Volume 1

ACTIONABLE GUIDELINES FOR THE IMPLEMENTATION OF CLIMATE SMART AGRICULTURE IN SOUTH AFRICA

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ABOUT THE STUDY

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EXECUTIVE SUMMARY

South Africa has adopted the principle of green economic growth, and has identified agriculture as one of the key sectors that will contribute towards the green economy (CSIR, 2014). Agriculture, and crop production in particular, can potentially contribute towards a low carbon, climate resilient and resource efficient growth path for South Africa. The realization of this potential is, however, threatened by changing climatic conditions caused by the global climate change.

Climate change projections for South Africa indicate increased temperatures across the country, an increase in precipitation in some parts of the country and a decline in precipitation in other parts; as well as increases in the magnitude and frequency of extreme events such as floods and droughts (Lumsden *et al*., 2009). The effects of climate change include increases in temperatures, reduced rainfall and water scarcity which will significantly impact agricultural systems in South Africa. Major impacts include reduction in the amount of land suitable for both arable and pastoral agriculture, the reduction in the length of the growing season and decrease in crop yields. Climate Smart Agriculture (CSA) is now widely promoted as the best approach for addressing both the causes and effects of climate change.

This review of literature was carried out to establish the status of climate smart agriculture (CSA) practices in South Africa to provide a basis for the development of actionable CSA guidelines for use in the rollout of CSA in South Africa and contribute to the country's transition to an all-inclusive green economy.

The review was conducted under three thematic areas, namely (i) CSA practices, (ii) CSA value chains, and (iii) CSA enabling environments. The CSA practices are inclusive of soil and water management, crop production, urban agriculture, and range management.

The value chains included: agro-processing and marketing. Aspects included under the CSA enabling environment were: climate information services, weather-indexed insurance, CSA knowledge dissemination, gender and social inclusion, CSA policies, institutional arrangements and infrastructure. The findings are summarized hereunder.

Practices

Soil and Water Management

The review of soil fertility management strategies revealed that maintaining or improving soil health is essential for sustainable and productive agriculture. It further indicated that the use of mineral fertilizers as a source of nutrients for plant growth is still critical for increasing productivity. However, chemical fertilizers adversely affect the health of naturally found soil microorganisms by adjusting the soil pH. Conventional farming practices that use chemical fertilizers alone should, therefore, be replaced with integrated soil fertility management (ISFM) approaches that combine optimally applied fertilizers with organic resources. The combination of conservation agriculture (CA) and ISFM has been found to be especially effective in the restoration of soil health and productivity whilst mitigating the emissions of greenhouse gases. This approach should, therefore, be vigorously promoted for widespread adoption. Conversion to organic farming, where possible, should be the ultimate objective as it has superior soil regeneration potential, while adapting to and mitigating climate change. Actionable guidelines are, therefore, needed for ISFM and organic soil fertility management strategies.

Soil water management

Climate change will alter the amount of precipitation and distribution, evaporation, runoff, and soil-moisture storage, whereas higher temperatures can lead to an increase in evaporation and crop water requirements in SA. Field rainwater conservation practices are a way forward to build resilience against climate change and variability through increasing productive use of green water (rainwater stored in the soil as soil moisture) to increase crop yield, while reducing water loss in the form of runoff and evaporation, and soil erosion. This can be achieved through introducing different climate smart agricultural water management practices that include in-field water harvesting, ex-field water harvesting; roof water harvesting and increasing infiltration capacity through improving the physical quality of soil. Some soil water management practices that can be used for adapting farming to climate change in SA are highlighted in this review. In-field rainwater harvesting (IRWH) practices such as no-till, minimum tillage, mulching, conservation agriculture, contour farming, raised beds, ridges, basin tillage, crop rotation, proper weed control, crop and cultivar selection and terraces constructed within the field are crucial to increase rainwater productivity as adaptation strategies to climate change. These IRWH practices increase infiltration and reduce runoff, evaporation and soil erosion. Ex-field rainwater harvesting practices such as jessour, cisterns, ponds, liman and stone dams which are listed in Table 2 and Table 3 (Chapter 3) can be used to trap rainwater that is lost in the form of runoff. Where irrigation is practiced, water use efficiency can be improved through the use of irrigation scheduling tools. The tools can be plant-based such as drone sensors or soil-based like the wetting front detectors (WFD) and Chameleon sensors (CS). Guidelines are needed on IRWH practices for rain-fed cropping and irrigation scheduling tools to help small-scale farmer to improve water use efficiency and adapt their farming to the effects of climate change and variability.

Cereal Based cropping systems

The Cereal-based cropping systems review revealed that information on no-till and conservation agriculture (CA) for smallholder and commercial farmers is available to feed into the CSA guidelines development. Guideline templates produced by Grain SA have been used for the actionable guidelines. Research is needed on varieties suitable for CA and intercropping systems, and cover crops to support growers in different agro-ecologies. More research funds need to be availed by government and private sectors to support regular agronomic work, especially long-term research. The focal point for support should be at provincial levels and work could include screening cover crops, agronomic management in different production situations, screening varieties for intercropping etc. Implementation of climate smart agriculture requires collaborative action from various stakeholders for effective implementation. The partnership of the Western Cape Department of Agriculture (WCDoA) and Stellenbosch University is an excellent example of where government and research institutions, together with cereal producers have collaborated to implement climate smart practices to improve small grain production in the Western Cape province. This could be a model for other provinces and institutions to follow in the implementation of climate smart agriculture in cereal based cropping systems in their provinces.

Sugar cane production

The sugar industry has been actively involved in the development and perfecting of numerous CSA practices through its research arm, the South African Sugar Research Institute (SASRI). The research and development is done under the thematic areas of variety improvement, crop protection, crop performance and management, and systems design and optimization. Outputs from the research programmes are transformed into practical knowledge and technology products. Recommendations for the application/uptake of better management practices (BMP) are made through the Sustainable Sugar Cane Farm Management System (SUSFARMS) to encourage the adoption of the BMPs. Implementation of the SUSFARMS® concept has been steadily expanding over the years, and it is recognised internationally. The concept is enabling the industry to comply with international sustainability standards, such as Bonsucro.

Fruit and wine Industries

The fruit and wine industries have identified several applicable adaptation and mitigation strategies. Adaptation options that are being implemented are divided into three main categories, namely: i) planning for climate change and variability; ii) sustainable / adapted soil and water management; and iii) sustainable / adapted crop management. Each of these broad categories is divided into numerous specific activities. Planning for climate change and variability is further divided into the following: weather, fire and pest monitoring systems; use of weather forecasting; disaster risk reduction and management; and, insurance and risk management. Sustainable / adapted soil and water management is further divided into the following: irrigation technology and scheduling; conservation agriculture; and, new sources of water for irrigation; Sustainable / adapted crop management is further divided into the following: crop breeding and cultivar development; site specific cultivar choice; biotechnology for adaptation of crops; and, technologies to manage rising temperatures. Mitigation of greenhouse gas (GHG) emissions can be enhanced through widespread use of a carbon calculator tool developed through the confronting climate change (CCC) project. Use of non-renewable energy in the form of solar and wind farms holds a lot of promise in minimising emission of GHGs. Adoption of these CSA practices enables farmers to be compliant with increasing consumer and retailer pressure for sustainable value chains. Use of fair labour practices and adoption of sustainable farming practices is being achieved through compliance with the Sustainability Initiative of South Africa (SIZA). The SIZA is aligned to global best practices such as the Sustainable Agriculture Initiative (SAI) Platform Farm Sustainability Assessment (FSA) tool and Global Gap. Farmers with SIZA certification can therefore export their produce anywhere in the world.

Urban Agriculture

The review on urban agriculture has revealed that approximately 60% of the South African population reside in urban and peri-urban environments (Davis, 2017), which creates food security and environmental challenges. People are adapting to this situation by engaging in urban agriculture which helps to green the urban environment whilst providing food and income for its residents.

Urban agriculture contributes to climate mitigation through moderating temperature, carbon sequestration and stabilizing soil physical properties. It is practiced in many South African cities and townships, mostly as home or community gardens. It however, faces problems of open land shortage and irrigation water scarcity.

This review has identified a clear need for adopting water and space saving strategies in urban areas through the use of environmentally friendly technologies. Possibilities include the use of rooftop farming, greenhouse production systems, hydroponic techniques, greywater recycling, composting, and renewable energy (solar and wind power). Urban agriculture started informally but it has now reached a stage whereby it requires formal recognition by Government and inclusion in its plans so that it can get the support it needs to make it a smart solution for urban food security as well as climate change mitigation.

Rangelands management

Rangelands cover approximately 72% of the total land area of South Africa (Tainton 1999) making them the largest single land use. Their proper management will have a huge impact on the greening of the country. South African rangelands have significant sensitivity and vulnerability to climate change effects that warrant intervention in the form of climate smart agriculture adaptive measures. Areas under commercial ranch and wild life production systems have lower levels of vulnerability, while areas under communal land use have relatively high levels of vulnerability. The holistic range livestock management is recommended as a CSA practice for South African rangelands to be implemented, especially in the communal rangeland systems.

Value chains

Agro-processing

The Agro-processing industry in South Africa is well developed but in the hands of a few companies that control it. This has made it difficult for small and medium enterprises to enter the value chains because of the lack of skills, finances and contracts with the main market players.

To create a more inclusive economy and to catalyse development in rural areas the government has come up with initiatives such as the Agri-Parks to bring agro-processing closer to production areas.

This will bring about reduction in post-harvest losses, transport costs and greenhouse gas emissions associated with transport. Implementation of the Agri-Parks is still underway and the need for guidelines to ensure sustainability is imperative. In the current environment of climate change and dwindling natural resources agro-processing activities have to be carefully planned and monitored. The planning should include measures to mitigate against greenhouse gas emissions such as the use of renewable energy sources in the agro-processing activities.

Since not all food produced in rural areas can be preserved at the Agri-Parks, attention should also be given to home preservation of food. Indigenous knowledge and new technologies for home preservation should be emphasized in communities to reduce waste and improve food security. Therefore, actionable home preservation guidelines to guide the implementation of home preservation in rural areas are needed.

Marketing

Adoption of CSA in the productive sectors of agriculture will result in increased productivity. This will not be a problem in the commercial farming sector which is already well connected to marketing channels. This is, however, not the case for the smallholder farming sector where marketing channels are not well developed. The planned introduction of Agri-Parks which will include a Rural Urban Marketing Centre (RUMC) and a Farmer Production Support Unit (FPSU) in District Municipalities highlighted in the review, will contribute to the alleviation of the marketing problem. These units will act as centres of marketing services from controlling input supply, logistic support, grading and packaging as well as auctions amongst others. The RUMC and FPSUs can act as CSA information conduits since they are (i) established in each district within the country thus making access to farmers and markets easier, and (ii) are involved in marketing functions, and thus can positively contribute towards CSA marketing. However, the initiative still lacks a clear framework as to how CSA initiatives can be incorporated in the whole marketing system relative to the productive subsystem. These initiatives include the possibility for group marketing which will improve market access, economies of scale, agri-business contracts and access to agricultural technologies, and thus adoption of CSA practices.

Enabling environments

Climate information services

Climate information services (CIS) are critical for effective risk management and achievement of CSA objectives. The CIS review revealed that South Africa is generating substantial CISs, but improvements are needed to ensure that timely advisories are effectively disseminated to farmers. Five challenges that confront efforts to use climate-related information to improve the lives of smallholder farmers were identified to be:

⇒ salience,
⇒ access,
⇒ legitimacy,
⇒ equity, and
⇒ integration.

These challenges have to be overcome for effective provision of CISs in South Africa. They informed the development of the operational climate services for smallholder farmers in South Africa.

Weather index based insurance (WII)

The ability of smallholder farmers to bounce back and make investments after experiencing a weather related shock will be improved upon by availability of appropriate agricultural insurance. Insurance products currently available in South Africa are not suitable for smallholder farmers, due to high cost. WII is a viable option though it is not yet available in the country. SAIA's Agriculture Insurance Forum has previously proposed models for launching WII, and they are currently doing further research on it. Though, government has not made a commitment to fund WII, their future intention to support it has been expressed through the draft Framework on Climate Smart Agriculture which was gazetted for public comment on the 3rd of August 2018. The government and private insurance providers in South Africa should take advantage of public sector insurance initiatives to launch and finance WII. Such initiatives include: The G7 Initiative on Climate Risk Insurance ("InsuResilience"); African Risk Capacity (ARC); Climate Risk and Early Warning Systems (CREW); and, the Global Index Insurance Facility (GIIF). It is therefore possible for South Africa to fill the existing gap in agricultural insurance. Launching an efficient WII facility will enable vulnerable smallholder farmers to reduce and manage risks associated with climate change.

CSA knowledge dissemination

CSA/CA in South Africa has been taken up by large-scale commercial farmers at a rapid pace when compared to small-scale farmers whereby the uptake has been slow and at times halting. Large-scale commercial farmers have shown their ability to adopt and adapt CSA/CA spontaneously, which could be attributed to support received from industry bodies and government. There is, however, little evidence of spontaneous uptake of CSA/CA among small-scale farmers even where there was government and donor partner support for CSA/CA. This could be related to the fact that very little attention has been given to promoting uptake of CSA, to date, in South Africa. As the momentum for promoting CSA/CA uptake increases those involved must consider lessons from elsewhere where the uptake of CSA/CA has been successful.

One key advantage that large-scale farmers have over small-scale farmers when considering whether or not to take up CSA, is the capacity and inclination to experiment, learn and adapt. Therefore, assisting small-scale farmers to do the same may be a good strategic option to consider. This could be achieved with the Farmer Field School approach, exemplified by the CA Farmer Innovation Programme for Smallholders described in this report. It must be borne in mind that CSA/CA is not a set of techniques that can simply be taught, but is a 'mind-set' to be cultivated and nourished over a sustained period. Therefore, it is recommended that the CA Farmer Innovation Programme for Smallholders be used as a model on the basis of which a core of government extension officers could be empowered to promote CSA/CA. These trained extension officers could then be used to rollout CSA/CA among smallholder farmers and perhaps with a commencement of a selected number of pilot projects in a number of provinces.

Gender and social inclusiveness

CSA has much to offer women farmers. However, based on the evidence from other African countries, much depends on the circumstances of particular women farmers, as well as the specific elements of the CSA/CA package that they are trying to adopt. In order to encourage CSA uptake by women, the implications of the technology for women's financial and time resources ought to be taken into account.

The environment for promoting CSA among women farmers is reasonably conducive in South Africa. The widely accessed social grants, for example, provides a safety-net, in the absence of which fewer women would probably be willing to venture into CSA. The major shortcoming of the South African environment is the lack of a functional mechanisation policy, in the absence of which many low-income women farmers would only be able to consider relatively labour-intensive forms of CSA/CA, which would likely limit their willingness to take it on, or the benefits from having done so.

Conclusions

This situation analysis has revealed that information on different CSA practices is available to feed into the actionable CSA guidelines. The practices reviewed and found to be feasible for the implementation or enhancing of CSA in South Africa were developed into actionable CSA guidelines described in volumes 2 and 3 of the CSA Guideline report. It should, however, be noted that most of the CSA practices are knowledge intensive so any guides produced should be viewed as work in progress to be improved upon as more academic and experiential knowledge is generated.

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AATF	African Agricultural Technology Foundation
ACDI	African Climate & Development Institute
AFIS	Advanced Fires Information System
AFOLU	Agriculture, Forestry and Other Land Use
AGRA	Alliance for a Green Revolution in Africa
API	Application Programming Interface
ARC	Agriculture Research Council
ARC-GCI	Agricultural Research Council-Grain Crop Institute
ARC-ISCW	Agricultural Research Council-Institute of Soil, Climate & Water
ARC-PPRI	Agricultural Research Council-Plant Protection Research Institute
ARC-SGI	Agricultural Research Council-Small Grains Institute
BBF	Broad Bed and Furrow
BMP	Better Management Practice
CA	Conservation Agriculture
CA-FIP	Conservation Agriculture-Farmer Innovation Programme
CARWG	Conservation Agriculture Regional Working Group
CCC	Confronting Climate Change
CEEPA	Centre for Environmental Economics & Policy in Africa
CGA	Citrus Growers Association of Southern Africa
CIF	Climate Insurance Fund
CIMMYT	International Wheat & Maize Improvement Centre
CIS	Climate Information Services
CLIP	Crop Livestock Intensification Project
CPSI	Centre for Public Service Innovation
CREW	Climate Risk and Early Warning Systems
CSA	Climate Smart Agriculture
CSAG	Climate Systems Analysis Group
CSIR	Council for Scientific and Industrial Research
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Department of Environmental Affairs
DFID	Department for International Development
DTMA	Drought Tolerant Maize for Africa
EWS	Early Warning System
ERWH	Ex-field rainwater harvesting
EU	European Union
FAO	Food and Agriculture Organisation
Fertasa	Fertilizer Association of Southern Africa
FSSA	Fertilizer Society of South Africa
FPSU	Farmer Production Support Unit
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Green House Gases
GIIF	Global Index Insurance Facility
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
INDC	Intended Nationally Determined Contribution
IMAS	Improved Maize for African Soils
IPCC	Intergovernmental Panel for Climate Change
IRWH	In-field rainwater harvesting
ISFM	Integrated foil fertility management
KARI	Kenya Agricultural Research Institute
KSA	Key Strategic Area
LDC	Less Developed Countries
LTAS	Long Term Adaptation Scenario
MFP	Mahlatini Development Foundation
NAC	National Agro-Meteorological Committee
NARES	National Agricultural Research and Extension Systems
NDP	National Development Plan

NCATF	National Conservation Agriculture Task Force-Malawi
NCCRP	National Climate Change Response Policy
NGO	Non-Governmental Organisation
NLP	National LandCare Programme
OPV	Open Pollinated Variety
RRWH	Rooftop rainwater Harvesting
SA	South Africa
SADC	Southern Africa Development Community
SADLF	Southern Africa Drought & Low Soil Fertility Project
SAG	SWITCH Africa Green
SAGIS	South African Grain Information Service
SAIA	South African Insurance Association
SANSOR	South African National Seed Organisation
SASA	South African Sugar Association
SASRI	South African Sugarcane Research Institute
SAWS	South African Weather Service
SGP	Small Grants Programme
SMS	Short Message Service
SPIS	Solar powered irrigation systems
SSA	Sub-Saharan Africa
SSDC	Sandy Soils Development Committee
SSG	Small Scale Grower
STATS SA	Statistics South Africa
SUSFARMS®	Sustainable Sugarcane Farm Management System
UCT	University of Cape Town
UFH	University of Fort Hare
UFS	University of the Free State
UKZN	University of KwaZulu-Natal
UNFCCC	United Nations Framework Convention for Climate Change
UNIVEN	University of Venda
UP	University of Pretoria
US	United States
USAID	United States Agency for International Development
WAMIS	Wide Area Monitoring Information System
WC	Western Cape
WCDoA	Western Cape Department of Agriculture
WC DEA& DP	Western Cape Department of Environmental Affairs & Development Planning
WEMA	Water Efficient Maize for Africa
WESSA	Wildlife and Environment Society of Southern Africa
WII	Weather Index-Based Insurance
WPS	Wind-powered systems
WRC	Water Research Commission
WUE	Water Use Efficiency

Definitions

Acidic soils	Soils with a pH below 7.
Alkaline soils	Soils with a pH above 7.
Agronomy	The use of science to manage soils and crops to produce food, fuel and fibre.
Agronomic efficiency	The difference between yield in a control plot and in a plot supplied with a particular nutrient divided by the amount of the given nutrient applied.
Biological nitrogen fixation	A process by which nitrogen (N_2) in the atmosphere is converted into ammonium (NH_4^+) by nitrogenase a biological catalyst found naturally in the symbiotic Rhizobium.
Blanket fertilizer recommendation	Generally applicable fertilizer use rates that do not consider variability in soils, farm management and climate.
Crop rotation	A practice of growing different crops in the same area in different seasons.
Crop residues	The part of the crop biomass that is left when the grain or tuber has been removed.
Commercial farming	A large scale production of crops and animals for sale.
Fertilizer	Any natural or manufactured material, which contains at least 5% of one or more of nitrogen, phosphorus and potassium.
Foliar application	Application of soluble fertilizer in the form of a spray on the foliage of plants.
4R Nutrient Stewardship	Is a way to increase crop yields, profits and environmental benefits by ensuring the ***Right fertilizer source***, is used at the ***Right rate***, at the ***Right time*** and in the ***Right place***.
Hybrid seed	Is seed produced by cross pollinated plants created to breed a desired trait or characteristic, the crosses are specific and controlled.
Harvest index	The ratio of grain/tuber to total biomass production.
Green manure	A green manure crop is grown for a specific period, and then ploughed under and incorporated into the soil when still green.
Integrated Plant Nutrition	Combined use of mineral and organic fertilizers to address site and soil specific deficiencies for improved crop productivity.
Limiting nutrient	Single nutrient that is in short supply that limits crop growth.
Nutrient deficiencies	Demand for nutrients is greater than the soil supply resulting in reduced or impaired plant growth.
Open pollinated variety (OPV)	Seed produced when pollination occurs by insect, bird, wind, humans, or other natural mechanisms. Due to lack of restrictions on the flow of pollen between individuals, open pollinated plants are more genetically diverse.
Organic farming	The FAO/WHO Codex Alimentarius Commission defines organic agriculture as a holistic production management system which promotes and enhances agro ecosystem health, including biodiversity, biological cycles and soil biological activity. It emphasises the use of management practices in preference to the use of off farm inputs. This is accomplished by using, agronomic, biological, and mechanical methods, as opposed to using synthetic materials, to fulfil any specific function within the system.
Rhizobia	Bacteria present in the soil that form root nodules with compatible legume plants and are able to fix atmospheric nitrogen (N_2) within the nodules.
Rhizobia inoculation	The process of applying commercially produced Rhizobia to legume seed or to the soil where legume seed will be planted to introduce compatible and effective symbiotic bacteria and improve nodulation and biological nitrogen fixation.
Soil fertility	refers to the ability of the soil to make plant nutrients available to growing plants.
Soil fertility gradients	Differences in soil fertility caused by differences in crop management (e.g., application of organic and mineral fertilizers) within a farm over the long term.
Soil pH	Soil pH is a measure of the acidity or alkalinity in soils.
Soil Texture	The amount of sand, silt and clay in the soil.
Spilt application	Is the application of the desired amount of fertilizer two or three times during the growing season as opposed to a single application.
Spot application	When fertilizer is applied to each planting hill.
Subsistence farming	The farmer only grows or produces enough to feed his or her family, often suffer food deficits.

1.1 Introduction

South Africa has adopted the principle of green economic growth, and has identified agriculture as one of the key sectors that will contribute towards the green economy (CSIR, 2014). Agriculture, and crop production, in particular, can potentially contribute towards a low carbon, climate resilient and resource efficient growth path for South Africa. The realization of this potential, however, is threatened by changing climatic conditions caused by the global climate change. This threat is underscored in the recently released special report by the United Nations Intergovernmental Panel for Climate Change (IPCC) (IPPC, 2018).

The report presents key findings on the implications of a global warming of 1.5°C as well as a comparison between a global warming of 1.5°C and 2°C above pre-industrial levels. According to Scholes (2018), the climate situation is already worse in southern Africa than in most other regions of the world. While the global average air temperature has risen by nearly 1°C since accurate weather records began a little over a century ago, in southern Africa temperatures have risen on average by twice this amount indicating that southern Africa crossed the 1.5°C warming level some years ago. This scenario calls for urgent interventions in all sectors of the economy to mitigate the emissions of greenhouse gases (GHGs) and to adapt to the effects of climate change.

In the agriculture sector, Climate Smart Agriculture (CSA) is now widely accepted as the best approach for addressing the effects of climate change in agriculture. It is defined as agriculture that sustainably increases productivity, resilience (adaptation), reduces/removes greenhouse gases (mitigation), and enhances the achievement of national food security and development goals. CSA promotes the transformation of agricultural systems and requires the transformation of agricultural policies to increase food production, to enhance food security, to ensure that food is affordable (low input-cost) while ensuring sustainable natural resource management and resilience to a changing climate.

A scoping study by Mnkeni and Mutengwa (2014) revealed that South Africa acknowledges the reality of climate change and has articulated a response to this challenge in the form of a "National Climate Change Response Policy" (NCCRP) published in 2011 (DEA, 2011). The policy highlights the need for the Agriculture, Forestry and Other Land Use (AFOLU) sector to invest in, and improve on, research into water, nutrient and soil conservation technologies and techniques, climate-resistant crops and livestock, as well as agricultural productivity in line with the National Development Plan (NDP) and 2030 Sustainable Development Goals (SDGs). The policy further highlights the need for financing models to promote the development of climate-smart agriculture that lowers agricultural emissions, is transitioning towards a low carbon sector, is more resilient to climate changes, and boosts agricultural production.

While there is a considerable body of knowledge on CSA in South Africa (Mnkeni and Mutengwa, 2014), there is a lack of practical guidelines for its implementation. The aims and objectives of this situational analysis are to review the current status of CSA in South Africa to provide a basis for:

Developing detailed guidelines for the implementation of CSA activities in South Africa, and Generating a policy brief on CSA to serve as a quick reference document for policy makers.

1.2 Background

South Africa has a dual agricultural economy, with both well-developed commercial farming and more subsistence -based production in rural areas. It has a land area of approximately 1.2-million square kilometres. Over ten percent (13.7%) of this land is potentially arable, 68.6% is grazing land, 9.6% is protected for nature conservation, 1.2% is under forestry and 6.9% is used for other purposes (Mukheibir and Sparks, 2006).

Of the arable portion, 2.5 million hectares is in the former homelands and is primarily used for subsistence/small-scale farming, while 14.2 million is used for commercial agriculture. Agricultural activities range from intensive crop production and mixed farming in winter rainfall and summer rainfall areas to cattle ranching in the bushveld and sheep farming in the arid regions.

Grains and cereals are South Africa's most important crops, occupying more than 60 percent of the land under cultivation. Maize (*Zea mays L.),* the country's most important crop, is a dietary staple, a source of livestock feed, and an export crop.

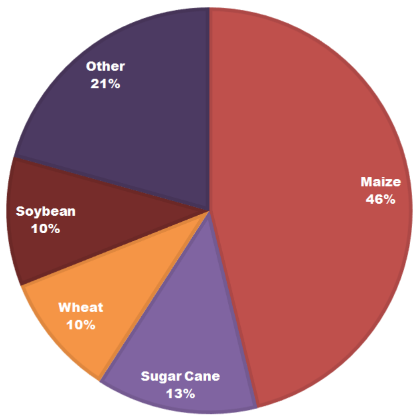


Figure 1.1: Contribution to the gross value of feed crops
Source: *DAFF, 2018.*

Another emerging farming system is urban agriculture. This is a form of subsistence agriculture that is increasingly being practiced in urban and peri-urban areas including areas around informal settlements. It is estimated that more than 60% of the South African population lives in urban or peri-urban settlements (Davis, 2017) implying that urban agriculture could play a significant role in improving urban food security whilst greening the urban and peri-urban environments.

There are several possible entry points for initiating CSA programmes or enhancing existing activities. For practical convenience the entry points are grouped under three thematic areas: (i) CSA practices, (ii) CSA value chains, and (iii) Enabling environments for CSA. The CSA practices include soil management, water management, crop production (cereal production, sugar production, fruit and viticulture production), urban agriculture, and range management.

The CSA value chains will include agro-processing, and marketing. The CSA enabling environments will include climate information services, weather indexed-based insurance, CSA knowledge dissemination, gender and social inclusion, policy engagements, institutional arrangements, and infrastructure. This situational analysis, therefore, sought to establish the current status of CSA implementation in South Africa in relation to the above entry points and the climate change adaptation and mitigation scenarios under consideration, in the country. Where applicable case studies at national, continental, and global level are highlighted.

The review paved the way for the development of actionable CSA guidelines considered necessary for the implementation of CSA in South Africa and contribute to switching the country.

2.1 Introduction

Soils are a fundamental agricultural resource and when these become degraded, farmers get caught up in a vicious cycle of poverty and food insecurity, compromising their ability to live healthy and productive lives. The productivity of land in Africa has been steadily decreasing due to land degradation. The major causes of the land degradation are unsustainable agricultural practices, such as; farming on steep slopes without sufficient use of soil and water conservation measures, mono-cropping, excessive tillage, or declining use of fallow without appropriate replenishment of soil nutrients, burning of crop residues, conversion of forests, woodlands and bushlands to permanent agriculture, or their excessive exploitation through fuelwood and timber harvesting, overgrazing of rangelands, and lack of proper soil organic matter management (FiBL, 2012). In South Africa, crop production systems based on intensive and continuous soil tillage have led to excessively high soil degradation rates with a reduction in natural soil fertility in areas under grain production resulting in the consistent recommendation of the use of huge quantities of chemical fertilisers that are biologically unnecessary, economically extravagant and ecologically damaging (Smith and Trytsman, 2017a).

Soil fertility depletion in smallholder farms is believed to be the fundamental biophysical root cause of declining per capita food production in sub-Saharan Africa (SSA) (Sanchez *et al*., 1997). In South Africa (SA), soil degradation and poor nutrient supply in arable lands, especially among smallholder farmers, are critical factors limiting crop yields (Mandiringana *et al*. 2005). The problem of soil degradation is worsened by climate change which is projected to affect Africa more than other regions of the world (Intergovernmental Panel for Climate Change (IPCC) 2007). Climate change is believed to be anthropogenically forced through increases in atmospheric greenhouse gas (GHGs) concentrations which are believed to be largely responsible for global warming.

Projected climate change in SA over the next 50 years shows a warming of between 1°C and 3°C; a potential reduction of approximately 5% to 10% of current rainfall**;** increased daily maximum temperatures in summer and autumn in the western half of the country; increased incidents of flood and drought; and enhanced temperature inversions (DEAT, 2004). The projected increases in temperatures, reduced rainfall and water scarcity will significantly affect agricultural systems in SA.

Major impacts will include a reduction in the amount of land suitable for both arable and pastoral agriculture, the reduction in the length of the growing season and a decrease in yields. Climate change is therefore, going to compound the food security challenges caused by biophysical and socioeconomic factors. Maintaining or improving soil health is thus essential for sustainable and productive agriculture.

The main aim of this section is to review soil management approaches that can improve crop productivity and food security whilst adapting to and mitigating climate change.

2.2 Soil Management

2.2.1 Soil conservation

Excessive tillage leads to soil erosion, which Lal (2001) defines as a multi-stage process involving the detachment, redistribution, and deposition of soil in depressions and finally in aquatic ecosystems. Several infield measures can be taken to minimize the occurrence of degradation. These measures include reduced tillage, crop rotations, mulching and residue management and are reviewed and described in Chapters 3 and 4 of this guideline.

Land Care, which is a community-based and government-supported programme, is working in partnership with the private sector to rollout conservation measures throughout the nine provinces of South Africa (South Africa Yearbook 2012/13). Through its SoilCare sub-programme, sustainable agricultural production systems such as diversification, management of input and conservation tillage have been and continue to be introduced to different parts of the country. The programme is playing a significant role in reversing soil and land degradation and contributes significantly to green job creation, poverty eradication, and food security (South Africa Yearbook, 2012/13).

2.2.2 Soil fertility management

Soil fertility can get exhausted through constant cultivation without fertilization and by mechanical practices that break down soil structure. Four soil management approaches for soil fertility management are reviewed in this section. These are fertilization, use of organic materials, integrated soil fertility management (ISFM), and organic farming.

2.2.2.1 Fertilization

Crop nutrients are the food that feed the plants, which in turn feed animals and people. Therefore, fertilizers constitute key ingredients for food security. Smil (2002) estimated that between 1952 and 2002 mineral fertilizers contributed 40% to the increase of global food supply. In a more recent study, Stewart and Roberts (2012) concluded, based on long-term field studies data they examined, that fertilizer inputs are still very critical to crop production. They showed that in temperate climates such as in the United States of America (USA) and England, the average percentage of yield attributable to fertilizer generally ranged between 40 and 60%. By contrast, in the more highly weathered soils of the tropics, fertilizer input was even more critical to crop production. They showed that after the second year of land clearing yields attributable to fertilizer and lime were 90% and above.

Fertilizers, however, also contribute to global warming through greenhouse gas (GHG) emissions. It is estimated that mineral fertilizers contribute about 2.5 percent of total global emissions from their production, distribution and field application based on 2007 estimates (IFA, 2009). A breakdown of the figure has shown that the largest part of these emissions (1.5%) occurs at the point of application/consumption of fertilizers accounting for 60 percent of fertilizers' emissions compared to 0.93 percent of total global emissions from the production of fertilizers and 0.07% from their distribution (IFA, 2009). This indicates that mitigation of GHGs emissions from fertilizer consumption can mostly be done through adoption of best management practices for increasing fertilizer use efficiency. This entails applying fertilizers following the principles of nutrient stewardship (*i.e. the*

4Rs or "four rights" viz right source, at the right rate, at the right time, and in the right place) as advocated by IFA (2009).

With regard to the 0.93% emissions attributable to fertilizer production, the fertilizer industry is actively taking steps to reduce emissions of ammonia and nitrous oxide, as well as nitrate leaching and phosphate runoff into surface and groundwater. These steps include the development of technologies such as:

⇒ foliar nutrient application;

⇒ manufacture of coated soluble granules to allow controlled release of nutrients in the root zone;

⇒ urea deep placement e.g., the use of super-granules of urea in rice production to improve nitrogen recovery;

⇒ the addition of inhibitors to slow the conversion of urea fertilizer to ammonia and thereby minimize potential ammonia loss to the atmosphere; and

⇒ fertigation whereby soluble fertilizer is added to irrigation water to deliver nutrients to the root zone in a more precise and timely manner.

Fertilizer application rates in SSA are, however, low ranging from 5–10 kg/ha which is way below the target of 50 kg/ha set by the 2006 Abuja Declaration (Fairhurst, 2012). However, in South Africa, considerable research attention has been given to the development of fertilizer guidelines in (van Biljon, 2010; Meyer and van Antwerpen, 2010) to encourage the optimal application of fertilizers. The Fertilizer Society of South Africa (Fertasa) has championed the development of fertilization guidelines for different crops over the years and these are published in the Fertilizer handbook (FSSA 1989 and 2007). Van Biljon, (2010) has, in addition, highlighted that soil acidity is one of the most limiting factors in maize production and one of the main factors endangering the sustainability of crop production in South Africa. This is consistent with the findings of Mandiringana *et al.* (2005) who found that arable soils in the Eastern Cape had low to critically low pH values, whereby depending on location, 75–100% of the fields tested low in pH. Accordingly, liming guidelines are also included in the fertilizer handbook. In general, levels of management and inputs are much higher on commercial farms in South Africa but are much lower in the smallholder farming sector where they may be at levels observed elsewhere in SSA.

Continued use of fertilisers, pesticides and other synthetic chemicals to address problems in agricultural production has led to poor soil health and resistance to insects, diseases and weeds. More soluble nitrogen fertiliser makes plants more susceptible to diseases and insects, and increases the weed problem (Stapper, 2006). Therefore, in the sections that follow, attention will be directed to more sustainable ways of managing soils.

2.2.2.2 Manures and other organic amendments

Animal manures are often used as sources of nutrients in smallholder farms in SSA including South Africa. However, it has been found that the quantity of manure or other organic materials is often insufficient to meet the nutrient demand of crops. For example, in livestock systems in West Africa, current average application rates of manure are very small (0.5–2.0 t/ha) and the potential transfer of nutrients in animal manure to crop fields is therefore on average, 2.5 kg N and 0.6 kg P/ ha of cropland and insufficient to meet crop requirements (Fairhurst, 2012). With respect to other organic materials such as the preparation of compost from straw, farming systems analysis has shown that there are many competing uses for straw such as use as animal feed, leaving little for the preparation of compost (Fairhurst, 2012).

Growing cover crops (e.g. *Mucuna pruriens*) and other plants on-farm or off-farm for use as soil ameliorants has also not gained acceptance despite promising results from researcher-controlled agronomic trials. According to Fairhurst (2012) farmers fail to adopt such practices because they are: (i) labour intensive; (ii) cannot provide sufficient nutrients to sustain productivity; and (iii) do not yield products that can be either eaten or sold in the market. According to FSSA (1989), prior to 1980 animal by-products and green manuring were the only kinds of amendments available in South Africa to improve soil fertility and the production potential of soils. Subsequently, however, a swing occurred towards synthetic fertilizers due to the ease of application and the unavailability of sufficient organic residues to meet demand.

It was estimated, for example, that in 1983 there were approximately 3 million tons of manure available in South Africa from various feedlots (cattle, broilers, and pigs) but this amount of manure could only meet 13.3%, 9.9%, and 27.7% of the country's requirements of N, P, and K, respectively (FSSA, 1989). Sustaining soil fertility and increasing productivity using organic resources alone has therefore, not succeeded.

2.2.2.3 Integrated Soil Fertility Management (ISFM)

Integrated Soil Fertility Management (ISFM) is a set of soil fertility management practices that include the use of fertilizer, organic inputs and improved germplasm combined with the knowledge on how to adapt these practices to local conditions, aiming at optimizing agronomic use efficiency of the applied nutrients and improving crop productivity (Fairhurst, 2012). It is premised on the understanding that agricultural intensification cannot occur without investments in soil fertility, and that both organic and mineral inputs are needed to sustain soil health and increase crop production (Vanlauwe *et al*., 2010).

ISFM necessarily includes the use of improved germplasm, organic inputs, and mineral fertilizer, applied using good agronomic practices, and adapted to local conditions (Vanlauwe *et al*., 2010). The strategy exploits the complementarities and synergies that result when several technologies are jointly applied (Place et al., 2003; Vanlauwe *et al.,* 2010). According to Roobroek *et al*. (2005), the first entry point of ISFM is focusing on the agronomy of crops and inorganic fertilizers. It involves selection of varieties, spacing and planting date as well as the fertilizer formulation, placement, rate and timing of application.

The second entry point of ISFM is organic resource management which may include the return of crop residues, application of manure, compost and other types of organic wastes along with rotation or intercropping with legumes and use of plant growth promoting microorganisms. The third and last entry point of ISFM deals with any other amendments that may be needed to alleviate limitations to productivity such as soil acidity, micro-nutrient deficiency, erosion, soil compaction or pests and diseases.

Each entry point of ISFM contributes to increasing the productivity and profitability of agricultural systems. The first entry point focussing on the management of crops helps to push up yield potentials as well as combating pests and diseases (Pypers *et al.* 2011; Shiferaw *et al.* 2008).

The different fertilizer practices in the ISFM strategy such as micro-dosing, deep placement, banding, and harmonizing of inputs with rainfall and nutrient demands help to enhance nutrient uptake and productivity of crops (Aune and Bationo 2008, Chivenge *et al.* 2009) and help to minimize the emission of the greenhouse gas (GHG) nitrous oxide from inorganic fertilizer use. Greater recovery of N fertilizers by crops, and retention of nitrate in soils, serve as indicators for reduced emissions of nitrogen oxides in tropical farming systems (Hickman 2011).

A study by Marandu *et al.* (2010) in the moist savannas of Tanzania demonstrated that maize crops retrieved between 16 and 25 kg N ha^{-1} from rotated green gram, pigeon pea and cowpea crops, thus minimizing the necessity for added fertilizer with resultant reduction in GHG emissions. Minimizing the necessity of added fertilizer has a significant environmental impact as substituting a urea input of 10 kg N ha^{-1} with improved nutrient recovery, for example, can reduce emission from its manufacturing by 20 kg CO_2 (Bernstein *et al*. 2007). Smith *et al*. (1997) estimated based on default emission factors that decreasing N fertilizer inputs by 10 kg ha^{-1} could mitigate the emissions of N_2O from soils by 60 kg CO_2 equivalent ha^{-1}. Zingore *et al.* (2005), in Zimbabwe, showed that incorporating the stover from maize crops reduced soil C losses by 10 to 20 tonnes of C per hectare over a period of 20 years. This indicated that combining fertilizers with organic materials enhanced carbon sequestration and mitigated the emissions of CO_2 from soils.

Smith and Trytsman (2017a) reported that many producers world-wide have achieved large improvements in soil health in a relatively short time when CA principles and practices and ISFM are used simultaneously. They reported a successful one-season soil rehabilitation process of degraded soil in North West Province, South Africa through the application of CA and integrated soil fertility management (Smith and Trytsman, 2017b). Therefore, the 40% of commercial farmers already practicing CA in South Africa (see Chapter 4) should be benefiting from the synergies of CA and ISFM.

Case study 2.1: Enabling adoption of ISFM practices in Malawi

Roobroek *et al.* (2015) describe a case study wherein since 2012 the Clinton Development Initiative (CDI) and Alliance for a Green Revolution in Africa (AGRA) have been running a program to scale up ISFM in Malawi. The ISFM system that was scaled up combined maize-soybean rotations with strategic use of inorganic NPK fertilizers and inoculation of legumes with N-fixing bacteria.

An out-grower contractual model is used in which commercial farms act as anchors for enabling better access of smallholder farmers to information, seed, fertilizer, credit and output markets (Figure 2.1). The anchor farms provided training of master farmers on ISFM practices and helped in farmer organization. A monitoring and evaluation program recorded the following achievements after running the program for three years:

1. Maize grain yields increased from an average of 2.0 to 4.6-ton ha^{-1}, and soybean yields from 0.7 to 1.3-ton ha^{-1}.
2. More than 18 000 smallholder farmers have adopted the ISFM practice with about 50% of the beneficiaries being women.
3. A total of 9 906 hectares of land had been converted to the ISFM system.
4. More than 30 000 farmers had received training on ISFM practices of whom nearly 50% are women.

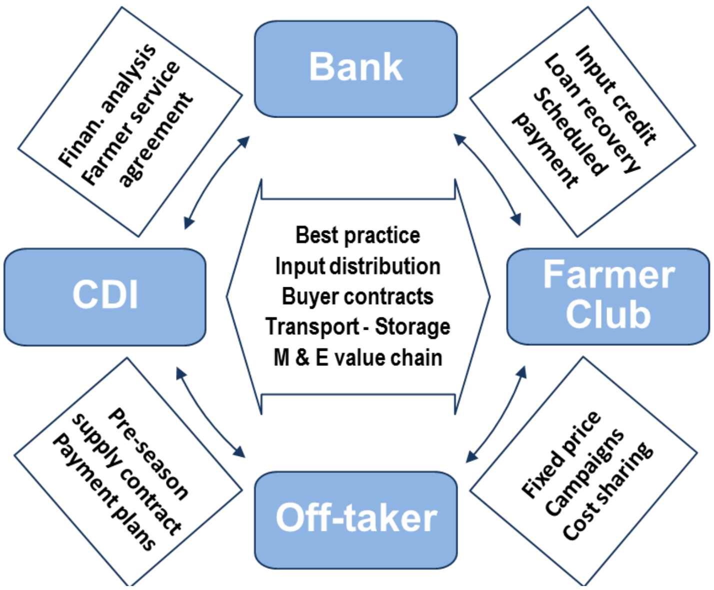


Figure 2.1: Framework of interactions between farmer clubs with anchor farmers, the Clinton Development Initiative (CDI), produce off-takers and banking partners
Source: *Roobroek et al. (2015)*

2.2.2.4 Organic Farming

Organic production systems are designed to a) enhance biological diversity within the whole system; b) increase soil biological activity; c) maintain long-term soil fertility; d) recycle wastes of plant and animal origin in order to return nutrients to the land, thus minimizing the use of non-renewable resources; e) rely on renewable resources in locally organized agricultural systems; f) promote the healthy use of soil, water, and air, as well as minimize all forms of pollution thereto that may result from agricultural practices (Codex Alimentarius 1999).

2.3 Methodologies of Organic Agriculture

There are various versions of organic farming approaches cited in the literature but only a few of the prominent ones are highlighted below:

A. Biodynamic farming

Biodynamic agriculture is a form of alternative agriculture very similar to organic farming (https://en.wikipedia.org/wiki/Biodynamic_agriculture) that uses specially prepared compost and field preparations. It treats the farm as a unified and individual organism, emphasizing balancing the holistic development and interrelationship of the soil, plants, animals as a self-nourishing system minimizing external inputs insofar as this is possible.

B. Permaculture

Permaculture is the design and creation of gardening ecosystems that are both self-sufficient and sustainable. This gardening process is organic, but it goes beyond simple organic gardening with a set of principles and a focus on working with nature instead of against it (https://www.maximumyield.com/definition/595/permaculture).

It is an approach that aims at designing human settlements and agricultural systems that mimic the relationships found in natural ecologies. Its intent is that, by rapidly training individuals in a core set of design principles, those individuals can design their own environments and build increasingly self-sufficient human settlements that reduce society's reliance on industrial systems of production and distribution that had been blamed as fundamentally and systematically destroying earth's ecosystems.

C. Biological farming

Biological farming is a chemical free method of farming that focuses on improving the microbiology to improve plant growth and produce yield. It includes (but is not limited to): organic farming, biodynamic farming, sustainable agriculture, or Natural Sequence Farming (http://www.groundgrocer.com/pages/Biological-Farming.html).

Biological farming methods present a viable way of producing high quality, nutritious produce without the use of large quantities of conventional fertilisers and pesticides or the use of gene modification. It predominately relies on the use of Aerobic compost and associated liquid inoculums, Bio-fertilisers and other organic additives and good management techniques to build soil. Biological farming works with natural systems and processes to build optimum soil, plant and animal health, while also incorporating the best of "conventional" farming methods to maintain production levels and quality.

D. Regenerative Agriculture

Regenerative Agriculture is a holistic land management practice that leverages the power of photosynthesis in plants to close the carbon cycle, and build soil health, crop resilience and nutrient density (http://www.csuchico.edu/

sustainablefuture/aginitiative/, https://thecarbonunderground.org/). Regenerative agriculture improves soil health, through the practices that increase soil organic matter. This not only aids in increasing soil biota diversity and health, but also increases biodiversity both above and below the soil surface, while increasing both water holding capacity and sequestering carbon at greater depths, thus drawing down climate-damaging levels of atmospheric CO_2, and improving soil structure to reverse the human-caused soil loss. Research continues to reveal the damaging effects to soil from tillage, applications of agricultural chemicals and salt based fertilizers, and carbon mining. Regenerative Agriculture reverses this paradigm to build for the future (http://2igmzc48tf4q88z3o24qjfl8.wpengine.netdna-cdn.com/wp-content/uploads/2017/02/Regen-Ag-Definition-2.23.17-1.pdf). Regenerative agricultural practices are therefore practices that include:

⇒ No-till/minimum tillage.
⇒ Increasing soil fertility biologically through application of cover crops, crop rotations, compost, and animal manures, which restore the plant/soil microbiome to promote liberation, transfer, and cycling of essential soil nutrients.
⇒ Building biological ecosystem diversity through inoculation of soils with composts or compost extracts to restore soil microbial community population, structure and functionality restoring soil system energy (C-compounds as exudates) through full-time planting of multiple crop intercrop plantings, multispecies cover crops, and borders planted for bee habitat and other beneficial insects.

