CLIMATE CHANGE ADAPTATION FOR SMALLHOLDER FARMERS IN SOUTH AFRICA

VOLUME 1: AN IMPLEMENTATION AND DECISION SUPPORT GUIDE. SUMMARY REPORT

E Kruger, MC Dlamini, T Mathebula, P Ngcobo, BT Maimela & L Sisitka

WATER RESEARCH COMMISSION

TT 841/1/20

Climate Change Adaptation for Smallholder Farmers in South Africa

Volume 1: An implementation and decision support guide. Summary report

E Kruger, MC Dlamini, T Mathebula, P Ngcobo, BT Maimela & L Sisitka

Report to the
Water Research Commission
by
Mahlathini Development Foundation

WRC Report No. TT 841/1/20

February 2021

Obtainable from
Water Research Commission
Private Bag X03
Gezina, 0031

orders@wrc.org.za or download from www.wrc.org.za or www.mahlathini.org

The publication of this report emanates from a project entitled *Collaborative knowledge creation and mediation strategies for the dissemination of Water and Soil Conservation practices and Climate Smart Agriculture in smallholder farming systems.* (WRC Project No. K5/2719/4)

This report forms part of a series of 9 reports. The reports are:

Volume 1: Climate Change Adaptation for smallholder farmers in South Africa. An implementation and decision support guide. Summary report. (WRC Report No. TT 841/1/20)
Volume 2 Part 1: Community Climate Change Adaptation facilitation: A manual for facilitation of Climate Resilient Agriculture for smallholder farmers. (WRC Report No. TT 841/2/20)
Volume 2 Part 2: Climate Resilient Agriculture. An implementation and support guide: Intensive homestead food production practices. (WRC Report No. TT 841/3/20)
Volume 2 Part 3: Climate Resilient Agriculture. An implementation and support guide: Local, group-based access to water for household food production. (WRC Report No. TT 841/4/20)
Volume 2 Part 4: Climate Resilient Agriculture. An implementation and support guide: Field cropping and livestock integration practices. (WRC Report No. TT 841/5/20)
Volume 2 Part 5: Climate Resilient Agriculture learning materials for smallholder farmers in English. (WRC Report No. TT 841/6/20)
Volume 2 Part 6: Climate Resilient Agriculture learning materials for smallholder farmers in isiXhosa. (WRC Report No. TT 841/7/20)
Volume 2 Part 7: Climate Resilient Agriculture learning materials for smallholder farmers in isiZulu. (WRC Report No. TT 841/8/20)
Volume 2 Part 8: Climate Resilient Agriculture learning materials for smallholder farmers in Sepedi. (WRC Report No. TT 841/9/20)

ISBN 978-0-6392-0227-3

Printed in the Republic of South Africa

EXECUTIVE SUMMARY

Climate change (CC) is the biggest threat of our time, with far-reaching consequences and devastating impacts on people, the environment and the economy. The adverse effects of climate change are already being felt. Besides mitigation, there is a growing need to adapt. South Africa is especially vulnerable to CC impacts, particularly in respect of water and food security, as well as impacts on health, human settlements, infrastructure and ecosystem services. A rapid adaptation response is necessary.

It is predicted that changes in climate will exacerbate these challenges, affecting food security and health, threatening water resources, and impacting on development. These impacts will be especially felt by the poor, as they will be more exposed to them and have fewer resources and financial recovery instruments to cope. Climate change is therefore predicted to result in further widening of the gap between the rich and poor (Ziervogel et al., 2014).

Adaptation to climate change presents South Africa with an opportunity to transform the economy, strengthen the social and spatial fabric, and become more competitive in the global marketplace (https://www.environment.gov.za/sites/default/files/legislations/session2_draftnational_adaptationstrategy.pdf).

Despite national programmes, directives and commitments, local authorities, communities and smallholder farmers remain largely unaware and uninformed about CC, adaptive strategies and potential actions. They have received little to no direct support through government-led initiatives and there is a distinct lack of coherent programming and activities to support rural dwellers to improve their livelihoods and resilience to CC. Implementation that is taking place, primarily under the auspices of civil society organisations (CSOs), is somewhat disparate and project-based, with a still limited understanding of the potential impact of these projects on CC resilience. There is a strong need for a coherent and more integrated approach which will incorporate the voiceless poor in participation processes and access to information and decision-making in transparent, equitable and non-discriminatory ways which will provide for their involvement in each step of the project cycle (from identification, formulation, implementation and monitoring to evaluation) (NDRC, 2020).

Agriculture remains vital to the economy in South Africa and agricultural development has significant implications for food security and poverty reduction. Although improvement of food security and improved nutrition as well as the promotion of sustainable agriculture and sustainable water management strategies are national policy priorities, strategies and implementation processes for the millions of impoverished rural dwellers are sorely lacking. Attempts to increase agricultural productivity for the smallholder sector have mainly focussed on commercialisation strategies and conventional farming practices, with very little change in production techniques and limited improvement in yields (Rusere et al., 2019).

Land tenure insecurity for millions of smallholder farmers (including women), declining soil fertility, severely restricted access to water, degraded ecosystems, poor market access, inadequate funding and inadequate infrastructure development continue to hinder agricultural development for smallholder farmers. These challenges are expected to be further exacerbated by climate change and developing adaptation mechanisms is a high priority (NDRC, 2020).

Economic development and agricultural expansion are often achieved at the expense of environmentally sustainable practices. Ecosystem functions, including biodiversity and water services, are key to increasing resource efficiency and productivity and ensuring resilience. Ecosystem-Based Adaptation (EBA)-driven agriculture linked to viable supply- and demand-side value chains has an important role to play in developing an agricultural sector that is well integrated into the broader landscape, is climate resilient and environmentally and socially sustainable (DEA and SANBI, 2016).

Climate Smart Agriculture (CSA) promotes increases in productivity and adaptation to climate change that encompass socially and environmentally responsible agriculture. Numerous approaches, technologies and practices to support CSA are already available. CSA includes both traditional and innovative agricultural practices and technologies that promote agricultural productivity and generate income, while boosting resilience to climate change (FAO, 2013).

The ideal combination of CSA actions varies from location to location. For this reason, site-specific assessments are critical aspects of CSA implementation, identifying the most suitable actions for each agroecological and socioeconomic context. Several decision support systems and tools have been developed, mainly by international and national research-based organisations for this purpose, but similar systems and knowledge-mediation processes appropriate to our smallholder context are, however, still lacking (UNFCCC, 1999). These decision support systems and prioritisation frameworks must characterise CSA practices, prioritise locally appropriate actions, assess costs and benefits, link national and local planning mechanisms and most importantly, must be built on community-based criteria, indicators and priorities (Care International, 2009).

Concrete actions must be taken to enhance the evidence base to underpin strategic choices, promote and facilitate wider adoption of appropriate technologies by smallholder farmers and develop institutional arrangements to support, apply and scale out CSA in the smallholder farming systems. Actions are required from a broad range of stakeholders from government and the public sector, private sector, academia and research and civil society organisations, among others.

This CSA decision support platform aims to improve regional and local planning by providing a coherent process for directing climate change and agriculture adaptation investments and programmes. With transparency and participation at the heart of this process, local knowledge and scientific evidence can work together to establish realistic pathways for increasing CSA adoption. Sustainable soil, water and natural resource-use options and practices effect increased productivity, food security and wellbeing for a range of smallholder farmers – from subsistence through to semi-commercial.

Defined research objectives were:

1. To evaluate and identify best practice options for CSA and Soil and Water Conservation (SWC) in smallholder farming systems in two bioclimatic regions in South Africa.
2. To amplify collaborative knowledge creation of CSA practices with smallholder farmers in South Africa.
3. To test and adapt existing CSA decision support systems (DSS) for the South African smallholder context.
4. To evaluate the impact of CSA interventions identified through the DSS by piloting interventions in smallholder farmer systems, considering water productivity, social acceptability and farm-scale resilience.
5. To test visual and proxy indicators appropriate for an incentive-based financing model at community level for local assessment of progress and tested against field and laboratory analysis of soil physical and chemical properties and water productivity.

The design of the decision support system (DSS) was regarded as an ongoing process divided into three distinct parts:

- **Practices:** Collation, review, testing, and finalisation of those Climate Resilient Agriculture (CRA) practices to be included. This allows for new ideas and local practices to be included over time. This also includes linkages and reference to external sources of technical information around climate change, soils, water management, etc. and how this will be done, as well as modelling of the DSS.
- **Process:** Through which climate smart/resilient agricultural practices are implemented at smallholder farmer level. This also includes the facilitation component, communities of practice (CoPs), communication strategies and capacity building.
- **Monitoring and evaluation:** Local and visual assessment protocols for assessing implementation and impact of practices as well as processes used. This also includes site selection and quantitative measurements undertaken to support the visual assessment protocols and development of visual and proxy indicators for future use in incentive-based support schemes for smallholder farmers.

Outputs of the development phase of this research process include the smallholder decision support platform, a series of facilitation and implementation manuals, stakeholder platforms for continued support (post-project) and lessons learned from the pilot implementation processes. Each subsequent use of the platform will produce investment portfolios and linked outputs for scaling out CRA, which will both create real action on the ground and provide feedback for improving the platform and establishing further best practice options.

Innovations for this four-year research process included the development of the CCA smallholder decision support processes for individuals (an online platform – www.mahlathini.org/dss/) and groups (a community-based facilitated process), community-level experimentation with 18 prioritised Climate Resilient Agriculture (CRA) practices in three different agroecological zones for improved soil and water management and productivity and a methodology for assessment of the impact of the implementation of these practices on community-level climate resilience. Both qualitative and quantitative indicators were developed for this purpose. Innovation in CRA included the introduction of several new practices into the smallholder farming system, including, for example, small-dam construction, spring protection using slotted pipes for seepage collection, shade cloth tunnels and bucket drip kits, cover crops and livestock integration into Conservation Agriculture (CA) and organic mango production. Social innovation included building social agency through learning groups organised to focus on environmental and water management, sharing of learning and practices, value chain development and microfinance options for the rural poor.

Capacity building at community level was intensive, with CRA implementation processes facilitated across three provinces – Limpopo (Mametja and Sekororo), KZN (Bergville, Midlands and southern KZN) and the Eastern Cape (King Williams Town), across 19 villages, with 250 participants. All participated in the innovation development process that included an improved understanding of CC, an analysis of CC impacts, exploration of CCA strategies, prioritisation of adaptive strategies, development of adaptation plans, experimentation with CRA practices, review of the impact of the practices on CC resilience and planning for expanded implementation. Capacity building at an institutional level took several forms: learning and mentoring for facilitators in six CSOs, knowledge sharing in learning networks (the Adaptation network, the Agroecology network and the Imvotho Bubomi learning network), information sharing in conferences, seminars and policy development structures and assistance in programmatic planning for organisations related specifically to indicator development and climate resilience. Capacity development for postgraduates included the completion of one BSc Honours degree (University of KwaZulu-Natal – Rural Resource Management) and two MSc degrees (Fort Hare University – Agricultural Economics, University of Pretoria – Soil Science), as well as the initiation of an MPhil (University of Western Cape – PLAAS).

This report is structured around the outcomes and outputs of the research process, touching only briefly on methods and results, as these were covered in detail in the 11 deliverable reports for this process. The overall report is divided into five sections:

1. Research methodology, which includes a research process outline and summary and a loose-standing CCA facilitation manual, inclusive of the DSS and the resilience impact assessments.

2. Climate change adaptation for smallholder farmers in South Africa, which includes an introduction and three loose-standing implementation reports:
    a. Climate Resilient Agriculture. An implementation and support guide: Intensive homestead food production practices.
    b. Climate Resilient Agriculture. An implementation and support guide: Local, group-based access to water for household food production.
    c. Climate Resilient Agriculture. An implementation and support guide: Field cropping and livestock integration practices.
3. Climate Resilient Agriculture learning materials for smallholder farmers, which includes a brief introduction and four loose-standing learning manuals in four languages (English, Sepedi, IsiZulu, isiXhosa):
    a. Soil management.
    b. Water management.
    c. Crop management.
    d. Livestock integration.
4. Summary of Learning and Recommendations.
5. Appendices: Capacity building, networking, conferences and publications.

