translated into local languages to ensure inclusivity and comprehension.

**Promoting localized cropping and farming systems:** Training should be tailored to the agroecological diversity within the province, aligning with the farming systems and resource capacities of each area.

- Design training packages that address the distinct climatic and soil characteristics of the Eastern Highveld, Central, and Southern regions.
- Encourage intercropping (e.g., cereal-legume systems), crop rotation, and cover cropping to enhance soil fertility, moisture retention, and pest control.
- Build capacity for sustainable vegetable and dryland crop production using CSA techniques such as mulching, composting, efficient irrigation, and shade netting.
- Promote mixed crop/livestock systems for nutrient recycling and diversified income streams.
- Soil and water are the foundation of agricultural productivity and resilience; thus, training should focus on practical, evidence-based methods to conserve and optimize these resources.
- Training in pest and disease management should be embedded within broader CSA and ecological farming approaches.
  - o Strengthen farmer capacity to recognize symptoms and signs of major pests and diseases through visual identification and field-based diagnostics.
  - o Promote the use of resistant cultivars and diversified cropping patterns to break pest and disease cycles.
  - o Train farmers on the use of registered biocontrol products and safe pesticide application following integrated pest management (IPM) principles.
  - o Develop community-based monitoring systems that use seasonal forecasts to anticipate outbreaks.

**Building financial literacy and access to CSA finance:** Without adequate financial capacity, the adoption of climate-smart practices remains limited. Training must therefore include financial management and resource mobilization components.

- Facilitate farmer access to government grants, credit facilities, and climate finance opportunities such as the *Green Climate Fund* and *Adaptation Fund*.
- Integrate enterprise budgeting, market analysis, and cooperative management into farmer training curricula.
- Encourage partnerships with agribusinesses, banks, and NGOs to co-fund farmer training initiatives and infrastructure development.

**Enhancing access to knowledge and digital tools:** Digital innovation and access to climate information are key enablers for resilience and timely decision-making.

- Build awareness of key platforms such as the *South African Weather Service (SAWS), Seasonal Climate Watch* and *DALRRD National Agro-Meteorological Committee (NAC) Advisories*.
- Promote the use of mobile phones for receiving weather forecasts, planning advice, and early warning alerts.
- Develop simple, farmer-friendly digital dashboards and applications for data recording, yield tracking, and decision support.

**Institutional collaboration and extension support:** Effective training depends on collaboration among institutions and consistent support from extension services.

- **Multi-Stakeholder Coordination:** Strengthen linkages between *DALRRD*, *DESTEA*, *ARC*, local universities, NGOs, and farmer cooperatives for integrated research and extension delivery.
- **Community-Based Extension Models:** Support the formation of *CSA Champions* and *Lead Farmer Networks* to facilitate farmer-to-farmer learning and mentorship.
- **Monitoring and Evaluation Framework:** Establish clear indicators to measure adoption rates, soil health improvement, yield gains, and resilience outcomes over time.

The pathway to climate-resilient and sustainable agriculture in the Free State lies in empowering smallholder farmers and extension officers through targeted, practical, and collaborative training. A robust training system that integrates science, local knowledge, and institutional support will accelerate the adoption of CSA practices, enhance productivity, and safeguard livelihoods in the face of climate uncertainty. By investing in people and partnerships, the agricultural sector can transition towards a more resilient and sustainable future.

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