E. Agro-ecology

Agro-ecology is a holistic science as well as a bottom-up approach to practising and organising agriculture to create just, ecologically sustainable and viable food systems.

Agro-ecology is based on co-operation – from fostering functional diversity in agro-ecosystems, to building relationships of solidarity between producer collectives, producers and consumers, and between movements resisting the corporate control of food. Agro-ecology promotes food sovereignty, which is the right of people to access and control the resources they need (including land, water, seeds, biodiversity, markets and technical support), to be able to make their own choices about the kind of food they produce and eat. produce and buy (www.biowatch.co.za). Agro-ecological practices build healthy soils, conserve water and foster and protect diversity.

The positive benefits of agro-ecology are agriculture and rural development that:

⇒ mitigates climate change by increasing carbon in soils;
⇒ conserving ecosystems, and avoiding fossil fuel use;
⇒ builds food sovereignty and self-sustaining and independent farmers and communities;
⇒ contributes to healthier livelihoods and better relationships between food producers and consumers;
⇒ maintains and enhances natural ecosystems and resources;
⇒ provides varied, nutritious, safe, affordable, and accessible food to communities;
⇒ helps to conserve traditional knowledge, culture and seed; and
⇒ builds resistance to corporate control of land and the food system.

Agro-ecology is climate smart because of its mitigation potential through its practice of conserving and building soils. Ecological farming uses very little mechanisation so that there is less soil disturbance. Chemical fertilisers are avoided, thereby avoiding the enormous energy consumed in breaking apart nitrogen atoms to obtain ammonia – the first step in most fertiliser production – and the nitrous oxide emissions. Instead, organic waste is returned to the soil as compost avoiding the methane produced if this waste was land-filled. Methane and nitrous oxide have a much greater impact on the climate than carbon dioxide.

Biowatch has been implementing agro-ecology and enhancement of genetic diversity in South Africa for over a decade and finds it to be effective in supporting farmers to deal with climate change and food insecurity (www.biowatch.co.za). The farmers Biowatch works with have revived the practice of using traditional seeds which they prefer to eat and also find more reliable to grow and store. They undertake dryland farming and use no artificial fertilisers or pesticides. Their soil is fertile, they feed their families and manage to grow surplus for the local market. According to Biowatch, the farmers have been empowered and are confident in themselves and their ability to face the future.

F. Traditional farming

Traditional farming is an original farming method handed down from generation to generation. It involves the intensive use of indigenous knowledge, natural resources and cultural beliefs of the farmers (https://definedterm.com/traditional_farming). It is an indigenous practice of cultivating land to produce crops, breeding, and raising livestock while managing natural resources in order to produce nutritious and continued food supply without external contribution but using self-reliance and locally available resources. Indigenous knowledge system is knowledge that has been preserved from generation to generation through oral and practical means.

2.4 Benefits of Organic Agriculture in relation to climate change adaptation

INFOAM (2009) reviewed several case studies on organic farming in Africa and concluded that:

⇒ Organic agricultural practices increase the nutrient and water retention capacity of soils through high organic matter content and soil cover. As a result, nutrients and water are used more effectively for agricultural production and less water is needed;

⇒ Soil fertility and soil structure improve when utilizing organic agricultural practices;

⇒ Organic agriculture increases biodiversity, by using trees and diverse crops, intercropping and crop rotations. According to Smith *et al.* (2011), on average, rates of biodiversity and crop diversity are higher on organic farms than conventional farms. The enhanced biodiversity in turn reduces pest outbreaks, the severity of plant and animal diseases, thereby increasing the production of high quality agricultural produce;

⇒ Organic agriculture decreases soil erosion caused by wind and water as well as by overgrazing;

⇒ Organic agriculture is well adapted to local circumstances as it encourages the use of local and indigenous farmer knowledge and adaptive learning techniques; and

⇒ Organic agriculture reduces the financial risk of farm operations, since farmers are less dependent on external inputs like synthetic fertilizers, seeds, irrigation equipment, etc. They do not have to borrow money to buy these inputs and are therefore financially less affected in case of crop failure.

These positive contributions of organic agriculture result in higher yields, and thereby, in increased food security and better options for development. For similar reasons, Eyhorn (2007) concluded that organic agriculture is an adaptation strategy that can be targeted at improving the livelihoods of rural populations and those parts of societies that are especially vulnerable to the adverse effects of climate change and variability. Herren *et al.* (2011) in citing Dobbs and Smolik (1996), Drinkwater *et al*. (1998)

and Edwards (2007) reported that bio-dynamic farms recorded a 100 percent increase in productivity per hectare due to the use of soil- fertility techniques such as compost application and the introduction of leguminous plants into the crop sequence. For small farms in Africa, they cite Hine and Pretty (2008) who reported a case wherein the incomes of approximately 30,000 smallholders in Thika, Kenya rose by 50% within three years after they switched to organic production. These findings indicate that sustainable methods of farming can result in increased productivity and profits in both developed and developing countries.

Organic agriculture is also a good mitigation strategy because it minimizes emissions through avoidance and carbon sequestration. The avoidance is achieved through lower N_2O emissions due to lower nitrogen input. This is based on the assumption that 1–2 percent of the nitrogen applied to farming systems is emitted as N_2O, irrespective of the form of the nitrogen input (Muller, 2009). Avoidance is also achieved through lower CO_2 emissions from avoiding farming system inputs such as pesticides and fertilizers produced using fossil fuel. Soil carbon sequestration is enhanced through agricultural management practices such as increased application of organic manures, use of intercrops and green manures which promote greater soil organic matter content and improve soil structure (IFOAM, 2008). Increasing soil organic carbon in agricultural systems is a mitigation option recommended by IPCC (2007).

2.5 Status of the organic sector in South Africa

A recent survey placed South Africa 8th on the continent in terms total area under certified organic farming (Kelly and Metelerkamp, 2015) but 21st when this area is expressed as a percentage of the total farmland in the country (Willer & Lernoud, 2015). South Africa, is therefore, lagging behind many African countries in the growth of its organic farming sector. It is unclear if the lack slow growth in the organic sector in South Africa could be related to the lack of a national policy on organic farming.

2.6 Conclusions

This brief review of soil fertility management strategies has indicated that maintaining or improving soil health is essential for sustainable and productive agriculture. It has shown that the use of mineral fertilizers as a source of nutrients for plant growth is still critical for increasing productivity. However, the application of fertilizers needs to be applied following established principles of nutrient stewardship so as to minimize their environmental impact. Guidelines have been prepared that reflect these principles of nutrient stewardship. Soil acidity is a problem in several areas therefore liming guidelines will need to be developed.

Chemical fertilizers are, however, known to adversely affect the health of naturally found soil micro-organisms by affecting the soil pH. Conventional farming practices that use chemical fertilizers alone should, therefore, be replaced with integrated soil fertility management approaches that combine optimally applied fertilizers with organic resources.

The combination of CA and ISFM has been found to be especially effective in the restoration of soil health and productivity whilst mitigating the emissions of GHGs. This approach should therefore be vigorously promoted for widespread adoption. Conversion to organic farming, where possible, should be the ultimate objective as it has superior soil regeneration potential while adapting to and mitigating climate change.

Case study 2.2: Cuba – A model of agro-ecological agriculture (Adapted from Third World Network (2015)).

Cuban agriculture was historically one of monocultures, export orientation, and natural resource exploitation. Therefore, prior to the collapse of the Soviet Union in 1990, Cuba traded sugar in exchange for fertilizers, pesticides and petroleum. Agriculture then was industrial, with heavy use of chemical pesticides and fertilizers.

Cuba experienced an economic collapse following the collapse of the Socialist block lead by the former Soviet Union upon which it was dependent for resources. Without resources from abroad, its fragile industrial agricultural system could not function resulting in low food self-sufficiency, high external dependency and many socio-economic problems. It was, therefore, forced to switch from its industrial agricultural system to one based on agro-ecological principles.

The process of conversion to agro-ecology took place at four levels:

⇒ Level 1 – increased efficiency of conventional practices, by for example, using legumes, reducing energy inputs, and improving technology efficiency;
⇒ Level 2 – Input substitution, e.g. biological pest control and better use of renewables;
⇒ Level 3 – system redesign, based on agro-ecological processes; and
⇒ Level 4 – agro-ecological connection; developing a culture of sustainability that considers all interactions between all components of the food system.

The contribution of small farmers to agriculture in Cuba also increased after the collapse of the Soviet Union. The farmer-to-farmer network has enabled many farmers to switch to organic and natural farming. It was estimated in 2014 that there were 20 000 families in Cuba practising agro-ecology up from 216 in earlier years.

These families used agro-ecological strategies such as polycultures, animal integration, crop rotation, green manure and organic amendments. The small farms they farmed proved to be very productive. Small farmers that worked 25% of the land were able to produce more than 65% of the domestic food supply.

3.1 Introduction

Water resources in South Africa (SA) are already subjected to high hydro-climatic variability both over space and over time (Schultze 2012). Climate change impacts on water in SA could exacerbate existing water-related challenges and create new ones related to climate variability, extreme weather events and changing rainfall seasonality (Bryan *et al*. 2009; Schultze 2012; Zhu and Ringler 2012; Spear *et al* 2015; Trenberth *et al*. 2007). South Africa is largely semi-arid. Semi-arid and arid areas are particularly exposed to the adverse impacts of climate change on freshwater for irrigation (Kundzewic *et el.* 2007).

Projected impacts are due to changes in rainfall and evaporation rates, further influenced by climate drivers such as wind speed and air temperature as well as soils, geology, land cover and topography across SA water catchments. This will result in changing the rainfall amount and distribution, evaporation, runoff, flooding, and soil-moisture storage, whereas higher temperatures can lead to an increase in evaporation and crop water requirements. Projections for national runoff range from a 20% decrease to a 60% increase based on an unmitigated emissions pathway, which reflects substantial uncertainty in rainfall projections.

Across the country, this ranges from increases along the eastern seaboard and central interior to decreases in much of the Western and Northern Cape. Areas showing the highest risk from extreme runoff include Kwazulu-Natal, parts of southern Mpumalanga and the Eastern Cape. Other areas show neutral to reduced risk from runoff, with the exception of the central and lower Orange River region. Specific areas of high risk from increased evaporation, decreased rainfall and decreased runoff include the south-west of the country, the central-western areas and to some extent the extreme north of SA. Climate change might also force smallholders to change the planting calendar of annual crops. As a result, farmers can switch from farming late maturing crop varieties to early maturing crop varieties. Bryan *et al*. (2009) reported that 86% of farmers in SA perceived that average temperature has increased and 79% of farmers noted that rainfall has declined.

A better understanding of farmers' perceptions of climate change, ongoing adaptation measures, and the decision-making process is important to inform policies aimed at promoting successful adaptation strategies for the agricultural sector. Bryan *et al*., (2009) reported that the most common adaptation strategies in SA include: use of different crops or crop varieties, planting trees, soil conservation, changing planting dates, and irrigation. However, despite having perceived changes in temperature and rainfall, a large percentage of farmers did not make any adjustments to their farming practices.

Factors influencing farmers' decision to adapt include availability of funds, government support, and access to fertile land and credit in SA (Bryan *et al.,* 2009).

Building resilience against climate change can be addressed by transforming agriculture and adopting climate smart water management practices. For instance, high temperature can aggravate water losses through evaporation. However, practices such as mulching and conservation agriculture (CA) can reduce soil temperature and thus reduce water loss by evaporation and optimize soil temperature as an adaptation to climate change.

Climate smart water management practices can significantly contribute in overcoming such an imbalanced hydrological change due to climate change. CA can increase the amount of biomass returned to the soil and influence rainwater partitioning by increasing water use efficiency (increased infiltration, reduced runoff and soil evaporation) (Araya *et al.,* 2015; Opolot *et al*., 2014) that can build resilience to climate change. The purpose of this review is to examine the status agricultural water management practices in South Africa in relation to adaptation and, mitigation of climate change with a view to inform the development of actionable climate smart soil water management guidelines.

3.2 Water conservation measures

One of the most effective options for better managing of rainwater is soil-water management (Lal, 2008) as a strategy to enhance climate change adaptation. This encompasses a wide spectrum of practices to improve the partitioning of rainwater, hence, improving the soil water balance, and ideally to integrate the broad scientific knowledge and expertise of scientists and extensionists with 'grass-rooted' local knowledge and farmers' experience. Such practices range from improving physical soil quality, i.e., primarily increasing rainwater infiltration capacity and plant-available water capacity through the use of soil amendments, conservation agricultural practices and other field water conservation practices, over farming practices such use of mulches and cover crops, to soil conservation practices, and runoff and flood water harvesting techniques.

Examples on the overviews of soil-water management practices with experiences from a variety of stakeholders worldwide is provided by WOCAT (2007; Liniger 2011). Table 3.1 provides an overview of soil-water management strategies and their purpose, and corresponding management options and types for increasing plant available water to improve crop productivity. The majority of these practices focus on harvesting of rainwater in its broadest sense. In situ or within-field water harvesting has traditionally been termed soil and water conservation practices.

Rainwater harvesting is the process of concentrating rainfall as runoff from a larger area for its productive use in a smaller target area (Everson *et al.,* 2011; Table 3.2). The collected runoff can be applied either directly to an agricultural field for crop production or be stored in some type of storage facility for supplemental irrigation. In other words, rainwater that could have been lost through runoff is now collected and used productively for crop production. Generally, rainwater harvesting systems are classified in to three categories (Table 3.2):

1. Macro-catchment (ex-field rainwater harvesting (ERWH). outside the farm/field/land boundary)

2. Micro-catchment (in-field rainwater harvesting (IRWH). inside/within the farm/field /land boundary)

3. Roof-top micro-catchment (non-field rainwater harvesting. artificial/ man-made runoff area)

Table 3.1: Soil-water management strategies, their purpose and corresponding management options and types for increasing plant available water to improve crop productivity

Soil-water management strategy	Purpose	Management options	Management type
In-situ water harvesting systems	Maximize infiltration capacity of the soil	Improve topsoil conditions	• Protective surface cover: cover crops, residue, mulches against disruptive action of raindrops • No or reduced soil disturbance by tillage • Conservation agriculture • Soil amendments • Fallowing under cover crops or natural vegetation • Temporary closure of grazing land and subsequent protection
		Improve subsoil conditions	• Deep tillage: subsoiler or paraplough to break-up water restricting layers
	Slow down and/ or impede runoff	Increase surface roughness	• Surface cover: cover crops, residue, mulches, geotextiles • Conservation agriculture
		Apply physical structures across slope or alongcontour	• Terracing: level terraces, bench terraces, Zingg, fanya juu, murundum, contour bund, graded channel terrace, orchard terrace, platforms, hillside ditches • Broad bed and furrow system • Contour field operations • Contour ridges and tied ridges • Impermeable and permeable contour barriers: stone bunds, walls, earth banks, trash lines, live barriers
	Harvest rainwater where it falls	Harvest runoff water	• Micro-catchments: contour bunds,teras, interrow harvesting, contour bench terraces, triangular and semi- circular bunds (half-moon, demi lune), eyebrow, hillslope catchments, Vallerani, zaï and tassa pits, meskat, negarim • Macro-catchments: stone bunds,large trapezoidal and semi-circular bunds, hillside conduit
	Optimize available water capacity and drainage beyond the rooting zone	Maximize water retention properties within rooting zone	• Soil amendments • Increase of organic matter pool • Conservation agriculture
		Maximize rooting depth	• Fertilizer/manure to speed up root development • Deep rooting crops • Break-up root restricting layers: chemical, biological/agronomical, mechanical, soil-hydrological solutions
		Optimize drainage beyond rooting zone	• Dry (early) planting • Recharge wells
Ex-situ water harvesting systems	Harvest rainwater and divert	Harvest floodwater	• Floodwater harvesting within stream bed: jessr, liman • Floodwater diversion: cascade systems
		Harvest groundwater	• Qanat
		Store harvested water	• Above ground: rooftop waterharvesting in jars and tanks, storage pond, lac Collinaire • Below ground: cistern
Evapotranspiration management	Minimize water losses from evaporation and excessive transpiration	Minimize soil evaporation	• Surface cover: residue, mulches • Conservation agriculture • Dry (early) planting • Seed priming • Fertilizer/manure to speedup shading • Adjust plant density and response farming
		Minimize unproductive plant transpiration	• Weed control • Crop rotations • Conservation agriculture • Water efficient crops (C4 vs C3)
		Minimize excessive evapotranspiration	• Windbreaks and shelterbelts • Agroforestry and intercropping • Shading materials

Source: *Cornelis et al. (2012)*

Table 3.2: Classification of rainwater harvesting sytems

Types of rainwater harvesting	Characteristics	Advantages	Examples
Macro-catchment (ex -field rainwater harvesting. outside the farm/field/land boundary)	• Overland flow harvested from catchment areas outside the farm/field/land boundary • Runoff stored in soil profile/ below-surface reservoir • Provision for overflow of excess water • Can be practised in arid and semi-arid areas below 450 mm annual rainfall	• Makes crop production possible in arid / semi-arid areas • Reduces risk of crop failure • Harvested water can be used for supplementary irrigation • Recharges aquifers	• Jessours • Liman • Contour stone bunds • Stone dams
Micro-catchment (in-field rainwater harvesting. inside/within the farm/field /land boundary)	• Overland flow harvested from short catchment lengths within the farm/field/land boundary • Runoff stored directly in the soil profile • No provision for overflow of excess water most of the time • Can be practised in semi-arid areas with rainfall between 450-700 mm	• Increases crop production in semi-arid areas • No ex-field runoff from the field • No erosion from the field • Low maintenance • Only dependent on rainwater from own field • Can be practised on small or large areas • Low implementation cost • No high-tech structures needed	• Small pits • Small runoff basins • Runoff strips interrow system • In-field rainwater harvesting (no-till, minimum tillage, mulching, basin tillage, crop rotation, proper weed control, crop and cultivar selection)
Roof-top micro-catchment (non-field rainwater harvesting. artificial/ man-made runoff area)	• Generally smaller catchment area compared to ex-field • Runoff stored in reservoir above/below ground surface • Tap / outlet normally attached to reservoir to access water • Can be practised in arid and semi-arid areas with annual rainfall of less than 450 mm	• Used to obtain water for irrigation purposes as well as domestic purposes • Has potential to supply drinking water when no water is available • Reduces risk of crop failure	• Rooftop water harvesting

3.2.1 In-field rainwater harvesting measures

In-field rainwater harvesting (IRWH) measures have been promoted to solve the problem of water shortages for agricultural production. IRWH tillage practices are useful in arid and semi-arid regions where irrigation water is not readily available or expensive to use. Viljoen *et al.* (2012) reported that the implementation of IRWH practices in the Free State Province in South Africa, increased the gross returns to the value of produce per home garden by approximately 22% per annum. The purpose of IRWH is to maximise soil water storage by minimising water loss through runoff, deep percolation and evaporation (Ngigi *et al*., 2006) which is useful to increase water use efficiency and build resilience against climate change and variability. IRWH practices such as mulching, CA, raised beds, ridging, contour furrows, bunds and bench terraces reduces the amount of runoff generated and controls soil erosion thus, reducing the negative side effects of excess runoff (Viljoen *et al*. 2012; Shiferaw *et al*., 2009; Ngigi *et al*., 2006). IMC is one of the cheapest and simplest forms of soil and water conservation system. However, in a semi-arid context, especially on coarsely- textured soils with low soil moisture storage capacity, the prospects of in-situ conservation may offer little or no guarantee against poor rainfall distribution (Ngigi *et al*., 2006). The benefits of soil moisture conservation are more visible when soil fertility improvement measures are considered and incorporated. Field water conservation practices are a way forward to build resilience against drought through increasing productive green water and crop yield, while reducing runoff and soil erosion. Table 3.3 indicates examples of IRWH practices.

Table 3.3: Most commonly practised micro-catchment rainwater harvesting systems in sub-Saharan Africa.

Type of the micro-catchment systems	Description	Countries of wider application	References
Mulching	The term 'mulch' refers to any material other than soil or living plant that performs the function of a permanent or semi-permanent protective cover over the soil surface	Ethiopia, Kenya, Zimbabwe, South Africa	Murungu *et al.,* 2011
Cover crops	A cover crop is a crop planted primarily to manage soil erosion, soil fertility, soil quality, water, weeds, pests, diseases and biodiversity in an agroecosystem. Recommended cover crops include sunn hemp, black oats, velvet beans, dolichos beans, cow peas, forage sorghum, dry beans, soya beans, clovers, chick peas, buckwheat, black oats, white oats, stooling rye, barley, wheat, lupins, lucerne, teff, rye grass, and vetch.	Ethiopia, Mali, Mozambique, Rwanda and Zambia	Lu *et al.* (2000), Yeheyis *et al* (2010)
Tied ridging	Ridging is a soil and water conservation practice characterized by individual earth blocks built along furrows. It has been widely used in different places and known under different names such as furrow-diking, diked furrows, tied ridges, basin tillage and basin listing.	Ethiopia, Kenya, Niger, Zimbabwe	Critchley *et al.* (1991), Jones and Stewart (1990); Nuti *et al.* (2009)
Raised bed planting	Farmers worldwide have developed in situ moisture conservation, based on generations of local experiences, which can increase the soil's ability to store water for plant use, reduce vulnerability to drought, and help to halt soil erosion and degradation. In semi-arid and arid regions, bed cultivation systems provide with opportunities to reduce adverse impacts of excess water on crop production by actively harvesting excess water and irrigating crops.	Traditionally used in Ethiopia	Sayre (2004), Araya *et.al.* (2015)
Pitting (Zai pits, Ngoro pits, trenches, tassa pits, etc.)	Zai pits: A grid of planting pits is dug across plots that could be less permeable or rock-hard; organic matter is sometimes added to the bottom of the pits; Ngoro pits: A series of regular traditional pits, 1.5 m square by 0.1–0.5 m deep with the crops grown on the ridges around the pits; Trenches: pits are made along the contour sometimes with a bund downslope either staggered or continuous to check the velocity of runoff, conserve moisture and increase ground water recharge	West Africa (Burkina Faso, Mali, Niger) East Africa (Tanzania, Kenya, Somalia, Uganda, Ethiopia) Southern Africa (Zimbabwe, South Africa)	Malley *et al.* (2004), Mupangwa *et al.* (2006), Reij *et al.* (1996), WOCAT (2010)
Contouring (stone/soil bunds, hedge-rows, vegetation barriers)	Stone and soil bunds: A stone or sometimes earthen bank of 0.50–0.75 cm height is piled on a foundation along the contour in a cultivated hill-slope, sometimes stabilised with grasses or other fodder plant species; Hedge rows: Within individual cropland plots, strips of land are marked out on the contour and left unploughed in order to form permanent, cross-slope barriers of naturally established grasses and herbs. Alternatively, Shrubs are planted along the contour	East Africa (Kenya, Ethiopia, Tanzania) West Africa (Burkina Faso) South Africa	Kiepe (1995a), Spaan (2003), WOCAT (2010)
Terracing (Fanya Juu, Semi - circular and hillside terraces)	Bunds in association with a ditch, along the contour or on a gentle lateral gradient are constructed in different forms. The Fanya Juu terraces are different from many other terrace types in that the embankment is put in the upslope position	East Africa (Kenya, Ethiopia, Tanzania)	Tengberg *et al.* (1998), WOCAT (2010)
Micro-basins (Negarims, half-moons, and eye-brows)	Different shapes of small basins, surrounded by low earth bunds are formed to enable the runoff to infiltrate at the lowest point, where the plants are grown. The differences between the different structures is basically in their shapes, Negarims (diamond), Halfmoons (semi-circular), etc.	East Africa (Ethiopia, Kenya, Tanzania, Uganda) West Africa (Burkina Faso, Mali, Niger)	Abdulkadir and Schultz (2005), FAO (1991), Spaan (2003)
Trapezoidal bunds	Trapezoidal bunds are used to enclose larger areas (up to 1 ha) and to impound larger quantities of runoff which is harvested from an external or "long slope" catchment.	Turkana District, Kenya	Critchley *et al* (1991)

3.2.2 Ex-field rainwater harvesting measures

Water harvesting is the process of concentrating rainfall as runoff from a larger area for its productive use in a smaller target area. The collected runoff can be applied either directly to an agricultural field for crop production or be stored in some type of storage facility for domestic use and/or supplemental irrigation. By collecting, storing and utilizing water runoff for irrigation, farmers are able to prevent soil erosion, stabilize water supply, and reduce reliance on other water sources. The AFRHINET project is developing technology and education materials on off-season rainwater harvesting irrigation management, which utilizes rainwater for micro and small-scale irrigation of high-value crops in arid and semi-arid regions in SSA is available at http://afrhinet.eu/. Table 3.4 also indicates the ERWH practices commonly practiced in SSA.

Table 3.4: Most commonly practised macro-catchment rainwater harvesting systems in sub-Saharan Africa.

Type of macro-catchment sys-tems	Description	Storage capacity (m^3)	Countries of wider application	References
Traditional open ponds	Runoff collected from ponds cultivated hill slopes, natural water-courses, footpaths or cattle tracks is stored in un-plastered and open ponds. The stored water usually suffers from losses due to seepage and evaporation	30–50	Mainly in East Africa (Kenya, Ethiopia, Tan-zania, Somalia)	Habtamu (1999), Ngigi (2003), Reij *et al.* (1996)
Cisterns	Runoff collected from bare lands, cultivated hill slopes or road catchments is guided and stored in underground storage tanks. The cisterns have plastered walls and covered surfaces. In most cases, settling basins are attached in front of the inlet to reduce sedimentation and otherwise, regular cleaning is required	30–200	East Africa (Kenya, Ethiopia, Tanzania, Uganda) South Africa (Zimbabwe, Botswana)	Wondimkun and Tefera (2006)
Earthen dams (micro- dams)	Larger sized rainwater storage systems such as ndivas in Tanzania and micro-dams in Ethiopia are communally constructed around foots of hill slopes to store the runoff from ephemeral or peren-nial rivers. The reservoirs are neither plastered at their walls nor covered on their surfaces. The water is mostly used for supple-mental irrigation communally and for cattle	(0.02–0.2)104 in Tanzania, and (0.1–3.1)106 in Ethiopia	East Africa (Tanzania, Ethiopia)Southern Africa (Botswana) West Africa (Burkina Faso)	Haregeweyn *et al.* (2006), Makurira *et al.* (2007)
Sand dams	Dams constructed to store part of the natural flow in seasonal rivers. The sand carried by the river will settle upstream of the dam and gradually fill the streambed. Hence, the sand will reduce evaporation and contamination of the water in the sand body behind the d a m	-	East Africa (Kenya, Ethiopia)	Aerts *et al.* (2007), Hut *et al.* (2008)
Ephemeral stream diversions and spate irrigation	Ephemeral streams from uplands are diverted from their beds (Wadis) at the agim (temporary diversion structure) to irrigate adjacent crop fields downstream usually before planting	–	Mainly in East Africa (Eritrea, Ethiopia, Tanzania)	Hatibu and Mahoo (1999), Tesfai and Stroosnijder (2001),WOCAT (2010)

Source: *Biazin et al. (2012)*

3.2.2.1 Jessour

Jessour is an ancient runoff water harvesting technique widely practised in the arid highlands. Jessour technology is generally practised in mountain dry regions (less than 200mm annually) with medium to high slopes. This technology was behind the installation of very old olive orchards based on rain-fed agriculture in rugged landscapes which allowed the local population not only to ensure self-sufficiency but also to provide neighbouring areas many agricultural produces (olive oil, dried figs, palm dates, etc.).

Jessour is the plural of jessr, which is a hydraulic unit made of three components: the impluvium, the terrace and the dyke. Although the jessour technique was developed to produce various agricultural crops, it now also plays three additional roles: (1) aquifer recharge, via runoff water infiltration into the terraces, (2) flood control and therefore the protection of infrastructure and towns built downstream, and (3) wind erosion control, by preventing sediment from reaching the downstream plains, where windspeed can be particularly high. In the Jessour, a dyke (tabia, sed, katra) acts as a barrier used to hold back sediment and runoff water.

3.2.3 Roof water harvesting

Rooftop Rainwater Harvesting (RRWH) is the technique through which rain water is captured from roof catchments and stored in reservoirs. Harvested rain water can be stored in sub-surface ground water reservoirs by adopting artificial recharge techniques to meet the household needs through storage in tanks. Capturing and storing rain water for use is particularly important in dryland, hilly, urban and coastal areas. Collecting water from roofs for household and garden use is widely practised across SA. Tanks and containers of all types from large brick reservoirs to makeshift drums and buckets are a common sight in rural areas. There are three main components to roof water harvesting: the roof, the gutter and the storage tank.

Advantages of collecting water from roofs are:

⇒ physically in place and runoff is immediately accessible,
⇒ water collected from roofs is generally much cleaner than from land runoff,
⇒ most of the rainwater falling on the roof can be collected, as there is little absorption or infiltration on the roof surface,
⇒ reduces the cost for pumping of ground water,
⇒ provides high quality water, soft and low in minerals,
⇒ improves the quality of ground water through dilution when recharged to ground water,
⇒ reduces soil erosion in urban areas,
⇒ rooftop rain water harvesting is less expensive,
⇒ rainwater harvesting systems are simple which can be adopted by individuals, and
⇒ rooftop rain water harvesting systems are easy to construct, operate and maintain in hilly terrains, rain water harvesting is preferred.

3.3 Drainage of excess water for high rainfall areas with clayey soils

Climate change can aggravate the problems of waterlogging in clay-like soils. A system used at planting time in order to drain excess water away from crops such as the Broad Bed and Furrow Maker can be used. The Broad Bed and Furrow (BBF) system has been mainly developed at the International Crops Research Institute for the Semi -arid Tropics (ICRISAT) in India (Krantz 1981, Pathak *et al.* 1985). The recommended ICRISAT system consists of broad beds about 100 cm wide separated by sunken furrows about 50 cm wide. The preferred slope along the furrow is between 0.4 and 0.8 percent on vertisols. The BBF has the following objectives:

⇒ to encourage moisture storage in the soil profile,
⇒ to dispose safely of surplus surface run-off without

causing erosion,

⇒ to provide a better drained and more easily cultivated soil in the beds. There is only a narrow range of moisture conditions during which the soil can be efficiently tilled or planted, and timeliness is a key factor, and

⇒ the possibility of the re-use of run-off water stored in small tanks. Small amounts of life-saving irrigation applications can be very effective in dry spells during the rains, particularly on soils with lower storage capacity than the deep vertisols.

The BBF system is particularly suitable for the vertisols. The technique works best on deep black soils in areas with dependable rainfall averaging 750 mm or more. It has not been as productive in areas of less dependable rainfall, or on alfisols or shallower black soils - although in the latter cases more productivity is achieved than with traditional farming methods. Other methods, with more emphasis on storage and irrigation within a package which includes BBF, are more likely to be viable for the alfisols (Ryan *et al.* 1979). It is also stressed throughout the ICRISAT research that the BBF system should not be considered in isolation, but only as part of an improved farming systems package.

3.4 Irrigation water use efficiency

Water availability for irrigation in much of SA is limited due to climate change and variability induced drought that evokes the urgent need for improvements in irrigation water management. For example, the Western Cape Province in SA have faced water shortages for agriculture and for human consumption in the last three consecutive years (2015-2017).

Smart irrigation approaches can address the inefficient watering of crops and land productivity, by ensuring greater water use efficiency. The choice of the irrigation system depends mainly on the water availability, soil type, topography, climate, energy availability, crop type, as well as the management skills of the farmer. Well-designed systems have a high potential efficiency, but poor design, insufficient maintenance and bad management could reduce the intrinsic efficiency of these irrigation systems.

The selection of an appropriate irrigation system for small-scale farmers is a huge challenge, since very often irrigation technology that is available is either too expensive and therefore out of reach for many small-scale producers or does not match the needs and managerial skills of the farmer. Changing from traditional irrigation methods like short furrow irrigation to drip irrigation may often result in low irrigation efficiency due to the farmer's lack of skills.

The suitability of the various irrigation methods, i.e. surface, sprinkler or drip irrigation, depends mainly on natural conditions (such as soil type, slope, climate, water quality and availability), type of crop, type of technology, previous experience with irrigation, required labour inputs and costs and benefits. Drip irrigation systems have the highest irrigation efficiency (>90%) while surface irrigation has the lowest efficiency (<65%). Sub-surface drip irrigation systems are the best irrigation in terms of irrigation efficiency.

A surface irrigation system is cheaper than overhead (sprinkler) and subsurface irrigation systems in terms of capital costs. However, surface irrigation systems are deemed to be more labour intensive than overhead and subsurface irrigation systems. Surface irrigation systems are suited to lands with uniform terrain and slopes less than 3%. Surface irrigation systems require soils with low to moderate infiltration capacities (Booher 1974).

A shift from the gravity irrigation to modern pressurised systems such as drip and sprinkler irrigation systems and improved conveyance efficiency provide an opportunity for reduced water demand in irrigation, but at a cost and with possible negative side effects on soil quality. A small, but growing amount of attention has been paid to deficit irrigation; or more specifically, irrigation below full crop-water requirements (evapotranspiration) aiming at the maximum production per unit of water consumed. Water productivity increases under deficit irrigation, but the application of this technique requires adjustments in the agricultural systems, imposing changes at different levels.

Water is only needed in those parts of the soil profile where roots are active and there is an evident need to avoid watering the soil when it is raining or at times of day when it less effectively used. Irrigation regimes can be realigned to optimising the soil moisture profile in relation to the ambient weather and root development. Controlling irrigation flow and timing with a basic link to climate data can improve irrigation water use efficiency and minimize irrigation water losses. At its most sophisticated, this involves soil moisture monitors that take into account soil types, soil compaction and the method of seeding, whether tilled or drill-seeded.

Plants experience water stress when evaporative demand exceeds the water supply from the soil (Araya *et al*., 2015; Slatyer, 1967). When plants are water stressed they close their stomata and cannot photosynthesize effectively. Optimal growth can be achieved only if plants have a suitable balance of water and air in their root zones. Some stages in the growth of a crop are particularly sensitive to moisture stress. Water shortages sufficient to hinder crop growth can occur without producing obvious wilting of foliage, while waterlogging can cause significant yield reductions too. Even short-term water deficits may affect growth processes (Hsiao *et al,* 1976). Plant species vary in water use and their response to water stress.

Water stress causes stomatal closure, prevents the uptake of carbon dioxide along with reducing water loss, and alters the colour and temperature of leaves (Nilson, 1995). Similarly, deficiency symptoms of plant nutrients can change the colour of the plant leaves. A drone technology can be used to take NDVI reading of the plant leaf colour changes at different phonological stages of the crop to develop the relation between crop moisture stress and crop yields (Veroustraete, 2015).

Irrigation scheduling is a major concern in SA where more than 80% of the farmers admit that the way they schedule irrigation is inefficient (Stirzaker *et al*, 2004). There are several approaches that can be used to improve scheduling. One involves the use of drone technology. This involves the collection of NDVI data can be used to improve irrigation scheduling and avoid crop yield losses due to moisture stress, excess water due to water logging and minimized irrigation water losses. Another option is the use of soil-based scheduling methods that use sensors to monitor moisture levels in the soil at appropriate locations and depths. Examples of such irrigation scheduling tools include Wetting Front Detectors (WFD) and Chameleon Sensor (CS). The WFD consists of a funnel, a long cylindrical tube with an indicator on top of it, a reservoir and a suction tube. They are installed in pairs (shallow and deep). The funnel and reservoir are buried in the ground, and the indicator is visible above ground. When a strong wetting front passes the installation depth, the polystyrene float in the plastic housing rises. WFD is cheaper and suitable to small-scale farmers as compared to drone technology.

The CS is a sensor designed to increase water management techniques for smallholder irrigators on their farms. It consists of three porous matric potential sensors with a temperature sensor which determine how wet or dry the soil is at three depths. Sensor arrays are placed at three different depths depending on the root zone depth that needs to be managed. A chameleon field reader is connected to the sensors and displays soil water tension in the sensors. The soil water tension in the sensors is displayed through three colours; blue 0-20 kPa, green 20-50 kPa and red >50 kPa. Red indicates low soil water or plants may be water stressed, while blue indicates enough soil water is available in the soil (or if soil is saturated) and green is the intermediary condition between wet and dry. Applications of the CS include providing information on when to irrigate to avoid water stress, how to avoid waterlogging, determining when the profile is susceptible to fertilizer leaching, and improving the usefulness of rainfall. This sensor can also help farmers determine where the roots are actively taking up water giving farmers insight on when to irrigate and how much water to apply.

3.5 Use of renewable energy in irrigation systems

Remarkable increase of agricultural load due to concentrative irrigation arrangement will consume a large amount of energy. Reducing dependency on fuel is important and prospects for rural development are enhanced through improved access to water and energy. Overall, solar and wind energy can play an important role in climate change mitigation, reducing greenhouse gas (GHG) emissions in irrigated agriculture by replacing fossil fuels for power generation with a renewable energy source. The environmental advantages of using solar and wind energy pump in irrigated agriculture include:

⇒ does not produce any GHG emissions.
⇒ potential for adaptation to climate change by mobilizing groundwater resources when droughts occur, or rainfall patterns are erratic.
⇒ potential for improving water quality through filtration and fertigation systems (more efficient application of less fertilizer overall).
⇒ Less pollution resulting from inadequate fuel handling (diesel pumps).

Renewable energy that include solar and wind powered irrigation systems are environmentally friendly and economically feasible ways to use them for irrigation pumping and thus, to replace the use of large quantities of energy currently provided by non-renewable fossil fuels.

Solar powered irrigation systems (SPIS) provide reliable and affordable energy, potentially reducing energy costs for irrigation. SPIS is promoted in the framework of national action plans regarding climate change as a way to reduce emissions from agriculture. SPIS has a potential reduction in GHG emissions per unit of energy used for water pumping as compared with pumps operated with grid electricity and diesel pumps. In rural areas where diesel fuel is expensive or where reliable access to the electricity grid is lacking, SPIS can provide a relatively flexible and climate friendly alternative energy source. SPIS can be used in both large-scale irrigation systems and small-scale irrigation.

Wind-powered systems (WPS) can be feasible in remote areas where electric utility power is unavailable, where the transport of fossil fuel is difficult and costly, and where adequate wind is available. Wind energy does not require water for its generation (Gleick, 1994; Martin & Fischer, 2012), Water use for the turbine construction phase has been deemed negligible (Gleick, 1994). There is also likely negligible water use in the washing or the turbine blades from time to time.

Taking renewable WPS as primary source and generating electric power on the spot, can save on the usage of conventional energy and save money for small scale farmers in long-term, and even provide new sights without environment destruction. Since the WPS converted into electrical energy is used to drive pumps while not to bring water directly, the wind turbine may locate at a different place from rivers, according to practical physiognomy conditions.

Case study 3.1: Conservation agriculture

According to FAO (2018), "CA is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment". CA is increasingly being promoted as a climate smart approach that can help arrest or reverse the processes of soil degradation, promote water conservation as well mitigate against climate change. Estimates of the size of crop fields under CA worldwide were close to 125 million ha (FAO, 2018), thus comprising 12.8% of the 1.6 billion ha crop land on Earth. However, the CA area coverage under smallholders' farm is only 0.3 % of the total area under CA worldwide (Derpsch et al., 2010). CA is defined therein as a system that simultaneously combines three pillars of agricultural production, namely minimal soil disturbance, retention of crop residues and crop rotations (FAO). A large proportion of SA has a semi-arid climate and therefore inadequate moisture characterized by long dry spells is often a major crop growth-limiting factor. This limitation is exacerbated by the growing threat of climate change which is causing shifting rainfall patterns and increasing drought frequencies in some areas (Maraseni and Cockfield, 2011). It is feared that the resulting crop yield penalty is likely to be much more severe for the SA smallholder farmers who are already farming on degraded soils (Hassan, 2006). Degraded soils are characterized by poor water holding and infiltration capacity (Stroosnijder, 2009). About 70–85% of rainfall in SSA is lost as blue water in the form of direct runoff and as deep percolation and white water losses in the form of evaporation and thus, less green water is available for crops (Rockström, 2003; Rockström, 1997). Water losses through direct runoff, deep drainage and evaporation are unproductive water losses while water loss through transpiration is considered as productive water loss (Araya et al., 2015a). Although water loss such as direct runoff especially deep percolation can be re-used, however, these are water losses in reference to the crop grown in a particular season. This imbalanced soil hydrology can be because of soil degradation that resulted from physical deterioration of the soil quality and absence of effective soil cover such as in the form of crop residue surface soil cover.

Generally, low crop productivity in SA is mainly related to three water-related deficiencies: (1) insufficient rainfall amount during the growing season to meet the crop water demand; (2) poor soil water holding capacity and infiltrability problems due to degraded soils that aggravate unproductive rainwater losses; and (3) erratic rainfall distribution during the growing season due to short and long dry spell damages to crops.
Reducing tillage and adding crop residue to soils increases the amount of biomass returned to the soil and influences rainwater partitioning by increasing water use efficiency (Araya *et al.,* 2016; Opolot *et al*., 2014; Rockström, 1997). Crop residue especially retained in the form of standing stubble can reduce runoff while mulching gives better coverage against evaporation.

Rainwater loss through evaporation is estimated to be 30 –50 % of the total rainfall (Cooper *et al*., 1987; Allen, 1990). Increasing the amounts of crop residues on the soil surface as a cover reduced evaporation rates and increased duration of drying up of the soil except after extended drought (Krishna *et al.,* 2004). On the other hand, repeated tillage can cause moist soil to move to the surface, which favours loss of soil moisture by evaporation (Aase and Siddoway, 1982). Rainwater loss in the form of surface runoff accounted for 10 – 25 % of the total rainfall (Casenave and Valentin, 1992). Generally, CA reduces soil erosion and protects soil from raindrops, wind and radiation, and thus from surface crust formation, as well as to increase water infiltration, reduce evaporation, and promote soil organic matter (SOM) accrual and biological activity (Araya *et al.,* 2015; Lobe *et al.,* 2001; Vanlauwe 2004).

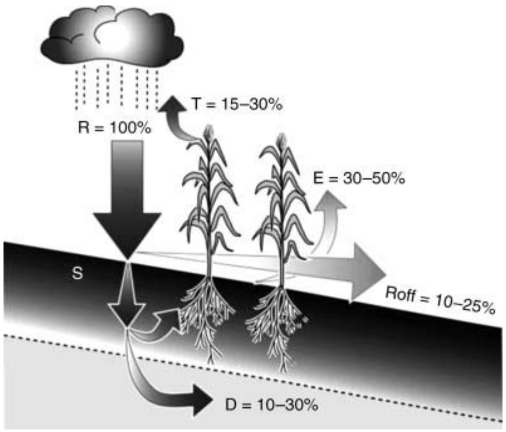


Figure 3.1: On-farm partitioning of rainwater (R) into runoff (Roff), drainage or deep percolation (D), evaporation € and transpiration (T). (S) refers to rootzone water storage. Interception by leaves is not considered. Values are synthesised data from rain fed savanna agro-ecosystems in sub-Sahara Africa (SSA) on controlled research farms
Source: *Rockström (2003)*

Case study 3.2: Conservation agriculture with trees

Conservation agriculture with high-value trees harnesses and combines the synergies of rapid improvement of livelihoods with sustainable crop production and productivity as well as environmental resilience (Bayala *et al.* 2011, Akinnifesi *et al*. 2011). CA with trees derives its strength from the complementary principles of CA and agroforestry and is based on five important principles: (i) minimize soil disturbance, (ii) maintain land/ soil cover, (iii) practice crop rotation, (iv) follow good agronomic management practices, and (v) incorporate nitrogen-fixing trees and high-value trees (World Agroforestry Center 2015). The addition of trees to CA is crucial for reducing soil erosion, improving soil fertility by bringing nutrients from deeper soil layers, mitigating climate change by storing carbon, increasing soil infiltration capacity, and improving green water resources that support improvement in crop yield.

3.6 Conclusions and recommendation

Climate change will alter rainfall amount and distribution, evaporation, runoff, and soil-moisture storage, whereas higher temperatures can lead to an increase in evaporation and crop water requirements in SA. Field rainwater conservation practices are a way forward to build resilience against climate change and variability through increasing productive use of green water and to increase crop yield, while reducing water loss in the form of runoff and evaporation and soil erosion. This can be achieved through introducing different climate smart agricultural water management practices that includes in -field water harvesting; ex-field water harvesting; roof water harvesting and increasing infiltration capacity through improving the physical quality of soil.

This review has highlighted the potential of some soil water management practices that can be practiced as a mitigation and adaptation to climate change in SA. IRWH practices increase infiltration and reduce runoff, evaporation and soil erosion. Ex-field rainwater harvesting practices such as jessour, cisterns, ponds, liman and stone dams which are listed in Table 2 and 3 can be used to trap the rainwater that is lost in the form of runoff. However, rainwater harvesting systems and their sustainability are highly site-specific, so local guidelines are needed to facilitate their adoption and minimize the consequence of their improper implementation. Irrigation scheduling tools are needed where irrigation is practiced to improve water use efficiency. These can be plant-based such as drone sensors or soil-based such as wetting front detectors and chameleon sensors. Implementation of IRWH practices under rain-fed conditions and the use of WFD and CS for irrigation scheduling will improve water use efficiency and significantly contribute in adaptation to climate change and variability

4.1 Introduction

Climate determines many factors important to crop production. Management decisions such as choice of crop, planting time, seeding rates, fertiliser types and rates, and many others are influenced by the climate. According to Schulze (2016) South Africa has one of the most variable climates in the world and managing this variability is a challenge that requires skilled operators. South Africa is a water scarce country that has historically faced a major climatic challenge of low and variable rainfall in producing its major crops.