ACKNOWLEDGEMENTS

The following individuals and organisations deserve acknowledgement for their invaluable contributions and support to this project:

Chris Stimie (Rural Integrated Engineering – RIEng)
Dr Brigid Letty and Jon McCosh (Institute of Natural Resources – INR)
Nqe Dlamini (StratAct)
Catherine van den Hoof (Researcher)
Dr Sharon Pollard, Ancois de Villiers, Bigboy Mkabela and Derick du Toit (Association for Water and Rural Development)
Hendrik Smith (GrainSA)
Marna de Lange (Socio-Technical Interfacing)
Matthew Evans (Web developer)
Khethiwe Mthethwa, Samukhelisiwe Mkhize, Sylvester Selala, Palesa Motaung and Sanelise Tafa (MDF interns and students)
Timothy Houghton and Desiree Manicom (MDF board members)

PROJECT FUNDED BY

WATER RESEARCH COMMISSION

The Maize Trust

USAID FROM THE AMERICAN PEOPLE

REFERENCE GROUP MEMBERS

Prof S Mpandeli	Water Research Commission
Dr S Hlophe-Ginindza	Water Research Commission
Dr L Nhamo	Water Research Commission
Dr O Crespo	University of Cape Town
Dr A Manson	KZN Department of Agriculture and Rural Development
Prof S Walker	Agricultural Research Council
Prof CJ Rautenbach	Previously of WeatherSA

COLLABORATING ORGANISATIONS

Institute of Natural Resources
https://inr.org.za

award
https://award.org.za

amanzi FOR FOOD
https://amanziforfood.co.za

SOCIO-TECHNICAL INTERFACING
https://foodtunnel.co.za

RIEng
http://www.rieng.co.za

TABLE OF CONTENTS

1 RESEARCH PROCESS AND METHODOLOGY

1.1 RESEARCH SUMMARY

The initial title of the research process, *Collaborative knowledge creation and mediation strategies for the dissemination of Water and Soil Conservation practices and Climate Smart Agriculture in smallholder farming systems* slowly morphed from this unwieldy wording to become *Climate Change Adaptation for Smallholder farmers in South Africa: An implementation and decision support guide*, as grappling with the concepts and processes provided a clearer direction over time. In addition, CSA was replaced by CRA as the latter definition more clearly represents the content and intent of the work done.

Climate Resilient Agriculture can be defined as “agriculture that reduces poverty and hunger in the face of climate change, improving the resources it depends on for future generations” (Christian Aid, 2018). Climate Resilient Agriculture aims to transform the current systems and has a wider perspective than increased production only. It supports food production systems at local, regional and global levels that are socially, economically and environmentally sustainable. Climate Smart Agriculture is defined as “an approach that guides actions needed to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate” (Christian Aid, 2018). It aims to tackle three main objectives: sustainably increasing agricultural productivity and incomes, adapting and building resilience to climate change, and reducing and/or removing greenhouse gas emissions, where possible (FAO, 2020). Main criticisms regarding the concept of Climate Smart Agriculture are that it also includes large-scale, high external input food production without properly accounting for social and environmental aspects, such as inclusion of small-scale producers and an ecosystem management focus (IFAD, 2016).

The research consisted of four parallel processes: the exploration of CRA **practices** appropriate for localised smallholder farming systems, the development of an individual and group-based **DSS**, the design and development of **community-based facilitation and implementation** processes for CCA and the development of qualitative and quantitative **indicators** to assess the impact of practices on resilience to CC.

Forty-four practices were included in the final decision support system. These were based on:

- Practices tried out, adapted and assessed for impact during this research process, and
- Practices not tried out but selected by smallholder farmer participants as prioritised options within their farming systems.

Several practices that were included in the initial database were removed, not because they did not have value in building Climate Resilient Agriculture systems, but because they required high levels of skill and resources or were not considered appropriate by smallholder farmer participants. Some examples include pitting (high mechanisation requirement), bioturbation (too generic as a “practice” and included in other practices), push-pull technology (resource requirements), gabions (high skill and resource requirements) and woodlots and hedgerows (not chosen by participant smallholders).

A few practices were included during the process due to specific interest from participating smallholders. These included, for example, water access (spring protection and water reticulation for household gardening irrigation), livestock fodder production and supplementation, organic mango production and small dams.

A document with one-page summaries of each practice is available on the web platform https://www.mahlathini.org/dss/resources/wrc-cca-practices/.

The final input parameters for the online decision support system (DSS) are summarised in Table one and two below. The original excel database is available on the web platform (https://dss.mahlathini.org/assets/dss-input.xlsx). Criteria used in the DSS and described in detail in the Facilitation Manual (https://www.mahlathini.org/dss/resources/wrc-cca-facilitation-manual/) are: proxies for the physical environment, farming system, farmer typology, resources and management strategies and facilitator scores. Each parameter was coded as 1, if relevant to a particular practise, or 0 if not, to make subsequent additions and changes easy to manage. Basically, each practice was compared with each of the above-mentioned criteria/ parameters and then scored (adding the number of 1s together), to provide a prioritised listing in the DSS according to the criteria chosen by the particular individual.

The proxies for the physical environment are open-source external databases linked to this excel sheet to geographically identify the individual's agroecological zone (AEZ), soil texture, soil organic carbon (SOC) and slope.

The Agroecological zone dataset used is: HarvestChoice; International Food Policy Research Institute (IFPRI), 2015, "Agro-Ecological Zones for Africa South of the Sahara", https://doi.org/10.7910/DVN/M7XIUB/ , Harvard Dataverse, V3.

South Africa covers 12 different AEZs. The sites currently covered in this study are located in three of these 12 AEZs: Tropics semi-arid – warm, sub-tropics semi-arid – warm, and subtropics sub-humid – cool. Semi-arid regions in South Africa are characterised by mean annual precipitation between 200 mm and 400 mm, and the sub-humid regions by mean precipitation between 400 mm and 1 100 mm.

The geographical distribution of these AEZ was delineated based on the average climate between 1961 and 1990, using the data from the Climate Research Unit (CRU) at the University of East Anglia and the data from VASClimO (Variability Analysis of Surface Climate Observations), a joint climate research project of the German Weather Service (Global Precipitation Climatology Centre – GPCC) and the Johann Wolfgang Goethe University in Frankfurt (Institute for Atmosphere and Environment – Working Group for Climatology). The data can be accessed from the http://gaez.fao.org/ website. Slope gradient data at around 1 km resolution have also been made available on this website.

The four soil texture classes were defined based on the clay silt and sand fraction taken from the AfSoilGrids 250 m soil database (https://www.isric.online/projects/soil-property-maps-africa-250-m-resolution/) and further regrouped as follows:

- Sandy soils: sand, loamy sand.
- Silty soils: silt.
- Clayey soils: clay, sandy clay and silty clay.
- Loamy soils: silty clay loam, clay loam, loam, silty loam, sandy clay loam, sandy loam.

This dataset also provides values for the soil organic carbon.

For the farming system category, the individual chose one or more of the categories of field cropping, vegetable gardening, livestock and trees and other natural resources.

The farmer typology was based on an individual's responses related to several socio-economic criteria: gender, dependency ratio, level of education, access to water and electricity, employment status, total income, market access, farming purpose and farm size and depending on the answers, placed the individual in typology A, B or C. See Table 1.

In addition, each CRA practice was given a resource management rating based on four resources, namely: water – in particular, quantity (1); soil – in particular, fertility (2); crops (3); and livestock (4) – in particular efficiency and resistance for both. Efficiency refers to the conversion of water, nutrients or land into the required output, such as biomass per unit area of land cultivation or seed generation of the plant itself. Resistance relates to crops or livestock that are, for example, better adapted to drought or heat conditions or better protected against diseases, etc.

The final step in the prioritisation process was the provision of an expert score for how well each practice could fulfil the management criteria chosen. This expert score was developed by the research team. See Table 2.

Table 1: Categories and rating for the individual DSS

			Criteria for confining the selected practices based on farmer's typology, physical environment and farming system (if practice not constrained = 1), based on Table 5 of report																			
			Proxies for physical environment													Farming system				Typology		
			AEZ			Soil texture				Soil OC			Slope									
Practice	**Images (PPT-CA practices)**	**Description**	**Tropics semi-arid warm**	**Subtropics semi-arid warm**	**Subtropics sub-humid cool**	**Sandy soils**	**Loamy soils**	**Clayey soils**	**Silty soils**	**<0.5%**	**0.5-2%**	**>2%**	**<5%**	**5-15%**	**>15%**	**Field cropping**	**Vegetable gardening**	**Livestock**	**Tree and other nat. resources**	**A**	**B**	**C**
Drip irrigation	None	Also called trickle or micro irrigation, applying water slowly and directly to the roots of plants through small plastic pipes and flow control devices. Emitters are integral to the functioning where turbulent flow prevents clogging to a large degree.	1	1	1		1	1	1	1	1	1	1			1	1				1	1
Bucket drip kits	Bucket drip kits	20 L bucket drip system for a 1 m x 5 m bed, with two dripper lines.	1	1	1		1	1	1	1	1	1	1				1			1	1	
Furrows and ridges/furrow irrigation	Furrows and ridges	Furrow irrigation is a method of applying water at a specific rate of flow into shallow, evenly spaced, u-shaped channels from the top end of the furrow. Flow occurs because of gravity and the amount of water applied is dependent on soil type, gradient, flow rate, evenness and the number of previous applications.	1	1	1			1	1	1	1	1	1			1	1			1	1	1
Greywater management	Greywater management	Irrigation practices involving greywater, including pre-treatment with ash or using sand filters. Specific bed designs for greywater include tower gardens and keyhole beds.	1	1	1	1	1	1	1	1	1	1	1	1	1		1			1	1	
Shade cloth tunnels	Shade cloth tunnels	Shade cloth structures (40% grey) assist in managing water through reduced evaporation, temperature and pest incidence.	1	1	1	1	1	1	1	1	1	1	1	1			1			1	1	
Mulching	mulching	Soil cover refers to vegetation, including crops and crop residues on the surface of the soil, ideally covering the projected surface area of crop roots.	1	1	1	1	1	1	1	1	1	1	1	1			1			1	1	1
Diversion ditches	Diversion ditches	Channel or furrow made across the main slope with its ridge on the downhill side. Part of infield RWH.	1	1	1		1	1	1	1	1	1	1	1		1	1		1	1	1	1

Grass waterways	Grass waterways	Shaped or graded channels with suitable vegetation, designed to intermittently carry surface water runoff at non-erosive velocities to stable outlets. Part of infield RWH.	1	1	1	1	1	1	1	1	1	1	1	1		1						1
Infiltration pits/banana circles	Infiltration pits	0.7-1.5 m deep pits/basins dug in water flow lines to control water movement and filled with organic matter for improved soil fertility. Various planting regimes including bananas.	1	1	1	1	1	1	1	1	1	1	1	1			1			1	1	
Zai pits	Zai pits	Hand-dug 0.6 m diameter and 0.3 m deep circular holes that collect and store water for crop use.	1	1	1		1	1	1	1	1	1	1	1		1	1			1	1	1
Rainwater harvesting storage	Rainwater harvesting storage, 1	The collection of runoff from rain, roof and other surfaces for productive use in and outside the field. Both infield and storage options are available.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Tied ridges	Tied ridges	Increases the water availability by collecting rainfall from an unplanted sloping basin and catching it with a furrow and ridge. Planting takes place on either side of the furrow where the water has infiltrated.	1	1	1		1	1	1	1	1	1	1			1	1			1	1	1
Halfmoon basins	Halfmoon basins	These are small, semi-circular earth bunds for catching water flowing down a slope.	1	1	1		1	1	1	1	1	1		1	1	1			1	1	1	1
Small dams	Small dams	2-5 m-deep pond constructed to catch water during the rainy season with a clay core, a wall (for larger earth dams) and a spillway to release excess water.	1	1	1		1			1	1	1	1				1			1	1	
Contours; layout and planting	Contours 1, contours 2	Ploughing and or planting along the contours of the land to minimise soil erosion. Can use line levels, A-frames, dumpy levels, etc. to mark contours.	1	1	1		1	1	1	1	1	1		1		1	1			1	1	1
Organic mango production	Organic mango production	Practices for management of mango trees and orchards in an organic system.	1	1		1	1	1	1	1	1		1	1		1	1		1	1	1	1
Fruit production	Fruit production	Propagation and growth of a range of fruit types for production throughout the year, using agroecological and organic methods.	1	1		1	1	1	1	1	1	1	1	1		1	1		1	1	1	1
Stone bunds	Stone bunds	Used along contour lines to slow down, filter and spread out runoff water, thus increasing infiltration and reducing soil erosion.	1	1	1		1	1	1	1	1	1		1		1	1		1	1	1	1
Check dams	Check dams	These are small dams constructed across a drainage ditch, or waterway to counteract erosion by reducing water flow velocity and allowing sedimentation of silt.	1	1	1		1	1	1	1	1	1		1	1	1	1		1	1	1	1
Cut-off drains/swales	Cut off drains	Swales are ditches and bunds constructed on contour to manage water flow and sedimentation. Mulching and planting occur in both the ditch and on the bunds.	1	1	1		1	1		1	1	1		1	1	1	1			1	1	1
Terraces	Terraces	A terrace is a level strip of soil built along the contour of a slope and supported by an earth or stone bund, or rows of old tyres, for example.	1	1	1	1	1	1	1	1	1	1			1	1	1			1	1	1

Strip cropping	Strip cropping	Strip cropping is a strategy for subdividing single fields on slopes into strips that follow contours. Where different crops are planted, a mixture of annual and perennial crops is usually used.	1	1	1	1	1	1	1	1	1	1	1	1		1				1	1	1
Water Access	Water access	Securing and developing local water sources for household-level water use and irrigation.	1	1	1	1	1	1	1	1	1	1	1	1			1	1		1	1	1
Targeted application of small quantities of fertilizer, lime, etc.	Targeted application fertilizer, lime	Use of site-specific fertilizer recommendation and more efficient use of fertilizer (using the right source, at right time, at right place and applying the right rate), liming to manage soil acidity (surface liming and incorporation).		1	1		1	1	1	1	1	1	1	1		1					1	1
Liquid manures	Liquid manure	Brews are made of animal and plant matter as liquid supplements to soil fertility.	1	1	1	1	1	1	1	1	1	1	1	1	1		1			1	1	
Agri-silvopastoral practices	Agri silvopastoral practices	Combining crops, pastures and trees to maximise soil improvement and productivity benefits.	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1
Conservation Agriculture	Conservation agriculture	Three main principles of minimal soil disturbance (no ploughing), soil cover (stover, mulching and cropping patterns) and diversity (inter-cropping, relay cropping and cover crops) upheld in the field cropping system.			1		1	1	1		1	1	1	1		1	1	1	1	1	1	1
Planting legumes, manure, green manures	Planting legumes	Use of legumes, manures (improved) and green manures in specific combinations to improve soil fertility and soil health.			1		1	1	1		1	1	1	1	1	1	1		1	1	1	1
Mixed cropping	Mixed cropping	Managing soil health and pest and disease incidence through crop combinations: mixed cropping, inter-cropping, crop rotation.			1		1	1	1	1	1	1	1	1	1	1	1			1	1	1
Herbs and multifunctional plants	Planting herbs	Managing soil health and pest and disease incidence through crop combinations: using herbs and multifunctional plants – including windbreaks, trap cropping, pest deterrents, bee fodder, etc.			1		1	1	1	1	1	1	1	1	1	1	1			1	1	1
Agroforestry	Agroforestry options	Land use management system in which trees or shrubs are grown around or among crops or pastureland.			1	1	1	1	1		1	1	1	1		1	1	1	1		1	1
Trench beds/shallow trenches/eco circles	Trenches and shallow trenches, eco-circles,	Intensive beds dug out and filled with a range of organic matter (dry/wet manure, bones, ash, etc.) to provide for highly fertile beds with high water holding capacity – e.g. trench beds, shallow trenches, eco-circles.	1	1	1	1	1	1	1	1	1	1	1	1			1			1	1	1
Improved organic matter	Improved organic matter	Improving organic matter content of soils for increased productivity for vegetables, fruit and field crops.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1
Nurseries and propagation	Nurseries and propagation	Propagation by seed, cuttings and grafting of a range of vegetable, herb and fruit crops, for increased diversity and continuity.	1	1	1	1	1	1	1		1	1	1				1		1	1	1	1

Natural pest and disease control	Natural pest and disease control,1	This is an ecologically based approach to managing pests and diseases including chemical, biological and other regulatory means.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1
Integrated weed management	Integrated weed management	The use of a combination of weed control practices, thus reducing dependency on any one type of control. This includes practices such as close spacing, late season weeding, soil health management (structure and porosity), composting, etc.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1
Improved crop varieties	Improved varieties	Improved varieties can be more productive, grow in drier years and potentially make better use of nutrients (early maturing, drought tolerant, improved nutrients).	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Seed saving/ production/storing	Seeds, seeds1, seeds 2	The practice of saving seeds or other reproductive material (e.g. tubers) from vegetables, grain, herbs and flowers for use from year to year for annuals.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1
Crop rotation	Crop rotation	A series of different crops planted in the same field following a defined order to improve soil health and to prevent the build-up of soil-related diseases.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1
Stall feeding and haymaking	Stall feeding	Feeding animals in stalls to reduce energy requirements of seeking out grazing; links to agroforestry systems, fallows and improved pastures.	1	1	1	1	1	1	1	1	1	1	1	1	1			1			1	1
Creep feeding and supplementation	Creep feeding	In cases where young livestock do not have adequate access to fodder or are “bullied” by older animals, enclosures that are only accessible to younger animals (i.e. small entrances) can be built. High quality fodder is placed in the enclosure that younger animals can feed on.	1	1	1	1	1	1	1	1	1	1	1	1	1			1			1	1
Rotational grazing	Rotational grazing	A system of resting veld to ensure grazing quality for livestock.	1	1	1	1	1	1	1	1	1	1	1	1	1			1			1	1
Tower gardens	Tower gardens	Above-ground beds, built with netting and poles consisting of soil enriched with compost and ash with a central filtration column for addition of greywater.	1	1	1	1	1	1	1	1	1	1	1	1			1			1	1	
Keyhole beds	Keyhole beds	Above-ground beds, built with stones consisting of soil enriched with compost and ash with a central filtration column for addition of greywater.	1	1	1	1	1	1	1	1	1	1	1	1			1			1	1	

Table 2: Further criteria for rating in the DSS – resources to manage and the facilitator/expert scores

	Criteria for selecting practices based on the resources to manage and related strategies (=1)																	
	Resources and management strategies													**Score by expert / facilitator**				
	Water (quantity)			**Soil (fertility)**		**Crop resistance and efficiency**				**Livestock resistance and efficiency**				**Resources (Score 0-3; level of importance of the resource in the practise)**				
Practice	**Harvesting**	**Retention**	**Use efficiency**	**Conservation**	**Improvement**	**Water**	**Heat**	**Nutrient**	**Disease**	**Water**	**Heat**	**Nutrient**	**Disease**	**Water**	**Soil**	**Crop**	**Livestock**	**CSA**
Drip irrigation			1			1								3	0	2	0	0
Bucket drip kits			1			1								3	0	2	0	1
Furrows and ridges/furrow irrigation			1	1		1								3	2	2	0	0
Greywater management			1			1								3	0	2	0	0
Shade cloth tunnels		1	1			1	1		1		1		1	3	1	2	1	1
Mulching		1		1	1	1	1	1						2	2	3	1	1
Diversion ditches	1			1										3	2	2	1	1
Grass waterways	1			1										3	2	2	1	1
Infiltration pits/banana circles	1	1		1	1		1							3	2	3	1	1
Zai pits	1	1		1	1		1							3	2	3	1	1
Rainwater harvesting storage	1													3	2	2	1	1
Tied ridges	1	1		1		1								3	2	2	1	1
Halfmoon basins	1	1		1		1								3	2	2	1	1
Small dams	1													3	2	2	1	1
Contours, layout and planting	1			1		1								2	3	2	1	1
Organic mango production		1	1		1	1	1	1	1					2	2	3	0	2
Fruit production		1	1		1	1	1	1	1					2	2	3	0	2
Stone bunds	1			1										2	3	2	1	1
Check dams	1			1										2	3	2	1	1
Cut off drains/swales	1			1										2	3	3	1	1
Terraces	1			1										2	3	2	1	1
Strip cropping	1			1										2	3	3	2	1
Water access			1			1				1				3	0	2	1	2
Targeted application of small quantities of fertilizer, lime, etc.					1			1						2	1	3	1	1

Liquid manures					1	1		1	1					1	1	3	1	1
Agri-silvopastoral practices			1	1	1	1	1	1				1		1	3	2	2	2
Conservation agriculture		1	1	1	1	1	1	1	1			1		2	2	3	2	2
Planting legumes, manure, green manures					1			1	1					1	2	3	1	1
Mixed cropping				1	1			1	1					1	2	3	2	1
Herbs and multifunctional plants				1	1			1	1					1	2	3	2	1
Agroforestry		1		1	1	1	1	1	1		1	1		2	2	3	3	1
Trench beds/shallow trenches/eco circles		1			1	1	1	1	1					2	2	3	1	1
Improved organic matter		1	1	1	1	1	1	1	1			1		2	3	3	1	3
Nurseries and propagation					1	1	1	1	1					0	2	3	1	2
Natural pest and disease control									1					1	1	3	1	1
Integrated weed management						1		1						1	1	3	1	1
Improved crop varieties (early maturing, drought tolerant, improved nutrients)						1	1	1	1	1	1	1	1	1	1	3	1	1
Seed saving/production/storing						1	1	1	1					1	1	2	1	1
Crop rotation			1		1	1		1	1					1	2	3	2	1
Stall feeding and haymaking										1		1		1	1	1	3	1
Creep feeding and supplementation												1	1	1	1	1	3	1
Rotational grazing				1	1							1	1	1	1	1	3	3
Tower gardens			1		1	1		1	1					3	2	3	1	1
Keyhole beds			1		1	1		1	1					3	2	3	1	1

The development of the community-based facilitation and implementation process was based on the methodological underpinnings of socio-ecological systems and innovation system development and are defined and discussed in the Facilitation Manual (https://www.mahlathini.org/dss/resources/wrc-cca-facilitation-manual/).

To engage in exploring the change in farming systems happening due to climate change and thinking into the kinds of changes required to consciously adapt to these changes requires both the process of learning (including new ideas and information into the mix) and the process of doing (how to implement and farm differently). Contemporary theories of learning and change (Lotz-Sisitka and Pesanayi, 2019) indicate that for knowledge or information to become meaningful 1) the information needs to be related to the situation and experience of the user, 2) the information must be mediated in context, and 3) new knowledge or information must expand existing knowledge and/or practice.

In this research process these ideas were embedded in communities of practice (CoPs). Actions for the CoP were based on the premises of inquiry, design, activities, communication, interaction, learning, knowledge sharing, collaboration, roles and social structures, and piloting and roll out of the processes. Examples of CoPs are learning groups, innovation platforms, forums, networks, and research and implementation teams.

Innovation systems development is an approach to learning and innovation that is used in international development as part of projects and programmes relating to sustainable agriculture. The approach involves collaboration between researchers and farmers in the analysis of agricultural problems and testing of alternative farming practices. It is a process in which farmers and other stakeholders engage in joint exploration and experimentation leading to new technologies or socio-institutional arrangements for more sustainable livelihoods.

The CoP process started with an introductory workshop with each of the learning groups, to discuss climate change, impacts on their livelihoods and farming and potential adaptive measures. These workshops also provided a space to introduce concepts and potential practices and discuss inclusion of these into their present farming systems, followed by practical demonstrations and setting up the farmer-level experimentation trial plots. Detailed outlines of the workshop agendas and processes are provided in the Facilitation Manual (https://www.mahlathini.org/dss/resources/wrc-cca-facilitation-manual/). This was essentially a group-based decision support process and all the aspects and criteria involved in the individual DSS were covered during the CCA facilitation process.

Several farmers in each learning group (CoP) volunteered to undertake on-farm experimentation, which created an environment where the whole group learned throughout the season through observations and reflections on the implementation and results of the chosen trials. Farmers compared various treatments with their standard practices, which were planted as control plots.

The group assessed and reviewed the Climate Resilient Agriculture (CRA) practices each season and based on their observations and learning, made decisions regarding the following season's implementation and experimentation. In this way, the farming system was continually improved and adapted. These learning groups/CoPs also undertook other joint or collaborative activities important to them such as exploring options for improved access to water, local marketing options and the like.

Farmer-level experimentation and demonstration of practices were undertaken for three consecutive seasons within this research process. Sites were chosen to be representative of different agroecological conditions within South Africa.