Agriculture's contribution to gross domestic product (GDP) has declined from 23% in 1920 (Stats SA, 2005) to 2% in 2015 (DAFF, 2016) with the diversification of the South African economy, but still plays a significant role. Important to note, agriculture has both backward and forward linkages to many industries, usually forming the backbone of input supplies into many processing industries. For instance, agriculture has backward linkages with the manufacturing sector. As a result of the agro-industrial sector contribution, GDP is from the manufacturing sector is 12% higher with also a 20% contribution to manufacturing employment statistics (Baleta and Pegram, 2014). Therefore, climate change will have both direct and indirect effects on the agricultural and South African economies unless strong adaptive and mitigation measures are inbuilt to make South African agriculture more resilient to climatic shocks.

The Departments of Environmental Affairs (DEA) and of Agriculture, Forestry and Fisheries (DAFF) and have led various efforts to produce climate change strategies to promote awareness and knowledge and to promote adaptation and mitigation measures. Studies by Musvoto et al. (2014), Schulze (2016) and Cobban and Viser (2017) all generally describe adaptive and mitigation measures required to make agriculture more resilient but fall short in pointing at specific technologies and guidelines that can be used by any interested parties. The current effort seeks to provide wherever possible, practical guidelines that allow farmers to lay their hands on crop production technologies, practices and technical know-how that they can use in the uptake and practice of climate smart agriculture (CSA).

4.2 Trends in cereal production in South Africa

Grains and cereals are South Africa's most important crops, occupying more than 60 percent of area under cultivation. Maize (*Zea mays L.*), the country's most important crop, is a dietary staple, a source of livestock feed, and an export crop. Approximately 60% of maize produced in South Africa is white and the other 40% is yellow maize. Yellow maize is mostly used for animal feed production while the white maize is primarily reserved for human consumption. Maize is the second largest crop produced in South Africa after sugar cane. The maize industry is important to the economy both as an employer and an earner of foreign currency because of its multiplier effects. This is because maize also serves as a raw material for manufactured products such as paper, paint, textiles, medicine and food. Wheat (*Triticum aestivum*) is the second most important cereal in the country. Other cereals of significance are barley (*Hordeum vulgare*) and sorghum (*Sorghum bicolor*). Maize and sorghum are produced in the summer, mainly under rain-fed conditions, whilst wheat and barley are grown in the winter, largely under rain-fed conditions in winter rainfall areas and under irrigation in the northern areas of the country. Oats are a minor crop grown in the winter.

Hectarages of non-cereals (Table 4.1) is much smaller and may suggest limited practice of crop rotation on farms where cereals dominate.

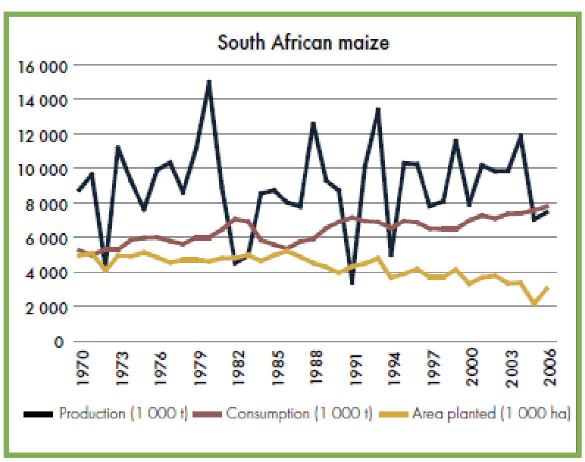
Table 4.1: Trends in hectarage and yield for groundnut, sunflower and soybean for 1996-2016

	Groundnut		Sunflower		Soybean	
	Area ('000 ha)	Yield (t/ha)	Area ('000 ha)	Yield (t/ha)	Area ('000 ha)	Yield (t/ha)
91-95	157.8	0.60	496.2	0.83	-	-
96-00	93.4	1.28	561.4	1.29	78.8	1.88
01-05	84.2	1.48	557.2	1.31	128.6	1.68
06-10	51.2	1.81	477.2	1.30	227.6	1.75
11-16	46.7	1.36	577.3	1.22	519.3	1.57

Source: *DAFF, 2016b*

South Africa's population is growing at almost 2% per year. The population was 57.5 million in 2018 and expected to grow to 82 million by the year 2035. This places immense pressure on food resources, which must at least double by 2035 to cater for the growing demand. Percentage reliance in South African diets has shown a decrease in consumption of cereals in favour of diversification to animal products such as poultry (Agricultural Statistics, 2008). Annual maize and wheat production fluctuate widely according to rainfall. The amount of hectares under cultivation has decreased whereas the production per hectare has increased; implying that on average, production has remained constant over time (Figure 4.1).

This is a concern, as consumption has increased with the growing population. Declining farming profitability and water scarcity (drought, declining rainfall or over- demand for water) has left South Africa with less than two-thirds of the number of farms it had in the early 1990s. In many instances, the lost farms have been changed to other land uses or consolidated into larger farming units to achieve effective economies of scale. Although the area under maize and wheat has decreased significantly over time, production remains relatively constant, indicating an increasing trend in intensified production.



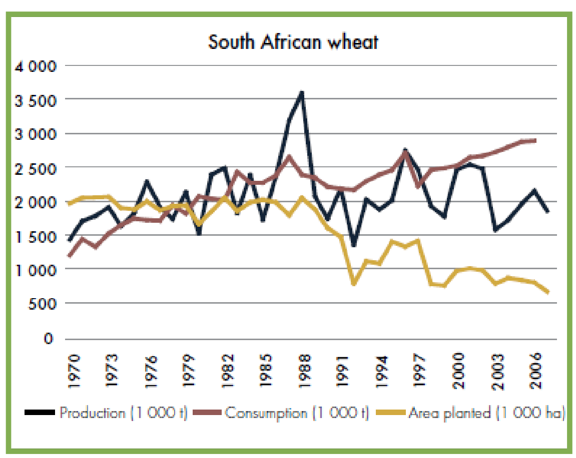


Figure 4.1: Maize and wheat production, consumption trends over a 40 year period in South Africa

Source: *Goldblatt (2010)*

4.3 Climate change and impact on production of cereals

A number of studies have looked at the impact of climate change on crop production in South Africa and Schulze (2016) provides an appropriate summary. The most important factor reported to be limiting crop production is the availability of water and in most cropping systems this is supplied directly by rainfall.

Statistical evidence suggests that temperature have steadily increased in South Africa in the last four decades, with average yearly temperature increasing by 0.13 ^{o}C between 1960 and 2003 (Kruger and Shongwe, 2004). This combination of low rainfall and increased temperature will increase evaporative demand and increase moisture stress on crops in those regions that are predicted to experience reduced rainfall in the future. The ability to contend with heat and drought stress will be important for maintaining stability in the production of major cereal crops.

Maize is the staple crop for countries in the SADC region and South Africa produces more than half of the maize in this region, making the impact of climate change on this crop of sub-regional concern. Average annual rainfall in South Africa is estimated at 450 mm compared to a global average of 860 mm whilst evaporation rates estimated at 1,500 mm/year are on the high side and will increase with expected high temperatures.

Changes that lower rainfall amounts and worsen distribution will have negative effects on crop production. Surface and underground water is limited, and agriculture currently consumes more than 50% of available water resources. With a growing population and increased demand for food in the future, there is little room to manoeuvre except to improve efficiency of irrigation systems and water use efficiency of crops to produce more food.

The temperature changes noted by Kruger and Shongwe (2004) show that there has been an increase in the number of warmer days and a decrease in the number of cooler days and some of these impacts are reflected in challenges faced in the production of winter small grains in South Africa (SmartAgri, 2017). There are numerous reports (Cobban and Visser, 2017; Johnston, 2016; Blignaut, 2009; Walker and Schulze, 2008; Midgley *et al.,* 2007; Benhin, 2006; Gberibouo and Hassan, 2005; Du Toit *et al*., 2002; Erasmus *et al*., 2000; Schulze *et al*., 1993) that offer some useful insights into the effects of climate change on cereal production in South Africa.

4.4 Climate smart approaches to adaptation to climate change

The picture across South African provinces with regards to adaptation is summarised in Table 4.4.

Table 4.2: Provincial climate change adaptation strategies

Provinces with climate change response plan	Provinces with no climate change response plans	Budget allocated	Dedicated institutional arrangements
Western Cape climate change response framework for the agricultural sector		Western Cape (minimal dedicated budget)	Western Cape
Gauteng climate change response strategy	Free State North West		
Eastern Cape climate change response strategy	Mpumalanga Northern Cape		
KZN climate adaptation plan		KwaZulu-Natal (minimal dedicated budget)	KwaZulu-Natal
Limpopo Green Economy Plan			

Source: *Adopted from Montmasson-Clair and Zwane (2016).*

The UN Framework Convention on Climate Change (UNFCCC, 2007) defines adaptation "as a process through which societies make themselves better able to cope with an uncertain future" and where "adapting to climate change entails taking the right measure to reduce the negative effects of climate change (or exploit the positive ones) making appropriate adjustments and changes. In the context of crop production, Schulze (2016) refined this concept of adaptation to changes:

⇒ in the natural system that is farmed (e.g. when, what, and where to plant a crop, how much fertilizer to apply etc.),
⇒ in the human systems that we operate (how and why), and
⇒ in changes in decision environment (e.g. increased crop prices)

The WRC has funded some projects that improve our understanding of adaptation to climate change in South Africa under KSA 4:

⇒ Adaptive interventions in Agriculture to reduce vulnerability of different farming systems to climate change in South Africa. Project number: 1882.
⇒ Insights into Indigenous Coping Strategies to Drought for Drought Adaptation in Agriculture: The Southern Cape Scenario.
⇒ Vulnerability, adaptation to and coping with drought: The case of commercial and subsistence rain-fed farming in the Eastern Cape.

Some adaptation measures as defined by FAO (2007) include: seasonal changes and sowing dates; different variety and species; water supply and irrigation systems; other inputs (fertilizer, tillage method); other field operations and new crop varieties as examples. Those important in the context of South Africa are reviewed in the following sub-sections.

4.4.1 Conservation agriculture in cereal based cropping systems

Successful conservation agriculture (CA) stories in South Africa can in part be attributed to work carried out by many organisations who have contributed in various ways. The organisations that have played a supportive role in the promotion of CA include:

1) Department of Agriculture, Forestry and Fisheries:

DAFF established a National Conservation Agriculture Task Force (NCATF) in 2009 to help with the promotion of CA. The NCATF is chaired by DAFF which is also the secretariat. Other role players in the NCATF are the Food and Agriculture Organisation (FAO), Agricultural Research Council (ARC), Grain SA, Maize Trust, Organized agriculture, Inputs suppliers (SA Lime, Afritrac), Civil society organizations (Farmers clubs and associations e.g. No Till Clubs), NGOs (such as the EcoPort Foundation and the CA Academy) and nine provincial LandCare Coordinators. The NCATF participates in regional CA group, the Conservation Agriculture Regional Working Group (CARWG) to share experiences with other projects in the southern Africa region.

Awareness and training of trainers on CA projects were initially started in Limpopo, Mpumalanga, Kwa-Zulu Natal, Eastern Cape and North West in 2010/11. Following that, projects were established in Mpumalanga, Limpopo, Kwa-Zulu Natal, Free State and Eastern Cape in collaboration with DAFF, FAO, ARC, Grain SA, Maize Trust and provincial Departments of Agriculture and then rolled out nationally in 2013/14. It has generally been observed that CA is gaining in adoption rate by commercial farmers because of the evidence-based opportunities for reducing input costs. Adoption rates are believed to be high in the Western Cape and the Free State.

2) Agricultural Research Council (ARC)

The ARC is the principal agricultural research organisation in South Africa. It focusses on conducting research that is environmentally sustainable and economically viable for farmers. Historically, it has supported research initiatives on CA with both commercial and smallholder farmers going as far back as the 1980s. The ARC started on CA working with commercial farmers in KwaZulu-Natal and then in 1997 started work with mostly smallholder farmers in LandCare related projects. Smith et al., (2008, 2010) cites 20 different LandCare-related CA projects in which the ARC participated with many of them implemented by the Institute for Soil, Climate and Water (ISCW). These projects involved hundreds of farmers directly and reached many others through awareness activities.

The ARC is conducting research on climate smart agriculture systems and climate and drought monitoring under its programme on Natural Resources Management and also conducts training and extension activities to promote CA. Conservation agriculture-related projects are included in this programme. The Grain Crop Institute (ARC-GCI) has some projects that are investigating how crop yield is affected under CA and insect and weed dynamics in the changing environment created by adoption of CA principles. The ARC-GCI has received funding from the Maize Trust for some of the ongoing work on CA.

The ARC-Small Grain Institute (ARC-SGI) has been funded by the Winter Cereals Trust to conduct trials on conservation tillage and provide solution to agronomic challenges in the production of wheat under CA. Targeted research was conducted on row widths, seeding density, fertiliser placement etc. resulting in recommendations that have helped popularise CA and its adoption in the wheat growing areas of the WC. Funding from the Winter Cereals Trust is being used to maintain a long-term trial at ARC-SGI comparing CA and conventional tillage and information from such trials is important for farmer decision making in managing these systems. ARC literature notes some benefits derived from the practice of sustainable production systems as improved water use, conservation of water, improved agricultural productivity, and better profits compared to traditional/conventional systems.

3) Grain SA

Grain SA is a voluntary farmer organisation established in 1999 through merger of four commodity associations for maize (NAMPO), soybean, sunflower and groundnuts (NOPO), wheat, barley and oats (WPO) and grain sorghum (SPO). The Grain Research and Policy and Farmer Development Programmes of Grain SA play important roles that support the promotion of CA in both the commercial and smallholder sectors of South Africa. Grain SA addresses issues of climate smart agriculture (CSA) under its research portfolio through breeding projects that are focussed on producing high yielding wheat varieties adapted to changing climatic conditions. Crop protection activities monitor incidence of new pests whilst conservation agriculture is a key project with a full-time facilitator.

In 2013, the Maize Trust (www.maizetrust.co.za) in cooperation with Grain SA initiated a conservation agriculture farmer innovation programme (CA-FIP) to mainstream CA through grain farmers. A total of four projects have been funded, two in the smallholder sector in Bergville, KwaZulu Natal and Matatiele in the Eastern Cape. The two projects in the commercial sector are Ottosdal in the North West province in collaboration with the Ottosdal No-Till Club and Reitz and Vrede in north-eastern Free State. The success of the two smallholder projects has resulted in upscaling of the work in Bergville to the KwaZulu-Natal Midlands and from Matatiele to southern KwaZulu Natal in a joint venture with Mahlatini Development Foundation (MFP) (www.mahlatini.org) (a participant in the SA Adaptation Network sharing experiences, practical approaches and frameworks relating to climate change adaptation).

5) Other projects with relevance to CSA include the Sandy Soils Development Committee (SSDC) that has been investigating the impact of CA on soil health on semi-arid sandy soils in the north-west Free State and the Carbon Footprint focussing on winter grain farming in the Western Cape. Grain SA has published a CA manual in English and Zulu that can be used as the basis for adapting to a guideline on CA in South Africa ("Conservation Agriculture for smallholders in South Africa: www.grainssa.co.za).

4) Western Cape Department of Agriculture (WCDoA)

The WCDoA launched a Conservation Agriculture Western Cape Association in 2011. The association has produced newsletters to promote CA. Conservation agriculture is advocated for winter grains, rooibos tea and potato production and is supported by an extensive research and support programme. Work has been conducted on eight crop rotation systems, including wheat, canola, lupins and pasture species in the Swartland. The economic sustainability of short- and long-rotation crop/ pasture production systems is also being investigated in the same province.

5) KwaZulu-Natal No-Till Club and Other Farmer Clubs

Successful uptake of CA has been achieved where farmers have been at the forefront of these initiatives themselves. The pioneer in this regard in South Africa is the KwaZulu-Natal No Till Club which was started in December 1997 by six farmers and has grown to a paid-up membership of 140, mainly farmers. The mission of the Club is to actively promote and facilitate environmentally friendly, economically sustainable conservation farming, for the benefit of all. Its members therefore practice climate smart agriculture through practicing No-till conservation agriculture. It shares its wealth of knowledge through the following activities:

i) An Annual No-Till Conference with a specific theme to promote CA. The conference plays a pivotal role in assisting farmers to understand and implement No-Till CA on their farms whatever the size.

ii) The No-Till Club Newsletter is published three times in a year in April, July and December. The purpose of the newsletter is to: (a) Stimulate interest for the adoption of No-Till CA throughout South Africa and Africa, (b) Provide a platform for providing professional advice to farmers, and (c) A tool to bring to the reader's new concepts, techniques and suggested practices.

iii) The No-Till Club Website - used to distribute CA knowledge and practices in South Africa and beyond. www.notilclub.com .

iv) Books – The Club has published three books with the following titles:

⇒ Guide to No-Till Crop Production in KZN. A book published some 10 years ago complied from chapters written by Agronomists, Soils Scientists and farmers on various aspects of the No-Till CA system.
⇒ Advantages and Benefits of No-Till complied by Dr Aubrey Venter. This is a book with a wealth of information of what effect the adoption of NO-TILL CA can have on the improvement and protection of the environment.
⇒ Beginners Guide to No-Till also complied by Dr Aubrey Venter and is aimed at what a beginner needs to know.
⇒ A booklet in ZULU on No-Till.

Other farmer groups inspired by the KZN No-Till Club are the CA Western Cape and Ottosdal No-Till Club in the North West, both of which are playing crucial roles in the promotion of CA in their regions and also hold annual conferences.

4.4.2 Switching crops and varieties

Switching crops can be used as an adaptation strategy, but limited funding afforded to well-adapted cereal crops such as sorghum research in South Africa presents challenges in preparing for any such switch. Successful switch would require considerable work to smooth out many impediments (e.g. breeding of improved cultivars, relatively less sorghum-processed goods in the market, low demand for processed products in the market, bird and pest tolerance) with the sorghum and millet value chains in South Africa. In regions where growers can afford to shift cultivation from maize to more water efficient and drought tolerant cereals (e.g. sorghum and millet), this is suggested during dry seasons. Sorghum and millet have inherited higher tolerance to heat and drought and this suggests they could be crops that can be used to adapt to climate change in South Africa. However, data presented in Table 2 showed a decline in sorghum production and earlier interest in the crop for biofuel production seems to have reduced. The ARC-SGI has been conducting research on sweet sorghum as a biofuel. Sorghum for food consumption has many health benefits but it lost importance as food to maize which was easy to produce.

Photoperiod sensitive cultivars traditionally cultivated by farmers were shown to be more resilient to climate change as they can counteract the temperature effect of shortening growth duration. Results obtained by Hadebe *et al.* (2017) in South Africa agree with findings by Sultan *et al.* (2013) with regard to comparative performance of hybrids and landraces. Hadebe et al. (2017) showed that landraces Ujiba and IsuZulu had higher biomass and grain water use efficiency (WUE) with late planting dates and low rainfall compared to hybrid PAN8816 and Macia. Macia is an improved open pollinated maize varieties (OPV). This suggests that there is need to improve heat and drought tolerance of higher yielding sorghum cultivars through breeding and that research agencies and the South African government should allocate more resources if sorghums and millets are to be a solution to adapt to climate change.

Plant breeding has been a tool that has been used to address adaptation to biotic and biotic stresses in the past before current concerns on climate change. The challenge with climate change, particularly in a variable agro-ecological environment as exists in South Africa and the southern Africa sub-region will be the reliability and accuracy of forecast with respect to future climates. However, as noted by Akinnagbe and Irohibe (2014) climate change is expected to intensify existing problems and create new combinations of risk in Africa. Farmers are aware of climate change and cite increased temperatures, reduced volumes and altered timing of rains as signs of change. Breeding for heat and drought tolerance has been used as a strategy to deal with these anticipated shifts in optimum growing regions and growing seasons for certain crops (DEA, 2013). The use of drought resistant varieties (listed below) of crops is a strategy that is commonly used by farmers as an adaptation strategy to reduced and increased rainfall variability. In the South African context, the primary responsibility for cereal breeding is the responsibility of ARC-GCI and ARC-SGI.

Water Efficient Maize for Africa (WEMA), a private-public partnership involving agricultural agencies of Kenya, Mozambique, South Africa, Tanzania and Uganda, and the International Wheat and Maize Improvement Centre (CIMMYT) and Monsanto was formed in 2008 to provide drought tolerant maize varieties as part of the African Agricultural Technology Foundation's (AATF) Drought Tolerant Maize for Africa (DTMA) project. In 2014, the ARC launched two conventional drought tolerant maize hybrids (Grain SA, 2015). In 2015, the Executive Council for Cultivation authorised the release of MON87460 (Grain SA, 2015) creating opportunity for enhancing the drought tolerance of conventional hybrids released by the ARC by incorporating the drought tolerance trait MON87460. Subsequent work has resulted in the release of a total of ten DroughtTEGOTM WEMA maize varieties with predominant characteristics of drought tolerance and high yield potential under optimal moisture.

Poor soil fertility of many African soils combined with low use of inorganic fertilizers (about 9 kg/ha for Africa compared to 100 kg/ha for south Asia) (Grain SA, 2012) contribute to low maize grain yields. To address this issue, the ARC is collaborating with the Kenya Agricultural Research Institute (KARI) and Pannar in developing low nitrogen tolerant varieties in a project "Improved Maize for African Soils (IMAS)". Materials that are being developed will be better at capturing the small amounts of fertilizer applied by farmers and will make more efficient use of the nitrogen that is taken up. The hybrids are undergoing final phases of evaluation and promotion among different stakeholders. Both the WEMA and IMAS projects are funded by the Bill and Melinda Gates Foundation and USAID.

Many smallholder farmers still rely on recycling seed of a wide variety of crops including that of open pollinated maize varieties (OPVs). Farmers operate local seed systems that have sustained production over the years with minimum investment to improve these systems. The Southern Africa Drought and Low Soil Fertility Project (SADLF) facilitated the release, promotion and setting up of community-based seed production by smallholder farmers in South Africa and other Southern Africa Development Community (SADC) countries.

4.4.3 Better use of short term and seasonal climate forecasts

Seasonal climate forecasts and reliable signals can be useful tools that allow farmers to make better informed decisions on when, what and how to plant. Numerous early warning systems, risk management and decision support tools are in use in South Africa. Resilient farming communities can be attained through reduction of risks of disasters through strengthening early warning systems and disseminating early warnings, as well as raising awareness through campaigns. An Early Warning System (EWS) is used to communicate monthly advisories and daily extreme weather warnings in support of disaster risk reduction for farming communities. This function is primarily being offered through the National Agro-Meteorological Committee composed of members from DAFF, South African Weather Service (SAWS) and ARC-Institute for Soil, Climate and Water (South Africa Yearbook 2012/13). The National Agricultural Disaster Risk Management Committee provides strategic guidance on policy and advises DAFF on issues relating to agricultural disaster risk management. The department frequently responds to hazards such as droughts, veld fires, floods and outbreaks of pests and diseases. They provide support to farmers that would have suffered losses, including infrastructure losses such as irrigation, soil conservation structures and dams (South Africa Yearbook 2012/13). The CSIR has also developed numerous early warning disaster detection tools. These include: (i) The Wide Area Monitoring Information System (WAMIS). The tool provides near real-time monitoring and mapping capabilities of natural events such as fires, floods, and droughts occurring within Southern Africa; (ii) The Advanced Fires Information System (AFIS). The AFIS is a satellite-based fire information tool that provides near real time fire information to users across the globe.

The Western Cape Department of Agriculture has a number of activities that support the use of seasonal climatic data:

⇒ Collect and summarise information on historical climatic and agricultural conditions - done on a monthly basis and the information disseminated to agricultural stakeholders.

⇒ Obtain and compare information based on climate and agricultural conditions of the past month with the long-term average or normal tendencies - done on a monthly basis and the information disseminated to agricultural stakeholders.

⇒ Render an advisory service to role players in agriculture and related organisations with regard to climatic and agricultural conditions in the WC - continuous service.

⇒ Using remote sensing products to assist in drought monitoring - continuous service.

4.4.4 Intercropping

Smallholder farmers who produce mainly for subsistence typically grow a wide range of crops in diverse mixtures that have been worked out over many years as part of an indigenous knowledge system (IKS). Intercropping that is practiced is a safeguard from abiotic and biotic stresses such as drought, pests and a means of maintaining soil fertility and productivity of degraded lands. The practice of intercropping allows for crop diversity which is important for improving soil health.

The eco-technology projects initiated by the ARC (ARC, 2012) and noted to be about 20 LandCare projects by Smith *et al.,* (2017) reached thousands of smallholder farmers across South Africa. These projects built on what people were already doing and intercropping practice is a strong component of the CA practices promoted by ARC-ISCW in these LandCare projects. The Bergville case study is one of the success stories noted in the promotion eco-technology amongst smallholder farmers. The Bergville study has continued as part of the Grain SA CA-FIP and offers valuable lessons in the implementation of intercropping. The Agroecology approach promoted by Biowatch also advocates for mixtures of crops and highlights the importance of community seed initiatives to ensure availability of seed, particularly of legumes for promotion of viable intercrop combinations.

Universities have contributed interesting information that shows that intercropping is more productive than mono cropping, even in dry areas of the country. Data generated has also assisted show the extent of the practice amongst smallholder farmers (Silwana and Lucas, 2002; Mpangane *et al.,* 2004; Maluleke *et al.* 2005). Ogindo & Walker (2005) identified intercrops to conserve water largely because of early high leaf area index and Tsubo *et al.,* (2005) found that soybean-maize intercropping was the best combination system during water scarcity periods. Other studies have noted the importance of intercropping in controlling pests, such as the maize stalk borer through intercropping maize with cowpea (Henrik & Peeter, 1997). Research on CSA is an important mandate of the ARC and this includes research on intercropping (ARC, 2012).

However, successful intercropping largely depends on adaptation of planting patterns and selection of compatible crops. Research is silent on which varieties were included in trials to provide some guideline on selecting plant types may form successful combinations. Equally important, legumes included in intercrop systems must be able to tolerate low light to avoid high yield depression. This requires selection of these varieties in intercropping situations and there is no evidence of this in the literature reviewed. In the trial conducted by Tsubo *et al.,* (2003) in the Free State, maize reduced bean yield by 90% whilst maize yield was not reduced by the bean crop.

4.5 Climate smart approaches to mitigating climate change

Climate change mitigation aims at limiting the magnitude or rate of long-term climate change. Measures include the reduction in green-house gas (GHG) emissions and increasing the capacity of carbon sinks.

Practices such as nutrient management; tillage and residue management; water management (irrigation, drainage); agroforestry; crop rotations; and land-use change can help mitigate green-house gas emissions (GHG) (Campbell *et al.,* 2011) and can contribute to increased crop productivity.

4.5.1 Conservation agriculture (CA)

Conservation agriculture can substantially reduce carbon dioxide (CO_2) emissions through reduced diesel use when no/reduced tillage is adopted. Minimal soil disturbance also results in less exposure of soil organic matter to oxidation thereby minimising release of CO_2 to the atmosphere. Crop residue retention can result in an increase in soil carbon in the surface layers, thereby contributing to sequestration. The KwaZulu-Natal No-Till Club has been a persistent voice that has promoted no-till land preparation and its members have successfully demonstrated environmental and financial benefits to the farmer of this practice. A number of authors have demonstrated the potential climate change mitigation brought about by CA in maize-based cropping systems in South Africa and southern Africa through increase in soil organic carbon when compared to conventional ploughing (Dube *et al.* 2012; Powlson *et al.* 2015; Njaimwe *et al.* 2016; Muzangwa *et al.* 2017).

Contribution of CA to carbon sequestration through increased crop productivity has been demonstrated under South African conditions by a number of authors. The work by Njaimwe *et al.* (2016) and Muzangwa (2016) demonstrate the importance of crop rotation and that by Murungu *et al.* (2011) and Dube *et al.* (2013) the importance of cover crops in increasing maize yield. Dube *et al.* (2013) showed a fourfold increase in maize yield with use of grazing vetch compared to farmer tradition of low input production of maize.

4.5.2 Nutrient management

DAFF and the ARC have crop production guidelines for various crops on their websites that guide farmer use of appropriate agronomic practices, including fertiliser recommendations. The Landcare programme that is being implemented throughout the country also contributes to cropland management through sub-programmes WaterCare and SoilCare. The ARC is recommending well-researched fertiliser rates for CA systems so as to minimise emissions of nitrous oxide (N_2O) into the atmosphere. The ARC is also promoting vermiculture technology, where organic household and farm waste is converted to high quality vermicompost and leachate by using earthworm composting in vermibins. The importance of this technology is that it is a profitable alternative for inorganic fertilizers in the absence of animal manure. Absence of animal manure is the rule rather than the exception on many small-scale farms that practice subsistence agriculture.

4.5.3 Crop rotation

Available evidence shows that cereal mono-cropping is not a sustainable practice and that increasing crop diversification is going to be beneficial both climate change adaptation and mitigation. More research is needed at local levels in various agro-ecologies of South Africa to work out rotations that are likely to benefit both the environment and farmers to encourage farmer shift to a wider diversity of crops. Rotation is considered by the ARC as one of their CSA approaches in the 2011/12 annual report notes that maize grain yield increased by 297% when rotated with a legume (ARC, 2012).

A study by Powlson *et al.* (2015) showed that of all the CA practices, crop diversification was found to have the greatest climate change mitigation potential from carbon sequestration in soils. The studies by Njaimwe *et al.* (2016) and Muzangwa (2016) both set up in the Eastern Cape province of South Africa agree with findings by Paulson *et al.* (2015). Rotations in the maize belt and wheat growing areas of South Africa are still very narrow and require sustained support with regards to both research and extension and if it makes economic sense and value chains are considered and established, farmers will adopt proposals to diversify.

In the Western Cape, rotation of wheat with legume pastures (medics and Lucerne) has improved soil health and the integration and management of livestock (Smith et al. 2017). Crop rotation with three or more crops (e.g. maize-soybean-wheat under irrigation) is used by 40% of farmers practicing CA, whilst 10% monocrop and 50% use two crops with maize-soybean being a popular combination (Findlater, 2015).

The North West Provincial Department of Agriculture is considering the option of crop diversity as an adaptation strategy. The Crop Science Division is looking at alternative crops such as Amaranthus, which has the potential to produce prodigiously under a variety of climatic conditions. Other possible avenues of research include crops such as millet, vergonia, etc. as alternatives to the more traditional cash and cereal crops.

4.5.4 Cover crops

The use of cover crops can be considered both an adaptation and mitigation strategy to climate change. Cover crops offer diverse services including biocontrol of nematodes and weeds (ARC, 2017) and can contribute to soil fertility when legumes are used and to soil health. The study by Findlater (2015) showed that use of cover crops is still work in progress with only about 20% of commercial farmers using annual cover crops and 25% using ley cropping 3 to 5 years with species such as weeping lovegrass (*Eragrostis curvula*). There has been more progress in the use of cover crops in the Western Cape with the support of WCDoA. Such support is crucial for ongoing agronomic evaluation of species and management strategies needed to generate information useful to support farmers. This type of research should be considered standard agronomic work which should be a regular and ongoing activity, particularly of provincial departments with some national support.

Grain SA has included a chapter on cover crops in its CA manual produced for smallholder farmers. Examples of legume cover crops for the warm season include: dolichos (*Lablab purpurea*), sunnhemp (*Crotalaria juncea*), cowpea (Vigna unguiculata) and lucerne (*Medicago sativa*), velvet beans (*Mucuna pruriens*), soybean (*Glycine max*) and mung bean (*Vigna radiata*) and for the cool season: hairy vetch (*Vicia villosa*), forage pea (*Pisum sativum*) and red clover (*Trifolium pratense*) among many others evaluated in different parts of the country. Research on a wide variety of summer and winter cover crops at the University of Fort Hare has shown their positive effects on soil health and maize productivity (Murungu, 2010; Musunda, 2010; Ganyani, 2011; Muzangwa, 2012; Muzangwa *et al*. 2013; Dube *et al.,* 2014ab; Mukumbareza, 2014; Musunda *et al*. 2015 and Muzangwa *et al.* 2015) and work is in progress where farmers are growing grazing vetch and oats as cover crops in their fields.

4.6 Integrated pest management

The LTAS (DEA, 2013) offers some insights into the potential implication of climate change for agriculture and impact of pests and diseases. The stages in the development and duration of life cycles of pests and diseases are closely related to temperature. The increases already measured and those forecast under different scenarios may suggest that there could be more life cycles of existing pests and therefore could anticipate more attacks on crops and increasing the bill for managing pests. The ARC maintains an ongoing surveillance programme as distribution of pests may change and new pests can emerge. The fall armyworm (*Spodoptera frugiperda*) that spread rapidly from north to southern Africa in the recent past is a case in point.

During drought seasons, maize is particularly susceptible to pests and farmers can experience complete loss. South African smallholder farmers are vulnerable to stem borer infestations during the cereal-growing season. Insect pest protected (Bt) cereal cultivars have been developed to combat the stem borer problem.

Pereira (2017) notes that changes in temperature and rainfall and seasonality in Africa could result in more suitable habitats for Witchweed (*Striga hermonthica*). Witchweed infestations in cereal (maize, rice, wheat, sorghum etc.) cropping systems presents major resource competition and parasitic effects that significantly reduce yields. Breeding attempts to Striga resistance have resulted in certification of 11 commercially released varieties.

Adaptive measures to the anticipated pest challenges are being addressed in breeding programmes. For example, ARC scientists at the Small Grain Institute identified 64 preliminary lines of wheat with a combination of resistance to leaf rust, yellow rust, stem rust and the Russian wheat aphid using a combination of molecular markers and conventional phenotyping (ARC, 2013).

The ARC-Plant Protection Research Institute (ARC-PPRI) also follows and promotes a holistic approach to the pest, disease and alien invasive plant problems, in line with the principles of integrated pest management.

Case study 4.1: Tillage systems

One of the studies conducted in the Bergville area, KwaZulu-Natal (Mchunu *et al.,* 2011), showed that small-scale farmers could still achieve positive benefits from the no-till system, even when practiced with grazed crop residue. After six consecutive years of no-till with grazed residue on the study site, benefits were observed such as:

- ⇒ Reduced soil erosion,
- ⇒ increased aggregate stability,
- ⇒ Increased microbial biomass and activity were observed.

Minimal soil disturbance and having some residue on the soil surface was identified to be the main driver in achieving the observed benefits. With minimal soil disturbance, whole aggregates (groups of *soil* particles that bind to each other more strongly than to adjacent particles) were preserved. Moreover, polysaccharides (adhesive exudates) from microbial activity, together with fungal hyphae, strengthened existing aggregates and promoted the formation of bigger and more stable aggregates; protecting more of the precious organic matter in the soil. Stability of aggregates and the dominance of structural crusts on the soil surface were some of the causes of reduced soil erosion in the no-till systems. Structural crusts form when raindrops hit the soil surface, causing partial disintegration of aggregates, thus forming a layer of fine particles with rough soil clods on the soil surface. These crusts are more resistant to erosion and their porosity promotes higher infiltration rates, compared to sedimentary crusts, which form when the impact of raindrops breaks up unstable aggregates.

Aggregates disintegrate into small soil particles, which are then transported by runoff water and are deposited elsewhere, as a thin layer on the soil surface. Upon drying, this layer hardens to form a sedimentary crust (Mchunu and Manson, 2015). The study recommended that in small-scale farming systems, farmers are encouraged to have at least 23% of their soil surfaces covered by residue, to assist in reducing erosion, protecting more organic matter in the soil and in promoting a better soil structure. Findings and recommendations by Mchunu and Manson (2015) seem not to account for differences in soil types under no till practices. In this regard, the South African Sandy Soils Development Committee (SDC) reported that after their 4-year trial, that it suggests that No-Till grain cultivation practices are not effective in sandy soils despite ongoing reports to the contrary (No-Till Club, July 2018).

Case study 4.2: The case of Mooifontein: Adoption of no-till practices

A large number of factors usually affect adoption of new practices. Adoption of climate change adaptation and mitigation factors requires a shift from the 'business as usual' approach and similarly is influenced by a number of factors. Research revealed that a large percentage of the farmers in the Mooifontein region still practise monoculture, a system in which the same crop is planted every year, rather than following a crop rotation plan. Increases in disease and pest damage and low productivity in the region has been attributed to the aforementioned farming methods.

One of the factors that have been blamed for slow adoption of adaptation measures to climate related challenges has been low literacy levels. Farmers' level of education is significant for adaptation education because it has been suggested that literate individuals are more likely to accept new innovations and contribute to more sustainable farming enterprises than illiterate farmers. Based on the financial (yield, capital and working costs and reduced risk) and environmental benefits (less erosion and more balanced eco-systems) obtained by growing crops under no-till conditions far exceed those of other tillage systems (Arathoon, 2010).

Consequently, the number of farmers growing crops under no-till is increasing annually in South Africa and in the Mooifontein region. Important to note, other reduced tillage practices (e.g. strip till, mulch till, mimum till, ridge till) can be employed to reap positive benefits (weed and pest reduction, breaking of soil hard pan, breaking of roots) of tillage while benefiting from reduced tillage.

Case study 4.3: Mulch and residue cropping

Mulch refers to the process when a farmer merely leaves the previous crops' residue on the surface of the soil (land), allows it to decay, and it ultimately becomes compost.

⇒ This sort of cover works well with a high population of maize crops, say where a farmer plants in excess of 45 000 plants per hectare, which will be mainly in the higher rainfall areas.

⇒ Where there is a lower plant population of an estimate of, 20 000 plants per hectare, then the cover left after harvesting will not be sufficient to actually achieve the type of mulch needed to accomplish the positive attributes.

The efficiency of a crop residue cover is dependent on how well it is spread over the soil surface of the land (Dlamini *et al.*, 2014). A long-term project was launched in two smallholder pilot study areas to investigate and promote the use of conservation agriculture for sustainable crop production. One of these case study sites was in Matatiele, Eastern Cape province of South Africa.

These smallholder projects were funded and established under the umbrella of the Farmer Innovation Programme (FIP) at Grain SA and the Maize Trust, through collaboration between the SaveAct Trust, Mahlathini Organics, the Maize Trust and Grain SA. The aim was to apply innovation systems and processes assisting smallholder farmers in growing maize and legumes using conservation practices (Dlamini *et al.*, 2014). Importance of maize production for Matatiele smallholder farmers is typical of South African settings where maize is a multipurpose crop (eaten as green mealies, dried and used as chicken feed, maize stalks are used for ruminant feed in winter.

4.7 Conclusions

This review was conducted to feed into the development of guidelines for climate smart agricultural practices that can be implemented by farmers. Information on no-till and conservation agriculture for smallholder and commercial farmers is available to include in a guideline. Suitable templates already exist in the form of guidelines produced by Grain SA. Missing data that needs to be generated from a research perspective is with regard to recommendations for varieties suitable for CA systems, cover crops and production guidelines. This also true for intercropping, information on varieties, production guidelines which are required to support growers in different agro-ecologies.

Aspects of CSA are knowledge intensive and any guide produced should be viewed as work in progress to be improved as users learn more. More research funds need to be availed by government to support regular agronomic work. The focal point for support should be the provincial levels and work could include screening cover crops, agronomic management in different production situations, screening varieties for intercropping etc.

This report indicates that switching to adaptable crops, use of climate forecasts, intercropping cereals with other crops, reduced tillage, nutrient management, cover cropping, and crop rotations are beneficial towards making cereal based crop production more climate smart in South Africa.

The strategies however, should be applied within context, and with limitations discussed in this report in mind. Implementation of climate smart agriculture requires collaborative action from various stakeholders for effective implementation.

The partnership of the Western Cape Department of Agriculture (WCDoA) and Stellenbosch University is an excellent example of where government and research institutions, together with cereal producers have collaborated to implement climate smart practices to improve small grain production in the Western Cape province. This could be a model for other provinces and institutions to follow and improve for better implementation of climate smart agriculture in cereal based cropping systems.

5.1 Introduction

South Africa is one of the leading producers of high-quality sugar and is in the top 15 of 120 sugar-producing countries in the world (SASA, 2018). Sugarcane production expands across the KZN coastal belt, spreading into the Midlands region. Agriculture in these areas is predominantly rain-fed, while moving north into Pongola and Mpumalanga into irrigated cane. The industry has over 20 000 registered growers producing about 20 million tons of sugarcane on 362 000 hectares of land each season which is processed into about 2 million tons of raw sugar in 14 industry mills.

The South African sugar industry makes significant contributions to the national economy of South Africa. This is achieved through its agricultural and industrial investments, foreign exchange earnings, its high employment and linkages with major suppliers, support industries and customers. It is a diverse industry combining the agricultural activities of sugarcane cultivation with the industrial factory production of raw and refined sugar, syrups and specialized sugars, and a range of by-products (DAFF, 2016). The industry produces an estimated average of 2.2 million tons of sugar per season.

About 75% of this sugar is marketed in the Southern African Customs Union (SACU) region and the remainder is exported to markets in Africa, Asia and United States of America. Based on revenue generated through sugar sales, in the SACU region and world export market, the South African sugar industry is responsible for generating an annual average direct income of over R12 billion. The sugar industry directly supports approximately 79 000 jobs, and indirectly supports another 350 000 jobs (DAFF, 2016).

Smallholder farmers (SHF) seem to be struggling to stay competitive in the industry. The total number of smallholder farmers growing sugar cane declined from 45 500 to 22 453 between 2007 and 2014 despite favourable policies and structures put in place to ensure their success in the industry. This decline was attributed to the volatile global sugar prices, debts, high costs of inputs, poor soils, poor farm management, high transaction costs, and high fees charged by contractors/milling companies (Gcanga, 2014).

It was reported that there is an apparent lack of adoption of recommended improved technology and practices by smallholder farmers (Eweg *et al*., 2009). This could be partly explained by the low education levels that were observed in the study, with almost 36% having no formal education. Additionally, limited access to financial and extension services can also be contributory factors.

5.2 Environmental standards/systems that the sugar industry complies with

Sustainable sugarcane agricultural production is promoted in the industry through the implementation of sustainability standards / systems. Such standards / systems exemplify legal requirements and best practices and, are also being used to meet the sustainability sourcing requirements imposed by customers in the sugar value chain. Currently four global voluntary sustainability organizations operate in the sugar industry; Fairtrade, Bonsucro, Organic, and Rainforest Alliance (Gcanga, 2014). Fairtrade sugar works with smallholder farmer organizations. Fairtrade Standards are designed to address the imbalance of power in trading relationships, unstable markets and the injustices of conventional trade.

The terms of trade are that most products have a set Fairtrade Minimum Price, which is the minimum that must be paid to the producers. In addition, producers get an additional sum, the Fairtrade Premium, to invest in their communities or businesses (Fairtrade, 2018).

Bonsucro (Better Sugar Cane Initiative) is an independent certification program for the sugarcane industry developed through a multi-stakeholder, global consultation process. It recognizes responsibly produced sugar and sugar derivatives like ethanol and gives equal weight to environmental, social and economic performance. It is a single certification system for sugar production that can be applied to the sale of raw sugar and of ethanol. This allows integrated mills to freely switch between the two while qualifying for sustainability requirements in both supply chains. Certification gives sugar producers preferred access to large-scale buyers who prefer to purchase from certified suppliers in order to achieve their corporate social responsibility goals. Bonsucro certification for ethanol meets European Union (EU) biofuel requirements for sustainability under the Renewable Energy Directive (RED) (Bonsucro, 2018). This directive only allows imports of sustainable biofuel into the EU. Organic focuses on the personal health of the consumer and soil conservation. Rainforest Alliance focuses on conserving biodiversity, improved livelihoods and human well-being, natural resource conservation and, effective planning and farm management systems (Rainforest Alliance, 2016).

The South African Sugar Association (SASA) also has memorandums (MOUs) of understanding with the World Wildlife Fund for Nature (WWF) and the Wildlife and Environment Society of Southern Africa (WESSA), both of which have a focus on environmental sustainability (Conningarth Economists, 2013).

The MOU with WWF places emphasis on the conservation of fresh water, estuarine habitats and the promotion of biodiversity. On the other hand, the MOU with WESSA has a focus on promoting and implementing environmental sustainability practices, and related education and social learning processes that will strengthen environmental and social change within the South African sugar industry. The agreement with WESSA allows facilitation and implementation of better management practices, that is, the Sustainable Sugarcane Farm Management System (SUSFARMS®) into the daily activities of the sugarcane sector (Conningarth Economists, 2013). The SUSFARM® standards enable milling companies and sugar cane growers to obtain Bonsucro certificates.

5.3 Climate-smart agriculture practices in the South African sugar industries

5.3.1 Investment in research, extension and better CSA management practices

The South African sugar industry has invested in research, extension, development, and delivery of better management practices in sugarcane agricultural production. The South African Sugarcane Research Institute (SASRI) is a leading sugarcane agricultural research institute in Africa. Research at SASRI is clustered within four multi-disciplinary programmes including variety improvement, crop protection, crop performance and management, and a system design and optimization programme (SASRI, 2017).

The goal of the **Variety Improvement Research Programme** is to conduct research and implement strategies for the continual release of high sucrose yielding, adaptable and pest and disease resistant varieties. Research is undertaken in four key areas: breeding and selection, variety characterisation, novel and improved traits, and, genomics and bioinformatics. The novel and improved traits sub-programme involve use of mutagenesis and research into production of transgenic sugar cane (Table 5.1).

The goal of the Crop Protection Research is to develop integrated management strategies that minimise the effects of pests, diseases and weeds on crop production in a sustainable manner. Research is undertaken in five key areas: biosecurity, crop resistance to pathogens and pests, biology and ecology of pathogens and pests, biological control, cultural and environmental practices, and agrochemicals.

The goal of the **Crop Performance and Management Re-**

search is to develop models and better management practices to enable stakeholders to enhance sustainable crop production. Research is undertaken in six key areas: crop physiology, crop nutrition, soil health, crop ripening, water management, and climate change. Under this programme, focus has been placed on: (i) increasing capacity to undertake climate change impacts research; (ii) future climate change impacts assessment; and (iii) future climate change adaptation options (Table 5.1).

The goal of the **Systems Design and Optimisation Research** is to investigate, develop and transfer innovative systems for use by growers and miller-cum-planters to optimise performance. Research is undertaken in three key areas: production sustainability, water management, and technology development. Among other activities, production sustainability used the SUSFARMS® progress tracker central database tool that was developed to extract, aggregate, display and report on individual sustainability indicators. The tool is used by Extension Specialists in reporting on grower and miller-cum planter progress towards implementation of best practices in each ecozone. Mills may use the tool to provide aggregated evidence of selected sustainability targets to their key customers.