Table 3 summarises the sites, number of participants and farmer-level experimentation undertaken with each village learning group, over a period of three years.

Table 3: Summary of farmer experimentation sites for this study

		Number of participants			Climate Resilient Agriculture practices tried*										
					Water			Soil		Crop/ tree resilience				Livestock resilience	
Area	**Village**	2017/18	2018/19	2019/20	Harvesting	Retention	Use efficiency	Conservation	Improvement	Crop diversification	Mixed cropping	Drought and heat tolarant crops	Integrated weed and pest management	Fodder and supplementation	Livestock integration
Mametja, Limpopo	Sedawa, Turkey, Willows, Botshabelo, Santeng	108	78	65	x	x	x	x	x	x	x	x	x		x
Bergville, KwaZulu-Natal	Ezibomvini, Stulwane, Eqeleni, Mhlwazini,	65	68	50		x	x	x	x	x	x	x	x	x	
Southern KwaZulu-Natal	Madzikane, Ofafa, Spring Valley	32	25	22		x	x	x	x	x	x	x	x	x	
Midlands, KwaZulu-Natal	Gobizembe, Mayizekanye, Ozwathini	27	28	41		x	x	x	x	x	x	x	x	x	
Eastern Cape	Xumbu, Berlin, Qhuzini, Dimbaza	18	15	45			x		x		x		x		

* This is a simplified categorisation of pratices, as most contribute to several objectives

Detailed implementation reports on the outcomes of the experimentation and learning processes for intensive homestead food production, field cropping and livestock integration and water access were produced (https://www.mahlathini.org/dss/reports/).

The development of qualitative and quantitative indicators was undertaken on several levels:

- For assessment of community-based and individual vulnerability and resilience to CC.
- For assessment of the impact of specific CRA practices on the sustainability/resilience of the farming system.
- For specific measurement of changes in biophysical and agricultural conditions and outputs such as crop growth, yields, runoff, water productivity, soil health, soil organic carbon, etc.

Indicators linked to outputs and impact of CRA practices are included in the specific implementation reports (https://mahlathini.org/dss/reports/wrc-cca-final-report-cra-implementation-intensive-homestead-food-production/

A specific monitoring framework to assess impact of the CRA practices on livelihoods and vulnerability was required to assess increased resilience. This framework worked alongside the entire monitoring and evaluation process and included activity, output and outcome indicators.

For this process, the Participatory Impact Assessment (PIA) framework was used to outline the indicators used at community level and provide for a qualitative assessment of increased resilience by community members. Impact indicators measure changes that occur in people's lives and can be qualitative or quantitative. These indicators look at the result of project activities on people's lives. Ideally, they measure the fundamental assets, resources and feelings of people affected by the project.

As impact measures change, there needs to be a starting point, or baseline from which the changes can be assessed. There are different types of indicators in a socio-ecological system, but all need to be measurable in some way.

Table 4 provides an example of a set of indicators which was designed for this research process, which shows the linkage between the vulnerability and impact indicators.

Table 4: Comparison of socio-ecological indicators used for vulnerability and resilience assessments

VULNERABILITY	RESILIENCE
Socio-economic indicators	
Economic: income (types, amounts), savings (types, amounts), markets (formal/informal)	Economic: income (types, amounts), savings (types, amounts), markets (formal/informal), access and sales
Social: gender, household head, social organisations	Social: social organisations
Human: education level, access to information	Human: access to information (sources), knowledge and skills
	Physical: access to water, electricity, equipment, farming (gardens, fields, livestock)
Access to resources	
Resources and infrastructure: access to water, electricity, equipment	Resources and infrastructure: improved access to water, improved access to equipment, equipment
Productivity	
Farming activities: gardens, fields, livestock, food provisioning	Increased farming activities: continuity, increased productivity, increased food provisioning, increased water use efficiency (RWH, access, availability, efficiency), soil fertility and soil health

The resilience impact monitoring and assessment process has two components:

- A focus-group-based participatory impact assessment process, and
- A questionnaire-based individual interview process. These are called Resilience Snapshots, as they are considered a measurement of change at a certain time (e.g. seasonally, annually), but are not considered an endpoint as adaptation and building adaptive capacity is an ongoing process.

Table 5 provides an example of a resilience snapshot exercise conducted in both Limpopo and KZN during 2019.

Table 5: Resilience snapshots undertaken in Limpopo and KZN in 2019.

Resilience indicators	Increase for Limpopo (N=26)	Increase for KZN (N=12)	Comment
Increase in size of farming activities	Gardening 1% Field cropping; - 98% Livestock; 6%	Gardening 18% Field cropping 63% Livestock 31%	Cropping areas measured, no of livestock assessed Dryland cropping in Limpopo has reduced significantly due to drought conditions and infertile soil
Increased farming activities	No	No	All involved in gardening, field cropping and livestock management
Increased season	Yes	Yes	For field cropping and gardening – autumn and winter options
Increased crop diversity	Crops: 21 new crops Practices: 11 new practices	Crops: 12 new crops Practices: 8 new practices	Management options include; drip irrigation, tunnels, no-till planters, JoJo tanks, RWH drums,
Increased productivity	Gardening; 120% Field cropping: 15% Livestock: 6%	Gardening: 72% Field cropping: 79% Livestock: 25%	Based on increase in yields (mainly from tunnels and trench beds for gardening CA for field cropping)
Increased water use efficiency	45%	25%	Access, RWH, water holding capacity and irrigation efficiency rated
Increased income	13%	13%	Based on average monthly incomes, mostly though marketing of produce locally and through the organic marketing system
Increased household food provisioning	Vegetables; 7 types ~10 kg/week Fruit; 5-10 kg/week Dryland crops (maize, legumes, sweet potatoes); 5-10 kg/ week	Maize; 20 kg/week Vegetables; 7 kg/ week	Food produced and consumed in the household
Increased savings	Not applicable	R150/month	Average of savings now undertaken
Increased social agency	2	2	Learning groups and local water committees
Increased informed decision making (0-5)	5	5	Own experience, local facilitators, other farmers, facilitators, extension officers
Positive mindsets: (-2, -1,0,1,2)	2	2	More to much more positive about the future: Much improved household food security and food availability

The monitoring and evaluation process, with forms, formats and facilitation approaches is summarised in the Facilitation Manual (https://www.mahlathini.org/dss/resources/wrc-cca-facilitation-manual/)

Quantitative indicators were based on a set of measurements undertaken for specific farmer-level experiments in both gardening and field cropping. These are outlined in the Tables 6 and 7.

Table 6: Quantitative indicators measured for gardening experiments

Parameter	Instruments	Dates
Evapotranspiration (Et_0)	Davis weather station	Continuous
Soil moisture	Chameleon water sensors	Continuous
Amount of water applied	Measuring cylinder	Continuous
Rainfall	Rain gauge	Continuous
Weighing of the harvest	Weighing scale	Continuous
Rand value of the harvest	Local market price	At harvest

The above indicators were used primarily for the calculation of water productivity, which in this case was used as a proxy for improved resilience. Practices included were shade cloth tunnels, mulching, mixed cropping, trench beds and irrigation scheduling. Details are provided in the intensive homestead food production implementation report on the web platform https://www.mahlathini.org/dss/reports/wrc-cca-final-report-cra-implementation-intensive-homestead-food-production/

Table 7: Quantitative indicators measured for field cropping experiments

Parameter	Instruments	Dates
Evapotranspiration (Et_0)	Davis weather station	Continuous
Soil moisture	Gravimetric soil water samples	4 times in growing season
Bulk density	Sampling	Once towards the end of growing season
Soil fertility	Sampling for analysis at CEDARA soil lab	End of growing season
Soil health	Sampling for analysis by Soil Health Solutions	End of growing season
Rainfall	Rain gauges installed in 5 sites	Continuous
Infiltration	Single and double ring infiltrometers	Once during the season
Runoff	Runoff plots installed in 3 sites	Continuous
Weighing of harvest	Weighing scale, including grain and biomass (lab analysis)	End of growing season, for maize only
Rand value of harvest	Local market price	At harvest

The above indicators were used for calculation of runoff, infiltration, soil fertility, soil health and water productivity for a range of practices within conservation agriculture, including, for example, intercropping with legumes, multi-species cover crop options and crop rotation. Details are provided in the field cropping and livestock integration implementation report on the web platform (https://www.mahlathini.org/dss/reports/wrc-cca-final-report-cra-implementation-field-croppind-and-livestock-integration/).

1.2 COMMUNITY CLIMATE CHANGE ADAPTATION FACILITATION: A MANUAL FOR FACILITATION OF CLIMATE RESILIENT AGRICULTURE FOR SMALLHOLDER FARMERS (65 PAGES)

This document is a loose-standing report: **Volume 2 Part 1:** Community Climate Change Adaptation facilitation: A manual for facilitation of Climate Resilient Agriculture for smallholder farmers, also available on the web platform (https://www.mahlathini.org/dss/resources/wrc-cca-facilitation-manual/).

The manual focusses on the process; the methodological and facilitation components of the research brief. It discusses methodological underpinnings and processes related to learning and change, social learning theory, social agency, communities of practice and innovation systems development and outlines how these concepts have been combined into a research framework for this work.

It then provides a discussion on the concepts of climate change, climate change adaptation and climate smart/ resilient agriculture within the context of smallholder farming systems in South Africa. Concepts of vulnerability and resilience are considered as is the contribution of local and traditional knowledge.

The process and elements in the design of the decision support process are described in detail both for the individual online version and the group-based facilitated process.

The manual then continues to provide the detailed workshop facilitation outlines and provides examples of the outcomes of each of the step wise workshop processes.

2 RESULTS: CLIMATE RESILIENT AGRICULTURE (CRA) IMPLEMENTATION

2.1 INTRODUCTION

Outputs and outcomes of the CRA implementation processes in the three different sites (EC, KZN and Limpopo) have been written up as three stand-alone reports:

- **Volume 2 Part 2:** Climate Resilient Agriculture. An implementation and support guide: Intensive homestead food production practices.
- **Volume 2 Part 3:** Climate Resilient Agriculture. An implementation and support guide: Local, group-based access to water for household food production.
- **Volume 2 Part 4**: Climate Resilient Agriculture. An implementation and support guide: Field cropping and livestock integration practices.

The reports are also available on the web platform (https://www.mahlathini.org/dss/reports/) and can be accessed using the following web-links:

https://www.mahlathini.org/dss/reports/wrc-cca-final-report-cra-implementation-intensive-homestead-food-production/

https://www.mahlathini.org/dss/reports/wrc-cca-final-report-cra-implementation-water-access/

https://www.mahlathini.org/dss/reports/wrc-cca-final-report-cra-implementation-field-cropping-and-livestock-integration/

The sections below provide brief summaries of the content for each of these reports.

Climate Resilient Agriculture aims to sustainability increase agricultural productivity and incomes while adapting farming practices to the changed circumstances and also making sure that farming is friendly to nature. It is about making changes to how we farm in a changing environment that will improve both our ability and the ability of the environment to cope with these changes.

The emphasis is at farm/household level. CRA aims to improve aspects of crop production, livestock and pasture management, natural resource management, as well as soil and water management as shown in the figure below.

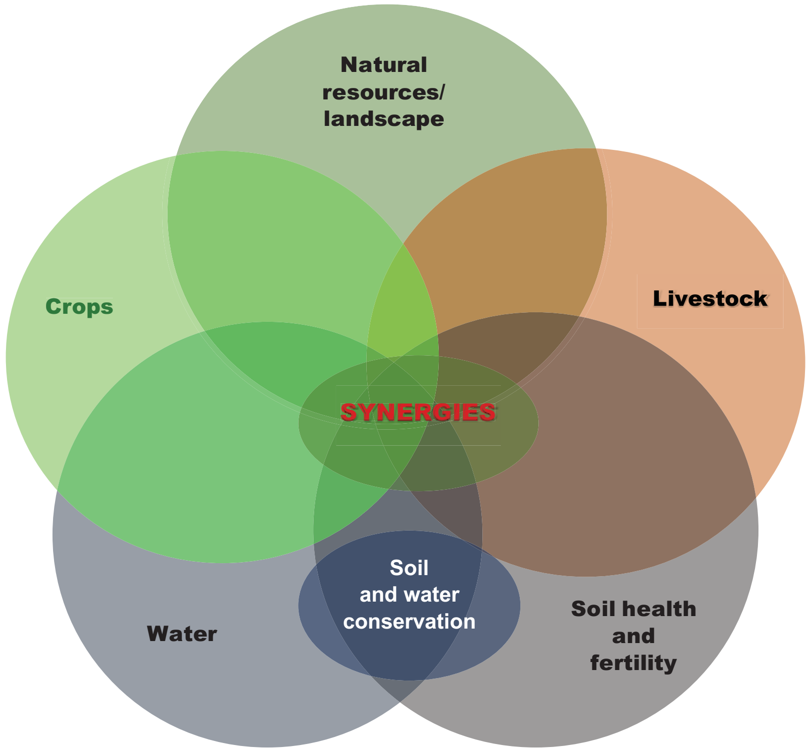

Figure 1: Household level implementation of CRA integrates across sectors (adapted from Arslan, 2014)

There are a range of farming practices that can be useful. The idea is for smallholders try out a 'basket of options' of practices across the different sectors or aspects, maximising synergies across the sectors. They compare these practices with what they are doing already, to observe the differences and to make decisions from there about changing their farming systems.