Water management research involves development and deployment of best management guidelines for drip irrigation. Under drought conditions, observations confirmed superior sugarcane appearance and growth under drip irrigation when compared with other irrigation systems. In technology development research, the MyCanesim® model can be applied for strategic evaluations (e.g. for researching climate change impacts) and for operational support (e.g. crop forecasting and irrigation scheduling) (SASRI, 2017). The research programmes are directly focused on sustainable sugarcane agricultural production and have been geared to address grower requirements and reduce risks associated with sugarcane farming.

Table 5.1: CSA activities being implemented and their effectiveness in the South African sugar industry

Role of stakeholder in sugar industry	CSA activities that are being implemented /researched by stakeholder	Effectiveness of activities in ensuring that production is sustainable and productive
VARIETY IMPROVEMENT AND TESTING		
Conventional Plant Breeding	Researching breeding for broad adaptability to future climate change	Wide adaptability provides more stable yields under variable production systems, variable growing conditions and management systems.
Molecular Plant Breeding	This is carried out via the combination of conventional, introgression and molecular breeding. Research on sugarcane leaves/tops as an alternate source of biomass is being conducted, along with bagasse for cogeneration and biofuel production. The outcome will not only allow sugarcane growers to get an extra income from sugarcane leaves, but also provide an avenue for less carbon emission from sugar industry through green cane harvesting.	The new sugarcane varieties that are released to the industry outperform existing varieties, not only in terms of their higher productivity but also their resistance to various pests and diseases. This reduces reliance on pesticides, which is an ultimate step towards greener environments without polluting soils or air.
Mutation Breeding	Mutation breeding for: i) drought and heat resistance; ii) integrated pest and disease management; and iii) resistance to sub-soil aluminium toxicity (allowing root access to sub-soil water in times of drought).	No impact as yet. Still in research phase.
Cultivar Testing	Cultivar adaptation research, Optimising management practices to improve productivity and elevated CO_2 research. Investigation on the influence of elevated CO_2 on the growth, yield and photosynthesis of sugarcane	Cultivar adaptation research – very effective Optimising management practices to improve productivity – difficult to quantify at this stage as the research is ongoing. Elevated CO_2 research – still in exploratory phases, so difficult to tell.
Biotechnology	Sugarcane drought tolerance induced by genetic modification The industry elected to opt for development of an insect (Eldana saccharina) resistant variety that would enable improved management and control of the industry's most significant pest (SASRI, 2017).	Effective. The project has shown that it is possible to insert genes from other plants (Arabidopsis) in to sugarcane to improve its ability to withstand water stress. Development and release of an insect resistant GM variety is a lengthy process. Commercialisation of a Bt GM sugarcane variety expected by 2032 (SASRI, 2017).
SUGAR CANE CROP MANAGEMENT		
Agronomy and Systems Modelling	Increasing capacity to undertake climate change impacts research: Algorithms for crop growth simulation models, Canegro and Canesim, are being researched and implemented to respond to heat and drought. Inter-disciplinary collaborative research with AgMIP (Agricultural Model Inter-comparison and Improvement Project) is being conducted to increase capacity to assess climate change impacts and adaptations. Assessment of climate change: past studies into weather trends, yield trends (implied climate change signal); current project on assessing the impacts of climate change that has already happened. Future climate change impacts assessment: point-based and regional studies of the impacts of climate change on crop yields and irrigation requirements under climate change in future. Regional scales considered include 48 'homogeneous climate zones' covering current sugarcane-growing areas, and 2000 'quinary catchments', covering land that is or could be suitable for sugarcane agriculture, now or in the mid-century (2050s) future – addresses productivity and resilience. Future climate change adaptions: assessment of changes to crop management, genotypic traits for drought adaptation, genotypic traits for higher fibre content, 1st and 2nd-generation bio-ethanol production – addresses productivity and resilience.	The research conducted so far has mostly been strategic in nature, considering future scenarios in 30-70 years' time. The outcomes of the work provide clear guidelines to growers and other stakeholders regarding appropriate and achievable climate change adaptations to take maximum yield advantage of expected climate change, on a reasonably fine-grained spatial scale. Overall, prospects for future yield potentials under climate change are favourable. The work has also highlighted areas for future concern, such as decreased sucrose content and increased irrigation demand. By highlighting these impacts decades before they are likely to be felt, stakeholders are more prepared to face these challenges.
CROP PROTECTION		
Plant Pathology	Disease screening to identify cultivars that have acceptable resistance to major diseases. The influence of climatic conditions on the development of important fungal diseases to allow growers to make more educated decisions when applying fungicides.	The release of cultivars with acceptable disease resistance has resulted in a reduction in disease incidence over time and has reduced the need for the application of fungicides in certain areas. Climate x disease models are currently being developed and validated and have not as yet been incorporated into recommended IPM strategies
Entomology	Calcium (Ca) silicates have been researched at SASRI as amendments primarily to provide silicon (Si) to the sugarcane crop and to ameliorate soil acidity. Silicon has a well-established role as a nutrient that enhances plant resistance to multiple abiotic and biotic plant stresses, in particular drought stress, salt stress, metal toxicity, insect pests and pathogenic organisms. Research at SASRI has demonstrated greatly increased insect pest (stem borer) resistance, especially under conditions of water stress.	Use of calcium silicates as lime replacements not only directly mitigates release of CO_2, it also improves soil health (neutralise soil acidity, provide nutrients) and tolerance of many crop plants to biotic and abiotic stresses (especially water shortage) that are likely to be more severe under conditions of climate warming. However, effectiveness has been limited by lower than expected uptake of Si from calcium silicates under field conditions.

Role of stakeholder in sugar industry	CSA activities that are being implemented /researched by stakeholder	Effectiveness of activities in ensuring that production is sustainable and productive
CROP PROTECTION Continued...		
Nematology	Integrated nematode management system is promoted in order to reduce the reliance on highly toxic nematicides. Soil sampling is promoted to determine composition of nematode communities and hence base nematicide application on soil sample results. Use of sustainable farming practices is promoted, such as trashing and green manuring which promotes good soil health and in turn will help the plant withstand the damage due to nematodes. Future research will focus on predicting nematode activity based on temperature and weather data. This will allow for nematicide applications to be based on nematode activity thus ensuring maximum benefit.	Some growers take advice such that an increase in soil samples was observed in certain areas. Growers are also interested in the new products due to the removal of Temik. They are also interested in timing of applications and being able to reduce nematicide applications, which reduces costs and minimises negative impacts on the environment. Most growers, however, do not want to take the long-term sustainable route and will take the short-term fix of applying a nematicide every year or not apply a nematicide at all.
EXTENSION SPECIALISTS		
Extension specialist/ Large scale grower	• Best Management Practices (BMPs) such as those found in the SUSFARMS® manual and Progress Tracker: • Runoff control/Farm layout planning (Land Use Plans) to minimise erosion and also optimise rainfall use. • Variety selection matched to climate, soils, rainfall etc. • Adjusting cutting cycles to minimise the damaging effects of Pest and Disease threats like Eldana. • Optimisation of irrigation systems to ensure effective use of available water. • Regular soil sampling to accurately apply the required nutrients/ameliorants. In response to dry conditions, fertiliser applications can be adjusted in order to avoid over application of fertilisers which could pollute natural water systems, as well as waste money. • Land Use Planning on all farms- withdrawing cultivation from marginal and wet areas and better utilization of these areas for different enterprises	Very effective
GROWER		
Planter (Large scale grower)	-Green Cane Harvesting - Drip irrigation in selected applications - Low Volume crop applications (ripening etc) - Cover Cropping in selected applications - PH Balancing using lime and/or gypsum - Variable rate fertiliser application based on soil sampling and analysis - Matching planting times to weather patterns	- Green cane harvesting – significant impact - Drip irrigation – significant - Low volume applications – low impact- Cover crop, Soil sampling/PH balancing – significant impact - Variable rate fertiliser application, - showing good potential - Matching planting times to weather patterns is a new field and influenced by recent past weather patterns
MIDLANDS SUSFARMS® COLLABORATION		
SUSFARMS® Coordination	The SUSFARMS® tool includes extensive information and questions relating to the environment, including run-off control, irrigation management, sugarcane variety selection, soil health, pest and disease management, and choice of land planted to sugarcane.	The most significant impact has been the drafting and implementation of Land Use Plans on farms – these specifically focus on responsible planning of the farm relating to run-off control structures (contours, terraces, grassed waterways), field widths and contour lengths, road layouts etc. The implementation of these structures ensures a reduction in waterborne erosion, safer transporting of farm workers, more cost-effective transport of cane from field to loading zone and easier management of sugarcane fields. This assists with long-term sustainability.

5.3.2 Extension services and farmer training

SASRI will only be effective if growers and miller-cum-planters adopt the technology developed by the institute (SASRI, 2017). Substantial emphasis is therefore placed on technology adoption. Outputs from the research programmes are transformed into practical knowledge and technology products. Training and development takes place through courses and a series of interventions by a network of extension specialists. All growers receive SASRI extension support and new entrants are targeted for special extension interventions. Extension specialists conduct ad hoc skills development activities as well as more formal training interventions in the form of grower field days. These events are focused on training and educating growers on a particular aspect of sugarcane agronomy or management practice within the sugarcane crop cycle.

SASRI also conducts four certificate training courses in sugarcane agriculture each year that provide specialist training at two levels: two junior courses held over three weeks are aimed at farm supervisors and two senior courses conducted over a five-week period, which are aimed at farm managers. A Fertilizer Advisory Service is specifically designed to provide recommendations on fertilizer and nutrient use to growers. Annually, the service receives thousands of soil and leaf samples that are analyzed with specific reference to the industry's soils and the requirements of sugarcane.

Growers also receive economic advice and support through CANEGROWERS. Working together with SASRI Extension using the SUSFARMS®, Annual Production Plans and Financial Plans, the economists are able to assist in budgets and cash flow preparation and analysis, looking for the best way to increase revenue and decrease costs.

All research outcomes are made accessible to sugarcane growers through a variety of channels including:

⇒ Technical publications, information sheets, bulletins, manuals and extension newsletters such as the Link and Ingede, which provide accessible technical information for growers on latest sugarcane practices and recommendations.

⇒ Custom-designed decision support tools to assist decision-making in respect of all aspects of farming. These include variety choice, weeds management, irrigation design, irrigation scheduling, and harvesting practices with a strong emphasis on the economic impact of specific practices.

⇒ SASRI's Extension Services are responsible for providing the essential link between SASRI's researchers and sugarcane farmers through consultation and feedback. Extension Services facilitate the adoption of technology and better management practices that encourage responsible and sustainable land use and deliver optimal productivity and profitability for the industry.

⇒ Recommendations of better management practices through sustainability standards / systems (e.g. SUSFARMS®).

5.3.3 Conservation Agriculture

The main principles of conservation agriculture consist of minimum soil disturbance, permanent soil cover and crop integration and crop rotations. These principles are embodied into the systems and practices which sugarcane agricultural growers are encouraged to adopt. Examples of these practices are demonstrated in the following subsections.

5.3.3.1 Land use planning

Land use planning is a fundamental requirement for farming and optimal crop production. A documented land-use plan will include details and specifications concerning:

⇒ staff / labour housing and workshop,
⇒ historically or culturally important sites,
⇒ soil parent material,
⇒ soil form including depth, taw (total available water) and erodibility,
⇒ non-arable and natural areas,
⇒ wet agricultural land (relic wetlands),
⇒ fields including number and area in hectares,
⇒ minimum tillage fields,
⇒ fields suitable for trashing, and
⇒ fields suitable for mechanization.

5.3.3.2 Soil conservation management

Soil conservation management practices are aimed at restoring soil health, reducing evaporation and run-off, suppressing weed growth, reducing soil erosion, reducing surface capping and compaction of soils. To support soil management, soil types (forms) are mapped and classified in terms of their erodibility. Practices include conservation terraces that are maintained through suitable creeping grass covers and revetts that have been spaced at 10 m intervals across the main axis of the waterway to prevent erosion until the vegetative cover is adequate.

Cultivated land is protected against excessive soil loss from the action of water and wind using alternate strips of cover crops which are left undisturbed for a year. Trashing and green cane harvesting of sugarcane is also practiced is some areas as a measure to conserve valuable moisture and to improve soil organic content.

Research pertaining to providing guidelines for the amelioration of top and sub-surface soil acidity and efforts to include the soil health index as part of the standard Fertilizer Advisory Service (FAS) reporting package and improving nitrogen fertilizer advice to growers are some of the industry efforts to improving soil conservation management.

5.3.3.3 Tillage

In addition to some of the soil conservation practices mentioned above, soil erosion is minimized through minimum tillage and correct row alignment (SUSFARMS® 2012).

5.4 Midlands Sustainable sugarcane farm management system (SUSFARMS®) collaboration

Globally, there is growing consumer concern on where products and goods are being sourced from and the impact of business operations on the environment and social spheres in which they operate. Sustainable sourcing of sugar means the ability to demonstrate that sugarcane farming and production of sugar at the mills meet all environmental, social and financial requirements. In this regard, some of the major purchasers of sugar have identified specific targets, as indicated in Figure 5.1 below.

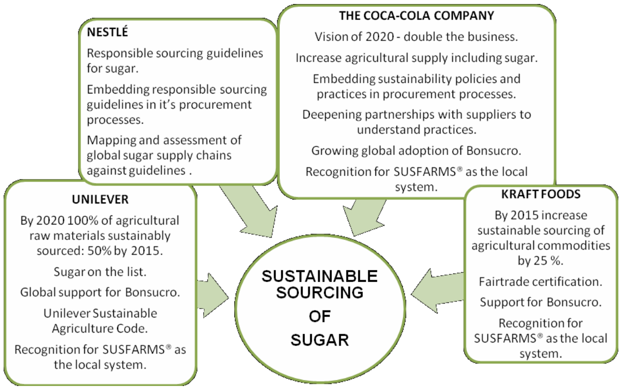


Figure 5.1: Specific targets for sustainable sourcing of sugar by some major sugar purchasers.

***Source**: Govender (2013)*

In support of sustainable sugarcane production, the SUSFARMS® is being implemented throughout the sugar industry. SUSFARMS® is a farm management system designed to encourage sustainable sugarcane production through the implementation of better management practices (BMPs). These BMPs reduce negative impacts on the environment, comply with legislation, maintain a high level of social responsibility and assist in ensuring financial sustainability. A SUSFARMS® manual containing 28 modules is freely available online (http://www.sasa.org.za/).

Implementation of SUSFARMS® and better management practices in the sugarcane growing regions is continuous. Sustainable farming practices and projects that can assist the industry in adapting and mitigating climate change are of importance to the industry. The industry has been proactive in this regard and continues to commission research to determine the potential impacts of climate change on the sugarcane industry. Following this research, further work has been undertaken to investigate the opportunities for sugarcane agriculture to adapt to changes in climate and climate variability. This work is being undertaken through SASRI and its collaborators.

5.5 Challenges and untapped CSA opportunities

Several external factors threaten the sugar industry's sustainability. The industry is recovering from the worst drought since the early 1990s, which has led to a decrease in production of 53% in some areas and the unprecedented temporary closure of two (2) mills in the 2015/2016 season, with other mills having a shorter than normal milling season.

Compounding the situation has been insufficient import tariff protection resulting in an influx of deep-sea and cheap imports. The flood of deep-sea imports, signing in of the Health Promotion Levy (HPL) together with the vilification of sugar, as a product in the media are all factors combined that have had a negative impact on sustainability and profitability of the industry. These challenges have eroded the financial viability of the industry and have pushed the sector to the edge of ongoing sustainability.

Certain practices – such as green cane harvesting that is understood to be environmentally beneficial and increase long-term sustainability – are being set aside in favour of practices that address shorter-term cash flow. Uncertainty regarding future economic sustainability of sugarcane farming, as well as uncertainty relating to land ownership, discourage growers from making long-term investments in their farms. Additionally, although climate change impacts on yield have been explored, the ability to assess socio-economic impacts of climate change is limited by the lack of clarity on future socio-economic scenarios (e.g. world commodity prices, local sugar-related and agriculture-related policies), the availability of suitable socio-economic models, as well as suitably-experienced staff members. This is understood to threaten both the economic and environmental sustainability of cane farming operations in some situations.

It is notable that the industry could play a significant role in the generation of electricity from sugarcane biomass for export to the national grid. Currently all 14 sugar mills are energy self-sufficient and produce electricity for own use. Thus, the industry has been quite proactive in reducing carbon emissions by generating power using bagasse, a renewable fuel source. However, there is currently no workable mandate and business case for bioethanol production or electricity co-generation using sugarcane residues as feedstock.

Government subsidisation of ethanol/biofuel production and cogeneration from sugarcane bagasse or biomass could help the industry to be more sustainable into the future, while simultaneously adhering to CSA principles. When this becomes a commercial reality, it would likely change harvesting practices in support of more trash being used for electricity generation. Diversification into fuel ethanol production will also support reduced carbon emission through penetration of sugarcane-based fuel bioethanol into the national fuel pool, thus minimizing reliance on petroleum fuels.

One of the biggest challenges is showing growers the benefits of long-term sustainable farming. This makes the plant healthy enough to, for instance, tolerate insect and disease attack due to an increase in free living and predatory organisms as a result of better soil health. As this takes a long term and is not visually easy to see, growers often do not appreciate the benefits and even if they do, they sometimes think it is too difficult to implement.

Generally, within the commercial sugarcane farming environment, the principles of CSA are well understood and can be implemented without much difficulty due to various socio-economic reasons. However, in the Small Scale Grower (SSG) context, a lot of training is needed for all levels of sustainability. The SSGs do not often see the link between activities done now and their future positive or negative outcomes.

Incentives for practices that reduce crop stress by promoting soil conservation, soil moisture, and soil health, and reducing burning of crop residues could also facilitate adoption of sustainable agriculture. For example, growers could be paid a premium price at the mill level for using sustainable farming systems. Use of examples of farms that are known to be implementing the practices successfully can be appealing to other farmers. Furthermore, establishment of a long-term trial in conjunction with a grower to monitor this over time will provide a permanent demonstration site.

5.6 Conclusions and recommendations

It is apparent that numerous CSA practices are being researched and implemented in the sugar industry. Research at SASRI is clustered within four multi-disciplinary programmes including variety improvement, crop protection, crop performance and management, and a systems design and optimization programme. These thematic areas are assisting to achieve CSA objectives in the industry.

Outputs from the research programmes are transformed into practical knowledge and technology products. There are several opportunities for training through courses and a series of interventions by a network of dedicated extension specialists. Multiple channels through which research outcomes are made accessible to sugarcane growers were identified.

The SUFARMS® is used as a farmer-extension tool to facilitate adoption of BMPs. Implementation of the SUSFARMS® concept has been steadily expanding over the years and is enabling the industry to comply with international sustainability standards, such as Bonsucro. Further improvement and refinement of this concept is encouraged to facilitate widespread adoption in the smallholder sector.

Numerous challenges that are threatening sustainability of the sugar industry were identified, and some possible solutions were suggested. The government is generally encouraged to incentivize adoption CSA practices, including generation of electricity using sugar cane bagasse. Diversification into fuel ethanol production will go a long way in reducing carbon emissions by minimizing reliance on fossil fuels.

6.1 Introduction

This section will focus on CSA practices being implemented in table and wine grape (viticulture) production, as well as subtropical production as examples of what can be achieved in the fruit industry. The critical importance and projected impacts of climate change on viticulture, bananas and citrus will be presented first, followed by CSA practices that are being researched and/or implemented by producers and other stakeholders.

South Africa is the world's 8th largest wine producer and it contributes approximately 3.6% of the total global volume. The wine grapes are grown on an average of 100 500 ha per annum. Average yields are at 14.42 t/ha and an average of 1.28 million tons of grapes are crushed per annum to produce an average of 990 million litres of wine. Of this total, an average 310 million litres of wine are exported annually, which makes viticulture an important forex earner in the country (Schulze and Schütte 2016a). The grape and fruit industry is of huge fiscal importance, representing almost a third of the Western Cape provinces' exports (https://www.fruitlook.co.za/).

Wine grape production is sensitive to climate change. It is affected by very high temperatures, reduced seasonal rainfall, higher frequency of heavy rainfall and flooding, more frequent and heavier late spring and early summer rainfall, and rising CO_2 levels. Other possible high impact climate risks for wine grape production include frost, hail and strong wind (WCDoA, 2018). Projected increased temperatures will affect berry parameters such as acidity, aroma and flavour. There are likely to be increasing problems with delayed and uneven bud break, as well as shifting phenological stages, all of which affect yield and quality (Schulze and Schütte 2016a). An increase in water deficits will result in more carbohydrates being available for grape ripening in moderate water deficit conditions and sugar accumulation may be increased via reduced partitioning to alternative vegetative sinks. Shifts in rainfall seasonality have potentially significant impacts. Recent trends towards wetter spring / early summer have negatively affected berry growth and disease incidence (e.g. botrytis) (Schulze and Schütte 2016a).

Varietal suitability will be affected and a disruption of historically grown combinations is likely. Red wine grape cultivars that will be more tolerant of climate change include Cabernet Sauvignon, Pinotage and Ruby, whilst cultivars that will be most vulnerable to climate change are Shiraz and Merlot. White wine grape cultivars that will be more tolerant include Chenin Blanc and Colombard, whilst Sauvignon Blanc and Chardonnay will be most vulnerable to climate change (Schulze and Schütte, 2016a; WCDoA, 2018a).

Bananas constitute the most popular fruit and globally the fourth most widely consumed crop by humans, after rice, wheat and maize (Schulze and Schütte 2016b). The majority of bananas grown in the country are either sold on local markets or self-consumed by farmers, while only a small fraction is exported to other countries (DAFF, 2017a). During the 2015/16 marketing season, subtropical fruits had a total gross value of R4.3 billion and bananas contributed 44% (R1.9 billion) to that value in South Africa. This makes bananas the most important subtropical fruit grown in the country. Per capita consumption for deciduous and subtropical fruits in South Africa during 2015/16 was 21.95 kg per year (DAFF, 2017a). Being tropical plants, production of bananas is limited by climate when grown under subtropical conditions in South Africa.

In the sub-tropics where bananas are grown in South Africa, they face substantial temperature and water deficit constraints. Additionally, it is also affected by numerous fungal, viral and bacterial diseases, including migratory nematodes. Schulze and Schütte (2016b) itemised the possible climate change impacts that could occur in subtropical banana growing regions of South Africa. However, it is notable that climate change will present opportunities and/or positive effects for sub-tropical bananas. These include:

i) increased temperatures and reduced incidence of frosts in certain locations will result in an increase in areas climatically suited to bananas in future;
ii) specific cultivar groups presently grown in cooler areas may become suitable for production in higher elevations; and
iii) production cycles from planting to harvest will be shorter due to accelerated growth rates.

This implies that bananas stand a chance of being delivered to the market much earlier in some areas.

Citrus fruits produced in South Africa consist of oranges, grapefruit, naartjies and lemons. In terms of gross value, the citrus industry is the third largest horticultural industry after deciduous fruits and vegetables. During the 2015/16 production season the industry contributed R14.8 billion to total gross value of South African agricultural production. This represented 25% of the total gross value (R57.3 billion) of horticulture during the same period (DAFF, 2017b). The impacts of climate change on citrus production were elaborated by Schulze and Schütte, (2016c), and WCDoA, (2018b).

6.2 Climate-smart agriculture practices in fruit production and viticulture

6.2.1 Adaptation strategies

Adaptation options that are being implemented by producers and researchers are divided into three main categories, namely: i) planning for climate change and variability; ii) sustainable / adapted soil and water management; and iii) sustainable / adapted crop management. Each of these broad categories is divided into numerous specific activities (WCDoA and WCDEADP, 2016).

Planning for climate change and variability is further divided into the following: weather, fire and pest monitoring systems; weather forecasting; disaster risk reduction and management; and, insurance and risk management. Sustainable / adapted soil and water management is further divided into the following: irrigation technology and scheduling; conservation agriculture; and, new sources of water for irrigation; Sustainable / adapted crop management is further divided into the following: crop breeding and cultivar development; site specific cultivar choice; biotechnology for adaptation of crops; and, technologies to manage rising temperatures (see Table 6.1).

Table 6.1: Summary table of adaptation activities in the fruit and wine industries

Adaptation option	Commodities	Primary purpose
1. Planning for climate change and variability		
a) Monitoring systems:		
Weather monitoring	All fruit crops	Farm management
Monitoring of pests and diseases on farms	All fruit crops	Maintenance of economic yield, and for phytosanitary requirements
Fire risk monitoring	All fruit crops	Fire identification and early response
b) Weather forecasting:		
Short-term weather forecasts	All fruit crops	Farm management
Seasonal weather forecasts	All fruit crops	Farm management, marketing planning

Adaptation option	Commodities	Primary purpose
1. Planning for climate change and variability Continued...		
c) Disaster Risk Reduction and Management:		
Early Warning System	All fruit crops	Preparation for harsh weather or climate disasters
Hail risk reduction using hail netting	All fruit crops	Maintenance of economic yield
d) Insurance and risk management:		
Some producers take hail and multi-peril insurance from Santam, Hollard Insurance, Old Mutual Insurer	All fruit crops	Risk assessment and management for economic benefit
2. Sustainable / adapted soil and water management:		
a) Irrigation technology and scheduling:		
Irrigation scheduling adjusted to avoid hottest part of the day e.g. at night	All irrigated fruit crops	Water savings (supply and cost considerations)
Switching to more effective irrigation such as drip irrigation	All irrigated fruit crops	Water savings, sustainable water management
Scaling down and irrigating optimally through use moisture probes for irrigation scheduling	All irrigated	Water savings, sustainable water management
"FruitLook"23 Precision irrigation based on satellite monitoring	All irrigated fruit crops	Water savings, sustainable water management
b) Conservation Agriculture:		
Mulching, composting, cover crops	Fruit crops	Boost yields by improving soil productive capacity (incl. soil moisture retention), sustainability. In fruit orchards and vineyards, the use of mulching is fairly widespread and various materials are used with others (e.g. organic mulches) being researched. Further research is needed on the benefits provided by these practices under 'normal' to stressful ('drought') conditions and in differing agro-climatic zones.
c) New sources of water for irrigation:		
Use of wastewater for irrigation	Irrigated vineyards	Save water, reduce impacts of waste. Re-use of water (e.g. winery wastewater) is not yet widespread and could be extended to other applications e.g. fruit packhouses.
3. Sustainable / adapted crop management:		
a) Crop breeding and cultivar development:		
Fruit cultivar and rootstock breeding and evaluation programme	Deciduous fruit and grapes	Development of pest and disease resistance, improvement of fruit quality to meet consumer preferences, and market development. Breeding for tolerance to heat and drought stress is not a top priority. However, low chill cultivars have been a focus for a long time, especially stone fruit. Apples are the crop most in need of low chill cultivars.
Citrus cultivar and breeding and evaluation programme	Citrus fruits	Pest and disease resistance, fruit quality, market development
b) Site specific cultivar choice:		
Smart use of terroir	Wine grapes	Improvement in wine quality
Shift from wine grape to raising and table grape production	Grapes	Improvement in yield and quality

Adaptation option	Commodities	Primary purpose
3. Sustainable / adapted crop management Continued...		
c) Biotechnology for adaptation of crops:		
Increasing resistance to abiotic stress through biotechnology	Wine and table grapes	Boost yield and quality
d) Technologies to manage rising temperatures:		
Rest-breaking agents sprayed on trees in late winter	Pome and stone fruit	Strong even budbreak, flowering and fruit set, fruit quality
Shade netting over orchards and fields	All fruit crops	Boost yield and quality, reduce heat stress.
Kaolin-based sprays	All fruit crops	Boost yield and quality, reduce heat stress. Kaolin spray is a pest control that has kaolin as the main ingredient. Also used for sunburn.

Source: *Adapted from WCDoA and WCDEADP (2016).*

6.3 Use of Fruitlook for efficient irrigation (https://www.fruitlook.co.za/)

In the Western Cape, FruitLook supports fruit and wine grape growers to make more informed decisions, which can lead up to 30% more efficient use of water. FruitLook is an open access online platform used to monitor vineyards and orchards using satellite imagery and weather information.

During the fruit growing season, weekly updates of various data sets are provided via the website. By combining radiation data with climatic data such as temperature, humidity, wind velocity and rainfall records for the area, Fruitlook supplies parameters that assist farmers to monitor evapotranspiration (water use), evapotranspiration deficit (if present), water use-efficiency, plant-growth and the nitrogen status of a crop.

Specific parameters recorded include biomass production, leaf area index, vegetation index, actual evapotranspiration, evaporation deficit, crop factor, biomass water use efficiency, nitrogen content in top leaf layer and nitrogen content of all leaves.

Most users ascribed improvements in water use efficiency to improvements in irrigation system design, better soil moisture probe placement and earlier detection of over- and under irrigation. Farmers can monitor overall block development per week, gain insight in the internal variation within a block and compare blocks with each other for a period of 27 weeks, from 1 October to 30 April of each year.

FruitLook was created in 2012 in cooperation with a Dutch service provider, eLEAF, and it is currently available free of charge though users should prepare to pay for the services in future.

Agricultural economists from the Department of Agriculture in the Western Cape estimated that a saving of 10% in production costs together with an increased production of 10%, could lead to an increased revenue of (on average) R 33 858 per hectare for table grapes.

The technology could help reduce production costs by about 10%, saving vine producers R4 130/ha, table grape producers R23 590/ha and deciduous fruit producers R25 160/ha (Kriel, 2015).

6.4 Mitigation strategies in fruit and wine industries

The major mitigation strategy being used to minimise carbon dioxide gas emissions is through the Confronting Climate Change (CCC) initiative (http://www.climatefruitandwine.co.za/About.aspx). The CCC initiative was conceptualised by the South African fruit and wine industry in 2008. It enables South African growers and service providers to measure their carbon footprint, identify 'carbon hotspots', develop creative solutions to reduce CO_2 emissions, and manage the perceptions of buyers and policy makers in order to secure long-term viability of the industry.

This is a very important initiative because the South African fruit and wine producers and exporters face potential business risks associated with consumer pressure, retail strategies and foreign policies that are increasingly evolving to reduce CO_2 emissions and mitigate the impacts of climate change. For instance, National treasury stated that appropriate and proactive actions must be taken to help transition our economy onto a low carbon growth path as articulated in the National Development Plan.

The carbon tax, together with the carbon offsets, is seen by government as an important and cost effective instrument to put our economy onto a more sustainable growth path.

With this in mind, a CCC carbon footprinting tool was developed, and has been independently audited by the Carbon Trust who endorsed it as a reliable and credible resource for measuring the carbon footprint of South African wine and fruit-related products.

The CCC Initiative includes an online carbon-footprinting platform that is updated regularly. To enable users to make effective use of the carbon-footprinting tool, a series of regular industry engagement workshops are held throughout the country. The three-hour workshops consist of:

i) carbon footprint workshops;
ii) train-the-trainer workshops and;
iii) emerging farmer workshops.

While participants have to pay for the first two workshops, emerging farmer workshops are fully subsidized by industry and the Western Cape Department of Agriculture. They are meant for interested members from small scale farming operations or developing agricultural companies. Also included on the online carbon-foot printing platform is a range of commodity-specific industry benchmark reports and up-to-date and relevant energy and emissions-related news and information.

Other mitigation options include widespread use of non-renewable energy in the form of solar and wind farms. Reduction in use of synthetic nitrogen fertiliser is also encouraged. This can be achieved through more precise application as and when the plant needs it (WCDoA, 2018). Nitrogenous fertilisers release nitrous oxide (N_2O) into the atmosphere, which is one of the GHGs.

6.5 The Sustainability Initiative of South Africa (SIZA)

Adoption of these CSA practices will enable fruit farmers to be compliant with increasing consumer and retailer pressure for sustainable value chains. This is especially so where products are destined for the export market. Pressure from international consumers and retailers regarding labour practices and environmental sustainability of activities on farms and in pack houses in the South African fruit industry supply chain was reported to have started as far back as 2006 (SIZA, 2016; SIZA, 2018a).

In 2008, the South African fruit industry took a decision to respond to the need to provide retailers and their consumers with assurances of fair labour practices in their supply base. Subsequently, the SIZA was developed as an ethical standard and programme that meets all global retailer requirements.

The SIZA Platform offers two separate standards for South African producers, one covering relevant social criteria and the other covering relevant environmental criteria (SIZA, 2018b). Hence, the SIZA monitors care for the environment and compliance with labour legislation through the Environmental Standard and the Social Standard respectively.

This platform is aligned to global best practices such as the Sustainable Agriculture Initiative (SAI) Platform Farm Sustainability Assessment (FSA) tool and Global Gap IFA v.5 (SIZA, 2018a). In 2017, SIZA and GlobalG.A.P reached a formal agreement through which GlobalG.A.P recognized SIZA's social module as an adequate standard to 'replace' GRASP (GLOBALG.A.P. Risk Assessment for Social Practices) audits in South Africa. This is in line with the SIZA mission to avoid audit duplication.

SIZA audit results will be reflected on the GlobalG.A.P database, thus enabling European buyers to monitor their suppliers' social compliance through the GlobalG.A.P / GRASP platform (SIZA, 2018b).

6.6 Challenges and untapped CSA opportunities

Several challenges still exist in the fruit and wine industries. The WUE of various types of trees needs to be determined on a continuous basis in order to improve irrigation efficiency by avoiding over- and under-irrigation. This is particularly important where farmers are still relying on traditional irrigation scheduling methods that rely on the use of soil moisture probes, etc. Sometimes the WUE varies with differing scion/rootstock combinations, such as in citrus (Dutra de Souza *et al*., 2017).

The main opportunities lie with expansion in the use of Fruitlook and the carbon calculator tool to improve water management and reduce carbon footprints, respectively. Currently, both tools are largely providing services to farmers in the Western Cape, which is a very small proportion of fruit farmers.

Some fruit farms have started constructing solar and wind farms, which are opportunities that can be exploited further to provide renewable energy. While the initial cost of construction is high, this has assisted in keeping packhouses running when Eskom power is down. Solar farms also reduce usage costs of electricity.

It is felt that there is need to stabilise the electricity tariff and/or perhaps subsidize solar installations. Government is urged to consider the provision of incentives to those who comply. By considering fiscal interventions such as giving tax rebates, the government will be assisting in subsidising the cost of implementing some costly CSA-related programs or practices.

The recent droughts have necessitated the deciduous fruit industry to work and deliver a product within the extreme restraints of very limited water. Extreme measures were required which included removing orchards, prioritising orchards, removing fruit, extensive use of technology in monitoring soil and plant status, mulching, overhead nets, irrigating at night and many more practices were introduced to ensure that marketable fruit was available to meet the requirement of the markets.

Policies which recognise the importance of agriculture and support the development and expansion of labour intensive industries and that are geared at increasing agricultures access to water are critical for future sustainability of the sector. Storage dams are critical in the Western Cape where it rains in the winter when the trees are dormant and require little water. In the summer when the trees are growing and require water, there is no rain. Therefore, there is need to store water in dams and to have access to underground water. There is also an active need to have more government support to fund research and development into climate resilient technologies.

6.7 Conclusions and recommendations

Potential adaptation and mitigation strategies that are applicable to the wine and fruit industries were identified. Adaptation options that are being implemented are divided into three main categories, namely: i) planning for climate change and variability; ii) sustainable / adapted soil and water management; and iii) sustainable / adapted crop management. Each of these broad categories is divided into numerous specific activities.

Mitigation of GHG emissions can be enhanced through widespread use of a carbon calculator tool developed through the confronting climate change (CCC) project. Use of non-renewable energy in the form of solar and wind farms holds a lot of promise in minimising emission of GHGs. Adoption of these CSA practices enables farmers to be compliant with increasing consumer and retailer pressure for sustainable value chains.

Use of fair labour practices and adoption of sustainable farming practices is being achieved through compliance with the Sustainability Initiative of South Africa (SIZA). The SIZA is aligned to global best practices such as the Sustainable Agriculture Initiative (SAI) Platform Farm Sustainability Assessment (FSA) tool and Global Gap.

Farmers with SIZA certification can therefore export their produce anywhere in the world. Several challenges and untapped CSA opportunities were identified. Some suggestions for overcoming challenges and for exploiting untapped CSA opportunities were provided.

7.1 Introduction

Farmers in South Africa are vulnerable to the impacts of climate fluctuations and weather extremes. Climate services are receiving increasing attention globally as an important component of the agenda on climate adaptation (Stigter *et al.,* 2013; Tall *et al.*, 2014; Mwenye, 2017). Effective climate information and advisory services offer great potential to inform farmer decision-making in the face of increasing uncertainty, improve management of climate-related agricultural risk, and help farmers adapt to change (Tall *et al.,* 2013).

Provision of climate information services (CIS) is therefore one of the requirements needed to achieve climate smart agriculture (CSA) objectives. Climate information services enable vulnerable communities to reduce the risks associated with climate, particularly extreme events, as well as allowing different sections of the economy to make informed decisions (Mwenye, 2017).

It is important to first define weather/climate "information", "advisories", and "services". Information in meteorology/climatology is passive in the sense that there is no indication coming with that information on how to use it. "Raw" weather forecasts and climate predictions are good examples (Stigter *et al.,* 2013). Information with recommendations on how to use it, or information otherwise made more client-friendly for solving specific problems, may be called advisories (Stigter *et al*., 2013).

Climate services refers to the provision of relevant weather and climate information, and a range of advisory services to enable decision-makers to understand and act on the information – within a suitable enabling institutional environment (Tall *et al.,* 2014). It includes the whole process of obtaining climate data, storing it, and processing it into specific products that are required by different users in climate-sensitive sectors such as agriculture, disaster-risk reduction and health, among others (Mwenye, 2017). A climate service therefore needs to be responsive to end-user needs.

CSA addresses climate change by systematically integrating climate information into the planning of sustainable agricultural systems (FAO, 2013). CSA is knowledge-intensive and therefore requires access to information to enable stakeholders and farmers to make informed decisions. Climate information can generally be divided into three types; short term (weather forecasts: 0 – 7 days), medium term (seasonal climate forecasts: 3- 9 months) and long term (climate variability and climate change projections: 10 – 50 years). Each has specific intentions and envisaged uses (Ziervogel *et al.,* 2010).

7.2 Guiding concepts of climate information services (CIS)

Climate services incorporates and expands on established weather information services that target agriculture. The atmosphere varies on a continuum of timescales, from sub-daily weather events to long-term climate change. These timescales of variability are often defined in terms of the dominant factors that drive them, and by extension, the source of predictability (Tall *et al.,* 2014).

Weather refers to environmental conditions at a given time and is predictable at a maximum lead time of about two weeks. Climate variability has a time scale of between two weeks and two decades. It is influenced by interactions between the atmosphere and its underlying ocean surface, such as those associated with the El Nino/ Southern Oscillation (ENSO) in the tropical Pacific.

At the long-term extreme of the continuum is climate change that has a timescale exceeding two decades. It is associated with natural and anthropogenic changes in the chemical composition and heat balance of the global atmosphere (Tall *et al.,* 2014).

Climate-sensitive agricultural decisions also have a range of time horizons. To be useful, the timescale of information should match the planning horizon of particular management decisions. Relevant timescales for farm decision-making range from daily weather forecasts, to seasonal prediction, to climate change; but seldom exceed two decades (Tall *et al*., 2014). Longer timescales associated with climate change are more relevant to institutional and policy decisions that influence options and incentives for farmers. Such institutional and policy decisions include plant breeding programmes, market development, and investment in infrastructure.

7.2.1 National framework of climate information services

At a national level, the national meteorological services are responsible for production of downscaled forecasts at different timescales. Other public Research Institutes and Universities can also generate such weather and climate information nationally. The national agricultural research and extension systems (NARES) adds value to the climate information so as to generate an agrometeorological advisory. The NARES represents a critical second layer in the climate services chain.

Agricultural extension services have the trust of farming communities, and they have to effectively translate climate information into management advisories, as one component of the suite of services that they provide. In some countries, NARES have developed quantitative tools to translate climate information into predictions of impacts on agriculture, and to support decision-making by farmers and other agricultural decision makers (Tall et al., 2014). The NARES can be assisted to reach out to farmers by other communication and boundary organizations that interact with farmers on a regular basis. Such organisations include media, agricultural extension, non-governmental organisations (NGOs), community-based organisations (CBOs), private sector players, etc. National level end users of climate services are in the agriculture sector and include rural development planners, policy makers, seed distributors, fertilizer industry, and the private sector. Vulnerable farming communities are the ultimate end users of the services. For maximum effectiveness, there should be forward and backward interactions between the various components of the chain of climate services at national level.

Stigter *et al.,* (2013) visualized extension agrometeorology as one that leads to the establishment of agrometeorological services by and with farmers. Five challenges that confront efforts to use climate-related information to improve the lives of smallholder farmers have been identified to be the following (Tall *et al.,* 2013):

⇒ Salience: tailoring content, scale, format and lead-time to farm-level decision-making; Agricultural stakeholders need to be given ownership and an effective voice in the design, implementation and evaluation of climate services. While institutional arrangements may vary, climate services that are relevant to farmers require partnership and a degree of co-ownership between meteorological services, agricultural research and extension services, and farmers. Climate information is most useful when it is downscaled, combined with management advisories and farmer training, and integrated with support (e.g., production inputs, credit, insurance) for management responses. Starting with farmers' local climate knowledge and traditional indicators can be an effective way to ensure that new information is relevant, and to build trust.

⇒ Access: providing timely access to remote rural communities with marginal infrastructure; Given the human resources challenges of reaching large numbers of farmers, mobile telephony—voice and text messaging—may be the business model of the future for delivering climate services in rural areas.

Community radio and cell phone integration is another opportunity. Multiple information channels should be employed to complement Short Message Service (SMS) and voice messaging, such as public address systems at the village level. The use of local language and appropriate formatting of information to suit farmers' literacy levels is key.

⇒ Legitimacy: ensuring that farmers own climate services, and shape their design and delivery; Legitimacy and salience are closely related in that climate services have legitimacy when they not only involve farmers but also do so in ways that address their concerns and result in relevant and actionable information.

⇒ Equity: ensuring that women, poor and socially marginalized groups are served; Gender and equity considerations in climate services include the types of information needed by different groups, different information channels used, and socio-cultural and/or institutional constraints to accessing information. The difficulty of prioritizing gender and equity issues within a limited range of problems is a constraint in itself. However, capacity for the integration of gender and social differentiation is needed at all levels, from extension agents in the field to the institutional and policy levels (Tall *et al*., 2013). Adoption of participatory approaches when generating and disseminating CIS can go a long way in addressing gender and equity issues.

⇒ Integration: providing climate information as part of a larger package of agricultural support and development assistance, enabling farmers to act on received information. Climate information from meteorological departments must be transmitted to farmers with an actionable point of entry into their decision systems. Additional information that must be supplied to farmers include plant protection, crop choices, market sources, and cultivation best practices to enable management of production and market risk (Tall *et al*., 2013).

Climate information from meteorological departments as transmitted to farmers must have an actionable point of entry into their decision systems, within a larger package of agricultural and development support.

Farmers need additional information on plant protection, crop choices, market sources, weather-probability of rainfall, and best cultivation practices to enable management of production and market risk. In addition, climate services should be coupled with field demonstrations, and cannot rely on mobile transfer of information alone.

7.3 Status of CIS in South Africa

A number of institutions produce different types of forecasts in South Africa. The South African Weather Service (SAWS) is the country's national meteorological service. It is the primary weather and climate information service provider in the country. The SAWS send forecasts to some users by e-mail and they also place the forecasts on their website (Ziervogel *et al.* 2010).

Additional dissemination of weather information is being done at provincial level, such as by the Western Cape Department of Agriculture which has a drought portal on its website (http://www.elsenburg.com/drought/ DROUGHT PORTAL).

The Water Research Commission (WRC) brought together multi-disciplinary scientists from more than seven institutions for purposes of generating CISs. This was achieved through two projects further discussed in this section.

7.3.1 The Department of Agriculture Forestry and Fisheries (DAFF)

The DAFF has a directorate on Climate Change and Disaster Management. Its aim is to facilitate climate change mitigation and adaptation, risk and disaster management. One of the specific functions is to ensure effective planning and implementation of an early warning system in support of associated sector risk management.

Since the end of 2002, the DAFF has been advising farmers on climate conditions and practices to follow, based on a long-term climate outlook, in order to reduce farmers' susceptibility to adverse weather conditions (Lumsden and Schulze, 2012).

7.3.1.1 Early warning unit

Resilient farming communities can be attained through reduction of risks of disasters through strengthening early warning systems and disseminating early warnings, as well as raising awareness through campaigns. An Early Warning System (EWS) is used to communicate monthly advisories and daily extreme weather warnings in support of disaster risk reduction for farming communities. Provinces are encouraged to further simplify, downscale and package the information according to their language preference and if possible use local media and farmers' days to disseminate the information.

Users are advised to be on the look-out and act on the daily extreme weather warnings as well as the monthly advisory. Monthly advisories can be found on DAFF's website and are also emailed to provinces.

National Agro-Meteorological Committee (NAC) meetings are held quarterly to facilitate continuous monitoring of the EWS; and to identify and address gaps in the system.

The Department frequently responds to hazards such as droughts, veld fires, floods and outbreaks of pests and diseases. They provide financial support to farmers that would have suffered losses, including infrastructure losses such as irrigation, soil conservation structures and dams (South Africa Yearbook 2012/13).

7.3.2 Agricultural Research Council (ARC) - Institute for Soil, Climate and Water (ISCW)

The Soil, Climate and Water division of the ARC provides a monthly agrometeorological bulletin. It contains rainfall, standardized precipitation index, rainfall deciles, water balance, vegetation condition index, vegetation conditions and rainfall, fire watch and agro-climatology.

7.3.2.1 Weather information dissemination

Dissemination of weather information is an important task for farming in South Africa, where weather-related disasters such as drought and disease outbreaks often occurs. ARC- ISCW is responsible for maintaining and developing the national agricultural weather stations network and databank.

They issue agricultural early warnings and advisories and have conducted projects related to weather information dissemination to farmers. One of the projects has been carried out in rural communities in Limpopo and North West Provinces.

This project is funded by the DAFF. The main aim of the project is to introduce and promote the use of weather and climate information to enhance agricultural production and improve food security.

The following methods are used to communicate information to famers:

⇒ Community Workshops
⇒ Quarterly presentations of current seasonal forecast to farmers at municipalities
⇒ A survey to evaluate the impact of the workshops
⇒ Radio and Social Media
⇒ Internet online questionnaire to evaluate the impact of the talk shows
⇒ Live tweets and Facebook comments of all the activities on radio and community workshops.

7.4 Council for Scientific and Industrial Research (CSIR)

The CSIR has capacity to provide short-range and seasonal weather forecasts. The CSIR's Natural resources and environment unit has the following on-going climate information services related projects (https://www.csir.co.za/natural-resources-and-environment):

7.4.1 Coastal flood risk viewer for improved disaster risk management and development planning

The CSIR coastal flood risk viewer is an interactive web-based tool to visualise the extent of coastal flooding in specific areas. This information is relevant for coastal development planning and disaster management in the light of climate change projections which indicate that sea levels will rise, and the frequency and intensity of ocean storm-related floods will increase.

While sea-level rise and storm-related flooding are related in occurrence, they are very different hazards. The sea-level rises constantly and relatively slowly with about 1-2 mm per year on South Africa's coasts. However, storm events are hitting our coasts seasonally. While they hammer the coasts for only hours or days, these sea storms can have massive wave heights reaching up to 10 meters, causing flooding, erosion of the coastlines, and destruction of roads, infrastructure and homes. It is for these storm scenarios that the tool will allow for visualisation of flooding of up to 10 meters above sea level.

The web-based tool was developed by pooling remote sensing, GIS and information technology expertise at the CSIR. The tool forms part of the Oceans and Coasts Information Management System, which is part of the implementation of the Operation Phakisa: Oceans Economy programme for the Department of Environmental Affairs (DEA). The BETA version of the web-based coastal flood risk viewer can be found at: https://ocims-dev.dhcp.meraka.csir.co.za/hazardlines/.

7.4.2 African-based earth system model

The CSIR is developing the first African-based earth system model to provide reliable projections of the potential impact of climate change on the African continent. This will help answer questions such as what might happen to the local climate if greenhouse gas concentrations continue to increase, as well as whether or not climate change will result in the more frequent occurrence of strong El Niño events and drought in southern Africa. CSIR experts in the fields of global change, high-performance computing as well as modelling and digital science are driving this multidisciplinary effort.

Only one out of the 30 earth system models in use have been developed in the southern hemisphere and therefore very few models can provide an adequate understanding on climate variability in Africa and the Southern Ocean, which is extremely important for global climate regulation. In 2015, the CSIR officially became a Coupled Model Inter-comparison Project six-registered (CMIP6) group of the World Climate Research Programme. CMIP6 is an experimental design for a framework for global climate change modelling until 2020. The CSIR is the first CMIP-registered group in Africa, meaning that the sixth assessment report of the Intergovernmental Panel on Climate Change will, for the first time, contain African-derived projections of future global climate change.

The reports assess the evidence of climate change that has occurred to date, combines climate change projections obtained from all leading climate change institutions globally and converts the information collected into a set of plausible climate futures.

The CSIR's investment in the development of this model is aimed at informing the country's adaptation strategies for climate change. Projections generated by the CSIR have directly informed the Intended Nationally Determined Contributions that South Africa has submitted to the 21st Conference of the Parties of the United Nations Federation Convention on Climate Change. The models have also informed the national communication on climate change of South Africa.

7.4.3 The Advanced Fires Information System (AFIS)

The AFIS is a satellite-based fire information tool that provides near real time fire information to users across the globe. This system provides fire managers across the globe with a unique tool to better manage the risk of wildfires close to high value infrastructure and property such as transmission grids or forest plantations.

AFIS provides users with fire prediction, detection, monitoring, alerting, planning and reporting capabilities through the use of Earth observation satellites, weather forecast models and Information and Communication Technologies (http://www.afis.co.za/. Some of the reported beneficiaries include AgriSA, Forestry SA, Nature reserves, National parks, etc. There is now an AFIS Mobile Application (iOS and Android) and a Fire report query tool, among others. Collaborators in developing AFIS include CSIR, DTI, DEA, DAFF, ECMWF, EUMESTAT, Linfiniti, NASA, University of Dundee, South African Space Agency (SANSA) and Vital fire.

7.5 South African Weather Service (SAWS)

The SAWS is the national provider of weather and climate-related Information. They use the latest and most technologically advanced equipment that aids monitoring and prediction of weather patterns and the collection of climatic-related information. The SAWS' issues bad weather early warning systems to the Republic of South Africa.

Nationally, the SAWS is the authoritative voice for severe weather warnings. SAWS has also produced Weather Awareness Brochures in 10 local South African languages. These are constantly available on the SAWS website, and they are updated when necessary.

The SAWS has a variety of weather products and services which can be customized to meet various needs. The portfolio of offerings includes smart phone based applications such as WeatherSmart, which has multiple features and options for accessing climate and weather information, including the following: (http://www.weathersa.co.za/product-and-services):

⇒ Location based forecasts.
⇒ Severe weather warnings.
⇒ Weather conditions and forecast for a specified location.
⇒ A seven-day forecast for all selected locations.
⇒ Minimum & maximum temperature(s).
⇒ Wind direction(s).

7.5.1 A climate change reference atlas

The purpose of the SAWS Climate Change Reference Atlas is not only to provide a visual platform for viewing various climate projections of rainfall and temperature, but also to add to the number of projections that are already available in South Africa for comparison. Future projections of rainfall and near-surface temperature are presented for the two 30-year periods extending from 2036 to 2065 (near future) and 2066 to 2095 (far future).

Projected changes are expressed relative to the historical 30-year period of 1976 to 2005. Daily model simulated values of rainfall totals and temperature averages are used to generate projections of annual change, as well as projections of 3-month seasonal change. The seasons considered are December-January-February (DJF), March -April-May (MAM), June-July-August (JJA) and September -October-November (SON).

7.6 Water Research Commission (WRC) constituted consortium

In July 2005, the WRC released a solicited call for a five-year project involving the application of rainfall forecasts to aid decision making in the agricultural sector. From the various submissions, each with their own unique strengths, the WRC constituted a consortium comprising of the University of KwaZulu-Natal (UKZN), the University of Cape Town (UCT), the SAWS, the University of the Free State (UFS) and the ARC, with the University of Pretoria (UP) also brought into the project as a sub-contractor to the UFS.

Additionally, the CSIR became involved in the project during 2010, through provision of short-range and seasonal forecasts to the UP, UFS and UKZN. Other forecasting products were also being issued by the Climate Systems Analysis Group (CSAG), which is at the UCT, as well as from UKZN in collaboration with SAWS (Lumsden and Schulze, 2012).

Among other outputs from the project were seven case study applications of weather and climate forecasts. The case studies were quite diverse in nature. Some had tailor-made advisories generated from the use of climate forecasts and crop growth models. Many lessons were learnt from interactions with farmers.

Some of the lessons included widespread use of traditional/indigenous knowledge in climate forecasting, as well as farmers' difficulty in understanding probabilistic seasonal forecasts. Some of the recommendations were the need for further research into effective ways of disseminating and communicating the tailored forecasts, as well as on appropriate education of forecast presenters and decision makers. These interventions were necessary not only for subsistence/emerging farmers, but for the commercial agricultural sector as well (Lumsden and Schulze, 2012).

A follow-on project has a duration spanning from 2015 to 2019. It is being led by the UCT and collaborating institutions from the first project are all involved. Two universities were added among the collaborators, namely University of Fort Hare (UFH) and University of Venda (UNIVEN). The aim of the current study is to develop a set of tools allowing for an operational and robust climate-crop-water integrated assessment of the production of medium-scale agricultural forecasts (including water demand).

Forecasts for the project are generated by the SAWS, CSIR and CSAG (UCT). A major focus of the project is on integration of seasonal forecast information with crop models (DSSAT, ACRU and AquaCrop) for improved decision making in farming. Economic models are also applied to determine the profitability of different crop management practices as dictated by scenarios generated from the seasonal forecasts. Smallholder farmers are being engaged in the Eastern Cape (through UFH) and Limpopo (through UNIVEN) provinces while commercial farmers are being engaged with in KwaZulu Natal province (through UKZN). Preliminary findings have shown that it is feasible to integrate seasonal forecast information and crop models under Southern African conditions. There is also some focus on application of Indigenous Knowledge and scientific seasonal forecasts for climate risk management.

7.7 Contribution of climate information services to CSA

Climate information services contribute to CSA by ensuring the sustainable production of food and income generation, thus enhancing adaptation, and increasing resilience to climate change (Mwenye, 2017). The SAWS provides some agricultural industry specific weather information to ensure the safety of lives and asserts of each South African citizen. Such information includes the "Weather API", which is a useful application in farming.

Weather Application Programming Interface (API)

The Weather Application Programming Interface (API) is offered in partnership with AfriGIS. This API allows users to access a set of functions and procedures to create applications from the following datasets: thunderstorms, lightning and, in the near future, weather alerts (hail, flooding, veld fires, etc). The Weather API can be accessed at the following link: https://developers.afrigis.co.za/portfolio/weather-api/ .

Typical users of the API might include Insurance companies, wanting to warn clients (including farmers) of impending thunderstorms, to possibly move their vehicles out of the way of the storm. Insurance companies can also use the data to verify client claims of hail or lightning damage against historical data.

This information will improve the efficiency of operating of Index-Based Insurance, or WII.

Provinces can also use this information to issue warnings to farmers in affected areas so that they can prepare to manage risks that will be brought by the weather events.

7.8 Challenges and untapped opportunities

The timely provision of relevant forecasts to farmers is limited by the lack of climate and agricultural information at appropriate scales, low-density observational networks, and the lack of analysed historical data. Institutional collaboration between meteorological services and agricultural extension services is poor, as is capacity for translating climate information into agricultural impacts through extension services (Tall *et al.,* 2013).

The uptake of seasonal forecast information in South Africa has not been widespread. The use of weather and climate forecasts has been limited mostly to the 1–3 day weather forecasts that are easily accessible i.e., in the news media (Ziervogel *et al*., 2010). High levels of illiteracy among the smallholder communities such as those observed among women in Limpopo (60%) might make it difficult for them to understand weather forecast information and use it effectively in the decision-making (Ubisi *et al.,* 2017).

Use of long-range forecasts is limited. The agricultural sector has not yet reached a stage of integrating information about changing intra-annual climate conditions in a systematic manner, which is a critical step needed in responding to longer term change. This is partly due to a lack of awareness of available products and in some cases, products are not tailored to suit user needs (Patt et al. 2007). Farmers in South Africa for example, have tended to respond to seasonal variability rather than pre-empt decadal change in rainfall and temperature (Thomas et al. 2007).

Climate change is perceived differently by men and women, and they adapt differently to its effects. Therefore, climate change interventions and support systems should take special attention of the gender dynamics (Ubisi et al., 2017). However, while women were reported to require less labour intensive adaptive options, there has not been reports suggesting streamlining CIS dissemination strategies by gender.

Access to extension services for climate change information was found to increase the likelihood of smallholder farmers adapting to new crop variety and diversify their enterprises (Ubisi *et al.,* 2017).

7.9 Conclusions and recommendations

Climate information services are critical for effective risk management and achievement of CSA objectives. The importance of providing relevant weather and climate information, and a range of advisory services to enable decision-makers to understand and act on the information was highlighted.

Collaboration between multi-disciplinary experts from climate and agricultural science, including farmers, is important to make this a reality. South Africa is generating substantial CISs.

Improvements are still needed to ensure that timely advisories are effectively disseminated to farmers. Five challenges that confront efforts to use climate-related information to improve the lives of smallholder farmers were identified to be: salience, access, legitimacy, equity and integration. These challenges still need to be overcome for effective provision of CISs in South Africa.

The case studies and resulting lessons provided insights on what will be needed to build effective national systems for the production, delivery, communication and evaluation of operational climate services for smallholder farmers in South Africa.

8.1 Introduction

Climate change impacts result in huge loses in agriculture, leading to high incidences of poverty amongst smallholder/emerging crop and livestock farmers in South Africa. After experiencing a weather related shock, it is often difficult for smallholder farmers to recover and make investments in improved agricultural practices. Although applied, traditional approaches to risk transfer and risk management are no longer adequate, especially because of the increase in frequency of climate variability and extreme events such as drought and flooding.

The traditional risk management approaches need to be complimented with agricultural insurance (Dick *et al*., 2011). An effective insurance option for smallholder farmers would help to make agriculture an attractive livelihood choice and assist in promoting agrarian reform in rural areas (Partridge and Wagner 2016).

If risk cannot be adequately managed, producers will become risk averse and they are more likely to take on less risky investments that are typically also low-yield investments thus restricting growth of the agricultural sector (Partridge and Wagner 2016).

In addition to incentivising and taking on higher-yield investments, being insured also makes producers more creditworthy, making lenders more likely to grant a loan that could be used for promising investment opportunities (Nnadi, *et al.,* 2013).

While the agricultural insurance market can often serve the commercial farmer, the rural farmer is often left in financial distress with no insurance coverage due to their high costs (Wells, 2012; Cohn *et al*., 2017).

The most widespread type of indemnity-based agricultural insurance is Multi-Peril Crop Insurance. However, there are some challenges in offering it to smallholders, linked to the fact that farm visits are needed to set up coverage and determine the damage (Rispoli, 2017).

This makes indemnity-based agricultural insurance expensive for smallholder farmers. The insurance industry has challenges in coming up with suitable products to service the poor. The major challenges, of course, are juggling the cost of servicing this market, while ensuring that premiums are affordable and products value adding, with the objective of running profitable business models (SAIA, 2017a).

Weather index-based insurance (WII) products for agriculture represent an attractive approach for managing weather risk, especially for smallholder farmers. Programmes conducted in several developing countries have proven the feasibility and affordability of such products (SAIA, 2016).

Index insurance is an approach that ties payments to regional agricultural outcomes rather than direct measurements of production losses on participants (Lybbert and Sumner, 2012).

Because it is based on an indirect indicator or a proxy for loss, index-based insurance can offer promising solutions for smallholder agriculture.

Agricultural index insurance is a tool that can reduce poverty, enhance livelihoods of smallholder farmers and address climate change effects (Rispoli, 2017), and it supports all the three pillars of CSA (Solana and Prashad, 2017).

These three pillars are namely: i) sustainably increasing agricultural productivity and incomes; ii) adapting and building resilience to climate change; and iii) reducing and/or eradicating greenhouse gas emissions, where possible.

8.2 Concepts and characteristics of Weather index-based insurance (WII)

8.2.1 Principles of Weather index-based insurance

Conventional crop or livestock insurance relies on direct measurement of the loss or damage suffered by the farmer. However, field loss assessment is normally costly or not feasible, particularly where there are a large number of smallholder farmers or where insurance markets are developed (Dick *et al.,* 2011).

Index-based insurance has become the preferred approach to insure smallholder farmers. Unlike traditional insurance, which requires the services of a local expert to assess economic loss with respect to a claim, index-based insurance draws on biometric data (supplied by satellite imagery or by surface weather stations) or on average yield data to model losses. WII is thus based on an indirect indicator or a proxy for estimating losses incurred by a farmer. By reducing administration, distribution and transaction costs, this innovative approach makes agricultural insurance affordable for smallholder farmers (Ribeiro, 2017).

Typical features of a WII contract are as follows (Dick *et al*., 2011):

⇒ A specific meteorological station is named as the reference station. Satellite imagery data is increasingly being used to compliment data collected from the ground.
⇒ A trigger weather measurement is set (e.g. cumulative millimetres [mm] of rainfall), at which the contract starts to pay out.
⇒ A lump sum or an incremental payment is made (e.g. a South African Rand amount per mm of rainfall above or below the trigger).
⇒ A limit of the measured parameter is set (e.g. cumulative rainfall), at which a maximum payment is made.
⇒ The period of insurance is stated in the contract and coincides with the crop growth period; it may be divided into phases (typically three), with each phase having its own trigger, increment and limit.

The key advantages are that it can reduce administrative costs, and the risks of moral hazards, adverse selection and asymmetric information. Because the product is standardised, it can be bundled with other services, such as credit or inputs, and delivered through aggregators (e.g. farmers' associations, commodity associations, input suppliers, etc). It also protects against covariate risks, which affect many people in the same area simultaneously (Rispoli 2017).

It is best suited to weather hazards that are well-correlated over a widespread area and where there is a close correlation between weather and crop yield. It is less useful where conditions are more complex. Localized risks, such as hail, or where microclimates exist (for example, in mountainous areas) are not suitable for WII. Other insurance products may be more appropriate in such situations (Dick *et al.,* 2011).

8.2.2 Levels of intervention and business models

Index insurance can be introduced at the micro-, meso- and macro-levels (Dick *et al.,* 2011). Various implementation models can be used to benefit vulnerable smallholder farmers. At the micro level, the policyholders are farmers, households or small business owners, who purchase insurance to protect themselves from potential losses caused by adverse weather events. Micro-level policies can also be distributed to farmers by organizations such as farmers' associations, input suppliers, processors or NGOs. The latter organisations will act as a distribution channel for micro products retailed to individual farmers. Meso-level institutions (farmers' associations, input suppliers, processors or NGOs) buy WII policies (e.g. portfolio or group insurance) to protect their own exposure and may create pay out rules that directly or indirectly benefit farmers.

At the macro level, governments and relief agencies will be the policy holders. Governments will receive early liquidity following disasters and relief agencies will be able to fund operations from the pay-outs.

It was reported that the most likely target group will be emergent and commercial farmers, as it is unlikely that the majority of poor smallholders would directly purchase insurance on a sustained basis. In that case, a thorough market assessment might suggest entry through an aggregator (e.g. agricultural processors, input suppliers, farmers' associations).

Aggregators are key to reducing transaction costs and reaching more clients. In this context, index insurance products could be designed to cover portfolios of aggregators (through meso-level products) as well as the household level risk of individual farmers (through micro-level products distributed by the aggregator) (Dick *et al*., 2011).

8.3 Using WII to encourage adoption of Climate Smart Agriculture (CSA) measures

Extreme weather events can devastate crop yields and food production, adversely impact food security and nutrition, and erode the livelihoods and assets of the poor. Total crop and livestock loss can threaten the food security and nutritional status of entire communities. Weather-related hazards can also be transmitted to other segments of the agricultural supply chain, such as processors, wholesalers, and transporters, and also to other sectors that support agriculture, such as banking, for instance through loan defaults (Ceballos *et al.,* 2016).

Insurance can play a role in supporting adoption of climate change adaptation pathways. There is a strong consensus that CSA is the way forward when it comes to adaptation practices for smallholder farmers. CSA is used to address climate change adaptation and resilience, because it fully integrates productivity and income challenges (Solana and Prashad, 2017).

In developing solutions for climate risks, the insurance industry should seek to understand CSA and link its products to adaptation and resilience practices. This will help to make management of climate insurance products sustainable since weather related risks occur on a regular basis (Solana and Prashad, 2017).

Index insurance can be bundled with other services, such as credit or inputs (Dick *et al*., 2011; Ripsoli, 2017). This allows farmers to take additional risks by investing in improved practices that increase productivity and food security, even in situations of adverse weather conditions (Ngara, 2017). Thus, insurance stabilizes the incomes of agricultural producers and reinforces the strength of the value chain (Ribeiro, 2017).

Ngara (2017) reported that WII can facilitate adaptation through short-term and long-term climate risk management, as well as adoption of some mitigation options. The response capacity of governments participating as policyholders in sovereign risk regional pools, such as the African Risk Capacity, will be enhanced.

The government will receive pay-outs when there are extreme weather events, enabling them to quickly and efficiently distribute aid to the most affected smallholders (Rispoli, 2017). Extreme weather events can also cause long-lasting damage to poor communities through the destruction of infrastructure (roads, schools, and hospitals), with staggering costs of recovery and rebuilding (Ceballos *et al*., 2016). Macro-level WII will enable governments and relief agencies to start rebuilding immediately, thus facilitating expeditious recovery of communities. This enhanced response capacity also enables achievement of rural development goals.

8.4 Status of agricultural insurance in South Africa

Of the 19 Agri-insurers in SA at the moment, there are only four that offer agricultural insurance. These insurers are Hollard Insurance, Santam, Landbank Insurance and Old Mutual Insure. Crop insurance in South Africa has two types of cover, that is, hail and multi-peril. When one considers large-scale natural disasters (e.g. drought/floods etc.) the current situation is that a farmer would need multi-peril insurance.

This cover is quite comprehensive but predominantly aimed at the commercial farmer with the capacity and scale to justify the cover and pricing. As a result, it is estimated that only some 30% of dry land South African crops are insured (Weise, 2017). The majority of smallholder farmers, if not all, do not have insurance cover because it is unaffordable for them. Index insurance is not yet available in South Africa, which therefore creates a gap in the insurance market.

The South African government is aware of the plight of smallholder/emerging farmers with respect to their capacity to manage risks associated with climate change. This can be seen from the Draft CSA Policy gazetted in 2018.

Section 6.4.15 of the Policy looks at options to increase crop and livestock weather-indexed insurance with an emphasis on smallholder farmers, foresters and small fisheries. Based on the draft policy, the following actions are proposed for implementation:

⇒ Develop and implement varied innovative index-based agricultural insurance packages for crop, livestock and fisheries value chains;
⇒ Invest in the agro-meteorological infrastructure to support index-based agricultural insurance;
⇒ Enhance the capacity of micro-finance institutions to act as agents to deliver innovative crop and livestock index-based insurance packages;
⇒ Raise awareness within the insurance industry of extreme weather and climate risks and communicate actions and opportunities;
⇒ Undertake farmer education to address their concerns regarding insurance products with a view to gain their trust; and
⇒ Explore government re-insurance to support insuring high-risk smallholder farmers.

The draft Policy proposes that the financing mechanism would include: (i) provision of guarantees or insurance against loss of harvest related to the changed practices; and (ii) guarantees that allow access to finance. The guarantees would be sourced from both public (national and international) budgets and the private sector to encourage adoption of CSA measures.

There have been other initiatives aimed at provision of index insurance in South Africa. In 2016, delegates from all over Africa, including South Africa, attended a technical workshop of the World Bank Group's Global Index Insurance Facility (GIIF), held in Johannesburg from 13 – 14 October 2016. The workshop was focused on operationalising agriculture index insurance. Participants were provided with an overview of index insurance concepts and products (SAIA, 2016).

Following a study supported by the National Treasury and DAFF, with the assistance of World Bank, South African Insurance Association's (SAIA) Agriculture Insurance Forum drafted a proposal on how to introduce insurance to smallholder farmers in November 2016. The Forum consists of DAFF, Land Bank Insurance, Santam, Hollard Insurance, Old Mutual Insurer and some reinsurance companies. They proposed introduction of Index Insurance, and that government provide subsidies on the premiums. Different models were proposed for commercial and smallholder farmers. SAIA's Agriculture Insurance Forum is currently involved in research to gather more information on index insurance for presentation to government. Government has not yet made a commitment to providing the subsidy, however. The partnership models have also not yet been finalised. However, it is likely that Private sector players will pool resources and they will then collaborate with the government.

The public-private venture could provide a solution that is affordable for producers while also being profitable for insurers, thus making it a sustainable insurance system. If the government of South Africa decide to co-finance index insurance then they will be following in the footsteps of countries like US, Brazil, Turkey, Spain and Sudan (Wells, 2012). Two things need to happen to make the cover accessible for the broader farming community from small scale and subsistence farmers to the larger commercial entities (Weise, 2017):

⇒ The product needs to be simple to administer and understand which will also make it cheaper to administer. It also requires some far-reaching investment in technology spread over the country to facilitate flow of information and administration.

⇒ The premium pool needs to be increased to provide for the claims and decrease the individual contributions.

The government also has to assist with information management infrastructure and by subsidising the premiums of farmers to make it viable and sustainable (Weise, 2017).

8.5 Challenges and untapped opportunities

While the focus on risk management in climate change presents opportunities for index insurance, there are still key challenges in implementing it in a way that improves resilience of vulnerable farmers. Overcoming these challenges will require collaboration by multi-institutional stakeholders from the private and public sectors, as well as the donor community.

Developing index insurance products requires capacity and expertise (Ripsoli, 2017), which is not widely available in South Africa. Adequate technical expertise in agricultural and actuarial sciences may not be available in most insurance companies. This limits development and functioning of WII. Good-quality agricultural data is not available especially in the smallholder farming communities. Such data is required for development of different insurance products, as well as estimating losses incurred by weather disasters for purposes of compensating affected farmers.

Smallholder farmers have limited awareness of the existence of agricultural insurance in general, or its relevance to them. This may partly explain why there is only an estimated 30% of dry land South African crops that are insured (Weise, 2017). The government and the insurance industry have to create awareness of its existence to facilitate adoption.

In order to effectively participate in offering WII, the private sector has to access global and regional financial bodies dealing in insurance schemes for the developing world, such as the Climate Insurance Fund (CIF). Sherk and Jobava (2017) reported the following about the CIF:

"The CIF has a focus on helping private sector players develop long-term climate insurance solutions. The specific objective of the fund is to reduce the vulnerability of low-income households as well as micro, small and medium enterprises to extreme weather events. CIF supports private companies involved in the value chain of insurance (mostly insurers, brokers, reinsurers and insurance distributors) to develop a climate insurance offering for low-income populations in Official Development Assistance (ODA) recipient countries. This initiative focuses on investment capital, technical assistance and premium subsidy funds to expand climate insurance through private sector channels to support the business sector and low-income households. The CIF has already supported innovative climate insurance schemes and will continue to build on this

knowledge to further invest in private sector initiatives, spurring the long-term development of climate insurance markets for poor and vulnerable groups globally."

The government and private insurance providers in South Africa can also take advantage of public sector insurance initiatives to launch and finance WII. Such initiatives include: The G7 Initiative on Climate Risk Insurance ("InsuResilience"); African Risk Capacity (ARC); Climate Risk and Early Warning Systems (CREW); and, the Global Index Insurance Facility (GIIF) (Sherk and Jobava, 2017). As explained earlier, the GIIF organised a WII workshop in South Africa in 2016. The South African government needs to take advantage of the existing working relationship with the GIIF.

8.6 Conclusions and recommendations

The ability of smallholder farmers to bounce back and make investments after experiencing a weather related shock will be improved by availability of appropriate agricultural insurance. Insurance products currently available in South Africa are not suitable for smallholder farmers, due to high cost. WII is a viable option though it is not yet available in the country. SAIA's Agriculture Insurance Forum has previously proposed models for launching WII, and they are currently doing further research on it.

Though the government has not made a commitment to fund WII, their future intention to support it have been expressed through the draft Framework on Climate Smart Agriculture. The government and private insurance providers in South Africa should take advantage of public sector insurance initiatives to launch and finance WII. Such initiatives include: The G7 Initiative on Climate Risk Insurance ("InsuResilience"); African Risk Capacity (ARC); Climate Risk and Early Warning Systems (CREW); and, the Global Index Insurance Facility (GIIF).

Case studies that were presented showed how WII is working in East Africa, for both crop and livestock insurance. South Africa should draw lessons from these case studies to launch an efficient WII facility for vulnerable smallholder farmers.

9.1 Introduction

After the industrial revolution, urban and rural livelihood followed different socio-economic paths. However, the fast development of urban economy and expansion of cities was not sustainable. Urbanization, in one way or the other, was implicated in food insecurity, poverty and climate change. Looking for better life, the working force of the rural community migrates to cities at an ever-increasing rate (Lwasa *et al.,* 2014; Philander, 2015).

This uni-directional migration results in a fast population growth in urban areas. As a reflection of such a phenomenon, population of the urban and semi-urban settlements on the African continent was 44% before the year 2014 (Lwasa *et al.,* 2014) and is expected to be double by 2030 (Crush, 2011). So far, more than 60% of the population of South Africa lives in urban or peri-urban settlements (Davis, 2017). This implies that South African cities are amongst the fastest growing in Africa.

Such a situation negatively affects production of the traditional (rural) agriculture, resulting in shortage of food supply. As the gap between food supply and demand continues to get wider, domestic food price escalates and access to food drops. As a result, low-income urban dwellers, who so far spend more than 50% of their income on food, face food insecurity and malnutrition (Philander et al., 2016).

Another negative effect of urbanization on rural livelihood is that with fast expansion of cities and towns, farmland continues to shrink because a considerable portion of the arable land is being used by city municipalities for residential, business and other different community development purposes and services (La Rosa *et al.,* 2015). This reduces food production because surface area, fertility and health of the traditional farms are considerably reduced.

This reduction of farmland (area) obviously makes the cities (even the whole country) depend on imported agricultural produce form other regions and/or countries. These imported or transported agricultural produce lack freshness as they reach the consumers days after harvesting. Also, the retailers keep a large quantity of fresh produce stock as they are not delivered on a daily basis. Some of the perishable produces are also delivered in a processed form or treated with preservative chemicals to increase the shelf life of the commodities.

In addition, as the farm industry grows, even if they are located near the consumers in the cities, they are specialized to produce specific crop to supply demand of certain processing factories (De Zeeuw, 2011). Products of such mono-cropping farming systems reduce the diversity of the available food, resulting in malnutrition.

Urbanization is also a major contributor to climate change. This includes increase of flooding, raising of temperature, water scarcity and environmental pollution. Flooding risk in cities emanates from an increase in rainfall and reduced water infiltration rate of the land as most of the surface land area in cities is covered with materials that keep water out. For example, roofs of houses, concrete floors and parking areas, and compacted or asphalted roads and pavement. Flooding risk cause more problems to poverty-stricken people in cities who live in informal settlements on hillsides, poorly drained areas and low-lying coastal zones (De Zeeuw, 2011).

Likewise, cities contribute to global warming through 'urban heat island effect'. This is the phenomenon that is observed in cities where several structures (buildings, tar-road and concrete surfaces) trap or absorb heat during the day and slowly release to the city atmosphere during the night. In addition, most of the large industries are located in urban and peri-urban areas.

These power generators, industrial activities, transportation and cooling systems, produce heat that adds to the warming up of the urban environment. AMS (2000) indicated that in hot days, temperature of urban areas may increase by up to 11°C compared to rural. In addition, cities contribute 70% of the greenhouse gas emitted globally (De Zeeuw, 2011).

Most of the suffering and risks (food insecurity, climate change, poverty, etc.) the world is facing are contributed mainly by urban and peri-urban environs, the industrial centers. They are also having the incompetency to act on adaptation and mitigation of climate change (De Zeeuw, 2011). Therefore, urban and peri-urban areas should come on board to implement some of the practices suggested to solve the climate change problems.

Urban agriculture has been advocated as a livelihood strategy through which climate change adaption and mitigation for food insecurity could be addressed (Lwasa *et al.,* 2014; Philandrer. 2016). An extensive review by Lwasa *et al.,* (2014), unequivocally confirms the positive role urban agriculture and forestry can play, if some of the challenges and risks that exist in the implementation of urban agriculture and forestry are managed properly.

Some of the challenges that need expert attention include man and environmental health-related concerns; and conflicts with other land and other resources (the scarce water resources, for example). Hence, one of the best solutions for almost all the urbanization collateral risks is promoting and introducing smart urban agriculture.

The objective of this review report is, therefore, to assess the status and contribution of urban agriculture in South Africa with a view to come up with actionable urban agriculture practical guidelines.

9.2 Urban agriculture

Urban agriculture is the practice of growing plants (crops, ornamental plants and trees) rearing of livestock within or on the city suburbs (in urban and peri-urban areas). This includes industrial plants that are established for processing and value adding of agricultural produce (De Zeeuw, *et al*., 2011). Urban agriculture has been popular even formally embedded in the setting of modern cities and towns. This farming system differs from traditional agriculture because it is done in the small open land areas or on rooftops and indoors in the densely populated cities, towns or townships (Dhakal *et al.,* 2015). Urban agriculture is also practiced in urban areas and townships of South Africa. Burger (2010) has summarized distribution of urban agriculture in South Africa according to province as indicated in Table 9.1.

Table 9.1: Distribution of urban farming practices in South African provinces

Province	2002		2007	
	Number	Proportion (%)	Number	Proportion (%)
Eastern Cape	48 036	77	52 344	64
Free State	8 621	14	8 512	10
Gauteng	3 180	5	12 441	15
Northern Cape	1 559	2	1 779	2
Western Cape	723	1	1 767	2
North West	602	1	5 190	6

Source: *Burger et al. (2009:22) cited in Crush (2011: 292)*

9.2.1 Role of urban agriculture in climate change mitigation, and poverty and food insecurity adaptation

Urban agriculture, particularly crop production, as part of the city greening, is a core player in mitigating climate change, poverty alleviation, enhancing food security and reducing malnutrition (De Zeeuw *et al.,* 2011).

9.2.1.1 Climate change mitigation

Green plants in the urban environment can reduce land degradation and stabilize ecosystems. They also reduce run-off water and promote percolation. Covering open land in cities with plants, therefore, would minimize flooding as they can enhance infiltration rate of rainwater. This will increase soil moisture, which is gradually released (through evapotranspiration) and raise the relative humidity of the urban environment.

In addition, plant root system stabilizes soils, especially on hillsides, which reduces erosion and risk of landslides. Plant leaves (canopies/shoot) also subdue the force of torrential rain fall which otherwise disturbs surface soil making it prone to erosion (de Zeeuw *et al.,* 2011).

Open soil surface easily heats and radiates solar radiation into the air, increasing the air temperature. Thus, maintaining urban open spaces green and enhancing crop production in cities could have adaption and mitigation benefits (de Zeeuw *et al.,* 2011), as plants reduce temperature in two ways, protecting soil surface from direct solar radiation and absorbing heat energy for life activities such as photosynthesis and evapotranspiration.

Urban agriculture reduces energy use and greenhouse gas emission. It is estimated that 11% of the air pollution comes from trucks that transport agricultural produces from the production site far from urban area to the cities. Urban agriculture cuts the number of trips of these heavy trucks, reducing heat and CO_2 emission. In addition, the power used to store in cold rooms to increase shelf life of transported perishable agricultural commodities lowers pressure on the environment and economy of households. Crop plants in urban agriculture sequestrate CO*2* in the process of photosynthesis to produce organic matter and releasing O_2 to the atmosphere. This reduces greenhouse gas, to certain extent, reversing negative contribution of urban industry to global warming.

9.2.1.2 Poverty, food insecurity and malnutrition adaptation

Urban agriculture improves livelihood of the community or families directly involved in the farming practice and to lesser extent the livelihood/economy of the whole urban community. Up to 44% of calories and 32% of protein uptake of household in Africa, especially in the tropical regions comes from urban agriculture (Lwasa *et al.,* 2014). When households in urban community produce crops, they can save money, which otherwise would be spent on buying food from the market. Surplus produce of urban agriculture can be sold to the local market and generate income (Moustir & Danso, 2006; Thornbush, 2015). This benefits not only the producer, but also it improves lives of the consumers because it is sold at a fair price as the marketing chain is shorter and transport cost is excluded

As urban agriculture expands and gets more intensive it could be labour intensive. Thus, people can be self-employed, and create jobs for others (De Zeeuw *et al.,* 2011). According to Lwasa *et al.* (2013), the number of people involved in urban agriculture worldwide is 800 million. About 200 million of these people who are involved in the urban agriculture do it as a business to generate income and create jobs for 150 million people.

The contribution of urban agriculture is not limited to an increase and access to food quantity wise, but also contribute to diversity and content (quality). As the food is locally produced, it reaches the consumers fresh and nutritious, with no preservatives and other shelf-life-increasing treatments/additives. Thus, it mitigates malnutrition. Being locally produced (no transport cost and passes though short trade chain), it is accessible at a fair price, reducing food cost for the poor urban residents who spend more than 50% of their income on buying food (Oxfam, 2014). The urban farming distribution in South African provinces in 2002 and 2007 (Table 9.1) shows that food price determines the proportion of urban settlers who are involved in producing food crops. The lower percentage of number of households involved in crop production in 2002 in the Eastern Cape and Free State Provinces, according to Burger (2009), is as response to the food prices increase. In 2002, increase in food price was high and poor households tried to adapt food insecurity through producing their own food, as an alternative source.

9.3 Enforcing integration of agriculture to urban livelihood in South Africa

South Africa has unsustainable development in urbanization livelihood with high unemployment rate and ever-increasing food prices (Philander, 2015; Davis, 2017). The urban population outnumbers the rural population, as more than 60% of the population of the country live in urban areas (Davis, 2017). This figure may include the peri-urban areas (commonly called locations or townships) mostly dominated by low income households (houses built by government for unemployed members who were disadvantaged during the Apartheid regime). In addition, climate change is taking its course and drought and water scarcity for irrigation and domestic purposes are becoming more common (Sheikh, 2006)).

Several researchers have tried to assess the situation and contribution of urban agriculture in South Africa. One of the studies was done by Philander (2015). The main objective of the study was to assess the contribution of urban farming (vegetable gardening) to food security, and to determine livelihood outcome of urban food garden in Langa suburb of Cape Town.

The authors used mixed methodology: quantitative (self-administered questioner given to 83 randomly selected participants) and qualitative data, where discussion sessions were arranged with 17 community members and 13 beneficiaries of the 'Urban Food Garden' Project, which was funded by the National Independent Trust (Public Works).

The result revealed that urban agriculture reduces food insecurity. As high as 82% of the respondents agreed that urban food garden contributes to food security. In addition, the authors highlighted that the practice has health benefit and it builds self-esteem of the people who are involved in the practice.

According the authors, the gardening projects in Cape Town are done in backyards due to the lack of open land within the town or peripheral areas. This implies that experts need to come up with technologies that overcome the land constraint. One of the advances in urban agriculture is utilizing rooftop space for agriculture (gardening) using hydroponic (soilless culture). Therefore, extension officers need to promote/show the producers that gardening, especially hydroponic, can be done anywhere where there is enough light for photosynthesis.

Averbek (2017) also assessed the contribution of urban agriculture in South Africa. The objective of the study was to provide quantitative information on the material benefits generated from urban farming in five informal settlements in Atteridgeville, Pretoria. The study indicated that more than 50% of the households of the surveyed area participate in urban farming (home gardening, group gardening and dryland farming in open urban spaces), which is higher than the estimated proportion of urban dweller worldwide, 20 - 30%, as reported by Thornbush (2015). Women were the predominantly active participants, indicating that it creates job opportunities for mothers while taking care of their children and other domestic chores.

The report of van Averbeke (2017) agrees with the views published by Thornbush (2015) which reveals that women comprise 65% of the total number of people who are involved in urban agriculture, worldwide. In addition, urban agriculture was found to have modest contribution to the total household income and food security.

The benefits that are derived from urban farming are not limited to income and food security but also reduces social alienation and strengthen family ties, as a means of poverty eradication. The participants described land shortage or limited access of land (for gardening) and water for irrigation as the main limiting factors for maximizing urban agriculture production.

This indicates that introduction of intensive cultivation technologies, such as hydroponics, is needed. These technologies would enable to maximize yield on the limited area available, including house walls (for vertical farming or hydroponic) and rooftops. In addition, the producers need to look for alternative sources of water such as harvesting rainwater and reusing greywater.

9.3.1 Practices that increase productivity and adaptation

As mentioned in the previous section, the world in general, and cities in particular, are under huge pressure of poverty, hunger and malnutrition. Almost all of these threats are results of human action, in pursuing advancement in modern technology. These technologies are innovated to make life easy in cities, but they are at the expense of the environment and future generations. Another cause of such threat is the ever-increasing population in cities. Unless this issue is addressed at its inception stage, it will have irreversible consequences.

Shrinking of arable land is one of the reasons that is making food supply in lagging behind the food demand. Extensive farming is unthinkable; it has phased out, leaving the space for intensive crop production as the only option available (Sheikh, 2006). This is essentially true in urban agriculture in the era of fast expanding cities.

In intensive cultivation, more inputs are invested to maximize productivity of a unit land area. The practice is applied on high value and responsive crops, including most of the vegetables, herbs and fruits. Where land surface area is extremely reduced, and climate change negatively affects productivity of crops, food security and poverty should be addressed through intensive cultivation techniques such as hydroponic or soilless culture, controlled (greenhouse) plant growing system, and using innovative systems that increase productivity of water as a scarce resource (Dhakal *et al.,* 2015).

9.3.1.1 Hydroponic systems technologies (Vertical and horizontal production)

The word hydroponics comes from two Greek words: ‘hydro’ – meaning water, and ‘ponos’-means labour or work. This implies crop production in water (or in solution). The technique is also referred to as ‘soilless culture’ to indicate that any soil or growing media used in the hydroponic system is passive in terms of influencing the chemical property of the plant root zone (Sheikh, 2006). Depending on the type of the hydroponic technique used, the inert material used plays major role in supporting the plant and balancing between air and moisture in the root zone.

A hydroponic system is a key sustainable agricultural practice in areas where there is acute shortage of land and/or irrigation water.

Therefore, hydroponic system is an appropriate technology in urban agriculture where there is limited/no-open land and scarce potable water (Sheikh, 2006). Hydroponic farming can be done anywhere where the plants can survive other factors such as temperature.

The system enables growers to efficiently utilize the scarce water and expensive nutrients. Hydroponic in South Africa is employed in protected and semi- controlled greenhouse/shade cloth. The most commonly produced crops under hydroponic system and protected cultivation systems are tomato, cucumber, and sweet paper.

9.3.1.2 Controlled and semi-controlled farming (Greenhouse and shed net facilities)

With or without the prevailing climate change, the natural climate restricts growing habitat of different plant species. High demand and costly transport of fresh produce encourages production of crops in controlled environments. In greenhouses, the producer creates artificial environment that allows the crop to grow and give the desired produce. This practice, in agriculture, can be described as season and/or plant habitat extension. This includes any structure that allows crops to grow beyond its natural growing season through creating artificial environment in facilities such as greenhouses (glasshouses and tunnel) and shade nets.

The advantage of farming under controlled system enables not only to produce crops out of their natural habitat and season, but also increase productivity per unit land area. This production technology is among the best solutions for urban agriculture to maximize productivity of the limited space available. Through constructing greenhouse, rooftops of urban houses can be utilized for crop production. In South Africa, cultivation under controlled condition is commonly around cities, tomato production around East London for example. This area is not ideal for tomato production but the farmers in the areas created an artificial environment that is conducive for the crop and manage to supply the local market with high quality produce all year-round.

9.3.2 Water saving, and water use efficiency technologies

Competition between the traditional commercial agriculture and ever-growing cities for finite water resource is one of the main problems that threaten both industrial growth and food supply. In cities, this can be alleviated by harvesting and using grey water and rain water for irrigation purpose, increasing water use efficiency through minimizing evaporation (applying mulching) and proper irrigation delivery techniques (drip and sub irrigation).

9.3.2.1 Reusing greywater and rainwater harvesting

Grey water refers to the water discharged after it has been used for household purposes such as dishwashing, bathing and washing clothes. This is less contaminated with heavy metals and disease-causing microorganisms compared to blackwater. Greywater, therefore, could be used for irrigation purposes without or with little treatment. Using grey water maximises water productivity and mitigates competition of domestic water use and water for irrigation (Dhakal, *et. al.* 2015).

Practicing of rainwater harvesting implies collecting rainwater and for later use. Small rooftop catchment can provide ample amount of water that would be enough for irrigation and other domestic uses enough until the next rainfall incidence depending on the water tank size. Placing the water tank at a raised platform further reduces energy required to distribute by using gravitational force (Dhakal *et al.,* 2015).

9.3.2.2 Irrigation Techniques

Drip (trickle) irrigation is used for delivering water to plants efficiently. However, this technique is appropriate for plants growing in rows. Drip irrigation enables the gardener to supply each plant with the required amount of water assisted with some devices that measure soil water deficit (for example tensiometer, pan-evapotranspiration) and water meter. It is possible to use this irrigation technique for fertigation to supply the plants with nutrients together with the water (as solution), as in the case of hydroponic system. The advantage of drip irrigation over sprinklers is that there is little water loss due to evaporation or runoff. The technique could be closer to 100% efficient if it is accompanied by mulching.

If the plant (crop) is broad casted on beds, it is better to use macro- or micro-sprinklers. Macro-sprinklers are for larger area and micro-sprinklers for small area and for fruit trees. These techniques have wider coverage and can also be used for foliar nutrient feeding.

Compared with drip irrigation, in sprinkler system there is high water loss due to evaporation and drifting when it is done during windy conditions. The ideal time for sprinkler event is morning hours when the wind is calm and the water on the leaves dries faster. If this technique is applied in the evening hours, the water on the leaves dries slowly and creates a conducive environment for diseases, especially fungi. Sprinkler irrigation cannot be used with mulching.

As in the case of drip irrigation, event of this irrigation technique is guided with information generated with soil moisture sensors, which are more exact in measuring how much water your plants are receiving and thus offer greater water savings.

9.3.2.3 Soil Mulching

Mulching in agriculture is covering the soil surface with plant debris, gravel or synthetic sheet like plastics. This is practiced for two main purposes: conserve moisture and suppress weed. Plant debris and other inert materials like gravel or pebbles, as mulching materials reduce evaporation from soil surface by reducing soil temperature (reflects solar radiation) that could increase evaporation. In addition, these mulching materials slow air movement within the mulching layer creating humid microclimate that discourages evaporation of soil moisture. Plastic sheets are moisture and air impermeable, thus keep the moisture in the soil. The plastic sheet should be covered with thin soil layer to avoid direct solar radiation; otherwise, it traps heat that can damage plant roots and kill useful soil microorganism.

9.3.2.4 Use of compost and vermicomposting fertilizers

Compost is decayed plant material. Composting is the practice of hastening the natural break down (decay) of plant materials with or without including animal manure. The composting practice can be done at any corner of the backyard best in a heap or also in a pit provided that it is well managed (provided with the balanced amount of air and moisture to saprophytic micro-organism.

Compost revitalizes soil fertility making the different nutrients that are fixed in the plants tissue through metabolism be released and be available to plants. It also improves soil health because it restores the populations of useful microscopic bacteria and fungi, along with earthworms, and many others, which form symbiotic or mutually benefiting partnerships with plant. Therefore, composting is not only cheap source of plant nutrients, but also prevents land degradation as it maintains soil chemical and physical at/near optimal status.

Vermicomposting or Vermiculture is a composting process that uses worms and micro-organisms to convert organics into nutrient-rich humus. Through composting and vermicomposting in urban environment, one can improve productivity of the garden, reduce volume of trash and save money that otherwise is spent for buying inorganic fertilizer, and paid for waste removal services. Although one should be aware that compost and vermicompost cannot fully replace other fertilizers because some nutrients, especially plant available nitrogen, are low content.