The main principles or concepts that we have focused on in choosing the practices are the following:

- Minimize external inputs
- Maximise internal diversity
- Focus on soil health and natural soil building techniques
- Take care of the environment
- Use available water as efficiently as possible.
- Work together, learn together and plan together

2.2 Climate resilient intensive homestead food production practices report (48 pages)

2.2.1 The present situation

Homestead food production is an important aspect of the smallholder farming system. These are small (0,01-0,5 ha; or 100-5000 m^2) plots adjacent to homesteads where participants plant a range of crops and fruit trees, with or without access to water for irrigation. The homesteads also host small livestock such as poultry and in some cases kraals for goats and cattle. A limited number of people also keep pigs. These plots are usually fenced. The large majority of smallholder farmers plant for household consumption and sale of surplus.

Production is constrained by infertile and badly structured soils. Often, the smallholders live in areas where soils are not ideal for cropping. This situation is worsened by repeated shallow tillage (with hand hoes and/or tractors), without addition of nutrients or organic matter, often for many years. The results are very low fertility soils, with many structural problems such as capping and compaction. This is now exacerbated by climate change, with alternating hot and dry conditions and heavy downpours adding extensive erosion of top soil to the list of woes. Productivity is generally extremely low.

In addition, access to water for irrigation is an enormous obstacle for most smallholders, who battle to have enough just for household use.

Diversity in cropping also tends to be low; with a focus generally on maize and pumpkins for field crops, as well as legumes in some cases. In terms of vegetables, planting consists mainly of cabbage, spinach, tomatoes and onions. In KZN and the Eastern Cape, participants may have a few un-grafted peach trees. In the subtropical areas of Limpopo lowveld, diversity is somewhat higher with more habitual planting of a wide range of trees (e.g. bananas, mangoes, avocadoes, paw-paws and citrus, as well as indigenous trees).

The challenge is thus to work with a combination of aspects; soil fertility, soil erosion control, water management, cropping, fruit tree production and livestock integration, to create a more productive and resilient, intensive homestead food production system, working within the confines of the local situation and resources.

2.2.2 CRA practices and impact on resilience

The Climate Resilient Agriculture (CRA) practices promoted through this study encompass vegetable and fruit production as well as small livestock integration; practices that are undertaken within the boundaries of the homestead. Practices also include soil and water conservation, as well as microclimate management.

The potential of practices to have an impact on productivity in a changing climate depends on a number of criteria. These criteria have been developed and fine-tuned with learning group members. The most common criteria can be summarised as; productivity, water use, labour, cost, ease of implementation and income potential. Farmers were encouraged to try out new practices alongside their normal/ traditional practices to be able to compare these practices and clearly observe potential advantages.

Comments from farmers about the overall process:

- *"Leaving the soil exposed to heat and rain and turning over the soil to plough and plant has destroyed the soil, making it infertile and very hard. Improving the soil takes time, but makes a big difference in growth of crops.*"
- *"I have learnt about practices that will help me continue with farming activities even though water is a struggle and the sun is too hot for any vegetable to survive in our environment. The little we have been given is better than nothing."*
- *"Climate change has been hard on us, especially on our farming activities. Farming seems impossible in this condition, especially with no rain. Being unemployed and relying on grants is even worse, as the head of the household; farming makes it better because you farm for both consumption and making an income."*
- *"I have experienced harsh weather with no rain and no harvests using our traditional ways of farming, which affected our livelihood as we had to buy all vegetables instead of growing them myself. Now I know how to deal with changes of climate, since I met Mahlathini and AWARD and they taught us practices that changed my life. I don't buy vegetables that I need every day, I pick from my garden."*
- *"It's not easy to implement new things, but if results are presented and examples are shown to prove that the practice is being tried by other farmers and it's working very well, then it makes it easier for us to try."*
- *"It's not easy to move from traditional ways of doing things to something new, because we sometimes associate change with risk that we are not ready for."*
- *"Seeing results from other people's gardens motivates us to try these ideas ourselves."*

- *"We progress much faster when we work together in learning groups, discuss issues and visit each other's gardens."*

This document provides a description of different CRA practices tried out by smallholder farmers in their learning groups, some examples of implementation, comments from farmers, assessment of impact and an overall rating based on farmers' views and in some cases, quantitative measurements.

Rating

As a means of providing a quick qualitative and visual summary of the impact of each CRA practice on the resilience of the smallholder farming system, a rating has been devised as follows:

Criteria	Descriptors	Score (1 point for each descriptor)
Improved food provision	More food, increased diversity, increased continuity	3
Improved soil conditions	Improved fertility, improved organic matter, improved soil health	3
Improved water management	Improved water holding capacity, efficient use of water, improved access	3
Uptake of practice	Experimentation with practice (no of people), continuation of practice after experimentation, increased implementation of practice	3
Skills and resources to sustain practice	Use of own resources, knowledge to implement practice adequately, access to required/external resources	3

The stars are filled (black) for each point provided in the score in the following manner:

★☆☆☆☆ Score 1 to 3

★★☆☆☆ Score 4 to 6

★★★☆☆ Score 7 to 9

★★★★☆ Score 10 to 12

★★★★★ Score 13 to 15

2.2.3 Innovation system process

The process started with an introductory workshop with each of the learning groups, to discuss climate change, impacts on their livelihoods and farming and potential adaptive measures. These workshops also provide a space to introduce concepts and potential practices and discuss inclusion of these into the present farming system, followed by practical demonstrations and setting up the farmer level experimentation trial plots.

Interested individuals in a local area or village come together to form a learning group. Several farmers in that group then volunteer to undertake on-farm experimentation, which creates an environment where the whole group learns throughout the season through observations and reflections on the implementation and results of the chosen trials. Farmers compare various treatments with their standard practices, which are planted as control plots.

The group assesses and reviews the CRA practices each season and, based on their observations and learning, make decisions regarding the next season’s implementation and experimentation. In this way the farming system is continually improved and adapted.

The report on intensive homestead food production includes a description of experimentation with each of the practices outlined in the table below with an analysis of the impact of this practice on improved farming resilience.

Table 8 outlines the practices introduced that farmers chose to experiment with and include into their farming system. It also gives a summary of the rating for each practice.

Using a combination of practices that focus on soil fertility, water holding capacity, diversification and micro-climate management have had a marked effect on productivity, yields and production. In some cases, smallholders have managed to double and even triple their production. The synergies created by combining a number of practices is crucial to this success.

Table 8: Summary of CRA practices tried throughout this farmer level experimentation and learning process.

Criteria	Improved food provision			Improved soil conditions			Improved water management			Uptake of practise			Skills and resources to sustain practise				
Climate Resilient Agriculture practices tried / **Descriptors**	More food	increased diversity	increased continuity	Improved fertility	improved organic matter	improved soil health	Improved water holding capacity	efficient use of water	improved access	Experimentation with practise (no of people)	continuation of practise after experimentation	increased implementation of practice	Use of own resources	knowledge to implement practise adequately	access to required /external resources	**Score**	**Rating**
1.3.1.1 Trench beds	1	1		1	1	1	1	1		1	1	1	1	1	1	13	★★★★★
1.3.1.2 Furrows and ridges	1			1	1		1	1		1	1	1	1	1	1	11	★★★★☆
1.3.1.3 Shallow trenches	1			1	1		1						1			5	★★☆☆☆
1.3.2 Composting	1			1	1	1	1				1		1	1		8	★★★☆☆
1.3.3 Liquid Manure	1			1						1	1		1	1	1	7	★★★☆☆
1.3.4 Shade cloth tunnels	1		1	1	1	1	1	1		1	1	1	1	1	1	13	★★★★★
1.3.5 Mulching	1			1	1	1	1				1		1			7	★★★☆☆
1.3.6 Eco-circles	1			1	1	1		1		1			1			7	★★★☆☆
1.3.7.1 Tower gardens	1	1		1				1			1		1			6	★★☆☆☆
1.3.8 Mixed cropping, crop diversification	1	1	1			1		1		1	1		1	1		9	★★★☆☆
1.3.9 Natural pest and disease control	1	1				1				1	1		1			6	★★☆☆☆
1.3.10 Seed Saving	1	1	1							1	1	1	1			7	★★★☆☆
1.3.11.1 Banana basins	1		1	1	1	1	1	1		1	1		1	1		11	★★★☆☆
1.3.11.2 Organic mango production	1	1		1	1	1	1	1		1	1		1	1		11	★★★☆☆
1.3.12 Stone bunds and check dams	1			1	1		1			1	1		1	1		8	★★★☆☆
1.3.13 Infiltration ditches (run-on ditches, diversion ditches)	1						1	1	1		1		1			6	★★☆☆☆
1.3.14 Rainwater harvesting (RWH)	1						1	1	1		1		1			6	★★☆☆☆
1.3.15 Small dams	1						1	1	1		1		1			6	★★☆☆☆

NOTE: The numbers in this table relate to the number of each practice as discussed in the intensive homestead food production report.

2.3 Climate Resilient Agriculture. An implementation and support guide: Local, group-based access to water for household food production report (17 pages)

2.3.1 The present situation

Water management in an intensive food production system consists of:

- Reduction in run-off and water erosion; mostly through measures such as diversion ditches infiltration basins, contours, stone bunds, check dams and the like.
- Improved water-holding capacity; mostly through increased organic matter in the soil, mulching and microclimate management (such as improved shade and reduced wind).
- Improved water-use efficiency; mostly through irrigation management, drip irrigation and greywater management.
- Improved access to water; mostly through small dams, spring protection and drilling of boreholes.

Improved access to water can take several forms and interventions are generally conceived as large infrastructure projects implemented through government and municipal processes. In this report, we focus on increasing local level access through processes that groups of individuals can undertake within their communities.

2.3.2 Group-based access to water sources

Water is considered a communal resource and as such water projects need to accommodate all community members. For the large majority of rural settlements, water access is about household water needs and it is this aspect that government services focus on.

It is possible to conceptualise water provision for agriculture at a village level, where an interest group of smallholders undertake to manage and use a specific water resource, such as a spring, or a borehole, with consent from the local authorities and Water Service Authority representatives. We do not include rivers and perennial streams in this activity, as water offtake and management from these sources is socially, politically and environmentally a lot more complicated and does require the whole community to be involved.

Group-based water management options have the advantage that participants can "own" their scheme and thus have a lot more control over their water access. It also has the advantage that the group itself designs, implements, maintains and manages access for the members. The members are responsible for water use and management and are accountable to each other.

- In this report two case studies are provided as examples of how this can be done:
- Spring protection and water reticulation for nine households in Ezibomvini, Bergville, KZN.
- Borehole installation and water reticulation for two village-based groups of 20 members each in Sedawa and Turkey, Limpopo.

2.3.3 Learnings and successes

This has been an extremely valuable process for building social agency in the learning group as well as for systemic and systematic learning for all the group members. They had to grapple with both the understanding of the technical aspects as well as the social process that they had to put in place and adhere to.

In each case, the whole group was involved throughout and learning took place through discussions, provision of information, working with the mapping and layout aspects, and practical work. A lot of the learning happened through trial and error, as participants started changing their perceptions and understanding.

In terms of the social aspects, participants initially believed it would be easy for them to manage the water use, but they quickly realised that it was very important to have upfront and strict rules to ensure that everyone received the same allocation of water. This was a deeply empowering process for learning group participants.