Composting is common in South Africa. People prepare compost for their own garden and/or directly sell the compost to gardeners or to garden/agricultural material suppliers. Vermicomposting is less common. There are few people who try to promote their vermicompost around large agricultural material suppliers, nurseries and others.

9.4 Practices that enhance mitigation

In the era of rapid urbanization, urban agriculture is being advocated as a means to mitigate the growing food insecurity of the urban poor (Crush, 2011). Revitalizing crop production in urban and peri-urban communities reverses the risk of hunger and malnutrition in cities and mitigates climate change, as different crop plants are of dual purpose: source of income/food and as green plants, moderate/buffer climate change and environmental pollution (De Zeeuw *et al.,* 2011). However, urban agriculture can be more climate smart when renewable energy such as wind and solar power are used.

Use of renewable energy technologies (wind power, solar powered water recycling).

Embracing intensive urban agriculture, needs energy to control the micro-environment in greenhouse, to pump water in hydroponics, etc. The ever-increasing electricity cost could be a bottleneck for urban agriculture. According to Chel and Kaushik (2011), sustainability of agriculture could only be realized by using renewable energy. Promoting renewable energy is a solution for both environmental health and economic constraint.

The two major renewable energies that can be used as alternative to fossil energy are solar and wind energies. These two sources of renewable energy are abundant everywhere and are most suited for urban agriculture and other domestic uses. Although higher initial capital may entail, once they are installed, these technologies are not subject to depletion, and they do not need additional input and do not emit greenhouse gases (Ali *et al.,* 2016). Access to these technologies will make urban agriculture viable in South Africa.

Case study 9.1: Urban agriculture in South Africa

There are several urban agriculture success stories in South African cities. Roof top garden on the Minerals Council's building, Johannesburg has proven that urban agriculture can be used as a means of solving the high competition for the limited land and potable water resources between gardening and the other socio-economic sectors in urban environment. The garden is part of project run by various organizations that want to make more produce available in the inner city and provide jobs for entrepreneurs who want to farm but do not have access to land.

Organizations supporting this Urban Agriculture Initiative led by the Minerals Council South Africa include the Johannesburg Inner City Partnership, the Wouldn't It Be Cool (WIBC) incubation and mentorship organisation, FNB, Africa Housing Company (AFHCO), University of Johannesburg, Stay City, Thebe Investment Corporation, BothaRoodt Fresh Produce Agency, and green business support organisation Sophiatown BizCre8. The garden grows herbs and other crops that are harvested and sold to the Johannesburg Fresh Produce Market and surrounding cafes and coffee shops.

The choice of the plant/crop grown in the garden grown in intensive cultivation system is crucial; it must be of a high value so that it can bring more income that can pay back the large amount of money invested to set and run the agricultural business. In this particular garden, a culinary herb, Basil (*Ocimum basilicum*) is grown using nutrient film technique (NFT). This hydroponic technique is very efficient in water and nutrient use because, nutrient solution is recycled around the root system of the plant.

Therefore, as an adaptation strategy, the farm uses a greenhouse to grow a summer plant year-round and to mitigate high competition for space and potable water he uses a rooftop and hydroponic system, respectively. In hydroponic, vegetative growth is very fast because plant root system does not spend much energy because the required amount of nutrients for the plants are readily provided with the water (fertigation system). Through this intensive cultivation production technology, the gardener manages to sell 100 kg of basil every 21 days at a fair price. This success story indicates that urban agriculture can contribute to food security in urban and peri-urban areas whilst greening these urban environments. This farming practice is, therefore, a good model of urban climate smart agriculture.

9.5 Conclusions and recommendations

It is becoming clear that dependence of the urban livelihood solely on industrial economy is not sustainable. Urbanization and its industrial growth have already caused huge damage to the environment and human life and productivity of the traditional urban agriculture.

This negative impact of urbanization could be adapted and mitigated through greening the cities and their environment with urban agriculture, which presents an opportunity of food production for urban residents, ensuring food security and malnutrition. Urban agriculture alleviates poverty in cities as households can save money as they consume their own produce; they can generate income by selling surplus produce and creating jobs.

Climate mitigation contribution of urban agriculture includes moderating temperature, carbon sequestration and stabilizing soil physical propertied. Integrating crop production system with the city structure is, therefore, a timely call. Urban agriculture is practiced in many South African cities and townships, mostly as home or community gardens. However, they are facing setback from lack of skill, shortage of open land and irrigation water scarcity.

This review clearly shown that promoting and adopting water and space saving, and environmentally friendly technologies is crucial for sustainable urban agriculture. In this regard, the role of rooftop farming, greenhouse production system, hydroponic techniques, greywater recycling, composting, renewable energy (solar and wind power) would be indispensable.

To make urban agriculture successful in South African cities, therefore, city planners, municipality authority and extension officers need to come on board to help make urban agriculture a smart solution to food security and environmental challenges in urban and peri-urban areas. A clear set of urban farming guidelines is critically needed.

10.1 Introduction

Greater parts of South Africa's land surface are marginal to crop cultivation due to low precipitation and is generally referred to as rangelands. Rangelands in the country largely comprise the grassland, arid savannah, semi-arid savannah, thicket, Nama Karoo, Succulent Karoo, and Fynbos biomes. The grassland biome comprises mainly the high-altitude areas of the country.

This biome is used for large stock production and shows large areas of fragmentation and degradation, probably due to overstocking, increase in human population and settlements. Arid savannah occurs mainly in south western part of the country, where a summer rainfall season tends to encourage woody shrub production, with some interspersed grass. Semi-arid savannah woodlands in northeast parts of South Africa is characterised by mopane and riparian shrubs.

The thicket biome occurs in the south-eastern coastal region in the Eastern Cape and karoo midlands and is mainly used for large commercial stock and game production (Palmer, 2003).

The thicket biome exhibits dense cover, with succulent shrubs, woody shrubs and low trees – including the Spekboom shrub. The Nama Karoo occupies the central and western regions of South Africa exhibiting a mix of shrubs, and grasses, and is mainly used for small stock production with however a growing trend in raising game animals of different species.

The succulent karoo occupies the southern and south-western parts of South Africa and characterised by rich flora biodiversity (Archer *et al.,* 2011). The fynbos biome (or Cape floristic kingdom) occurs within South Africa's winter rainfall region, although some relic communities of summer rainfall fynbos exist to the north (for example along the escarpment edge in the area of Mariepskop, Mpumalanga).

This biome is recognized as a global hotspot for biodiversity and forms the only floristic kingdom in the world completely within the borders of a single country (South African National Parks, 2013).

10.2 Use of rangelands in South Africa

The rangelands cover about 72% of the total land area of South Africa (Tainton 1999) making them the largest single land use. Livestock and wildlife production are the major activities that occur on vast areas of rangelands used as extensive ranching enterprise under freehold tenure or as public communal land.

For ranch and communal land users, livestock is a productive asset to generate income, make profit, and form part of food security strategies directly or indirectly.

Livestock are the main source of draft power, skins, transport and manure, and fulfil many sociocultural functions such as payment of dowry, establishment and reinforcement of relationships and source of prestige within the pastoral society. Game production and tourism are important activities that show a growing trend in some parts of the country.

Products from rangelands also support manufacturing industries through supply of raw materials including wool and meat as well as extracts from native plants for medicinal, and cosmetics and lotion industries with some plants harvested for ornamental purposes for local or commercial use.

Rangelands, if properly managed can serve as a great potential to store carbon and nitrogen. For example, the thicket biome exhibits dense cover of important tree species (e.g. *Portulacaria afra*,) that could sequestrate greater quantities of Carbon (Sasha *et al.,* 2013).

10.3 Rangeland land use systems in South Africa

Three animal production based land use systems are widely recognized in South Africa, namely communal, commercial ranch and wild animal land use. The production systems differ in terms of available grazing resources, production objectives, management and use of the rangeland resources.

10.4 Communal land use

In South Africa, communal rangelands make up about 13% of the land surface and support a quarter of the country's population and half the country's livestock (Scogings *et al.* 1999). These communal areas comprise the former 'bantustans' and 'Coloured Reserves' created under the racial segregation policies of the apartheid regime. The communal land use is mainly for either mobile (arid) or sedentary (semi-arid regions) livestock production ranging from small to medium (regarded as emerging farmers) scale.

Every community member owning livestock has equal access to resources without temporal and/or spatial restriction. Vast communal grazing lands that have been used continuously without applying formal grazing land management. Many communal grazing lands have fencing to serve as boundary and restrict cattle movement to the main roads.

10.5 Commercial livestock ranching

The red meat industry, which is part of commercial livestock ranching, contributes approximately 12% to the gross value of agricultural products produced in South Africa. Commercial ranches are mainly private owned by a single person or family members (with the exception of few states owned ranches that have commercial set up but are used mainly for research and breeding purposes). The farmers raise single or mixed livestock species primarily for commercial sales of live animals and/or their products.

Most commercial ranches practice rest-rotate grazing with their land divided into homogenous units by fencing. Commercialisation is seen as key to improving productivity in rangelands, despite the fact that the past success of commercial farming in South Africa has relied heavily on state subsidies and repressive labour regimes. Most commercial livestock ranches are managed by rangeland managers with secondary education and even some degree of tertiary education.

10.6 Wildlife land use

Wildlife land use includes national parks, nature reserves and game ranching all keeping diverse species of wild animals. Unlike the commercial livestock farms, they do not practice strict rest-rotate systems. Production and management practices in wild animal production systems vary depending on the objective. For instance, game ranching, a fast-growing sector in the country, with growth rate record of 6.8% per annum (Tomlinson et al., 2002), focuses mainly on ecotourism, trophy hunting and venison production. Since 1960s, some commercial farmers have been converting part or the whole their farm to game ranching to diversity or increase their income and augment protein supply (Carruthers 2010).

The rate of conversion of land from livestock to wildlife production in South Africa was estimated to fall in the range of 2–2.5% annually (DEAT 2005). Less incidence of livestock diseases, livestock theft and competitive agricultural markets have been reported in game ranching compared to livestock ranches.

10.7 Rangeland degradation in South Africa

In South Africa, rangeland degradation is evident and spreading in large areas of both private and communal land use systems although the debate has been polarised between these two land use systems. Land degradation is a threat to land productivity and therefore, to people's livelihood, that may cost an estimated amount of some US $40 billion annually (FAO 2010).

Land degradation in South Africa is observed both under communal and freehold tenure systems at different levels and extent, but a more pronounced levels and extents of degradation have been perceived to occur in the communal land use.

Degradation in the communal areas are related collectively to rural population density and poverty as well as the biophysical environment (Hoffman and Todd, 2000). However, the main attributes can be summarised as:

i) overuse or misuse of the rangeland resources without following formal management practices or applying management practices;
ii) the inability of land users to respond decisively to the change in the rangeland condition;
iii) concentration of livestock per unit of land due to increased population density and/or due to reduced grazing land arising from increased settlements or land alienation for other public purposes;
iv) lack of adequate access to resources; and
v) inappropriate policy frameworks (Vetter, 2013).

Climate change can speed up degradation process. For example, a higher frequency of drier spells or a lower critical rainfall season can reduce vegetation cover, expose the soil for frequent erosion and can worsen if the area is subject to overgrazing or inappropriate water use.

10.8 Projections of climate change in South Africa

There is a growing realisation that the Earth is warming, and that future temperature increases and other climate changes at the global scale are highly likely. However, projections at regional and local scales, which are required for policy and land management planning, are more complicated and far less robust.

Over the next century, South Africa climate predictions based on the general circulation models (GCM) projected the summer season to show an extension with a continental warming of between $1^{o}C$ and $3^{o}C$, with the maximum focused on regions of aridity, and the minimum along the coastal regions (South Africa climate change impact).

Changes in precipitation are projected to show a high degree of variability between GCM models and even from year to year within the same model. An earlier coupled ocean-atmosphere model (HadCM2, a leading GCM in the last IPCC assessment) and a recent current-generation fully coupled ocean-atmosphere model (CSM) differed slightly, but overall, they indicated that the total annual precipitation in South Africa will decline mostly in summer months, while will remain relatively stable in the other seasons.

The HadCM2 indicates that the annual rainfall will decline in 5-10% of the normal annual rainfall, whereas the CSM model shows similar trend, but with greater regional structure (Kiker, undated).

10.9 Observed climate change impacts and projections for South African Rangelands

The climate change projections predicted over southern Africa by the GCM simulations suggest a general aridification of arid and semi-arid rangelands, where periodic drought conditions prevail under normal rainfall variability. The aridification will adversely affect herbage biomass (by implication forage production), and the marginal costs of commercial livestock ranch enterprise.

A rise in the minimum temperature has a potential to reduce plant killings from frosts, whereas the increase in atmospheric CO_2 has fertilising effect to promote growth of woody or invasive plants (e.g. woody plants) that may not have great forage values as grasses. The proliferation of woody plants in turn will reduce grass abundance due to a high competition for soil and water.

Temperature, CO_2 and rainfall are substrates to plant life, and determination of their current status and trends will concurrently inform changes that will happen in the biomass production, plant structure (grass and woody vegetation) as well as change in species composition within each layer of the plant group (i.e. grass and woody plants). (Kiker, undated))

There are few reports in South Africa that show the predicted change in bulk pasture yield of rangelands and yield by the common native forage species owing to climate change impacts. The only model that was used to project climate change impacts on rangelands, known as CENTURY, looks carbon and nitrogen dynamics in grasslands.

The model was tested with climate change only and climate change coupled with the effects of elevated CO_2 concentrations to explore the possible mitigating effects of higher CO_2 levels. Three vegetation biomes of semi-arid South Africa, referred collectively as rangelands, were included, namely the lowveld site near Bloemfontein, a moist highveld grassland site near Pietermaritzburg and a savannah (middleveld) site at Nylsvley. This model predicted no change in the forage production potential over most of the grassland area due to the cancellation of the drying effect of higher temperatures and lower rainfall by the increased water use efficiency of plants. Over the savanna biomes, however, forage production may decrease by about one fifth with concomitant decrease in the grazing capacity adversely affecting the cattle ranching industry. Such predicted loss of forage biomass reduces the national free-range cattle herd of about 10% (Kiker, undated).

With climate change affecting pasture yields and productivity, changes in the commodity price of major food products from animal source are also inevitable. This increase in the price of meat, and milk products is expected to reduce access to food among resource-poor households, a situation that will increase the incidences of malnutrition and undernourishment among children.

The large productivity increases or decreases emphasize the importance of continuing technological improvement and investment in agricultural research and extension, along with productivity-enhancing investments in climate -smart agriculture.

A changed climate was also predicted to increase fire intensities by about 20%. An increase in air temperature of 2°C by itself would increase the fire intensities by 7% in an average savanna fire. However, the predicted fire intensities could fully occur if fuel biomass is available, because an increase or decrease in grass fuel load would have a proportional effect on fire intensity.

10.10 Climate smart Adaptation and mitigation options

Given the projected climate change scenario mentioned previously and anticipated impacts, adaptation response is a clear priority. Options for adaptation in Africa including the southern region are still at infant stages deserving learning of the best-practice and assembling together those that have been learnt from regions within Africa or outside the continent, researching and place them in to action. One of the most important priorities for adaptation in rangelands is the need to project the benefits beyond adaptation to climate change such as additional livelihood benefits (e.g. job creation, poverty alleviation and green economy outcomes).

In view of this context, besides being a climate smart practice, Midgley *et al.* (2012) agreed that adaptation must simultaneously achieve socio-economic benefits as well as biodiversity and ecosystem conservation.

10.11 Adaptation strategies

When developing and implementing climate change adaptation actions, policies and processes on rangelands, it is essential to have a good understanding of local vulnerabilities to climate change in their ecological and social contexts.

Certainly, South African rangelands subject to different land use and management systems respond differently to climate change, and therefore, may need different climate smart adaptive and mitigation measures. Also, different rangeland biomes may need different approaches and practices of climate smart adaptation and mitigation.

Nevertheless, collectively, framework for planning adaptive actions/measures, described in Spittlehouse and Stewart (2003) cited in (Sasha *et al*., 2013) could apply. The framework consists of:

i) defining the issue;
ii) assessing the vulnerability of the rangeland resources and land users to change;
iii) developing adaptive actions to be taken at present and in the future.

Climate change adaptation strategies can be considered a sustainable rangeland management plans aimed to minimize risks of failure or cope through resilience strategies (Spittlehouse and Stewart, 2003). Rangeland users should select adaptive practices that are locally appropriate, and they should work with other communities and stakeholder to improve these practices. Successful climate smart practices will require a mix of pre-emptive and reactive strategies that respond to the combined changing challenges and opportunities posed by climate change and other social, economic and institutional pressures. Adoption of new management practices will take account of:

i) the fact that climate change is different from the naturally high year-to-year climate variability inherent in the arid and semi-arid rangelands;
ii) both adverse effects and opportunities of climate change,
iii) establishment and implementation of applicable new climate smart technologies and demonstration of their benefits;
iv) buffering against failure of new practices during less favourable climate periods;
v) alteration of transport and market infrastructure to support change in production and
vi) development and modification of government policies and institutions to support adoption and implementation of the required changes.

Adaptation strategies that incorporate the above considerations are more likely to be of value, as they will be more readily incorporated into existing on-farm management strategies.

Besides, the following guidelines was proposed (Midgley *et al.,* 2012) to implement adaptive measures on South Africa rangeland ecosystems

i) Involve relevant stakeholders in integrated and adaptive planning and implementation.
ii) Locate adaptation approaches in the context of the broader landscape.
iii) Develop adaptation responses that are locally contextualized.
iv) Develop linkages with national and subnational enabling frameworks.
v) Safeguard communities against risks and costs.
vi) Carefully consider project financial sustainability from the start.
vii) Develop a robust monitoring and evaluation system.

viii) Track cost-effectiveness and resilience outcomes.
ix) Establish learning networks and communities of practice.

10.12 Climate smart technologies and practices for rangeland systems

A wide range of CSA technologies and practices are currently in use in many African countries, but these are limited to crop production and management and to agroforestry. Climate smart practices to rangelands and cultivated pastures are not fully developed. The CSA technologies and practices should promote adaptation and resilience, with mitigation as a co-benefit. Table 10.1 and 10. 2 presents proposed climate smart adaptation and mitigation practices to address climate change impacts on South rangelands and work out at the institutional & policy as well as individual or communal farm levels. Part of this practices is learnt from Australia (Stokes *et al.,* undated).

Table 10. 1: Institutional, Industry and Policy-level adaptation options

Policy: Develop linkages to existing government policies and initiatives (e.g. policies on greenhouse sinks, natural resource management, water resource allocation, rural development, poverty alleviation). This concept is lacking in the context of South Africa
Supporting transitions: Policies and mechanisms to provide technical and financial support to introduce new practices that are more adapted to the emerging climate. E.g. for introducing Holistic rangeland management into communal grazing lands; initiating integrated catchment management to enhance resilience to climate change and restore degraded rangelands through development of micro catchments. In South Africa, one of the major challenges to implement already known practices of rangeland management as an adaptive measure or to conduct research or trials on best practices is lack of technical and financial support.
Seasonal weather and climate forecasting—With climate information services, farmers will be able to plan their planting (cultivated pasture) and make grazing planning and decision (natural pasture). Also, farmers will also be able to make projections about rainfall distribution patterns and temperature variations. This is particularly important to emerging and small scale communal farmers. Local ICT companies and meteorological institutions must be supported in providing the most accurate and reliable information to emerging and small scale farmers. A sound approach should be implemented to put in place climate information services including weather stations at local level and to communicate them to farmers without complexion. Scientists and the national meteorological agencies, and ICT companies should work together to develop more accurate and specific seasonal rainfall forecasts and to raise capacity of partners to do longer-term analysis and provide more targeted information for farmers and extension agents who are working to assist them. The forecast information provided includes the total rainfall, the onset and end of the rainy season, plus a 10-day forecast across the rainy season as well as min and max monthly temperature. The information is conveyed to farmers as agro-meteorological advisories that are tailored to meet their local needs. In many parts of South African rangelands, it is not possible to get weather data because there are no stations established further at the local levels.
Climate data and monitoring: Maintenance of effective climate data collection, distribution and analysis systems to link into ongoing evaluation and adaptation. Monitor climate conditions and relate these to forage yield and quality aspects to support/facilitate adaptive management. Develop climate projections that can be downscaled so as to be relevant to farm and catchment scale. In the country, this monitoring system is not established at institutional levels, and therefore, deserve due attention.
Participatory based research, development and training: Undertake further adaptation and mitigation studies that include restoration of rangelands; control of bush encroachment or invasive species, and their suitability and cost effectiveness to inform policy decisions. Maintain the research and development base (people, skills, institutions) to enable ongoing evaluation of climate/CO_2/ (species or land use)/management relationships, and to streamline rapid R&D responses (for example, to evaluate new adaptations or new climate change scenarios). This R&D needs to be developed in a participatory way so that it can contribute to training to improve self-reliance in the agricultural sector and to provide the knowledge base for farm-scale adaptation. Although, there are attempts to undertake restoration, and bush control trials, they are far from adequate to cover the geographic and climate variability. These activities are often limited by financial support.
Cultivar development and native plant conservation: Cultivar development—in the realm of cultivar development, this would include developing varieties that withstand higher temperatures. But it would also include varieties that are resilient to drought, pest, weeds flooding, etc. The best new varieties would be ones resilient to more than one threat considering it takes many years to develop and test new cultivars. Conservation of native species provides access to global gene pools so as to have suitable options for higher temperature regimes and changed moisture availability and possible more climate variability.
Model development and application: Develop further grazing systems modelling capabilities that link with meteorological data distribution services, and can use projections of climate and CO_2 levels, natural resource status and management options to provide quantitative approaches to risk management for use in several of these cross-industry adaptation issues (e.g. AussieGrass: Hall et al. 1999). These models have been the basis for successful development of participatory research approaches that enable access to climate data and interpretation of the data in relation to farmers own records and to analyse alternative management options. Such models can assist pro-active decision making on-farm and inform policy and can extend findings from individual sites to large areas.
Water conservation and management—along with cultivar development, supporting farming techniques should be developed. These might include irrigation (for cultivated pastures and water harvesting (for both native rangelands and cultivated pastures). One of the critical issues surrounding climate change is the variability in weather, with floods and droughts both becoming more frequent. Water conservation and supplementation are both important to develop when feasible, especially in arid and semi-arid areas. In communally used areas, research for development work to build climate-smart farming systems through integrated water storage, crop and livestock production should be conducted. Increase water use efficiency by 1) a combination of policy settings that encourage development of effective water-trading systems that allow for climate variability and climate change and that support development of related information networks, 2) improve water distribution systems to reduce leakage and evaporation, 3) developing farmer expertise in water management tools and enhancing adoption of appropriate water-saving technologies. Structures to retain water in degraded rangelands must be put in place such as contour ridges, micro catchments etc. Research need to explore the best, less labour and cost intensive practices in terms of establishment and maintenance as well as in terms of retaining water more efficiently. These are now widely practiced in degraded rangelands of South Africa
Pests, diseases and invasive plants: Maintain or improve quarantine capabilities, monitoring programs and commitment to identification and management of pests, diseases, weed and invasive species threats. Improve the effectiveness of pest, disease, weed and shrub management practices through predictive tools such as quantitative models, integrated pest management, area-wide invasion control management, routine record keeping of climate and pest/disease/invasion threat.
Land use change and diversification: There are no strong programmes in any responsible Institutes to Undertake risk assessments to evaluate needs and opportunities for changing species, management or land use/location in response to climate trends or climate projections.
Agroforestry: many cultivated pasture lands are not integrated with agro forestry. Integrating trees with cultivated pasture crops can have several advantages when done properly. Trees can sometimes serve as "nutrient pumps," bringing nutrients that are too deep for crops. They can be used to enhance soil nitrogen, when nitrogen-fixing trees are planted. Their leaves can serve as mulch which might suppress some weed growth but would also help cool the soil, overcoming some of the impacts of temperature rise on crop growth. Furthermore, the litter would eventually be converted to soil organic matter (SOM), which has important properties in relation to soil nutrient retention.
Natural resource base: There has been adequate research to determine the impact of climate change (interacting with land management) on natural resource degradation
Communication: Ensure communication of weather and climate change information or any climate smart practices as it becomes available.
Support for infrastructure development: This includes support to districts or local administrations or to the local farmers to develop or maintain roads, dams, drinking water points, fencing etc; fencing and maintenance of communal grazing lands

Table 10.2: Farm level adaptations to global change

Practices	Implemented in South Africa?
Managing pasture productivity and grazing pressure	
Practice rotational grazing and resting	Not practised under the communal land use
Apply optimum stocking rate	Not practised under the communal land use
Use the right kind of animal species	Not practised under the communal land use
Uniform distribution of animals	Not practised under the communal land use
Improved animal breeds	Not practised under the communal land use
Effective grazing planning	Not practised under the communal land use
Fencing rangelands	Not practised under the communal land use
Division of rangelands into paddocks or camps	Not practised under the communal land use
Practice Herding	Few communal and commercial ranches practice herding
Feed supplementation during periods of shortage of critical time	
Use of non-conventional feed;	Commonly practices in the ranch systems, but not very common under communal land use
Use of molasses and urea lick	Commonly practices in the ranch systems, but not very common under communal land use
Fodder tree plantation	Hardly practiced in all land use systems
Develop a practice to utilize native browse species as protein and mineral supplements	Hardly practiced in all land use systems
Forage and fodder conservation	
Plan Hay production	Not a common practice under communal land use, but practiced by some commercial farmers
Plan Silage production	Not a common practice under communal land use, but practiced by some commercial farmers
Practice grazing reserve for use during critical periods by classes of animals that deserve special attention e.g. calves & pregnant cows	Not a common practice under communal land use, or commercial farmers
Drinking water management and maintenance	
Ensure adequate water supply and uniform distribution of watering points	Not a common practice under communal land use, but practiced by commercial farmers
Water harvesting	Few communal farmers practice it, but many commercial farmers practice it
Practices	Implemented in South Africa?
Grazing land management and control of invasion and bush encroachment	
Burning rangelands	Not a common practice in communal land use, but some commercial farmers practice it
Rest-burn-rest	Not a common practice in communal land use, but some commercial farmers practice it

Practices	Implemented in South Africa?
Grazing land management and control of invasion and bush encroachment	
Incorporation of alternative biological, chemical and mechanical methods for reducing woody and invasive shrub plants	Not adequately practiced by communal or commercial farmers
Range condition assessment	Through assessment is not commonly conducted by communal or commercial farmers
Range condition monitoring	Through assessment is not commonly conducted by communal or commercial farmers
Species inventory	Through assessment is not commonly conducted by communal or commercial farmers
Mapping vegetation trends	Through assessment is not commonly conducted by communal or commercial farmers
Willingness to community training	Few commercial farmers are willing to train communal farmers
Restoration of degraded rangelands and management	
-deep soil ripping	Not practiced
Soil surface scarification	Not practiced
Shrub plantation and scarification	Not practiced
Reseeding using native plant species	Practiced by land care on few selected degraded rangelands
Micro-catchments	Not commonly practiced
Water harvesting using semi-circular bunds	Not commonly practiced
Seed collection and multiplication of native pastures	Not commonly practiced
Exclosures	Not commonly practiced
Fodder and forage crop cultivation and management	
Provision of additional nitrogen through sown legumes	Common on commercial farms, but few communal farmers practice it
Provision of phosphates to both improved and unimproved pasture	Common on commercial farms, but few communal farmers practice it
Provision of urea and phosphates directly to stock via reticulation	Common on commercial farms, but few communal farmers practice it
Practices	Implemented in South Africa?
Introduction of responsive stocking rate strategies based on seasonal climate forecasting	Not commonly practiced
Development of regional safe carrying capacities i.e. constant conserva-tive stocking rate	Not commonly practiced
Where appropriate, development of software to assist pro-active decision making at the on-farm scale	Not common
Manure management (e.g. recycling and bio-digestion) and crop-livestock integration.	Not common

Practices	Implemented in South Africa?
Managing pests, disease and weeds	
Improve pest predictive tools and indicators	Not common
Improve quantitative modelling of individual pests to identify most appropriate time to introduce controls	Not common
Increased (but cautious) use of biological and other controls	There has been limited practices
Increased use of insect traps for sentinel monitoring and for population control	Not common
Veterinary service	Adequate in commercial farms
Dipping animals	Commonly practiced
Animal husbandry and managing health	
Selection of animal lines that are resistant to higher temperatures	Not common
Modify timing of mating based on seasonal conditions	Not common
Modify timing of supplementation and weaning	Not common
Construction of shading and spraying facilities	Not common
Increase use of trees as shading and reducing wind erosion	Not common

Source: *Partly adopted from Howden et al. (2003)*

10.13 Holistic Range livestock management as CSA practise for South African Rangelands

One paradigm that holds out almost unique promise as climate smart agriculture on vast rangeland is Holistic Land and Livestock Management (HRLM). Holistic Planned Grazing is claimed to have positive long-term effects on rangelands, enhancing ecosystem functions and services HRLM was developed over the years by Allan Savory and then by the Savory Institute and its affiliates. HRLM recognises that under proper care, livestock and gazing resources are symbiotically related, just as they typically are (or were) in nature, thus HRLM generally rejects calls for massive reductions in stocking rates in favour of more thoughtful approaches to managing land and livestock interactions.

To date, despite being somewhat controversial among academics, HRLM has largely been taken up by commercial farmers, both in Southern Africa and elsewhere. But it has particularly great potential in communal grazing scenarios provided its practices can be successfully adapted to the social and economic realities in these areas. Among other things, the approach involves merging the management principles of HRLM, with the challenges commonly associated with Community-Based Natural Resource Management (CBNRM).

The advantage of HRLM in this context however is that, even under unfavourable conditions such as those that prevail across South Africa's former homelands, HRLM significantly boosts the livelihood benefits associated with livestock rearing, which inspires community members to accept CBNRM whereas they might otherwise resist it.

There are some crucial societal factors such as community's reception to change, community cohesion and synergy that need to be created before an initiative such as HRLM can be introduced – but this forms part of introducing HRLM via the community mobilisation phase. To implement this practise, the specific community must show the required commitment and interest needed for successful implementation, but it would also be important to urge policy, institutional and traditional authority support – if the initiative is to be a successful pilot project with the potential to roll-out the concept into other communal farming areas, it would also be important to gain the support of loaning/funding institutions and government.

A multi-stakeholder approach is therefore needed. HRLM is one of the only practises that can successfully allow for stocking rates that cannot be achieved in commercial animal husbandry systems.

A succinct example of this is that on average in semi-arid South African rangelands the optimum stocking rate would be 1 standard livestock unit (SLU) grazing on 5-6 hectares of veld (1:5-6); while HRLM, if implemented correctly could allow a rate of 1:1 or possibly even better than this rate.

10.13.1 Success stories of HRLM

Some farms in South African have adopted holistic planned grazing (HPG) as an adaptation or mitigation practice, but there has not been so far conclusive evidence generated to inform as a success story. In Zimbabwe, vegetation monitoring and landscape function analysis showed that holistically managed grazing lands had a significantly higher rangeland condition (composition, cover, standing crop and soil health) than adjacent communally used rangelands.

Overall grazer density on holistically managed grazing land was 42% higher than that of the adjacent communal rangelands (Peel and Stalmans, 2018). Finer-scale satellite collar data for holistically managed grazing land yielded a calculated stocking rate of 0,55 LSU ha^{-1} y^{-1} or 24 590 kg km^{-2}, which constitutes high-density grazing. An energy flow estimate shows that the grazing resource would, on average, not be limiting for livestock on ACHM but limiting on SCR. HPG may include an element where kraals are inserted into degraded rangelands for a short period.

Overall, ACHM shows stable perennial composition with smaller tufts significantly closer together. This study concluded that HPG yields positive long-term effects on ecosystem services (soils and vegetation) and points to the HPG approach enhancing the sustainability of livestock and wildlife in this environment (Peel and Stalmans, 2018).

10.14 Conclusions and Recommendations

This document has highlighted that South African rangelands have significant sensitivity and vulnerability to climate change effects that warrants immediate action for climate smart agriculture to be in place as an adaptive measure.

To address the potential harmful effects of climate change, adaptive measures for further consideration at institutional, industry and policy-level as well as at farm levels are given. Many of the proposed measures have not been in practice in the country. The three main land use systems under the extensive rangeland ecosystems in South Africa have different vulnerability to climate change impacts.

Collectively, areas under commercial ranch and wild-life production systems and associated land users may not be under high levels of vulnerability. However, areas under communal land use systems could be categorized as highly vulnerable.

Where possible, long-term studies need to be conducted to evaluate potential adaptation activities to restore degraded rangelands; control of bush encroachment or invasive species, evaluate drought tolerant pasture cultivars for their suitability and cost effectiveness. Climate data and vegetation monitoring need to be initiated at several selected local areas to understand the relationship between climate change and forage yield and quality to support the adaptive management of rangelands.

The implementation of holistic range livestock management as CSA practise for South African Rangelands, especially the communal rangeland systems needs to be initiated without delay.

11.1 Introduction

Food security in South Africa is still a challenge irrespective of significant policy attention and interventions by government, NGOs and civil society. Nationally South Africa is food secure producing enough food to meet the requirements of the population (Labadorios *et al.* 2011) but according to the General Household Survey 2016 (Stats-SA 2017) 22.3 % of the surveyed households had inadequate or severely inadequate access to food.

There are still communities that are vulnerable especially in informal settlements and marginalized rural areas because of high unemployment, increase in food prices and the recent drought in the country.

Food production is done by both well-developed commercial farmers and small scale and subsistence farmers but recently there has been a decrease in subsistence production of food and an increase on dependency on purchasing food which has impacted negatively on food security.

On the other hand, research has indicated that between a third and a half of the food produced each year globally, is lost or wasted (Lundqvist *et al.,* 2008, Gustavsson *et al.,* 2011). The loss can occur at any stage of the value chain from production, processing, packing, distribution and post- consumer food waste. A study conducted by CSIR (Nahman and de Lange, 2013) estimated that food wasted across the value chain in South Africa amounted to 10.2 million tonnes per year.

The monetary value is estimated at R 61.5 billion per year. According to WWF- SA, (2017) out of the 31million tons of food produced annually 10 million tons is wasted. The loss comprises of 44% fruit and vegetables, 26% grains, 15% meat and 13% roots, tubers and oil seed.

The biggest loss of about 50% occurs early in the value chain at farm level. Some of the reasons given for such high losses at production level include:

- ⇒ Poor quality of the produce especially from smallholder farmers due to lack of inputs, high incidences of pests and diseases, harvesting too early or too late (Bokelmann and Adamseged, 2016).
- ⇒ Poor postharvest handling techniques and lack of cold storage facilities on farms (Gustavsson *et al.* 2011).
- ⇒ Processing facilities far away from production centres
- ⇒ Inadequate infrastructure and poorly organized markets (Bokelmann and Adamseged, 2016).

Food lost, and food wasted has serious impact on the environment. From the European Commission's Emissions Database for Global Atmospheric Research it has been reported that the total carbon footprint of food loss and waste is around 4.4 gigatons of carbon dioxide equivalent per year or about 8% of the total anthropogenic greenhouse gas emission (FAO, 2015). According to FAO, (2013), the water footprint for food that is lost and wasted is 250 km^3.

Land that is utilized to produce the wasted food is equivalent to 1.4 billion hectares. With an increasing population and changing climate it is about time that food wastage is taken seriously. There is a general agreement that if food loss and waste can be significantly reduced it could be the most fundamental strategy of improving food security and achieving a sustainable food future (WWF-SA, 2017).

South Africa as a signatory to the Sustainable Development Goals is committed to reducing waste by 50 % by 2030 (Goal 12.3). The New Growth Path (NGP, 2010), National Development Plan (NDP, 2011), and the Industrial Policy Action Plan (IPAP, 2013) have all identified agro-processing as key to reducing post-harvest losses, promoting food security and job creation, especially in rural areas where unemployment rate is above the national average of 27.2 % reported for quarter 2 of 2018 (Stats SA July 2018) this sector has the potential to stimulate growth and create jobs because of its strong backward and forwards links to other industries that can drive economic growth. The sector's contribution to the total manufacturing value-add in 2016 was 16% (Stats SA). As part of reviving economic activity and including rural population in the economy the government is promoting downstream value adding and processing at local level.

All the Agro-processing activities, whether by the big commercial companies or by SMME's, have to take place in the context of changing climate and the limited natural resources such as water, energy and land. According to Ridoutt et al., (2016) the interest on climate change on the food industry is based on the fact that changing temperatures and rainfall patterns affects yield, and the quality of the produce. Similarly, climate extremes and natural disasters affect supply and distribution networks. Processors depend on water as an ingredient or for cleaning the facilities and on the other hand there is an increasing concern globally on the greenhouse gas (GHG) emissions associated with the food systems and other manufacturing facilities.

Therefore, the objective of this literature review is to highlight the situation of the Agro-processing value chains in South Africa and the extent to which they are climate smart.

11.2 Agro-processing Industry in South Africa

South Africa has a wide range of climatic zones from semi -arid and dry, to sub-tropical. As a result, a variety of crops, livestock and fish are found in the country. These conditions have created an agro-processing industry that delivers a wide variety of products.

The industry is involved in the processing of freshwater aquaculture, exotic and indigenous meats, nuts, herbs and fruit. It also involves the production and export of deciduous fruit; production of wines for the local and export market; confectionary manufacturing and export; and the processing of natural fibres from cotton, hemp, sisal, kenaf and pineapple (Brand SA, 2012). The industry is well developed and concentrated with a few corporates sometimes vertically integrated throughout the value chain.

There are about 7 000 Agro-processing businesses in South Africa (Coetzee, 2012) dominated by few large firms who operate on commercially sustainable premises. The growth and strategies of the lead firms that are listed on the Johannesburg Stock Exchange have been reviewed by Nhundu *et al.,* (2017) who observed that the high entry barriers made it difficult for new firms to enter and compete effectively in the sector.

The sector has grown more rapidly than other sectors in the economy contributing 4.8% (R 132 billion) to the GDP compared to primary Agriculture which contributed 2.4% (R 84 billion) (Stats SA, 2015). It is also the largest employer in the country accounting for 13.6% of total manufacturing employment (Ncube *et al.,* 2016).

The strong link of Agro-processing with primary agriculture makes agro-processing industry critical for employment creation and poverty eradication. Because of the few corporates who control the value chains, small companies (SMMEs) and small scale farmers are disadvantaged in that they cannot enter the chains due to lack of skills, finances and contracts with the main market players (Louw *et al.,* 2013,).

In order to address this challenge and to create a more inclusive economy, the government has developed several strategies to support and develop SMEs agro-processing. The strategy is to assist in developing a sustainable and inclusive agro-processing industry that will allow for raw materials to be processed closer to the point of production and contribute to reduction in post-harvest losses as well as integrating the SMME's into the existing commodity chains. Agro-processing strategies were developed by DAFF and provincial governments and in 2014 a national Agro-processing forum was established to coordinate, integrate and align policies, strategies, programs, projects and activities meant for supporting the Agro-processing sector (DAFF, 2014).

The members of the forum are the Departments of Agriculture, Forestry and Fisheries, of Trade and Industries, of Economic Development, of Rural Development and Land Reform, of Small Business Development, of Science and Technology, Provincial Departments of Agriculture, CSIR, Various Special Economic Zones involved with Agro-processing and Local Economic Agencies (DAFF, 2014) with DAFF and DTI leading. The main role of the Forum is to facilitate implementation of the National Development Plan (NDP), Industrial Policy Action Plan (IPAP) and Agriculture Policy Action Plan (APAP) policy and strategies on Agro-processing.

11.2.1 Agro-processing Value Chains

Agro-processing Value Chains are defined as the full range of activities which are required to bring a product or service from conception, through the different phases of production involving a combination of physical transformation and the input of various producer services to the final customer and disposal after use (Hellin and Meijer, 2006). According to Hellin and Meijer, (2006) the key role players in an Agro-processing value chain can be divided into three main groups which are:

⇒ The value chain participants (input suppliers, farmers, traders, processors, exporters, wholesalers, retailers and consumers).
⇒ Enabling environment (infrastructure, policies, financial institutions etc).
⇒ Service providers (Extension services that support value chain operations) .

A very large part of agricultural produce undergoes some kind of transformation between harvesting and final use. The industries involved have been classified by International Standard Industrial Classification (ISIC), (2013) as follows:

⇒ Food and beverage
⇒ Tobacco products
⇒ Paper and wood products
⇒ Textiles, footwear and apparel
⇒ Leather products
⇒ Rubber products

The kind of activities that take place in a value chain will vary depending on the commodity and the products that are being manufactured.

11.2.1.1 Maize Value Chain

Maize is the most important field crop produced in South Africa followed by wheat (DAFF 2017). White maize is used for human consumption while yellow maize is for animal consumption. It is a staple food for the majority of the population.

According to Prospectus on the South African Maize Industry (undated), approximately 10 to 12 million tons of maize is produced annually. On average 4.1 million tons is used for human consumption, 3.9 million tons for animal feed, and 650 000 tons for starch and glucose industries. South Africa is a net exporter of maize and about 1.8 million tons are exported annually. Some of the products made from maize include:

⇒ Corn starch, corn syrup, high fructose corn syrup, dextrose and corn oil (wet milling).
⇒ Flour, maize meal, grits, oil and bran for animal feed (dry milling).

Figure 11.1 shows the maize value chain from production to the consumer.

The key role players are: input suppliers, farmers, silo owners, traders, importers, exporters, millers, animal feed industry, other processors, retailers and customers.

11.2.1.2 Wheat Value Chain

In South Africa, wheat is the second most important field crop and it is used mainly for human consumption with a small portion as animal feed. Wheat production per year on average is 1.7 Million tons except for 2015/16 where production dropped to 1.4 million tons due to the drought experienced in that year (Midgley, 2016).

The total consumption of wheat in South Africa exceeds the amount produced and therefore South Africa is a net importer of wheat. Interventions are needed to increase local wheat production to reduce imports.

Wheat imports fluctuate but on average the amount imported is 1.18 million tons per annum (Midgley, 2016). There are between 3 800 and 4 000 commercial wheat producers in the country providing about 28 000 jobs (DAFF, 2017). The milling industry employ about 3 800 people in baking, animal feed manufacture and production of other wheat based goods.

Besides flour and wheat meal, wheat is also used in production of non-food products such as synthetic rubber and explosives. Wheat starch is used for sizing textiles. The straw is made into mats, carpets, baskets, and used for packing material, cattle bedding, and paper manufacturing. Bran from flour milling is an important livestock feed while germ is a valuable addition to feed concentrate. Grain can be fed to livestock whole or coarsely ground. Some wheat is cut for hay.

Figure 11.2 shows the key players in the wheat value chain as input suppliers, wheat farmers, silo owners, wheat importers, millers, bakeries, animal feed manufacturers, manufacturers of wheat based products, wholesalers, retailers and consumers.

Figure 11.1: Maize Value Chain

Source: *DAFF, (2017)*

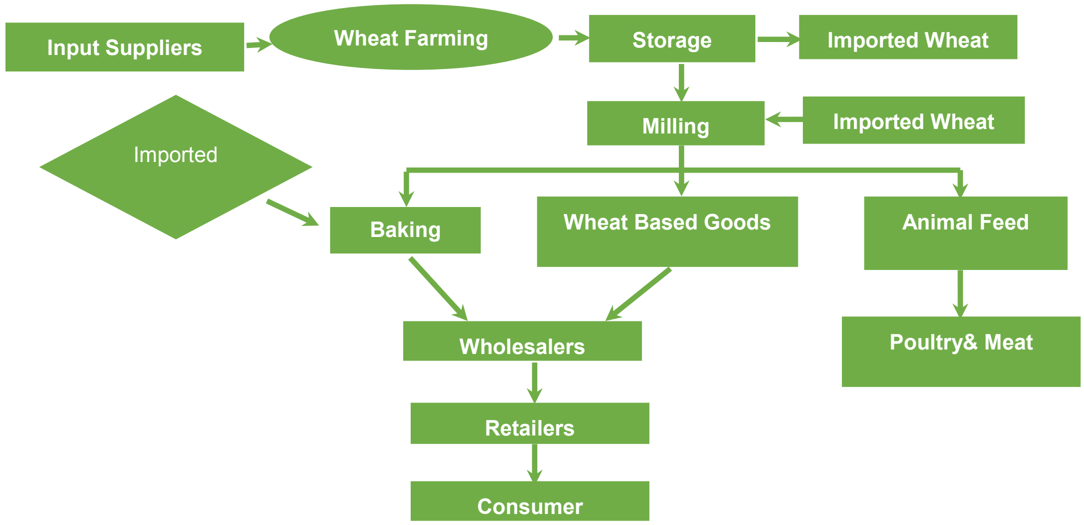


Figure 11.2: The wheat market value chain
Source: *DAFF (2017)*

11.2.2 Agro-processing in Rural Communities

In an economy where people are hungry and unemployed, food loss and waste also exist especially in the rural areas. The amount of post-harvest losses is significant especially with perishable commodities like fruits and vegetables. Table 11.1 below shows the postharvest losses of various products.

The lower and upper ranges in Table 11.1 represent commercial farmers and small-scale farmers, respectively.

The amount of food that is lost if preserved and made available could be used to feed the hungry and alleviate poverty. These farmers face challenges which prevent them from participating in agro-processing value chains (Thindisa, 2014). A summary of the factors that limit participation of smallholder farmers in Agro-processing are indicated in Figure 11.3.

Table 11.1: Post Harvest Losses of Various Agricultural Products.

Agro-processing segment	Category	Range of Loss
Food and Beverages	Roots and tubers	10 – 40%
	Milk	8 – 16%
	Fruits and Vegetables	15 – 44%
	Cereals, Oilseeds & pulses	15 – 30%
	Fish and Sea food	10 – 40%
	Meat	5 – 8%

Source: *DAFF, (2016)*

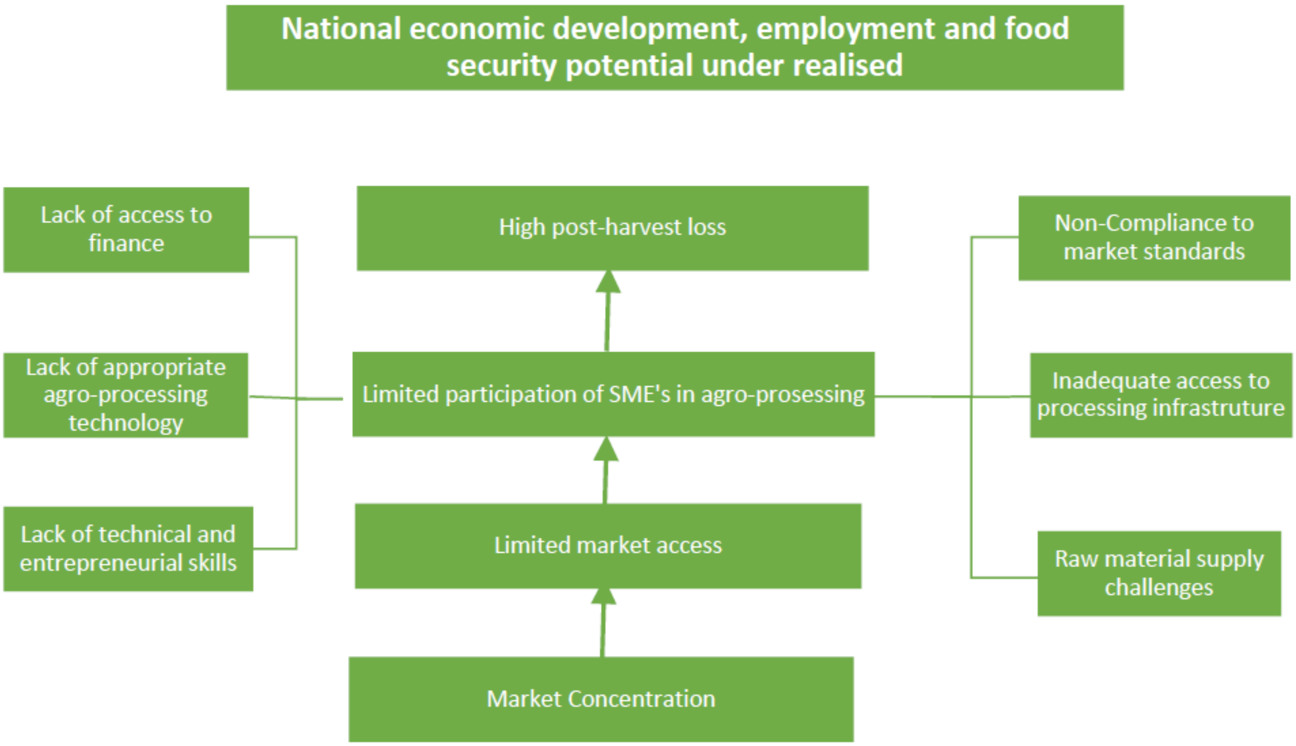


Figure 11.3: Factors that limit smallholder participation in Agro-processing
Source: *Thindisa (2014)*

The Government has taken a conscious decision to revitalize agriculture in the rural areas in line with objectives stated in the National Development Plan, (2011), New Growth Path, (2010) and Medium Term Strategic Framework (2014 - 2019). The Agri-Park model has been adopted as a way of creating entities that serve as catalysts around which rural industrialization and economic transformation will take place. An Agri-Park is a networked innovation system of agro-production, processing, logistics, marketing, training and extension services, located in a District Municipality. As a network it enables a market-driven combination and integration of various agricultural activities and rural transformation services (DRDLR, 2017).

The concept draws on existing models from countries such as Mexico, India, Netherlands, amongst others and experience and empirical evidence from these countries show that Agri-Parks offer a viable solution in addressing social and economic inequalities, unemployment and poverty by promoting agro-industrialisation within small-scale farming and emerging commercial farming sectors (Pakiso, 2016). The Lead implementer is the Department of Rural Development and Land Reform (DRDLR) working together with DAFF and other government spheres.

The objectives of Agri-Parks as articulated in DRDLR,

(2017) are:

⇒ Establish Agri-Parks in all of South Africa's District Municipalities that will kick start the Rural Economic Transformation for these rural regions.

⇒ Promote the skills of, and support to, small holder farmers through provision of capacity building, mentorship, farm infrastructure, extension services, production input and mechanization inputs.

⇒ Enable producer ownership of the majority of Agri-Parks equity (70%) with the state and commercial interest holding minority shares (30%).

⇒ Bring under-utilized land (especially in Communal Areas Land reform farms) into full production within three years starting from 2017 and expand irrigated agriculture.

⇒ Improving Household Food and Nutrition Security in rural areas.

11.2.2.1 The Agri-Park structure

The Agri-Park is made up of three key units.

a. Farmer Production Support Unit (FPSU) which is an outreach and capacity building unit providing farmers with production, technical and infrastructure support.

b. Agri Hub Unit where the farmers produce is processed in large scale. The Agri -Hub also provides quality production support services to the farmers including product development and improvement, Research and Development and training.

c. Rural Urban Market Centre responsible for marketing and distribution of primary products from FPSU and processed products from Agri-Hub. Also facilitates information flow between markets and producers.

The conceptual value chain of the Agri-Parks is shown in Figure 11.4 below. One Agri-Park will be established in each municipality in South Africa and a total of 45 000 jobs in value addition are expected to be created by 2020 in these entities, and 300 000 small holder farmers established (DRDLR, 2016).

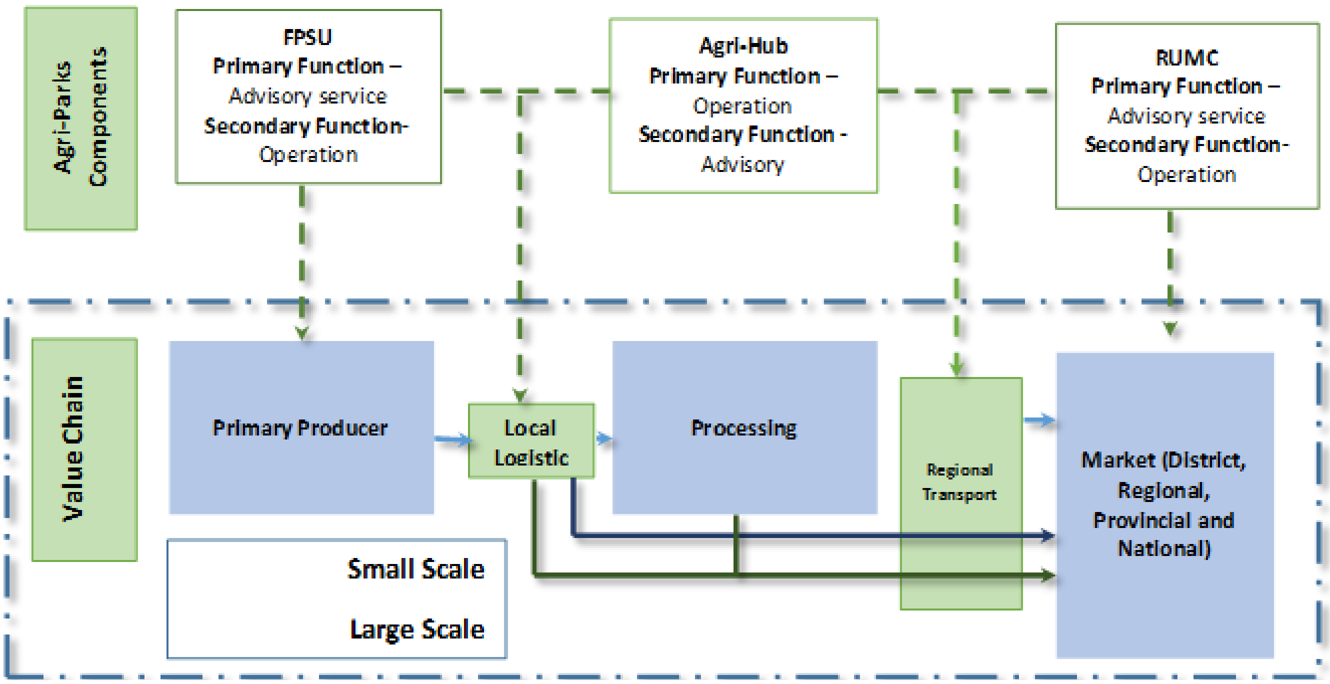


Figure 11.4 The Agri-Park Value Chain [FPSU – Farmer Production Support Unit; RUMC – Rural Urban Marketing Centre}

Source: *DLDLR 2016*

11.2.3 Home Food Preservation

Not everything that is produced in the municipality can be processed at the Agri-Park. Food produced from backyard gardens can be preserved at household level for future use. In the past, rural households produced most of their food and preserved these for future use when they did not have money to buy. Today most of that knowledge has not been passed on to newer generations and somehow there is a belief that food comes from the super market.

For example, in the Eastern Cape 70 % of the rural population which is considered food insecure spend more than 60% of their income on food. The Ilima Agri-Park initiative at University of Fort Hare has developed technologies for adding value to locally produced vegetables that could be used for community and household vegetable and fruit preservation. There is need to determine existing food preservation practices and determine how the existing knowledge can be complemented with new technologies in order to improve household food security. "

In developed countries such as the USA, home food preservation received much emphasis especially after the Second World War. As a result, in 1980 a centre on home food preservation was established at Penn State University (University Centre for Excellence in Home Food Preservation) to provide reliable information on food safety and quality for home processors.

Later on, in 2000 the National Centre for Home Processing and Preservation was established at Georgia University offering courses on home food preservation. In spite of industrial developments for the USA home food preservation is still being practiced today not because they have to but because they like to.

11.3 Climate Smart Mitigation in Agro-processing

The increasing awareness of the impact of climate change on society has led to worldwide interest on how industrial activity including Agro-processing is combating these changes. Substantial literature is available on the impact, adaptation and mitigation of climate changes on agricultural production as indicated in earlier sections of this report but not as much from post-harvest to the consumer stage. Climate change impact can be experienced at any level of the value chain and the results will be felt throughout the chain in terms of efficiency, continuity and product quality (Ridoutt *et al*., 2016).

GHG emissions have been increasing steadily since 1970. According to the Intergovernmental Panel on Climate Change (IPCC) committee of the United Nations annual increase of GHG emissions has been growing at an average of 1.0 gigatons of Carbon dioxide equivalent. In 2010 manufacturing (including construction) contributed 28% of energy use and 13 gigatons Carbon dioxide equivalent emissions and is projected to increase by 50 – 150% by 2050 unless energy efficiency improvements are accelerated (Mitchell, 2017).

11.3.1 Mitigations against GHG Emissions

In the maize and wheat value chain examples given above and in fact in all chains, sources of GHG emissions include transport, manufacturing activities and waste management activities.

11.3.1.1 Transport

The key transport mode in the wheat and maize chain is road using diesel trucks. Produce is ferried from farms to storage silos then to millers and then to retailers and finally to consumers.

These trucks burn the fossil fuel and produces CO_2 which contributes to global warming. The contribution of transport activities to GHG emissions vary depending on the value chain. Air freight and shipping by sea are important in the fruit industry and these contribute even more to GHG emissions (UNIDO, 2017).

Possible approaches to reducing emissions from transport include:

⇒ Maintaining and replacing vehicles to minimize emission and fuel waste.
⇒ Optimization of delivery routes.
⇒ Matching loads with vehicles.
⇒ Driver training.

11.3.1.2 Manufacturing activities

Emission form manufacturing activities contributed more than 10 % compared to farm and distribution activities in a vegetable value chain (UNIDO, 2017). Other cases reviewed by the same author (sugar, poultry, animal feed, pome fruit and grapes) indicated that the bulk of the emission came from manufacturing. High consumption of energy during manufacture leads to a bigger carbon footprint. Some of the mitigation activities reported by the industry include:

⇒ Reducing electricity used by introducing renewable energy sources (implementation of the National Solar program)- (Pioneer Foods, 2016),
⇒ Improving efficiency of production machinery and equipment and where necessary installing new more efficient equipment (AVI Ltd, 2017), and
⇒ Optimizing storage space in cool rooms and chillers (AVI Ltd. 2017).

11.3.1.3 Waste

Preventing food losses and food waste at all stages of the supply chain is a key priority for any company ready to support the UN Sustainable Development Goal 12.3 (which is to halve food waste by 2030) (European Food Sustainable Consumption Round Table, 2018). The focus should be to use raw materials and resources optimally and reduce waste in the value chain. Solid waste disposed at landfills contribute to GHG emissions during decomposition because it has an organic fraction that releases Carbon dioxide and Methane into the atmosphere. Indirectly food waste also contributes to emissions associated with the production, transport and processing before it became waste. Food waste and loss emission profile has been described by Porter et al., (2016) who indicated that the worldwide annual emission from food waste rose to almost 3.5 times between the period of 1961 and 2011. To reduce waste, the industry has taken some steps such as:

⇒ Recycling within the company and encouraging consumers to recycle by including recycle logos on packaging.
⇒ Use of residual sunflower husks and other biomass to co fuel boilers and reduce carbon emission from fossil fuels.
⇒ Electricity form waste water (RCL, 2016).
⇒ Composting areas near processing facilities.

11.3.2 Mitigation against drought and floods

Droughts or Floods affect the quantities and quality of water

⇒ The amount of rainfall affects the amount of water available in the catchment area. Drought can bring about competition for water rights between farmers, communities and the processing industry.
⇒ Water quality is negatively affected especially if there are long periods of drought or floods into the catchment area. This can create new challenges in the hygiene management systems.
⇒ Too much rainfall can damage the infrastructure and therefore create logistics problems.

11.3.2.1 Mitigation against water quantities and quality include:

⇒ Accurate measurements of water consumption and creating awareness for all employees about saving water.
⇒ Boreholes and Holding tanks.

⇒ Water effluent recycling.

⇒ Regular water quality assessment.

11.3.3 Climate Smart Agriculture Mitigation Strategies in the Agri-Parks

The main cause of food spoilage and loss of food in developing countries are the lack of storage facilities, on farm pest infestations, poor handling and inadequate transport infrastructure (Giovannucci *et al.,* 2011). Introduction of Agri-Parks close to areas of production will have a positive effect on climate change. The key issues that will be achieved by the Agri-Park are:

⇒ Reduction of post-harvest food loss, especially perishable products, due to close proximity of appropriate storage facilities. This will also reduce GHG emissions caused by food waste and increase food security.

⇒ Reduction in transport costs and GHG emissions caused by transporting food over long distances to processing facilities.

⇒ Shared facilities will also reduce GHG emissions and costs.

With regards to water and energy consumption in the Agri-Parks, plans from many of the districts have identified water and energy scarcity together with waste management as challenges in the establishment of the Agri-Parks. However, it is not clear from the business plans how these challenges are going to be addressed. Starting one Agri-Park in each of the district municipality in South Africa is going to demand a lot of water and energy and therefore careful planning is required with a set of indicators in place to monitor the impact on the environment.

Opportunities:

In response to the impact of climate change, the above mentioned activities are taking place in many food processing facilities, however there is still room to do more. Mitchel, (2017) quoting the IPCC report, listed the strategies put forward by the committee for reducing emissions as follows:

Reduction of the energy intensity of the industry sector by 25% through upgrading, replacement, and deployment of best available technologies and innovations.

Reduction of other gases besides CO_2 (Methane, Nitrous oxide and fluorinated gases).

Application of cross-cutting technologies and measures to improve performance and efficiency by cooperation between companies, e.g. in sharing infrastructure and information.

11.4 Conclusions

The potential of the Agro-processing industry to contribute to the economy, improve food security and reduce food loss cannot be overemphasized. The industry in South Africa is well developed but dominated by a few companies. This has made it difficult for Small and Medium Enterprises to enter the value chains because of a lack of skills, finances and contracts with the main market players.

To create a more inclusive economy and to catalyse development in rural areas the government has come up with initiatives such as the Agri-Parks to bring agro-processing closer to production areas.

This will bring about reduction in post-harvest losses, transport costs and greenhouse gas emissions associated with transport. Implementation of the Agri-Parks is still underway and the need for guidelines to ensure sustainability is important. Since not all food produced in rural areas can be preserved at the Agri-Parks, attention should also be given to the home preservation of food. Indigenous knowledge and new technologies for home preservation should be emphasized in communities to reduce waste and improve food security.

In the current environment of climate change and dwindling natural resources agro-processing activities have to be carefully planned and managed. Preparedness in terms of adaptation and mitigation against climate change has to be prioritized and actionable guidelines prepared for their

12.1 Introduction

Exposure to climate change for sub-Saharan Africa (SSA) has compromised agricultural productivity, especially given the high reliance on rain fed agriculture (Totin *et al*., 2018). Combined with high population growth and transformation of consumption patterns, this will have an effect on the marketing of agricultural commodities, which will equally need to transform.

South Africa, with more than one million people directly depending on agriculture for their livelihoods; a source of employment for 70% of the country's labour force and employing a greater proportion of women relative to men will also need to transform its farm commodity marketing to keep pace with climate change (Elum, Modise, & Marr, 2017). The country is highly susceptible to climate change impacts, caused by extremes of temperatures and rainfall (Elum *et al*., 2017).

Agro-based households in South Africa have exhibited a 26% decline between the period 2011 and 2016 mainly attributed to climate changed induced droughts. This is at the backdrop of a 17.1% increase in the countries' total population between 2011 and 2016 (StatsSA, 2016). In the country, 8.38% of the agricultural households practice backyard agriculture relative to 8.7% on farm land and 5% on communal land.

Forty-four percent of the agricultural households practice it as a main source of food whilst 37.5% engage in agriculture as an extra source of food. Only 10.4% of agro-based households engage in agriculture as source of income (StatsSA, 2016). Thus, in terms of marketing of climate smart agriculture, this would be relevant to the 10.4% of the households that tend to initiate and drive agricultural commodities through the value chain, even though the subsistence producers can also add to the chain in times of excess.

Agricultural marketing in the small holder sector of South Africa tends to be influenced by market infrastructure and information, contractual agreements, social capital group participation, tradition and expertise on grades and standards (Jari & Fraser, 2009). The de-regulation of the South African agricultural sector in 1997, through the Agricultural Products Act of 1996, into a free market induced smallholder farmer participation which had otherwise been the utilised to a large extent by commercial farmers (Jari & Fraser, 2009). This dualistic nature of agricultural systems of commercial farming on one side and smallholder farmer has also been mirrored in the marketing system.

This is based on the fact that the former entered the marketing system purely from a commercial and profit-making standpoint, whilst the latter are pursuing poverty reduction and survival objectives. Any negative impact to the agricultural sector and marketing system through climate change for instance, would have different effects on the two distinct and highly differentiated marketing systems.

South Africa has 1.28 million households engaged in crop production, with 40% exclusively practicing dryland production. In 2016, the country had 31% of the crop producing households producing grains and food crop farming (StatsSA, 2016). Maize is the most significant grain crop in South Africa, with 59% of the production being for white maize mainly for human consumption and 41% being yellow for animal feed production.

The country has a strong research and development sector especially in terms of maize seed through institutions such as the Agricultural Research Council (ARC) and Maize Trust. There exist research institutions that provide inputs such as fertilisers and machinery. The input suppliers which include the retail sector and government institutions provide farmers with inputs who produce and store, and later on utilise both either or combined markets of traders, local markets or for exports (DAFF, 2017b).

The throughput then follows either through one or all of 3 markets which include maize milling, feeds production or other processing. The processed maize then goes through

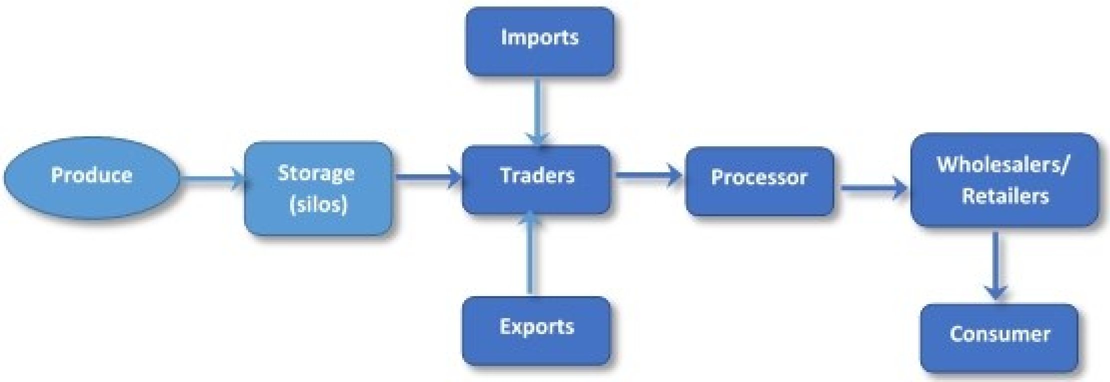


Figure 12.1: Sorghum value chain
Source: *DAFF (2017a)*

either or both wholesale/retail and export markets and through to the consumer.

Most of the maize produced is consumed locally, with transport costs, price, quality and exchange rates being major determinants of whether the country imports or is self-sufficient in terms of meeting domestic demand (DAFF, 2018). Sorghum production in South Africa serves two markets namely the human consumption and animal feed component, whereas wheat is utilised for human consumption (DAFF, 2017a, 2017c).

In SSA, and South Africa inclusive, marketing systems of the various cereal crops have been documented. However, this has gravitated more towards product and derivate movements along the value chains. Not much has been documented in terms of possible effects of climate change along this marketing system. Furthermore, any mitigatory strategies such as climate smart agriculture (CSA) have not been documented. Table 12.1 shows CSA marketing related problems.

Climate change induced transformation in consumption patterns and high population growth pressures will have effect on marketing agricultural commodities and value chain competitiveness, requiring transformation. This transformation will pertain to the structure, conduct and performance; institutional support; an enabling environment; and access to inputs, credits and markets.

A. Structure conduct and performance (SCP) - Kizito (2012) identifies structure as the stable features influencing rivalry amongst buyers and sellers within a market, whereas conduct is the relative behaviour adopted by market participants in adjusting to the market. The performance is the outcomes that are deemed good or preferred by society. Climate change has induced growing concern over market projections in the future and subsidies from developed countries, tending to shift markets. Agricultural commodity prices have also experienced sharp increases and volatility due to climate change.

B. Access to market information – Marketing of agricultural commodities is affected by expertise and access to information especially on grades and standards, food safety norms and lack of skills. Extension provides access to new information and tools that can be used in CSA marketing (Rasheed, n.d.). Extension personnel have however not been successful in promoting CSA marketing due to weaknesses in capacity at the individual and organizational levels, e.g. capacities to anticipate and respond quickly to changes, promoting planned adapta-

Table 12.1: Environment, structure, conduct and performance of extension (access to information), finance as well as research and development (R&D) in agricultural marketing for Climate Smart Agriculture (CSA)

Environment in which the Marketing Information Systems (MIS)/Finance/Research and Development (R&D) for CSA marketing operates: (1) CSA government policies, (2) key macro-economic indicators and social-economic characteristics (e.g., inflation levels, interest rates, GDP from agriculture, employment, transport and feeder roads, market infrastructure, storage and credit facilities, literacy and education levels, and user voice); (3) CSA market structure, vertical coordination, and price discovery methods; (4) agro-climatic conditions, pests, and diseases; (5) the level of CSA ICT usage in a country, (6) geographical setting; (7) cultural factors; (8) lack of effective demand for improved information by some users; (9) seasonality of crop production; and (10) security		
Structural design	**Conduct (behaviour)**	**Performance (outcomes)**
1. CSA MIS/Finance/R&D perceived mandate (Aims, objectives, and clientele) ⇒ Policy formulation and monitoring ⇒ Food security planning and monitoring ⇒ Attainment of efficient markets ⇒ Attainment of "fairer" agricultural markets ⇒ Clientele (e.g., farmers, traders, consumers, government, donors) 2. CSA Institutional home, organization, and coordination ⇒ Public-, private-, farmer organization, or trader and NGO-based MIS/Finance/R&D ⇒ Provides complementary services that generate or increase value of information ⇒ Geographic coverage and range of commodities ⇒ Assuring coordination among stages • Integration of CSA MIS/Finance/R&D Activities • Centralized or decentralized CSA MIS/Finance/ R&D activities • Specialization in CSA MIS/Finance/R&D products ⇒ Design of incentives for CSA MIS/Finance/R&D staff ⇒ Profit orientation of the CSA MIS/Finance/R&D 3. Nature of commodities covered (e.g., staple, cash, or perishable commodities)	1. CSA information provided ⇒ Market news ⇒ Market analysis ⇒ Business reports 2. CSA ICT used in transmission and diffusion ⇒ Traditional ICT (e.g., radio, television, and fax) ⇒ Modern ICT (e.g., email, internet, SMS) 3. CSA Funding strategies 4. SCA Data collection methods used ⇒ Structured questionnaire and enumerators ⇒ Wiki approach (users SMS or update web) 5. CSA quality control methods used 6. Feedback mechanism used	1. Reliability of CSA MIS/Finance/R&D 2. Credibility of CSA MIS/Finance/R&D 3. Accessibility to different clientele to CSA MIS/Finance/R&D 4. Timeliness of CSA MIS/Finance/R&D 5. Sustainability of CSA MIS/Finance/R&D ⇒ Financial support ⇒ User support ⇒ Cost minimization **Some Impact Indicators** 1. Production, marketing, and consumption behaviour of CSA products 2. Revenues (income) obtained from CSA 3. Reduction in transaction costs of CSA 4. Welfare changes among actors in CS marketing 5. Integration of CSA markets 6. Policy decisions and outcomes in CS marketing

Source: *Adopted from Kizito (2012)*

tion and mitigation measures (Rasheed, n.d.). Extension and marketing information systems issues that have a bearing on marketing of agricultural products are those highlighted in Table 12.2 (Kizito, 2012).

Access to marketing information helps attain efficient and competitive markets through the reduction of information asymmetry among food systems participants (increasing market transparency), leading to reduction of transaction costs (i.e. negotiation, signing and contract enforcement) (Kizito, 2012). Access to market information increases bargaining power resulting in fairer markets; reduces and manages price risks allowing for better production, marketing and consumption decisions; and it provides a source of information to governments, donors and researchers for better policy formulation, monitoring and evaluation (Kizito, 2012).

C. Climate Finance – Climate finance still lacks an internationally agreed definition, but broadly refers to resources that catalyze low-carbon and climate resilient development. The financial needs relate to creating an enabling environment including policy development and cross-sectoral planning, capacity building, research and technology transfer and implementation and monitoring of mitigation and adaptation strategies (Giacomo Branca, Lipper, & Sorrentino, 2015). Climate finance can act as a catalyst to unlock additional sources of finance, tighten the links between financial institutions and smallholder farmers and SMEs, act as catalyst for the design and adoption of innovative mechanisms in leveraging additional sources of finance (and expertise) and provide technical assistance to build capacities (IBRD/World Bank, 2016). Finance helps to improve access to inputs. Some of the finance for CSA pertained to insurance and other risk management instruments; private sector instruments; market-based instruments e.g. carbon finance. Even though financial institutions have started to consider climate in their financing decisions, it has not been fully integrated into their risk and investment processes, usually because of policy uncertainties. There is lack of financial capacity to cope with climate change impacts, making farmers reliant upon aid relations. Farmers do not find insurance an appealing option due to the market being limited. There is lack of prioritization of funding in implementing climate change adaptation strategies. Furthermore, even though various government and non-government initiatives have been undertaken, they lack coordination, reducing composite financial strategy geared towards a climate resilient economy. Technology adoption is influenced by access to adequate finance because the new technologies involve high costs (Senyolo, Long, Blok, & Omta, 2018). Some of the additional barriers to climate finance include difficulty in demonstrating short term quick wins, limited capacity in assessing what is needed to finance adaptation and mitigation, fragmentation of climate finance sources, broken links between financiers and farmers, as well as lack of capacity and readiness at the country level along the marketing chain (IBRD/World Bank, 2016).

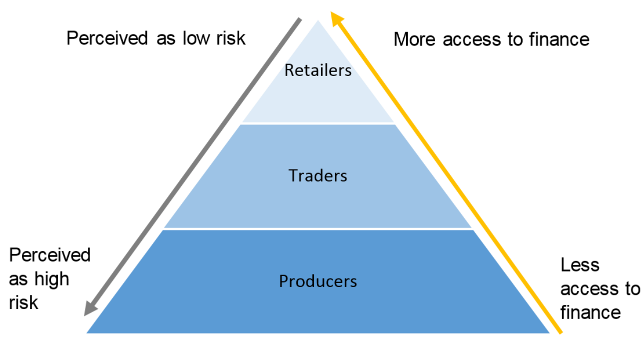


Figure 12.2: Risk Profiles along the Agricultural Marketing Chain
Source: *IBRD/World Bank (2016)*

Table 12.3: CSA financial instruments available to agricultural marketing players

Financing instrument	Modalities
In kind	Smallholder farmer can often only invest labour to increase farm productivity. Opportunity costs and basic needs that require cash severely limits investment capabilities
Reinvestment of profits	Important to build capital stocks and to finance inputs and small capital items. Saving schemes operated by groups or women are often most effective due to their financial discipline
Food/cash for work (productive safety nets)	Enables investment in CSA practices with long-term benefits in terms of increased productivity and climate benefits (e.g. terracing, small-scale dams and integrated irrigation systems).
Debt finance	Loans are not widely accessible for farm productivity and climate resilience enhancing activities, but however accessible to other marketing chain actors. Joint liability groups, structured finance to secure lending, risk insurance and innovative mobile phone financial transaction services can reduce transaction costs and risks, increase access and adoption rates
Equity finance	Direct investments in smallholder farming systems are feasible if strong cooperative or social business aggregation structures exist. Respective funding from investors are increasingly available based on supportive governance and regulatory systems
Grants and subsidies	Governments can provide CSA incentives and leverage private capital for agricultural and climate-smart investments. Temporary support and complex grant management procedures are often barriers for successful up-scaling

The risk profile influences how much financing is available, with smallholder farmers less able to access finance than SMEs. The further up the marketing chain, the easier it is to access finance because of aggregation and integration, better able to meet the lending criteria of financiers.

Agricultural finance and risk management are rapidly evolving, with microfinance institutions and commercial banks increasingly providing options in using alternative collateral to finance investments (Branca, Tennigkeit, Mann, & Lipper, 2011) (Figure 12.3).

C. Marketing research and development – Marketing research and development is required to produce technological innovations that can accelerate the scaling up of CSA. Research investments should target developing crop varieties, tree species, livestock and fish breeds, as well as entire sustainable and resilient farming, food, water, land and energy management practices and systems (Rasheed, n.d.).

According to Steenwerth *et al.* (2014) questions pertaining to challenges for food systems in the wake of climate change require comprehensive, collaborative investments and science-based actions. However, most transformative CSA changes have been targeted to achieve food security, poverty relief, mitigation and adaptation targeting policy makers, rarely in the marketing chain domain. CSA emphasizes the involvement of scientists with farmers, land managers, agro-foresters, livestock keepers, fishers, resource managers and policymakers (stakeholders) to empower them in the formation of palatable choices to enact adaptive capacity and resilience 'on the ground' and within broader policies (Steenwerth *et al.,* 2014).

However, there has been limited focus on the marketing chain for CSA products advances in technology. Poor ICT and road infrastructure induce high transaction costs. There is also an issue on the balance between provision of food for human vs livestock consumption.

D. Institutional support – Institutions produce distinct combination of incentives and sanctions shaping patterns of political influence and organization and lead political and economic actors towards a certain kind of behaviour (Purdon, 2004). However, institutions have been rarely mentioned in climate change literature (worse for CSA marketing), which only focusses on policies rarely discussing how and who will implement these policies. Efficacy of mainstreaming CSA depends on successful institutional performance (Hossain & Huq, 2013).

According to Negra *et al.,* (2014) different positions amongst different stakeholder groups inhibit policy innovation necessary in accelerating CSA approaches. Furthermore, there is lack of farmer support; limited vertical and horizontal integration; middlemen manipulation; with stringent contract enforcement and regulation. There is lack of institutional support in decision making, information dissemination, financial support and access to markets in coping with climate shocks. Stable platforms are needed through which different stakeholders can explore shared risks and negotiate policy priorities. Transparent and credible information sharing is a key function of multi stakeholder institutional arrangements (Negra *et al.*, 2014).

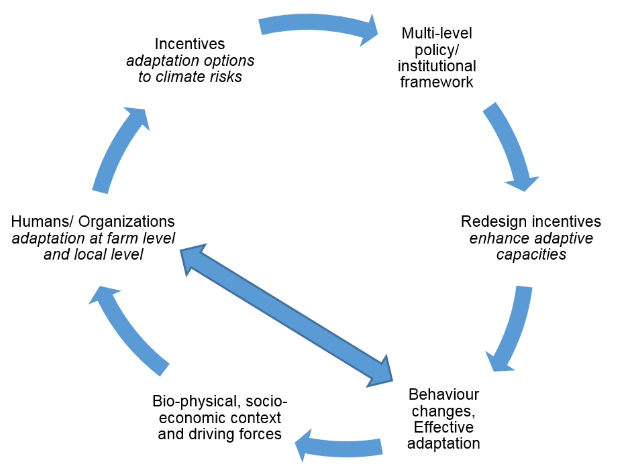


Figure 12.3: The role of institutions in promoting adaptive capacities of the households and the communities
Source: *Hossain & Huq (2013)*

There exists CSA institutional support vacuum at the country and international organizational levels (Leeuwis, Hall, van Weperen, & Pressing, 2013).

Climate change is not just an issue of technological adaptation but also for institutional adaptation within and be-

Box 12.1: Inconsistency in institutional support for climate smart agriculture

Secure marketing of agricultural produce enhances the likelihood to invest in and innovate with new technologies and techniques. Furthermore, market-oriented production farmers are likely to adopt high-cost technologies relative to farmers aiming for food security.

The study found lack of adequate government support from government. There were also policy inconsistencies for example government supporting market-related practices and products such as preference to GMOs over agro-ecology. Furthermore, different stakeholder do not speak the same language, with lack of consensus. For example, the mechanisation programs still purse convectional implements parallel to promotion of conservation agriculture.
Source: *Senyolo et al. (2018).*

yond the agricultural innovation system, including wider policy, regulatory and market regimes.

E. Enabling environment – The dualistic nature of the agricultural system in South Africa means a bias towards the commercial sector with a lack of enabling environment for the subsistence and the communal ones, especially in climate change induced impacts. Thus, there exists two different and highly adapted marketing systems, interference thereof likely to have differing effects. Smallholders are missing out in participating in new, higher value, production and marketing channels, mainly due to low volumes of production, limited ability in meeting quality requirements and lack of reliability.

F. Access to inputs, credits and markets – There is lack of product bundling with different institutions providing varied support. There is likely to be duplications and resource wastage unlike when there is amalgamation of institutional support. Greater access to both local and international output markets improves adoption of CSA. Closer proximity to input markets improves use of inorganic fertilizers, with a further market likely to utilise organic fertilizers. Access to inputs, credits and markets are mainly caused by low individual production, poor market information and contacts, inability to meet quality and reliability, and competition from corporate sized farms. Furthermore, there is inability to produce for the market but for subsistence purposes. Participation in agricultural input and output markets is limited by high transaction costs, limited access to improved technologies, and lack of productive assets.

G. Infrastructure – Lack of transportation, road infrastructure, communication links and infrastructure, and storage facilities constrain ability to participate in the market. There exists large distance between where people live and the markets. Lack of infrastructure discourages complementary private sector investment in setting up value-adding industries. Extreme climate change damages transport, storage, bridges, fuel supplies and other infrastructure. There exists a shortage of logistic infrastructure capacity during peak periods. According to Corfee-morlot *et al.* (2012) in low income and least developed countries, the major challenges in low carbon, climate resilient (LCR) infrastructure pertain to weak enabling conditions for investments, lack of basic infrastructure (e.g. transport, energy and water), sluggish economic growth and strong demographic growth putting pressure on infrastructure, high dependence on natural resources, high vulnerability to climate change and climate-related disasters, low adaptive capacity and insufficient financial and technical capacity.

h. Group marketing – Group marketing improves social capital and is significant in participating in both formal and informal markets as it links farmers with other value chain actors. FAO (2013) highlight that collective marketing can encourage market access through creation of a marketing cooperative, providing a place where produce can be prepared and packed for transportation to markets and other distribution centers. This is an avenue through which CSA produce could flow through the marketing chain. However, some of the challenges in collectivization has pertained to accessing good transport, favourable markets, marketability of products, as well as accountability and transparency amongst members. In enhancing public extension delivery there is need to diffuse and adopt through collectivization, especially in value chains given the limited resources for extension services (Essegbey, Nutsukpo, Karbo, & Zougmore, 2015).

The objective of the desktop study was highlight how practising CSA has affected the structure, conduct and performance of the marketing system in South Africa, with SSA as reference. Particularly, the study investigated access to finance, infrastructure and collectivization in incorporating CSA initiatives in commodity marketing systems.

12.2 Climate change and marketing

Weather and climate tend to have a bearing on the efficiency of the food system of any country. Effective value chain management can mitigate climate risks and improve small-scale producer and processor access to stable markets (AGRA, 2014). Climate Smart Agriculture (CSA) attempts to sustainably achieve food security and development goals in light of a changing climate and increasing food demand (FAO, 2010; Totin *et al.,* 2018).

This amongst other things involves traditional and innovative practices that increase adaptive capacity at multiple scales (from farm to nation) (Campbell, Thornton, Zougmoré, van Asten, & Lipper, 2014). Marketing of farm produce from farm to fork is one such practice that need to adapt to CSA. Participation in high value production chains reduce climate change risk through provision of multiple marketing options. However, most current policies in SSA remain heavily oriented towards production and less geared to invest in and promote marketing services. This orientation needs to change quickly in order to help farmers to adopt climate-smart land and water management practices (AGRA, 2018).

A host of policy-related issues needs to be addressed. In crop production, these relate to seed systems, the uptake of environmentally friendly soil management options, and the improved effectiveness of and access to agricultural output markets. Successful CSA implementation requires changes in behaviour and strategies, as well as changes in the usual timing of agricultural practices. For instance, in a study by Ncube *et al.* (2016) in Eastern Cape and Limpopo Provinces, it was observed that the transition of smallholder from exclusive livestock or crop production into mixed farming should also incorporate the transformation of the market to be locally-based and oriented towards subsistence production, further advocating for promotion of schemes that improve access to markets.

Without appropriate institutional structures in place, these innovations may overwhelm smallholder farmers. Strong institutional support is required to promote inclusivity in decision making; improve the dissemination of information; provide financial support and access to markets; provide insurance to cope with risks associated with climate shocks and the adoption of new practices; and support farmers' collaborative actions (AGRA, 2014, 2018).

Improving yields through improved crop production without creating an enabling environment in terms of accessing inputs, post-harvest facilities and market outlets might down play the advantages of CSA. According to Hassan & Nhemachena (2008) unfettered access to markets would encourage farmer adaptation to climate change. Some of the institutions that are involved with marketing information and research of grain crops in South Africa are shown in Table 12.4.

Table 12. 4: Institutions involved with marketing, information and research of crops in South Africa

Commodity	Institutions
Maize	DAFF; Grain South Africa; SAGIS; Maize Trust; ARC
Sorghum	Sorghum Forum; Sorghum Trust; SAGIS; Southern African Grain Laboratories; Crop Estimates Committee; ARC
Wheat	Winter Grains Trust; ARC-Small Grain Institute; SAGIS; Crop Estimates Committee

Source: DAFF (2018)

According to AGRA (2018) adoption of CSA requires greater access to local and international markets. There is need for more attention on the management of food value chains to deal with climate change and improvement of links between small-scale producers and processors to stable markets (AGRA, 2018). Access to markets has different impacts on use of CSA.

Closer proximity to markets increases the probability of adopting inorganic fertilisers for instance (AGRA, 2018). The further away from a market, the more likely the use of composting and soil conservation. Thus market access can limit adoption of CSA. Elum *et al.* (2017) found out that lack of access to formal markets also impinged adaptation to climate change in South Africa.

In KwaZulu-Natal, Hitayezu, Zegeye, & Ortmann (2014) found that only a few small-scale farmers practiced market oriented farming such as sugarcane. Furthermore, lack of access to public and private infrastructure severely constrains their ability to participate in the market economy. Consequently, without external intervention, the ability of the farmers to absorb and recover from climate-related shocks and stresses remains constrained.

Promotion of group marketing and improving access to markets through road construction could facilitate farmers' adoption of climate-smart land management practices as well enhance climate smart mechanization. According to Livingston, Schonberger, & Delaney (2011) there exist large distances from where people live and the markets, making them remote.

There is also an urgent need to encourage market development to deal with prevalent market failures in Africa. This requires governments to realign their budgets to reflect these objectives by increasing their commitment to investment in public goods that support agricultural growth, such as: road, rail and port infrastructure; irrigation facilities to promote dry season farming; storage and processing facilities; research and development; agricultural extension systems; market information systems; and various institutional changes (Godfray *et al.,* 2010)

The pace of change, or volatility, within each market domain has increased rapidly in the past decade (Becerra-Fernandez, Xia, Gudi, & Rocha, 2008). Agricultural commodity prices have experienced sharp increases due to climate change, volatile global food and energy prices, and a reliance on farmers' and rural communities' own devices (Gardebroek, Hernandez, & Robles, 2014; Hazell, 2013).

According to Hazell (2013), although smallholder farms in Africa are opening up new market opportunities to private sector investments, many smallholders are also missing out on participation in new, higher-value, production and marketing channels (value chains); they also lack ready access to modern inputs, credit, and market outlets.

This is due to low individual volumes of production (lack of aggregation); poor market information and contacts; limited ability to meet the high quality and reliability requirements of many high-value buyers; competition from corporate-sized farms; and the inability of smallholder farmers to produce enough food to feed their families, much less surpluses for marketing purposes.

12.3 Access to financial services in funding adaptive technologies, practices and processes

According to Cooper *et al.,* (2008) a broad range of investor stakeholders are demanding integrated climate risk management strategies. One of the reasons has been to have a clearer picture of the climate and seasonal variability in the establishment and sustainability of viable market enterprises and financing schemes. Policy makers are also gripped with making agricultural investment decisions on the type of development initiatives to promote and support (Cooper *et al.,* 2008). Heltberg, Siegel,

& Jorgensen (2009) identified that finance could be used to reduce exposure and mitigate effects of climate change.

According to Heltberg *et al.* (2009) social funding and community development projects support small projects in terms of infrastructure, social service, microfinance and enterprise development. In crop production, microfinance institutions can help jumpstart access to finance for inputs, especially fertilizers, which are expensive for most farmers. Besides funding, they provide other services, such as storage and marketing of produce. Farmers can pay using their produce instead of cash (AGRA, 2018). Zwane & Montmasson-Clair (2016) however identifies that there is a lack of prioritisation of funding in implementing climate change adaptation strategies in South Africa.

Less Developed Countries (LDCs) lack the necessary financial capacity to cope to climate change impacts, critically dependent on aid relations and associated debt dynamics (Huq, Reid, Konate, Rahman, & Sokona, 2003).

A substantial study was done by Bouwer & Aerts (2006) looking at the possible climate change financial instruments that are available to any country. They identified 8 possible sources of funding that is available, namely funds under the UNFCC, the Global Environment Facility (GEF), Non-Compliance Fund, disaster relief and risk reduction, public expenditures, including public-private partnerships, insurance and disaster pooling, development assistance and foreign direct investment (Bouwer & Aerts, 2006).

A study by Elum *et al*. (2017) showed that even though farmers were aware of climate change and the potential effects, they did not find insurance an appealing option

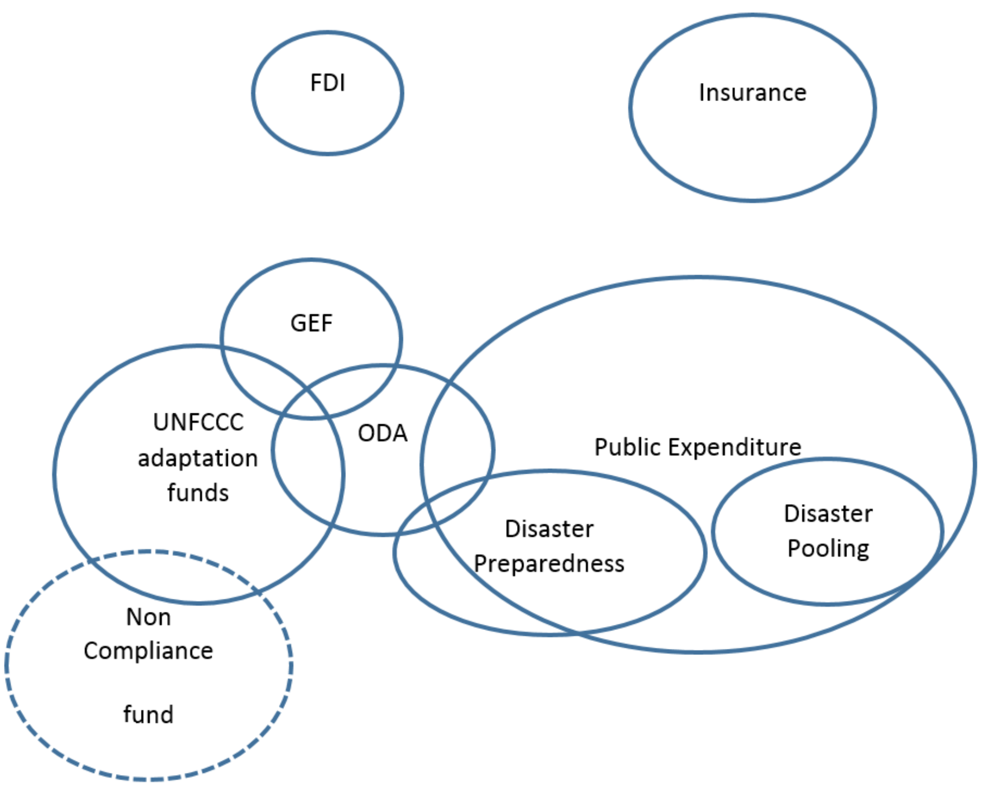


Figure 12. 4: Relationship between different potential sources of funds for adaptation in developing countries
Source: *Bouwer & Aerts (2006)*

mainly due to the market being very limited.

Barrett (2008) noted that finance for CSA pertained to insurance and other risk management instruments; private sector instruments; market-based instruments, e.g., carbon finance; and improving access to financing. Key areas identified for technology development and transfer include: drip irrigation, water harvesting, drought-tolerant crop varieties, renewable energy, knowledge systems, and best practices.