2.4 CRA Implementation. An implementation and support guide: Field cropping and livestock integration practices report (39 pages)

2.4.1 Current status of field cropping

2.4.1.1 Limpopo

Dryland cropping is a common practice, although it has declined dramatically with the five-year drought in the area (Lower Olifants' region), compounding ongoing reduction in cropping due to low soil fertility, access to seed and inputs and lack of labour.

Learning group participants are very keen to re-initiate or continue field cropping aspects of their farming. Presently most participants undertake this activity within their extended homestead plots, with only a small proportion of participants having access to larger fields and or supplementary irrigation options.

With the shift in weather patterns and climate variability, (increased heat, late onset and unpredictability of rains) the field cropping practice in the area has already shifted; surprisingly away from the more drought tolerant crops such as millet and sorghum, towards maize with supplementary irrigation. This is due to much greater predation of the millet and sorghum by birds (in particular), but also monkeys and wildlife than was experienced in the past. Farmers are aware of bird-resistant sorghum varieties but have not been able to access seed. They also practice protection of the seed heads with netting as an adaptive strategy. Planting of traditional leguminous crops such as ground nuts, jugo beans (Bambara ground nut) and cowpeas is still popular, as is planting of pigeon pea and moringa. Other field crops include pumpkin and watermelon. Some farmers have started experimentation with different planting calendars.

2.4.1.2 KwaZulu-Natal

In the Bergville area of KZN, communities still practice field cropping primarily for food security and rely on their maize harvests for food. Dryland cropping, focusing almost exclusively on maize and extensive livestock management are the main activities. There has been a sharp reduction in field cropping over the last 15 years, given stress factors such as uncontrolled livestock, increased poverty, difficulties in accessing tractors, expensive inputs and climate change.

In the Midlands and southern KZN regions, with higher rainfall and easier access to markets in urban centres, the focus has been more on the production of green mealies and livestock feed (yellow maize). These farmers also focus on other field crops such as potatoes, amadumbe (taro), pumpkin, beans and sweet potato and produce a range of vegetables. Here a much larger proportion of the fields are fenced, compared to Bergville, as livestock invasions in these more densely populated areas is a large risk factor with cropping.

In more general terms, field cropping in KZN is hampered by soil acidity, lack of appropriate nutrient and weed management and continued monocropping of maize. Maize yields are generally very low and average ≤1 t/ha.

2.4.2 Climate resilient field cropping practices

CRA field cropping practices include a suite of practices that focus on soil and water conservation and soil health alongside the conventional soil fertility and soil structure considerations. Attention is also given to crop diversification, crop types and varieties that are more suitable to the changing conditions. Different planting dates are considered, as are options for extending the growing season. Livestock integration is considered to be an important aspect of the process and includes the development of climate resilient local value chains.

Sustainable and regenerative agricultural practices such as conservation agriculture (CA), that conserve and increase soil organic carbon (SOC) and improve soil health, are increasingly promoted in Southern Africa as an alternative to conventional farming systems (Smith et al., 2017). CA depends on the simultaneous implementation of three linked principles: (1) continuous zero or minimal soil disturbance, (2) permanent organic soil cover, and (3) crop diversification, specifically with the inclusion of legumes and/or cover crops (FAO, 2013).

Complementary practices supporting CA implementation in smallholder farming systems include appropriate nutrient management and stress-tolerant crop varieties, increased efficiency of planting and mechanisation, integrated pest and disease and weed management, livestock integration, and enabling political and social environments (Thierfelder et al., 2018).

To pilot these practices in different localities, participants organised themselves into learning groups, considered local adaptive measures and included practices promoted through the smallholder decision support system that were appropriate to their own systems. Generally, these practices are piloted through the innovation system development process and local farmer-level experimentation. Farmers deepen and expand their experimentation options over a three- to four-year period of learning and try out different options. This is crucial in knowledge-intensive farming systems.

Practices that were piloted by the learning groups included: CA, intercropping, crop rotation, micro-dosing with fertilizer, drought tolerant crops, integrated weed and pest management and livestock integration through production of cover crops appropriate for livestock fodder as well as production of hay and winter supplementation. Soil and water conservation practices included planting on contour, stone lines, check dams and planting agroforestry species such as Pigeon pea and Sesbania sesban.

2.4.3 Sites and participants

Sites were chosen to be representative of different agroecological conditions within South Africa.

The process starts with an introductory workshop with each of the learning groups, to introduce the concepts and practices and discuss inclusion of these into their present farming systems, followed by practical demonstrations and setting up the farmer-level experimentation trial plots.

Interested individuals in a local area or village come together to form a learning group. Several farmers in that group then volunteer to undertake on-farm experimentation, which creates an environment where the whole group learns throughout the season through observations and reflections on the trials' implementation and results. They compare various treatments with their standard practices, which are planted as control plots.

During each season, a set of CA experiments is decided upon, followed by demonstration workshops at farm level, implementation by all volunteers and ongoing monitoring. Observations are recorded and discussed with the learning groups in their seasonal review of their experimentation process, to allow for planning of the next experimentation cycle.

For the field cropping piloting process, CA formed the backbone of the experimentation process, around which other practices were built and included. The CA principles best embody the adaptive processes required, with outcomes that include improved soil organic matter, soil aggregation and soil health as well as improved water holding capacity and reduced runoff.

The participants and practices implemented are summarised in Table 9.

Table 9: Field cropping experimentation participants and practices implemented over three seasons in KZN, EC and Limpopo.

Province	Area	Village	Practices	Number of participants (No. in brackets indicate those who got a harvest)		
				2017/18	2018/19	2019/20
Limpopo	Mametja	Sedawa, Turkey, Willows, Botshabelo, Santeng	CA, intercropping, drought tolerant crops, livestock integration, stone lines, check dams and planting agroforestry species	28 (0)	45 (15)	35 (10)
KZN	Bergville	Ezibomvini, Stulwane, Eqeleni, Ndunwane	CA, intercropping, crop rotation, micro-dosing with fertilizer, drought tolerant crops, integrated weed and pest management and livestock integration	95 (76)	78 (59)	94 (80)
	SKZN	Madzikane, Ofafa, Spring Valley	CA, intercropping, crop rotation, micro-dosing with fertilizer, drought tolerant crops, integrated weed and pest management and livestock integration	30 (21)	40 (29)	60 (51)
	Midlands	Gobizembe, Mayizekanye, Ozwathini	CA, intercropping, micro-dosing with fertilizer, drought tolerant crops, integrated weed and pest management and livestock integration	32 (26)	62 (54)	122 (91)
EC	King Williams Town	Xumbu	CA, deep ripping, intercropping, crop diversification and short furrow irrigation	8 (0)	15 (0)	6 (0)

This report focuses on a qualitative assessment of CA introduction in Limpopo and inclusion of several quantitative assessments for the Bergville area in KwaZulu-Natal. In the Eastern Cape, crop failure was experienced for all three seasons of implementation, which reduced opportunities for learning and continued farmer-level experimentation.

2.4.4 Farmers comments regarding Climate Change impacts on field cropping

- *"Lack of rainfall and changes in rainfall patterns have been a major challenge with regard to both field cropping and homestead gardening."*
- *"Pest outbreaks which are associated with extreme heat have been worse, especially on maize."*
- *"Repeated crop failure has meant that we no longer have seed to plant our field crops."*
- *"When it does rain there is now a lot more erosion, because the soil is not covered."*

2.4.5 Farmers comments regarding CA implementation in the context of CC

- *"The CA process has brought the community together and is helping farmers to groom each other to improve our farming."*
- *"Better yields have been observed, specifically for maize, as well as better weed knowledge and management skills."*
- *"Maize planted after Lablab can be highly productive. However, lablab and cover crops are inedible and they are very attractive to livestock, hence most farmers are resistant to diversifying, they only use maize."*
- *"Those who obtain higher yields are the hard workers, as weeds are likely to be a big problem if weeding is not done carefully and on time."*
- *"Soil management has improved under CA, both soil fertility and much reduced erosion and yields have improved dramatically."*
- *"CA is cost effective and cheaper than conventional tillage as tractors need not be hired and fertilizer and other inputs are used sparingly."*
- *"Most of the participants have decreased fertilizer use and increased use of manure on their fields. The results are still good."*
- *"Having savings groups has helped a lot in terms of buying inputs for field cropping."*

The report outlines the results of the varied experimentation undertaken in Limpopo and KZN. Advantages of this approach can be summarized as a reduction in run-off from CA plots, increased permeability and improved soil structure, increased soil organic matter and soil carbon and improved yields. Water productivity for CA single and multi-cropping options is considerably higher than conventionally tilled plots. Farmers also appreciated the reduction in labour associated with CA and a reduction in input costs.

2.4.6 Livestock integration

Livestock are an important component of the smallholder farming system and crop-livestock integration can offer important gains in terms of sustainability and climate resilience.

Aspects of crop-livestock integration that were considered are the following:

- Inclusion of fodder species for poultry and livestock into the cover crop mixes in the rotation and multi-cropping system, including summer (sunflower, millet, Sun hemp, Dolichos beans, cowpeas) and winter (Saia oats, fodder rye, fodder radish) cover cropping options.
- Winter fodder supplementation and
- Strip cropping with perennial fodder species.

Results from these experiments are discussed in the report. Despite the advantages in soil health, yields and fodder availability that these experiments have shown, farmers have been slow to expand the areas under cover crop production due to a combination both of difficulty in paying for seed and a conception that due to limited field sizes and labour, a focus entirely on food production for themselves is the only option. Farmers have appreciated the practice of winter fodder supplementation using hay bales and protein supplementation, as this has shown short term weight and health gains in their livestock.

2.4.7 Facilitators' reflections on the CA learning process

- The concept of CA is knowledge intensive and difficult to convey in one learning session, especially linked to deeply entrenched habits that work in opposition to the principles, such as clearing and burning of weeds, wide spacing and the like.
- It would be ideal to be able to run workshops through the whole cropping season to make observations and deepen the learning.

- Because the innovation system approach to learning relies on positive results from the farmer-level experimentation, difficult cropping seasons, where hot and dry conditions seriously hamper germination and growth, tend to be problematic for introduction of a new practice. Farmers associate the lack of results with the practice, rather than the season. It can be almost impossible to disentangle different factors, such as lack of soil fertility on the performance of the trials as well. It is thus common to have very variable results within a group, with some participants faring reasonably well and other failing completely. Under such conditions, uptake of these practices tends to be low.
- Participants somehow believe that CA cannot be used on larger fields as they have now got into the habit of believing this is only possible with tractors and with assistance provided in provision of seed. The concept of manual weeding is one they are not prepared to consider.
- The habit of planting without any addition of soil nutrients or manure is a very common practice, specifically in Limpopo, and is a big challenge when trying to improve yields. It is, however, extremely difficult to persuade participants to collect and use manure. Many have no access and would need to buy this from people who do, which is a constraint.

3 Climate Resilient Agriculture learning materials for smallholder farmers

3.1 Climate Resilient Agriculture learning materials for smallholder farmers (English, isiZulu, siPedi)

Farmer-level learning materials/handouts have been produced in four languages under the themes of water, soil, crop and livestock management:

- **Volume 2 Part 5:** Climate Resilient Agriculture learning materials for smallholder farmers. (English, isiZulu, siPedi):
  a. Water management.
  b. Soil management.
  c. Crop management.
  d. Livestock integration.

And are also available on the web platforms below.

3.1.1 Water management (12 pages)

(https://www.mahlathini.org/dss/handouts/wrc-cca-water-management/)

3.1.2 Soil management (14 pages)

(https://www.mahlathini.org/dss/handouts/wrc-cca-soil-management/)

3.1.3 Crop management (12 pages)

(https://www.mahlathini.org/dss/handouts/wrc-cca-crop-management/)

3.1.4 Livestock integration (5 pages)

(https://www.mahlathini.org/dss/handouts/wrc-cca-livestock-integration/)

These handouts are designed to provide learning support for CRA practices and provide brief descriptions and examples of implementation of these practices.

4 SUMMARY OF LEARNING AND RECOMMENDATIONS

The key success of this process was the use of a social learning approach (learning groups or CoPs, local facilitators and individual experimentation) for promotion and implementation of a range of CCA responses. Participants learnt a lot about analysis of climate change impacts and analysis of the impact of their activities and improved their decision-making capacity; both individually and jointly.

The key challenges were:

- Lack of positive engagement of the authorities and government officials.
- Local droughts linked to lack of water provision in these communities.
- Lack of funding support for the smallholder farmers and
- Internal conflicts related to competition for resources and local political instabilities.

In general, however, these communities showed great fortitude in the face of their almost overwhelming problems and this, more than anything, led to them embracing and working with the concepts and approaches introduced.

Many of the learnings for the farmers themselves are woven into the body of the reports – relating to their farming, their personal motivations and understanding and their societies. Learning was supported by the strong participatory nature of this process as well as the innovation systems concepts where learning happens through cycles of practice, observation and analysis. Local facilitators played an important role in the continued motivation and participation of the learning group participants. Participants felt that learning in the groups vastly outweighed what they could have learned on their own and have organised so that they can continue to work together.

Learning within the supporting organisations – MDF and other NGOs such as AWARD, INR, Lima RDF, Seeds of Light, K2C and Hoedspruit Hub was substantial for the fieldworkers and interns involved, where they had to internalise and work with a lot of new information about farming practices and resource management, local conditions and societies, and effective facilitation in a social learning environment.

Some advances were also made through working with other CSOs active in the project areas – stakeholder interaction resulted in collaboration and some limited sharing of implementation budgets. Cementing the process around climate change and adaptation assisted stakeholders to more clearly understand the need for this cooperation.

The attitudes of stakeholders and staff slightly more removed from the process, however, (mostly government and municipal structures), was a lot more difficult to assess, where responses ranged from somewhat incredulous to (in most cases) openly sceptical. Many came to this process with preconceived ideas and concepts, which reduced their ability to engage positively. These misunderstandings were underpinned by linear and contradictory thought patterns about what development and resilience means and not so much a product of ignorance as a product of our institutional paradigms. There is generally very little respect or empathy for smallholders and their survival imperatives, with most stakeholders engaging in the process from a perspective of personal gain, rather than from a perspective of what would be best for people and the environment they live in.

With respect to the CRA practices identified and tested, it became clear over the four years of implementation that the greatest impact on resilience lies in the synergies developed through implementing multiple practices within a system perspective and that designing ways in which complex systems with multiple variables can be tested is a crucial aspect of this work. It is important also to appreciate the inherent limitations of specific practices and the need for local and contextual adjustments in implementation of CRA. Practices that clearly address a felt need in a particular locality and build on what participants already know and are doing are the most likely to be incorporated into that farming system. Essentially, it is a process of shifting paradigms and building new habits and patterns, which takes a concerted effort, over time.

Farmer-level record keeping for measurement of specific variables and to increase the in-depth observation of practices is an important element of learning and implementation. It needs to be well-managed and information gleaned needs to be clearly incorporated into the farmer learning process to have much meaning. This process is complicated considerably by the low levels of literacy in the villages, which means that people are not used to keeping records or writing down information. Generally, farmers are willing to do the record keeping, but regard this as something that they are doing for the research process and for the facilitators, rather than something they are doing for themselves.

The development and use of visual proxies for some of the soil- and water-related indicators was restricted both by the lack of enthusiasm for record keeping by farmers and by high levels of variability due to climatic conditions. This high variability in and between seasons often meant that the changes in the indicators were more likely related to changes in weather than changes in farming practices. As a result, students and interns were brought on board to monitor these indicators more closely. In their case, their lack of experience hampered the reliability of their records as many of the indicators, although visual, required practical knowledge of soils and water movement. Seasonal field-based learning workshops were thus conducted for both farmers and students to ensure ongoing and reliable monitoring.

In summary, key learnings were:

- Working with learning groups within a social learning process and using farmer-level experimentation to promote and cement implementation of new ideas was very successful in shifting participants' implementation towards Climate Resilient Agriculture practices.
- Social agency increased and developed within these groups, allowing participants to tackle some of the intractable problems and issues in their villages; notably access to water, sharing of information and resources, and joint marketing initiatives.
- The ongoing learning and mentoring approach also assisted staff and other stakeholders involved in this process to internalise best practice options in Climate Resilient Agriculture as well as facilitation imperatives for such highly participatory processes.

This has been an extremely valuable learning exercise and lessons learnt are considered widely adaptable to other rural situations and for scaling up interventions in community-based CCA. We now have a successful working model for how implementation can go forward. We believe this process is applicable for national implementation and can be used as a basis for implementation by the relevant institutional role players.

We would strongly suggest further support by the WRC for continued implementation and scaling of this approach and for exploration of ways to access institutional support and develop appropriate and sufficient financing mechanisms.

Our recommendations for future implementation include:

- Further development of the DSS to fully incorporate all agroecological zones in South Africa.
- More experimentation and resilience assessment of longer-term CRA practice options, such as agroforestry, rangeland management, landscape rehabilitation and erosion control.
- Participatory analysis and learning around climate change impacts and potential adaptive strategies and practices is crucial for allowing local-level agendas in climate change adaptation to develop and mature and need to be included in regional and national CCA implementation strategies and processes.
- Learning groups, working within a social learning and innovations systems methodological approach are a powerful avenue for building motivation and effecting positive change at a local level and need to be incorporated into CCA implementation approaches more broadly.
- Within this context, focussing the actual implementation of Climate Resilient Agriculture practices on individuals is important.
- Collaborative activities among participants are an emergent property of this approach; with the added advantages that they are not externally motivated and introduced and participation is entirely voluntary.
- Implementation of Climate Resilient Agricultural and land management practices provides for a significant improvement in adaptation capacity and resilience; but only if implemented coherently.

- Introduction of a suite of options for adaptation is important; to allow participants to experiment with and implement a range of options across soil, water, crop, livestock and natural resource management. It is the combined effect that allows for the change, rather than any one particular practice.
- Working with a smallholder farmer-level decision support process for implementation of baskets of Climate Resilient Agriculture practice options works extremely well in terms of learning and adoption.
- A focus on soil and water conservation, microclimate management (e.g. shade house structures and Conservation Agriculture), soil organic matter and rainwater harvesting is crucial in underpinning improved productivity and production. Attempting to expand on conventional agricultural practices in this context is not feasible, given the already extreme conditions and intense competition for dwindling water resources in these types of catchment.

5 APPENDICES

5.1 CAPACITY BUILDING

Capacity building has been undertaken on three levels:

- Community level learning
- Organisational capacity building
- Post graduate students

5.1.1 Community level learning

This has consisted of learning and mentoring for285 participants in 19 village-based learning groups, across 5 areas in three provinces (KZN, Limpopo and EC). The learning process consisted of a series of climate change adaptation (CCA) workshops:

- CCA workshop 1: Exploration of climate change (CC) concepts, the impact of CC on smallholder livelihoods and adaptive measures
- CCA workshop 2: Exploration of CCA strategies and prioritization of CCA practices appropriate to the group and locality
- CCA workshop 3: Action plan for implementation of CCA practices, learning group establishment and outline of farmer level experimentation
- CCA workshops 4-6: Learning workshops for specific CCA practices including theory, practical demonstrations and farmer level experimentation plans.

Table 1 provides a summary of capacity building activities for each of the areas for the three-year period for implementation (2018-2020)

Table 1: Communities of Practise (CoP) capacity building in three provinces (2018-2020)

Province	Site/Area; villages	Demonstration sites	CoPs	Collaborative strategies
KZN	Ntabamhlophe	- CCA workshop 1 - CCA workshop 2 - CCA workshop 3 - CCA workshop 4 - CCA workshop 5 - Monitoring and participatory impact assessment (PIA) - Monitoring and review of Conservation Agriculture (CA) experimentation - CA experimentation introduction (2nd round)	- Farmers with NGO support (Lima RDF)	- Tunnels and drip kits - Individual experimentation with basket of options - Conservation Agriculture
KZN	Ezibomvini, Eqeleni, Stulwane	- CCA workshop 1 - CCA workshop 2 - CCA workshop 3 - CCA workshop 4 (training) - Water issues workshops 1,2 - Water issues follow-up - CCA workshop 5 - Monitoring and review of CA experimentation - Fodder and supplementation learning process - Natural P&D control learning - Water issues continuation (Spring protection) - Strip cropping and CA experimentation continuation - Finalisation of tunnel experimentation	- CA open days, cross visits (LandCare, DARD, ARC, GrainSA), LM Agric forums,	- Tunnels (Quantitative measurements) - CA farmer experimentation (Quantitative measurements) – case studies - Individual experimentation with basket of options; monitoring review and re-planning - Livestock integration learning group and experimentation focus
KZN	Gobizembe, Mayizekanye, Ozwathini	- CCA workshop 1 - CCA workshops 2 and 3 - CCA workshop 4 - Monitoring, review and re planning - Monitoring of garden, tunnel and CA experimentation - PIA and Natural pest and disease control learning session - CA experimentation continuation, Mayizekanye open day	- CA open days - Umgungun dlovu DM agriculture forum	- CA farmer experimentation - Gardening level experimentation; tunnel, trench beds drip kits, etc.
	Madzikane, Ofafa, Spring Valley	- CCA workshop 1 - CCA workshops 2-4 - Set up of gardening and tunnel experimentation - Madzikane Forum open day – strip cropping and CA mechanisation. - Strip cropping and CA experimentation continuation	- CA open days - Madzikane stakeholder forum	- CA farmer experimentation - gardening level experimentation; tunnel, trench beds drip kits, etc

Limpopo	Sedawa, Turkey, Willows, Botshabelo, Santeng	- CCA workshop 1 - CCA workshop 2 - CCA workshop 3 - CCA workshop 4 - Water issues workshops 1-2 - Water issues follow-up - CCA workshop 5 - Poultry production learning and mentoring - CA learning and mentoring - Monitoring, review and re-planning - Soil and water conservation and small dams learning and experimentation - Monitoring of CA experimentation - Open day; Value adding and processing - PIA's (Mametja, Sedawa, Turkey) - Water Committees – boreholes and reticulation - CC impact and adaptation strategies workshop – new villages - CA experimentation continuation - PGS; Organic marketing and small business workshop	- Agroeco-logy network (AWARD/ MDF) - Maruleng DM	- Review of CSA implementation and re-planning for next season Tunnels (Quantitative measurements - CA farmer experimentation (Quantitative measurements) – case studies - Individual experimentation with basket of options - water committee, plan for agricultural water provision
Limpopo	Lepelle	- Water issues workshops 1-2	-	- Water committee, plan for agricultural water provision
Limpopo	Tzaneen (Sekororo-Lorraine)	- CCA workshop 1 - CCA workshop 2 - Assessment of farmer experimentation	Farmers learning group	- Tunnels and drip kits
EC Alice/ Middle drift area	Qumbu, berlin, Dimzaba, Qhuzini	- CCA workshop 1 - CCA workshop 2 - CCA workshop 3 - CCA workshop 4 and 5 - Monitoring, review and re-planning - Set up tunnel experimentation process - Learning sessions in CA, NP&D control and tunnel construction	Imvotho Bubomi Learning Network (IBLN) - ERLC, Fort Cox, Farmers, Agric Extension services, NGOs	- Monitoring and review of implementation of CSA practices and experimentation - Training and mentoring - CA, furrow irrigation, - Planning for further implementation and experimentation and quantitative measurements

5.1.2 Organisational capacity building

This consisted of a number of activities:

- Learning and mentoring for facilitators and interns in six Civil Society Organisations (MDF, AWARD, Lima, Seeds of Light, K2Cand Zimele), to understand and facilitate farmer level innovation processes for community level climate change adaptation
- Knowledge sharing in learning networks (the Adaptation network, the Agroecology network and the Imvotho Bubomi learning network)
- National workshop (AWARD). Building adaptation capacity, literacy and justice on climate change in the communities of South Africa 22-23 August 2019. The workshop was to share lessons learnt and provide a space for implementing organisations to network. Around 40 participants from Civil society, government and Universities. Presentation title: "Climate change adaptation decision support system for smallholders"

- National workshop (DARDLEA, CSAG) 6 August 2019. The development of a national risk and vulnerability framework: Learning from practice. Attended by a broad range on national stakeholders (around 60 participants) including Municipal and government officials, NGOs, Universities, consultants in the field. Presentation title: "Risk and vulnerability assessments for community level climate change adaptation"
- A pre-scoping workshop was held with a number of different agroecology stakeholders and a representative from the QCTO (Quality Council for Trade and Occupations) at the University of Johannesburg on the 4th of July 2019
- Rhodes University, learning and sharing workshop 7 October 2019. GEF5 Sustainable Land Management Project: Securing multiple ecosystems benefits through SLM in the productive but degraded landscapes of South Africa. Facilitation of a process for project team members to explore methodologies for vulnerability and impact assessments – using the WRC smallholder decision support process in CCA as a basis and
- A collaborative process was put in place with the Institute of Natural Resources to use the workshop methodology for exploration of climate change impacts and adaptive strategies as a way to discuss potential natural resources rehabilitation strategies to support the Umkomazi Restoration Project (Umgeni Water) pilot phase (2019-2021).

5.1.3 Post graduate students

Progress with ongoing studies:

- Mazwi Dlamini: M Phil – UWC_PLAAS. Registered in 2018. *Factors influencing the adoption and non-adoption of Conservation Agriculture in smallholder farming systems, and the implications of these for livelihoods and food security in Bergville, KwaZulu-Natal*
- Khethiwe Mthethwa: M Agric – University of KwaZulu-Natal. Registered in 2018. *The contribution of Climate Smart Agriculture (CSA) practices in adapting to climate change: The case of smallholder farmers in KwaZulu-Natal*

Both these candidates are to complete their studies in 2021.

Finalised post-graduate studies:

- Khethiwe Mthethwa: B Agric Honours – University of KwaZulu-Natal. November 2017. *Investigating the sustainability of adoption of conservation agriculture by small-scale farmers in Bergville.*
- Sanelise Tafa: MSc Agric Economics – University of Fort Hare. October 2017. *Farm level cost-benefit analysis of conservation agriculture for maize smallholder farmers in Okhahlamba Municipality in KwaZulu-Natal Province, South Africa*
- Palesa Motaung: M Soil Science – University of Pretoria. November 2020. *"Evaluating soil health of smallholder maize monocrops and intercrops using qualitative and quantitative soil quality assessment methods".*

5.1.3.1 Khethiwe Mtehthwa Abstract B Agric Honours

Farmers have gained necessary skills and knowledge to be able to sustain the adoption of CA (Conservation Agriculture), suggesting that farmers can stand on their own and continue to practice CA even in the absence of the CA promoters. It was also found that farmers who adopted CA are willing to share their experiences and knowledge with other farmers in the area. This increases the likelihood to expand the adoption of CA. More research needs to be done to find out communication strategies that can be used to communicate new innovations, which is technology and knowledge-intensive like CA. It is recommended that more research be undertaken to find out whether farmers are willing to extend mixed cropping in their plots. Further research also needs to be conducted to find out more about factors which have influenced small-scale farmers to abandon CA practices.

5.1.3.2 Sanelise Tafa Abstract MSc Agric Economics

On-farm economic benefits between conservation and conventional agriculture are not thought to be as pronounced. General inferences can be made, however, a comprehensive assessment of the net private benefits from greater use of conservation tillage is necessary. With the use of Gross Margin as well as appraisal indicators such as Net Present Value, Benefit Cost Ratio and Internal Rate of Returns, the study revealed that there are more incentives for adoption of conservation agriculture over conventional agriculture. The study therefore recommends that the promotion of conservation agriculture should be encouraged and this is promising more incentives in the long-run.

5.1.3.3 Pales Motaung Abstract M Soil Science

Soil quality (SQ) is often used interchangeably with soil health and is considered as an indicator of sustainable land management. The manner in which a soil is managed can bring about changes to biological, chemical and physical SQ. SQ cannot be measured directly so we measure SQ indicators. Conservation agriculture (CA) is proposed as one of the practices that can be employed to improve soil health of degraded lands.

The aim of this study was to conduct visual and analytical soil quality assessments using biological, chemical and physical SQ indicators. SQ was measured and compared on 3 treatments including maize only (M), maize + beans (M+B) and veld samples to establish the ideal cropping system.

The study further aimed to interpret SQ results using the quantitative Cornell Soil Health Manual (Cornell soil quality index (SQI)) and Soil Management Assessment Framework (SMAF) SQ indexes and the qualitative Mahlathini Visual Soil Assessment Health Manual (VSA) to provide a SQ score. Lastly, the ability of the VSA to accurately indicate SQ was established through comparison to SQ ratings obtained from the quantitative SQ indexes

Five farmers' plots, with 3 separate treatments arranged in a random block design were evaluated for SQ. Soil samples were taken to determine the role of CA on SQ in the Stulwane area. The veld treatment was used as a bench mark. The M and M+B were each under seasonal rotation either with beans (B), maize + cowpeas (M+C), M or M+B.

Results were interpreted using the quantitative Cornell SQI and SMAF SQ indexes and the qualitative Mahlathini VSA to provide a SQ score. Correlation analyses were utilised to establish the relationship between visual and analytical SD methods.

The study found that M exhibited better biological, chemical and overall SQ than the M+B intercrop. Furthermore, the M SQ results were often-times comparable to the veld samples which exhibited the highest SQ overall.

The VSA indicated that all the plots have moderate SQ with Veld > M > M+B. The Cornell SQI indicated that the veld and M plots have good SQ while the M+B exhibited medium SQ. The SMAF evaluation showed that all the treatments exhibit good SQ with M > veld > M+B.

Correlation analyses revealed that the VSA is weakly correlated to both the Cornell SQI and the SMAF at an insignificant level. The Cornell SQI and SMAF were each moderately and positively correlated to the soil biological quality (SBQ).

The M plots may have benefited from the rotations from previous seasons while the M+B, although also under rotation, may have suffered due to increased competition for resources during the comparatively dry year (526 mm) preceding and leading up to sampling. These findings reiterate the variable nature of CA and its reliance on prevailing climate for success.

Adoption and implementation of CA should be carefully designed to suit the prevailing conditions of the area under consideration. Good SQ can be experienced under maize monocultures over maize intercropping provided that the maize monoculture is under consistent rotation. VSA's may not always be correlated with quantitative SQ indexes but may still provide a reliable indication of SQ.

5.2 NETWORKING AND CONFERENCES

5.2.1 Presentations at conferences and seminars

- 2nd African Conservation Agriculture Conference (2 ACCA) 9-12 October 2018. Presentation titles for E Kruger: *"Doing Conservation Agriculture the Innovations Systems way"* and *"Soil health aspects of CA in smallholder farming systems in South Africa"*
- National Climate Change Committee Stakeholder Forum 11 November 2018. Presentation title *"Community Based Climate Smart Agriculture"*
- Agroecology network workshop 22 November 2018. Presentation title by E Kruger *"Agroecology best practices in CCA"* and by Betty Maimela "*Taking stock – Linking Mahlathini farmers to markets"*
- The Virtual Irrigation Academy (VIA) conference 13 June 2019, Hosted by the University of Pretoria. Presentation titles: *"Farmer level experimentation and use of chameleons for irrigation scheduling"* by E Kruger and "*Farmer experimentation and learning"* by Samukelisiwe Mkhize
- The Maize Trust 17 June 2020. Hosted by MDF. Presentation and field visit to Bergville: *" Climate change adaptation using Conservation Agriculture approaches appropriate to smallholder farmers"*
- Agroecology Network: Agroecology smallholder farmers open Day.12 March 2019. Hosted by AWARD and MDF
- Fourth Ukulinga Howard Davis Memorial Symposium 20-21 August 2019. Developing resilience through partnerships and collaboration. Hosted by UKZN. Presentation title*:" A smallholder level decision support system improves resilience to Climate Change"* and
- Okahlamba Land and Agriculture Summit 27 October 2019. MDF worked collaboratively with the KZNDARD (Mr Harland Wood) to present a paper called: *"Climate change, adaptive strategies and a success story in the Okahlamba municipality – Climate Resilient Agriculture implementation by smallholder farmers".*

5.2.1.1 Awards

- LandCare: Best Civil Society Organisation in LandCare, 2018
- 2 ACCA Conservation Agriculture Champion award 2018
- AFSA biannual food systems celebration: Best Southern African Film award October 2020

5.2.1.2 Videos (Available on www.mahlathini.org/resources/videos/)

- Xumbu Primary School Climate Change Adaptation presentation
- Lepelle water issues community video
- Sedawa water issues community video

5.2.2 Webinars

- 17 June 2020. Host; AWARD. Title; Building networks and skills for climate change preparedness with small-scale farmers in the Olifants' River Catchment. Section presentation by E Kruger: *"Agroecology learning, mentoring, monitoring and networking for smallholder farmers in the Lower Olifants"*
- 19 June 2020: Host; The Integra Trust. Title; Heal the land, heal the people. Section presentation by E Kruger: *"COVID-19, climate change resilience and regenerative agriculture in smallholder farming systems"*
- 23 November 2020: Host; The Adaptation Network. Title; Nature Based Solutions. Section presentation by E Kruger: *"Implementation strategies for nature-based solutions for smallholder farmers"*

5.3 PUBLICATIONS

- Water Wheel:
  - "A smallholder farmer level decision support system for climate resilient farming practices improves community level resilience to climate change. No 1: community climate change adaptation process design" (November 2019)
  - "A smallholder farmer level decision support system for climate resilient farming practices improves community level resilience to climate change. No 2: Impact of climate resilient practices on rural livelihoods" (December 2019)
  - "A smallholder farmer level decision support system for climate resilient farming practices improves community level resilience to climate change. No 3: The smallholder farmer CRA decision support system" (February 2020) and
- In Press: CAB International: Conservation Agriculture in Africa. Chapter 21 "*CA Innovation Systems build climate resilience for smallholder farmers in South Africa*", by Erna Kruger, Hendrik Smith, Phumzile Ngcobo, Mazwi Dlamini and Temakholo Mathebula.

6 References

Care International, 2009. *Climate Vulnerability and Capacity Analysis Handbook..* [Online] Available at: https://careclimatechange.org/tool-kits/cvca/

Christian Aid, 2018. *briefing: time fo climate justice.* [Online] Available at: https://www.christianaid.org.uk/resources/about-us/time-climate-justice [Accessed 20 August 2020].

DEA and SANBI, 2016. *Strategic Framework and Overarching Implementation Plan for Ecosystem-Based Adaptation (EbA) in South Africa 2016-2021.* Department of Environmental Affairs, Pretoria, South Africa.

Department of Agriculture, Fisheries and Forestry, 2013. *Climate Change Sector Plan for Agriculture Forestry and Fisheries (CCSP)*

FAO, 2013. *Climate Smart Agriculture Source Book.* Rome, Italy: Food and Agriculture Organisation of the United Nations.

FAO, 2020. *Climate smart agriculture.* [Online] Available at: http://www.fao.org/climate-smart-agriculture/en/ [Accessed 20 August 2020].

IFAD, 2016. *Climate Resilient Agriculture development: Scaling up note.* [Online] Available at: https://www.ifad.org/documents/38714170/40264252/climate_sun.pdf/15655fe0-d06f-434e-b4ea-df9017c93ef2 [Accessed 20 August 2020].

Lotz-Sisitka, H. and Pesanayi, T., 2019. *Mediation Processes to support systems approaches to knowledge flow in Water for Food Social Learning Networks. Rhodes University, South Africa.,* Pretoria, South Africa: WRC Project No K5/2713/4. Project Title: Amanzi [water] for Food': Developing a social learning network approach to knowledge dissemination and uptake in the agricultural learning system.

NDRC, 2020. *Climate Change and Agriculture: Improve climate resilience and soil health.* [Online] Available at: https://www.nrdc.org/issues/improve-climate-resilience-and-soil-health

Rusere, F., Mkuhlani, S., Crespo, O. & Dicks, L., 2019. Developing pathways to improve smallholder agricultural productivity through ecological intensification technologies in semi-arid Limpopo, South Africa. *African Journal of Science, Technology, Innovation and Development,* Volume 11(Issue 5), pp. 543-553.

Thierfelder, C. Baudron, F., Setimela, P.,Nyagumbo, I., Mupangwa, W., Mhlanga, B., Lee, N. and Gerard, B. 2018. Complementary practices supporting conservation agriculture in Africa. A review. Agronomy of Sustainable Development, Volume 38:16.

UNFCCC, 1999. *Compendium of Decision Tools to Evaluate Strategies for Adaptation to Climate Change. Final report.* Bonn Germany. UNFCCC Secrateriat.

Ziervogel, G., New, Mark; Archer van Garderen, E., Midgley, G., Taylor, A., Hamann, R., Stuart-Hill, S., Myers, J. and Warburton, M. 2014. Climate change impacts and adaptation in South Africa. *WIRE's Clim change*.