Case study 12.1: Funds under UNFCC

Under the Nationally Determined Contribution (NDC) on adaptation, mitigation, finance and investments for climate change in South Africa (under UNFCC), for the period 2020-2030, the country pledged US$0.17 billion per annum in developing a National Adaptation Plan, and begin operationalization, build necessary institutional capacity for climate change response planning and implementation; take into account climate considerations in national development, sub-national and sector policy frameworks; and develop early warning, vulnerability and adaptation monitoring system for climate vulnerable sectors. Furthermore, the estimated expenditure from 1971-2000 for the development of a vulnerability assessment and adaptation needs framework increased from US$0.4 to US$22.8 billion, with a projected expenditure of between US$0.42 and US$29.8 billion from 2020-2030.

According to DEA (2011) South Africa has a duty to reduce vulnerability to climate change, not only for herself, but for the neighbouring countries as well. It also needs to promote climate change resilient infrastructure and foster regional development and integration.

DEA (2011) highlighted that South African companies have started utilising climate change mitigation strategies in their strategies and governance. Financial institutions have also begun to consider climate considerations in their financing decision, however it has not been fully integrated into their risk and investment processes. One reason for this is policy uncertainties (DEA, 2011). Since 2007, in the South African private sector there has been an increase in a number of new specialist venture capital, infrastructure and clean funds that have been directed towards project development, awareness building and adaptation projects. The country has been utilising several government finance and market based interventions such as the Treasury's Green Fund, carbon tax and the South African Renewables Initiative. These instruments are however uncoordinated, reducing potential of a composite financing strategy geared towards a climate resilient economy (DEA, 2011). There is a need for coordination of finance flows and shared information platforms that is usable to key decision makers and investors to plan development interventions. The DEA (2011) identified a climate change financing mechanism that can be adopted by South Africa (Figure 12.5).

Case study 12.2: Funds under GEF

Largest independent financial organization providing assistance and grants to both government and non-government entities for implementation of projects. In developing countries to date it has provided US$10.5 billion grants and US$51 billion in co-financing over 2 700 projects in 165 countries.

Projects funded must link local, national and global environmental challenges and promoting sustainable livelihoods. Some of the financed project under GEF include the GEF Small Grants Programme (SGP) which invests in developing underprivileged communities on biodiversity and climate change mitigation. The SGP programme provides support to community-based organizations and other stakeholders on environmental sustainability projects.

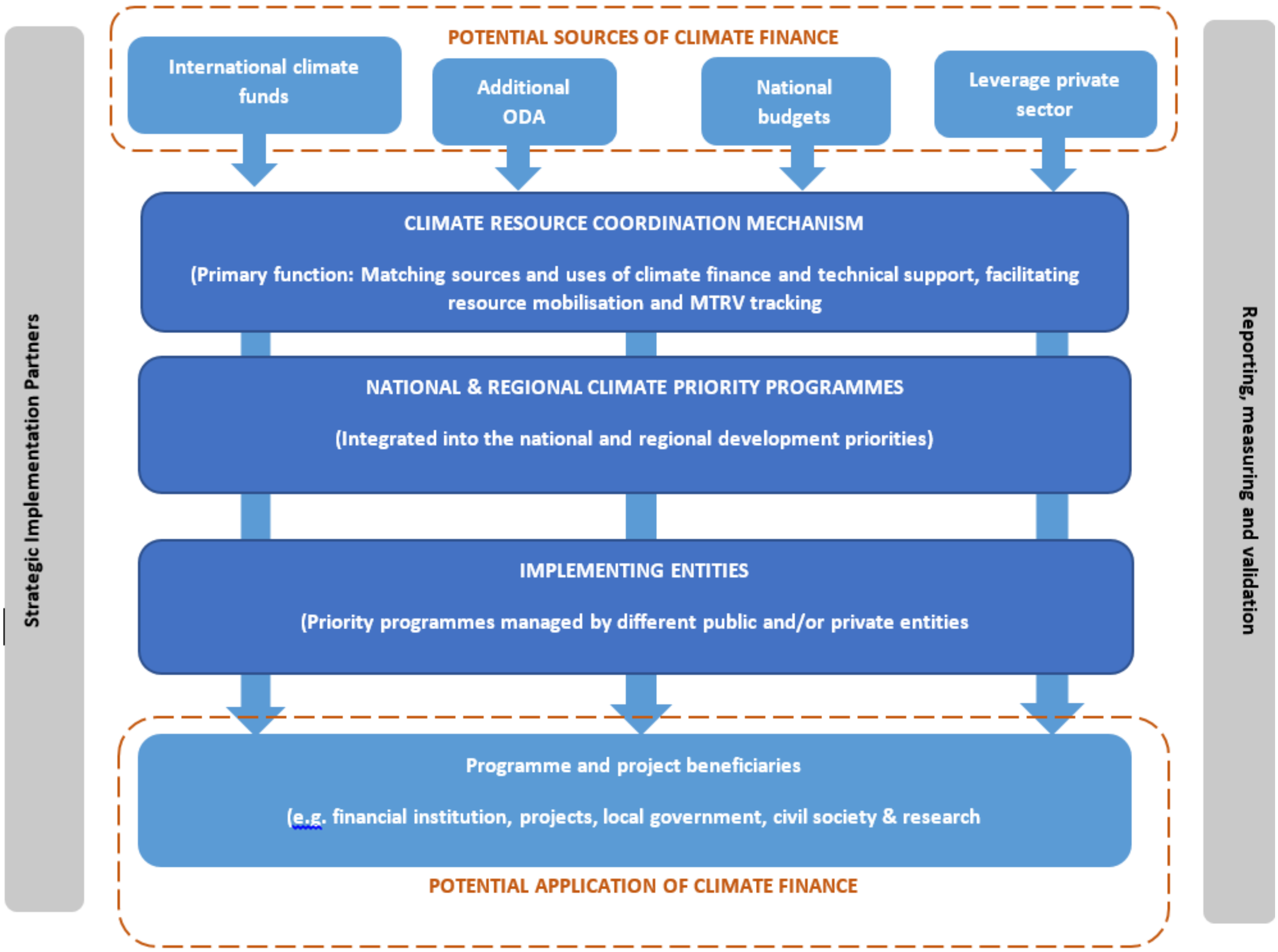


Figure 12. 5: Climate coordination prototype for South Africa
Source: *DEA (2011)*

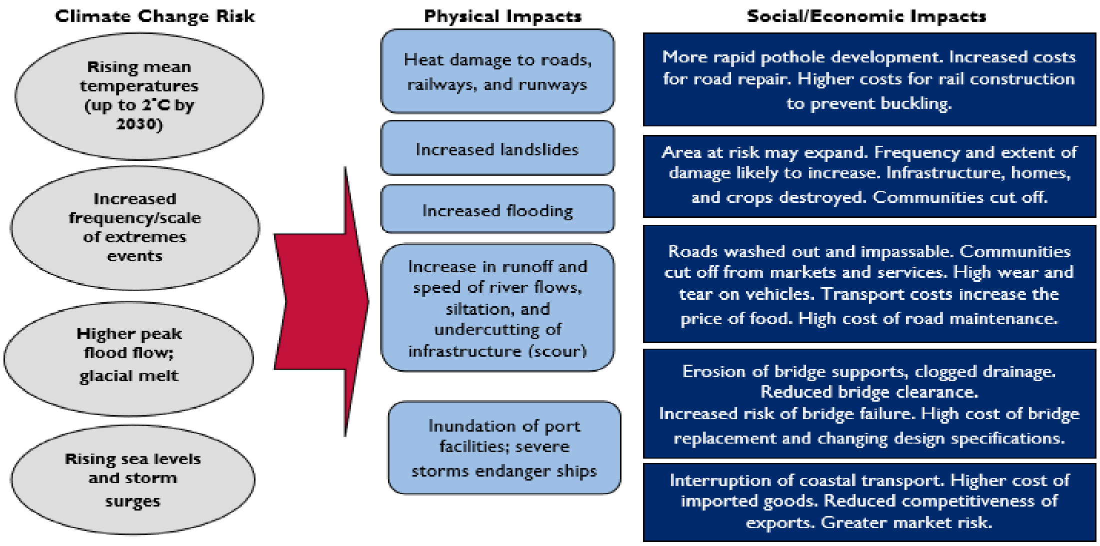
12.4 Investments in agribusiness infrastructure and market information

Lekgau, Matlou, & Lubinga (2017) postulate that climate change is a restraining force in agribusiness. To circumvent these forces in the production and trading of agricultural commodities, there is a need to adapt and mitigate climate change effects, trade distortions and implement proper policies. Furthermore, there is the need to improve infrastructure, farming and agro-processing while contributing to skills development (Lekgau *et al.*, 2017). Infrastructure is essential for economic performance, growth and development. Extreme climates damages transport, storage, bridges, fuel supplies and other infrastructure (USAID, 2014).

Case study 12.4: Climate change implications on transport infrastructure in Uganda.

Source: *USAID (2014)*

Climate change hazards such as flooding destroys infrastructure



The state of Uganda's infrastructure results in high transport costs and increasing transaction costs along the commodity value chain. This makes the use of purchased inputs such as fertiliser, seed and fertiliser prohibitively expensive. High rural-urban transport costs creates incentives for poor people to live close to their food source- effectively reducing real price of food.

In South Africa, some of the identified climate change adaptation strategies include integration of markets, distribution and transportation to provide infrastructure to supply food (Kiker, 1999). South Africa should build upon initiatives such as the Agri-Parks project in resourcing small towns with infrastructure.

Climate-proofing food and agriculture processing should form part of this approach (DEA, 2016). An initiative that can be utilised in incorporating CSA in the value chain can be through the Agri-Parks described in section 11.2.2.1 of this report. Farmer Production Support Unit (FPSU) and the Rural Urban Marketing Centres (RUMCs) components of the Agri-Parks serve as centres of marketing services from controlling input supply, logistic support, grading and packaging as well as auctions amongst others.

The FPSUs and RUMCs can act as CSA information conduits since they will be (i) set up in each district within the country thus making access to farmers and markets easier and (ii) are involved in marketing functions, and thus can positively contribute towards CSA marketing. However, the initiative still lacks a clear framework as to how CSA initiatives can be incorporated in the whole marketing system relative to the productive sub-system.

12.5 Collective marketing of farm inputs and outputs

High transaction costs, limited access to improved technologies, and lack of productive assets limit farmers participation in agricultural input and output markets (Barrett, 2008). Hence, promoting group marketing and improving access to markets through road construction could facilitate farmers' adoption of land management practices that produce high returns, but require the purchase of external inputs – namely inorganic fertilizer and improved seeds. Land management practices that include the use of both inorganic fertilizer and organic inputs are climate-smart, since they simultaneously increase productivity, carbon sequestration, and profits, and reduce climate-related risks and enhance resilience to climate change.

Unfortunately, adoption rates for these practices are low due to limited access to agricultural extension services, poor market access, and lack of climate smart mechanization. Promotion of group marketing and improving access to markets through road construction could facilitate farmers' adoption of climate-smart land management practices as well enhance climate smart mechanization (Barrett, 2008).

Increasing climate smart mechanization and improved market access could also attract young people to farming – something that would lead to favourable outcomes since young farmers have greater propensity to use new climate change-related knowledge and strategies.

Even at the retail level, there are few agro-dealers with market penetration into rural areas, resulting in limited competition. For those few retailers in the supply chain, fertilizer brings small margins compared to other agricultural inputs.

Retailers' ability to carry product is also constrained by expensive credit with high collateral requirements. Low margins on low volumes also discourage the investment of time and effort to build retail fertilizer businesses. Retailers also lack marketing and business management skills, and often do not have the technical knowledge needed to advise farmers on the correct use of fertilizers. These barriers limit supply and prevent the availability of sufficient quantities of the right quality and type of fertilizers, at affordable prices, and at the right time in the planting cycle (AGRA, 2018).

An enabling environment will encourage investments in local manufacturing (if raw materials are available), blending plants, bulk importation, and bagging in-country, all of which will reduce transportation costs and hence fertilizer prices.

This can be done by reforming and strengthening national regulatory systems and policies and, at the regional level, harmonizing regulations to build wider markets and encourage investment. Improving market information systems is also an important strategic step that will enable farmer groups and individual smallholders' access to current and more accurate information about input prices (fertilizers, seed, and others). These same systems help improve farmer access to relevant output market information (AGRA, 2018).

Promoting group marketing and improving access to markets could facilitate farmer adoption of land management practices (Barrett, 2008). African farmers' outputs are constrained by inherently low soil fertility, poor access to inputs such as seeds of improved crop varieties and affordable fertilizers, and an inadequate transport, storage, and marketing infrastructure that limits access to output markets (AGRA, 2018).

There is a need to design comprehensive initiatives that would lead to greater uptake of improved staple crop varieties and hybrids; better access to affordable credit, more cost-effective storage and transport services, and (especially) to input and output markets.

According to Ortmann & King (2007) agricultural cooperatives have played a role in the commercial agricultural sector in South Africa before 1994, not privy to smallholder sector.

This was through input supply, marketing agents and providers of services. Cooperation is essential in improving access to assets, information, desire to enhance bargaining strength, income enhancement, assurance of product markets, services and markets for high value crops and economies of size. It tends to reduce transaction costs, stimulate market entry and promote growth. This was due to the increasing importance of food grades and standards, contract farming and market failure (Ortmann & King, 2007).

According to Shiferaw, Hellin, & Muricho (2011) producer organizations in Africa should exhibit good governance, be homogenous and of optimal size, transparent and market oriented if they are to succeed in improving market access.

Collective marketing should prioritise agribusiness opportunities over social welfare objectives. As markets become increasingly important, private sector players such as the smallholder farmers themselves become significant.

However, as it takes too much time and too many resources to reach each individual farmer, approaching producer cooperatives is a good strategy for building a broad base of support for climate-smart practices in the farming community.

Producers' cooperatives and unions are intended to reflect producers' interests, but their capacity to influence public policies tends to be limited. Nonetheless, close collaboration with producers' cooperatives or unions has high potential payoffs, as their legitimacy and influence reach wide networks of farmers.

Moreover, there are growing opportunities for inclusive partnerships involving governments, private sector agribusinesses, and development organizations to collaborate on CSA issues such as carbon finance (AGRA, 2018).

Shiferaw *et al.* (2011) identified a conceptual framework on factors influencing success of collective action for producer organizations (Figure 12.7)

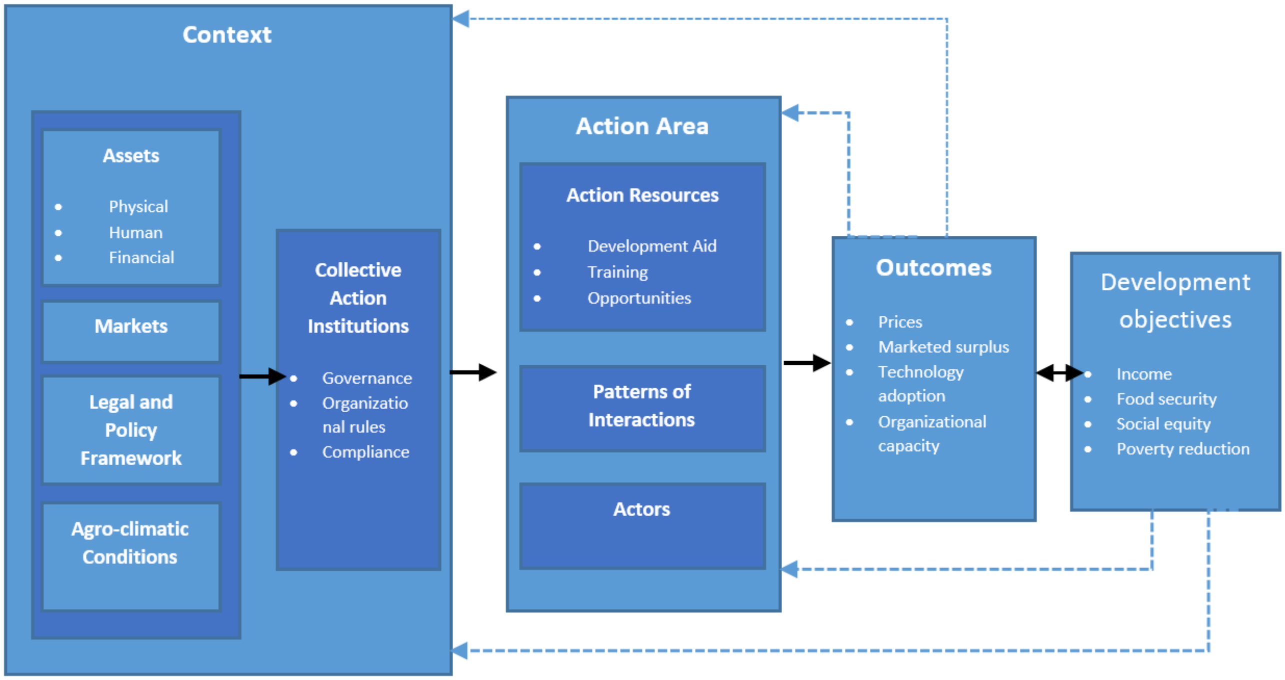


Figure 12.7: Factors influencing the success of collective action for producer organizations
Source: *Shiferaw et al. (2011)*

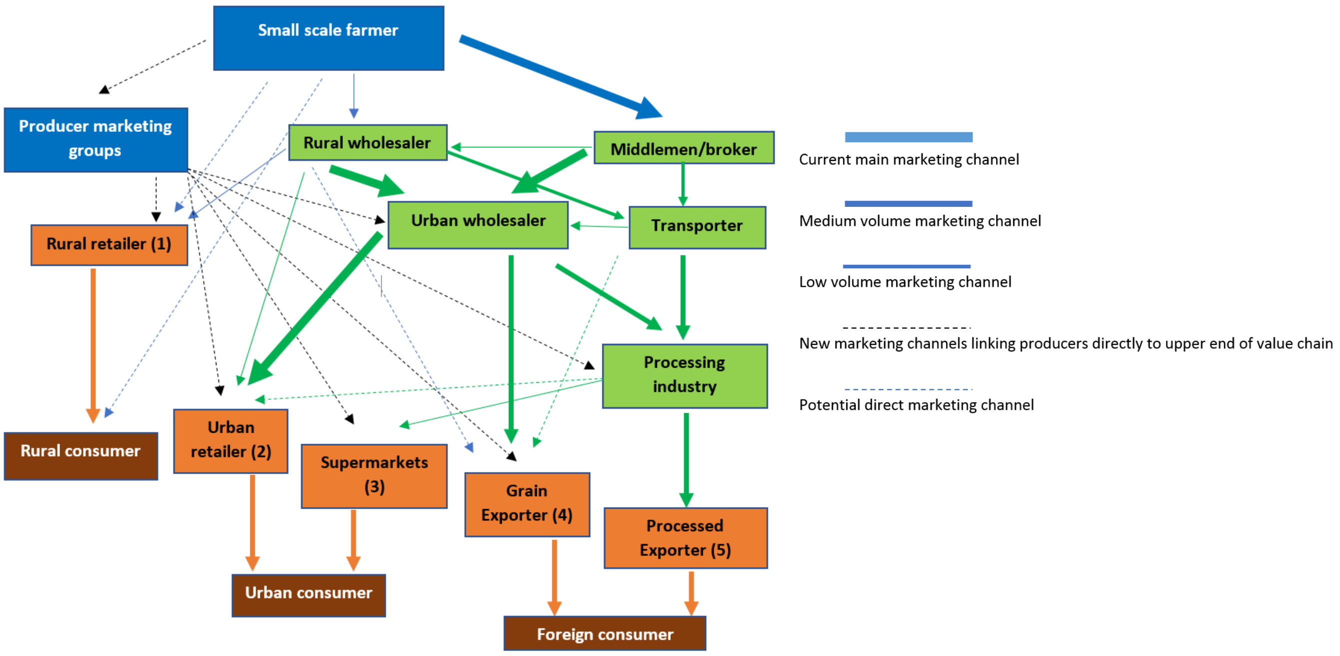


Figure 12.8: Role of producer marketing in grain markets
Source: *Shiferaw et al. (2011)*

In assessing performance of producer organizations in improving market access in Africa, Shiferaw *et al.* (2011) observed that small organized producers tend to share information on market conditions, standardize production practices, monitor quality, supply homogenous products, absorb shocks through arbitrage. This can be advantageous in introducing CSA products into the market, as shown in Figure 12.8 where group marketing has access to more markets relative to individual producers (Shiferaw *et al*., 2011).

Farmer groups seek to improve members' access to agricultural technologies and know-how on productivity management practices, including post-harvest grain handling and storage (Shiferaw *et al.,* 2011). Factors enhancing success of producer organizations include group characteristics, organizational rules and governance systems, type of products and markets, role of public and private sectors. For producer organizations to succeed they should identify market opportunities, define benefits to members, formulate clear rules and norms for collective action, partner with private sector, target external financial and technical support, provide enabling legal and policy framework as well as be innovative (Shiferaw *et al.,* 2011).

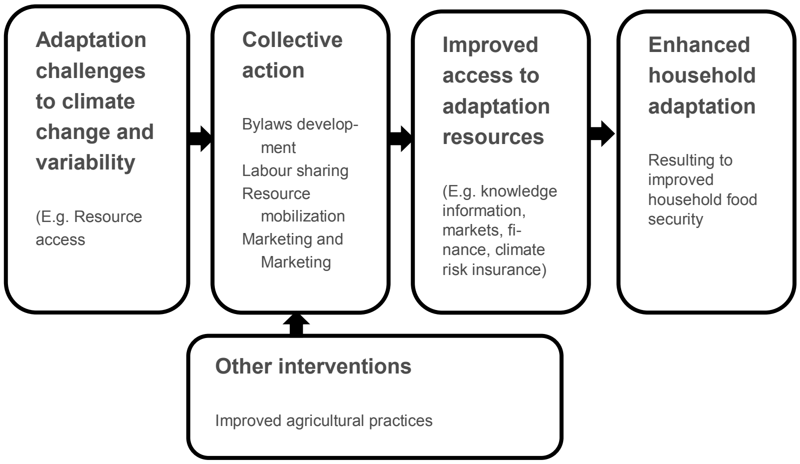
In terms of CSA, Bryan, Deressa, Gbetibouo, & Ringler (2009) identify that collective organizations tend to organize to manage climate risks. In terms of marketing this could be through provision of informal credit, product characteristics, shared risks and economies of scale and size amongst others.

Case study 12.3: Enhancing adaptation to climate variability in the East African highlands: a case for fostering collective action among small holder farmers in Kenya and Uganda

Authors: *Ombogoh et al (2016)*

The success of collective action depends on rural institutions. There is need to improve capacity of these rural institutions in climate change adaptation strategies.

Conceptual framework



Membership to collective groups was mainly based in accessing financial services such as banking, savings and loan schemes. Established a positive relationship between climate change and group membership. The main group activities that enhanced climate change adaptation included internal group capacity, asset mobilization and management, collective marketing, development of internal group capacity, risk spreading processes and financial resources. Market information and pooling of resources (economies of scale) in accessing input and output markets was important. Collective action tends to reduce transaction cost and compete with other commercial farmers. Enabling factors to collective action included group governance, information flow structures and organizational arrangements. However, there were some challenges in collective action such as free rider problem, limited finance and scope.

12.6 Cluster farming to attract agribusiness contracts

Cluster farming can help access funds, land and machinery useful for farmers to enter formal markets (Cloete, Van Der Merwe, & Saayman, 2015). Farmers in clusters collaborate through buying production inputs together to save costs. Farmers receive support to produce a crop to a specific standard and the joint output is then pooled together, giving the farmers critical volumes.

Marketing agents are eliminated and can compete with commercial farmers at produce markets. Production becomes more profitable and sustainable (Cloete *et al.,* 2015). According to Smalley (2013) cluster farming can benefit surrounding rural economies through technology transfer and other spill over effects.

This can be indispensable in terms of CSA. In terms of exports, clustering is used to meet bulk export compliance to sell their products under larger companies (KPMG, 2012). There is thus need in exploring the prospects of introducing agricultural practices and techniques under CSA. Newsham, Kohnstamm, Naess, & Atela (2018) however noted that cluster farming and contract farming may be compromised by climate impact putting farmers at risk of not complying to meet contract requirements. However, climate change may also present opportunities where prospects of production were previously slim.

In Malawi, AGRA (2014) found that the Clinton Development Initiatives (CDI) utilised the ISFM to enable maize and soya farmers better access to markets through pre-season contracts amongst others.

Besides the yield increases of maize from 2 t/ha to 4.6 t/ha, and soyabean from 0.7 t/ha to 1.3 t/ha, there were 408 additional farmer associations and increased sales to contract buyers. In terms of CSA, this could be an indispensable strategy in orienting farmers towards markets.

12.7 Conclusions

Climate change will have an impact on marketing of agricultural products. Sub Saharan Africa (SSA) countries including South Africa will need to transform and keep pace with climate change. Climate Smart Agriculture (CSA) sustainably achieves food security and development goals and has been identified as a viable strategy to adapt marketing systems in light of changing climate. However, much of the policy in SSA concerning CSA still remains oriented towards the productive sector with little consideration to the marketing sector. The objective of the study was to highlight how practising CSA has affected the structure, conduct and performance of the marketing system in South Africa and SSA in general.

In SSA, agricultural marketing tends to be influenced by market infrastructure and information, contractual agreements, social capital group participation, tradition and expertise, amongst others. This has created a tier system of commercial and smallholder marketing system in terms of access and effects of these factors. Climate change tends to have differentiated effects (requiring differentiated strategies) on the two marketing systems. Some of these differentiated factors pertain to proximity to markets; environmentally friendly marketing systems; greater access to markets (local and international); infrastructure; group marketing; market development; storage and processing facilities; research and development; extension systems; market information systems; institutional transformation; and access to financial services, amongst others.

Financial services are critical in reducing exposure and mitigate effects of climate change, through financing infrastructure, social service, microfinance and development projects. There are various climate change financing instruments available in SSA, South Africa inclusive. What is evident however is that most of the climate change finance was directed towards the productive sub-system, especially pertaining to drip irrigation, water harvesting, drought-tolerant crop varieties, renewable energy, knowledge systems, and best practices. CSA has had little perspective in terms of financing towards the whole marketing system of agricultural commodities in SSA. Access to information has also been an impediment on utilising CSA initiatives in the marketing system of crop commodities in SSA. Farmer groups was also identified as a CSA initiative in SSA but still exhibited the same limitation of concentrating on the productive sub-system relative to others such as the transport, processing and retailing, amongst others. Group marketing improves market access, economies of scale, agribusiness contracts and access to agricultural technologies, and thus adoption of CSA.

13.1 Introduction

In terms of stimulating the uptake of CSA, it is logical to assume that promoting the dissemination of knowledge is an important undertaking. However, 'dissemination of knowledge' does not do justice to the complexity of what is involved in the uptake process. This section seeks to explain why this is the case, in part by looking more broadly at the question of how innovative practices are spread over time.

It is fair to say that the dissemination of knowledge of CSA among South African farmers is starkly divided between the large-scale commercial farming sector, and the small-scale farming sector. The irony is that embrace of CSA is far more advanced in the former, despite the fact that this sector receives almost no government support, in particular extension, whereas in the latter, CSA is little advanced, despite the fact that government support is focused on the small-scale farming sector. According to an assessment by Findlater, "40% of commercial farmers across all grain producing areas of South Africa have adopted all CA principles" (cited in Smith, Kruger, Knot and Blignaut, 2016: 220-221)[1]. While there are no known estimates for small-scale farmers, it is likely not more than 5%.

This discrepancy can be attributed to four factors:

⇒ The relative wealth of large-scale commercial farmers means that they are better able to take up CSA and promote it to one another. For instance, large-scale commercial farmers are in a better position to invest in CSA-appropriate technologies such as no-till planters, but at least as important, some large-scale farmers have taken it upon themselves to promote CSA to their peers, at own expense, for example through active 'no-till clubs' and newsletters. The underlying motivation for adoption of CSA is that it enhances profitability (Smith *et al.,* 2016), while the motivation to promote the approach to one another appears to relate to a concern for the health of the sector.

⇒ Government support to small-scale farmers is generally quite weak, with a small overall footprint. For example, according to Statistics South Africa, over the period 2014-2017, only about 2% of small-scale farmers were exposed to extension support in an average year, although the share reaches about 7% for 'commercially-oriented smallholders' (Aliber and Hall, forthcoming).

⇒ Despite having acknowledged the importance of CSA for a number of years, government has not clearly committed to it. This is illustrated by the fact that government's main cropping programme, called the Fetsa Tlala Food Production Initiative, which commands an operational budget of over R800 million per year (though considerably more if one takes into account the time-contribution of extension staff), has not adopted CSA as a production method. The vast majority of production under Fetsa Tlala is of maize, which in 2016/17 amounted to about 123 000 hectares (DAFF, 2017a), amounting to about one third of the total hectarage of smallholder maize production for that year (CEC, 2017). However, Fetsa Tlala generally works by means of provincial agriculture departments tendering for the services of contractors who undertake the land preparation, with no requirement that they practice minimum tillage, and with no provision for cover crops or crop rotation.

⇒ National government lacks a coherent or functional mechanisation policy or programme, while the same can be said of provincial agriculture departments. In

1. On the other hand, Kassam, Friedrich, Derpsch and Kienzle (2015) estimated that that as of 2013, only about 360 000 hectares of commercial farmland were under CA in South Africa, which would represent about 10% of the area under grains in a typical year. The difference could be ascribed to the fact that larger commercial farmers are less likely to be using CA, or that we cannot have much confidence in our figures.

principle, a strategic mechanisation policy or programme could do much to advance CSA.

Apart from the fact that DAFF is working to finalise its policy on conservation agriculture, there is some sign of change in a positive direction. For example, the draft National Policy on Comprehensive Producer Development Support embraces CA/CSA, even identifying it as a key 'output' in its 'theory of change' (DAFF, 2018). Moreover, the draft National Policy acknowledges the need for a more coherent mechanisation policy and draws a connection between such a policy and the opportunity to promote CSA, while citing the particular challenge of the high cost of CSA-appropriate equipment such as no-till planters. Unfortunately, there is little recognition that most tractor services accessed by small-scale farmers at present are provided by local tractor owners who provide such services as informal SMMEs without benefit of government support, and possibly a more effective strategy would be to support these entrepreneurs, which could include for example subsidising the acquisition of CSA-appropriate equipment and providing intensive training in CSA[2].

Another positive sign is that a few years ago DAFF decided to dedicate 15% of the LandCare budget to CSA/CA, which amounts to roughly R10 million per year. This money is used by provincial agriculture departments among other things to purchase no-till planters appropriate to small-scale farmers (personal communication, K. Mampholo, DAFF, 2018). But this R10 million should also be put in perspective – it represents less than 0.07% of the annual budget going to the agriculture, forestry and fisheries.

13.2 Extension Officers' knowledge of CSA in South Africa and efforts to train them

It is difficult to ascertain the extent of extension officers' knowledge of CSA. Key informants from DAFF and some of the commodity organisations describe extension officers' knowledge of CSA as low, due to lack of training and exposure, although there is gradual improvement over time. What can be said is that because DAFF's conservation agriculture policy has not yet been finalised, efforts to promote understanding and application of CSA have been piecemeal and limited, although they do exist, and appear to be gaining momentum.

Moreover, it should be appreciated that although there are a great many worthy private sector and NGO-based initiatives to support small-scale farmers, collectively they have a very small footprint even relative to the small footprint of government – less than 30 000 black farming households per year, versus the approximately 300 000 receiving support from government (based on an analysis of data from Stats SA's General Household Survey). Moreover, virtually all of those households receiving support from sources other than government, are also among those receiving government support. In the words of Smith et al.,

Smallholder CA promotion interventions are mostly done through projects funded by various agencies, mostly government. Peaks of adoption seem to be reached with some of these projects implemented, while unfortunate declines tend to follow most project completions and the drying up of funds, with only small pockets of enthusiasm and participation remaining. Smallholders' major constraints regarding availability of resources, such as land, production inputs, labour, information, financial means, markets and access to infrastructure, severely limit adop-

2. Zulu-Mbata, Chapoto and Hichaambwa's (2016) quantitative study of the update of CA in Zambia came up with the surprising but logical result that access to local tractor services generally has the effect of discouraging uptake of CA; people hire these tractor services largely to save labour time, but since these service providers are not equipped with either CA-appropriate equipment or knowledge, then that means that in order to preserve the labour-saving benefits of tractor services, they either limit the extent to which they take up CA, or avoid it altogether.

tion of CA. (Smith et al., 2016: 222).

The main vehicle for training extension officers are SETA-accredited short courses, which usually last one week. Every year, provincial agriculture departments spend a fair amount of money on such courses, according to their own particular priorities. However, it should be stressed that, in a typical year, only a small portion of the training offered to extension officers consists of training in CSA/CA (personal communication, G. Gayiya, EC DRDAR, 2018).

As of now, there are various SETA-accredited short-courses that have a bearing on aspects of conservation, including soil conservation, such as unit standard number 116169, 'Understand how sustainable farming systems conserve natural resources', which is a National Qualifications Framework (NQF) level 1 module worth 4 credits; and unit standard number 116121, 'Apply sustainable farming practices to conserve the ecological environment,', which is an NQF level 2 module worth 5 credits. There is also national certificate in 'LandCare Facilitation' requiring 125 credits.

However, the module that is mostly focused on CSA/CA is the 'short course' on conservation agriculture, which contributes to the NQF level 4 national certificate qualification in 'General Agriculture' (qualification code 20290). While the number of service providers accredited to provide this particular course is not clear[3], the number accredited to provide the full General Agriculture qualification is only 26 (SAQA, 2018). Based on some of these service providers' websites, the qualification is typically offered as a one-year course costing about R30 000 per learner; of this, most is in terms of web-based distance learning, while two weeks consist of a 'two-week practical learning component', of which some relates to crop farming[4]. In other words, at best this short course provides an introduction to CSA.

Although the focus of this section is on the extent to which extension could assist in spreading knowledge of CSA/CA, it is also worth bearing in mind that it is often the case that training farmers is not extension officers' only function; in addition, extension officers often serve as the front-line of government in terms of providing material support to farmers. This is certainly the case in South Africa, and some have raised it as a problem, insofar as it seems to encourage a 'culture of entitlement' among farmers (Aliber, Gwala, Yusuf, Rahim, Mushunje, Arwari, Makhunga and Shiliga, 2018). Assisting farmers to take up CSA/CA is often conceptualised as a twofold process involving both knowledge transfer and some kind of material support. While offering material support no doubt encourages the uptake of CA, one should be mindful of the challenges this may pose later on. A recent study trying to understand the lack of uptake of minimum tillage practices in Zambia puts this issue in focus:

The practice of giving handouts in the form of farm inputs, implements, and foodstuffs by projects/programs promoting CF [conservation farming] was identified as one of the causes of variable use rates observed over time. In such a setting, farmers' use of CF technologies may represent a quid pro quo arrangement where they are required to practice some form of CF in order to receive material support. Dis-adoption may follow the next year if the ma-

3. It has proven difficult to get precise information about this short course (e.g. from the AgriSETA and SAQA websites), which in itself is a concern. The short course appears to be an amalgamation of several separate unit standard modules, collectively worth 26 credits relative to the 131 total credits required for the qualification. There is a 23-page assessment guide bearing the logos of DAFF and AgriSETA and dated September 2015, entitled "Conservation Agriculture: Advance Short Course," which indicates a unit standard code of 20290; however, this appears to be erroneous, since 20290 is the code for the qualification of which this short course is only a small part. Most unit standard modules are worth 4 to 6 credits, thus this short course would appear to comprise roughly 5 unit standards.

4. See e.g. https://agricolleges.com/national-certificate-in-general-agriculture/

terial support is discontinued. While development facilitators may argue for smart start-up subsidies, focus group results suggest that failure to continue receiving the subsidy is associated with dis-adoption. (Ngoma, Mulenga and Jayne, 2014: vi)

The authors furthermore conclude that, "There is need to revolutionize development facilitation in the area of CF and design extension programs that provide farmers with incentives to adopt CF practices based on underlying economic viability rather than on the basis of gifts in exchange for adoption" (Ngoma et al., 2014: 36); in other words, extension officers should stay true to their core function of training and facilitating the acquisition of new knowledge; moreover, this knowledge must include not only the techniques of CSA/CA/CF, but a deep understanding of its benefits, such that farmers can make educated decisions of adoption not based merely on the influence of handouts.

13.3 'Farmer-to-farmer' interaction and extension, and the adoption of CSA

There is a vast literature on the diffusion of innovations in agriculture. The classic economic model is that of Griliches (1957), who supposed that when a new method becomes available (whether through organised research or fortunate accident), it is initially adopted slowly by relatively well-off, risk-tolerant 'early adopters', sometimes also called 'pioneers'; then, as awareness of the innovation gradually spreads – often accompanied by refinements and cost reductions – the rate of adoption accelerates; eventually, however, the rate of adoption decelerates towards saturation – ultimately, as many farmers adopt the innovation as find it appropriate or helpful or affordable[5].

Griliches supposed that the rate of adoption was a function of the relative profitability that it had to offer individual decision-makers, but also how informed these decision-makers were, which in turn was largely related to their access to formal channels of information dissemination. However, Griliches' seminal work set off a vast amount of work that pushed the thinking further. Mansfield in particular hypothesised that information imperfections constrained adoption but would diminish in importance as knowledge about of the innovation became better known, not only through formal channels but particularly by means of word-of-mouth communication among one's peers, e.g. actual and potential adopters in one's social sphere (Mansfield, 1961).

The importance of informal transmission of knowledge among farmers is now almost a truism. Studies in developing countries in particular highlight the importance of farmer-to-farmer interaction in spreading information and assisting with the diffusion of innovations. Gathecha, Bowen, Silim and Kochomay (2012), for example, showed that Kenyan farmers' knowledge of improved pigeon pea varieties derived first and foremost from other farmers. Aliber et al. showed that small-scale farmers in the Eastern Cape learned from other farmers more than from any other source, including far more than from government extension officers (Aliber *et al.,* 2018).

The evidence for CSA is less clear. A study on the adop-

5. Graphically, the diffusion process is usually represented by a sigmoid ('S'-shaped) curve in which the horizontal axis is time and the vertical axis is share of farmers adopting. For an almost perfect example, see B. Bellotti and J. F. Rochecouste (2014), Figure 2 on page 25.

tion of minimum tillage in north-east China does indicate the importance of the influence of neighbours and perceived profitability, but these are not necessarily greater than the influence of support from government (Andersson and Halvarsson, 2013). According to a study conducted in Kenya and Uganda, "A diverse group of agents at the meso-level serve as formal sources of agricultural information for village level networks, where horizontal diffusion then takes place as farmers adapt technological advances according to local knowledge" (Gunter, Moore, Eubank and Tino, 2017); in other words, the information initially arrives via formal channels, and is then adapted to local circumstances.

The common thread is that CSA/CA cannot simply be adopted, it must also be adapted to local circumstances, which can be a challenging and time-consuming process. To draw an analogy which will prove instructive below, the same can be said for integrated pest management (IPM). Peshin, Vasanthakumar and Kalra write,

The theory [of diffusion of innovations] is not considered adequate to manage the process of dissemination of IPM technology. The inadequacies may be due to the attributes of IPM innovation as well as due to the sophisticated demands of IPM technology that was not amenable to the limited version of the theory…. IPM is a combination of different technologies that has not diffused as other … technologies. Diffusion of IPM requires educating the farmers for its adoption and it must deal with farmers' needs, perceptions, constraints, objectives and its complex demands. IPM is location specific and it requires several years of experiments, trials, repetitions and validations in a given area. It requires a clear understanding about the IPM tactics. The IPM tactics may vary from crop to crop and area to area. It needs a planned strategy of imparting knowledge and skill and active learning and active adoption by the farmers. (Peshin et al., 2009: 1)

Even though Griliches and others identifying with the technology diffusion acknowledge the importance of local adaptation, for IPM, the extent of local adaptation – and in particular the incessant nature of adjustment and refinement and, indeed, further innovation – is qualitatively greater to the point that 'adoption' is too simplistic a conceptualisation.

The same can be argued for CSA. Putter and others have explicitly made the point that the adoption/adaptation of CSA presents similar challenges to that of IPM, and thus requires similar measures. To the extent farmers learn from one another, it is in an active/inter-active manner that does not sit easily with the traditional notions of diffusion.

In recent years 'farmer-to-farmer extension' approaches have been seen as a strategic means of capitalising on the fact that farmers readily learn from one another; their other advantage is that they can compensate for the fact that government extension services are failing to reach farmers in sufficient numbers (Kiptot, Karuhanga, Franzel and Nzigamasabo, 2016). Judging from the literature, most formal farmer-to-farmer extension approaches adopt some kind of 'training of trainers' strategy, which in turn is not dissimilar to the 'master farmer' approach that has been around for some decades. The idea is that relatively progressive or successful local farmers become 'lead farmers' who can serve as an intermediate tier between the formal extension service and farmers, thus effectively expanding government's reach at a reasonable cost. There have been few studies on the efficacy of such approaches in promoting CSA. One recent study conducted in Malawi found that:

…motivated lead farmers are more effective at diffusing CA practices to their followers. Second, lead farmer familiarity with and adoption of CA both matter to the spread of CA practices, but familiarity appears to matter more. Third, lead farmers are found to play a more critical role in increasing awareness than adoption of the CA practices.

Finally, F2FE [farmer-to-farmer extension] is a complement rather than substitute for other sources of agricultural extension in Malawi's pluralistic extension system. (Fisher, Holden, Thierfelder and Katengeza, 2018: 322).

This is not a very encouraging assessment. The reason would appear to be that, even if this common approach to farmer-to-farmer extension does represent a strategic way of extending government's reach, it does not necessarily embrace or encourage a different pedagogy to conventional 'training and visit' extension, which is premised on the notion of encouraging the diffusion of innovations.

Another recent study involving 325 semi-structured interviews conducted in 85 communities across 20 case study locations in six countries (Ethiopia, Kenya, Uganda, Malawi, Zambia, and Mozambique), also offered a rather sobering assessment. The first concern is that lead farmers are often perceived by other farmers as not having reliable knowledge to share. That presumably could be dealt with through more careful selection of lead farmers, and/or more robust efforts to train them.

The second concern is more social in nature, and possibly less tractable. The issue is that many farmers who would in principle benefit from interaction with the lead farmers, either feel reluctant to approach the lead farmer, or worse, feel excluded from the lead farmer's 'group'. It is worth quoting the study at length:

Respondents identified informational exchange mechanisms as the primary constraint to their access to community informational resources. Emotive language was used by all respondents to describe their attempts to obtain information, such as 'forgotten', 'worry', 'difficult', 'abandoned', 'hard', and 'struggle'. The primary driver of these concerns was the need for invitation to learning opportunities, which were perceived to be lacking (e.g. 'If they [lead farmers] invite me I will go but they didn't come to ask me' – J16; 'You cannot go somewhere where you are not invited' – E10). This underscored an element of passivity in obtaining information from those within their community (e.g. 'someone should come and invite me. I cannot just go and join a group just because I want to learn' – Y23) and the 'burden' of informational exchange was placed on the lead farmer, and not with the individual (e.g. 'I don't know [how to obtain invitation]. I always hear after they have gone. I am never invited' – Q22).

The majority of respondents further perceived a lack of proactive engagement from the lead farmer in their community (e.g. 'they [lead farmers] have not come out and talked to people to tell them what to do and what benefits they will reap' – E9; 'He [the lead farmer] has never trained anyone in this community and we just hear that he has his own group' – J13). Respondents also tended to perceive lead farmers as actively unwilling to engage with them (e.g. 'I have been asking [the lead farmer] about the new system but he always told us that other people would come to teach us' – G8; 'when I go to [the lead farmer], he gives the phone number to ring someone else' – Q22). Such experiences were common across respondents, suggesting more than a disgruntled minority may exist beyond the study respondents. This perceived lack of opportunity to learn manifested as jealousy towards lead farmers and those connected to lead farmers (e.g. 'It's like a secret organization because they have their own people and what goes on in that group is done by the group members only' – J13), often because there was a perceived blockage of information reaching the community (e.g. '[the extension officer] passes through and visits the lead farmer and what happens there is not known' – Z11). (Brown, Llewellyn and Nuberg, 2018: 199).

A more encouraging picture of the role of farmer-to-farmer extension supporting CSA is given by Degrande and Benoudji (2017, p.18): "F2FE approach is efficient for promoting CA, provided the training is practical and accompanied by a regular follow-up of pilot farmers by expert-trainers". However, the initiative they are 'assessing' is their own, moreover it does not appear be modelled on T&V style extension, but rather on farmer-centred innovation (see next section).

13.4 Use of Farmer Field Schools for CSA knowledge dissemination

While there are various alternative extension approaches around the world, one that has gained much attention over the years is Farmer Field Schools. Started in Indonesia in the late 1980s, Farmer Field Schools (FFSs) are a group-based learning process whereby farmers meet on a regular (e.g. weekly) basis at a designated site, assisted by a facilitator (Pontius, Dilts and Bartlett, 2002). The group-based, facilitated process is not the only distinguishing feature of FFSs; arguably the most essential element of the approach is that it prioritises the importance of farmers learning for themselves and from one another through direct experience, as opposed to being passive recipients of information and technologies provided by others, e.g. extension officers (Duveskog, 2013). This does not preclude accessing 'external' information and technologies; rather in principle it means that farmers will be more selective and effective users of such information and technologies (Duveskog, 2013)[6].

FFSs have now expanded to many parts of Sub-Saharan Africa (Davis, Nkonya, Kato, Mekonnen, Odendo, Miiro and Nkuba, 2012). The FFS approach is gradually gaining attention among development actors as a community-based, demand-driven, non-formal education method that appears to meet both the technological and social needs of farmers. Farmer Field Schools have proven to be a cost-effective way of helping small-scale farmers to realise their potential and become more self-reliant, in particular by facilitating a process by which they become better able to understand their challenges, learn and adapt (Braun, Jiggins, Röling, van den Berg and Snijders, 2005). When initiated with care, Farmer Field Schools are able to catalyse a learning and sharing culture of agricultural expertise, which means the 'contact time' with government extension officers has potentially far greater impact than through the conventional 'training and visit' approach.

When FAO developed the FFS approach in Asia in the 1980s, the rationale in large measure was to reduce farmers' dependence on insecticides, in particular by empowering farmers to adopt IPM. The thinking was that IPM requires a high degree of observation, judgement, adaptation, and continuous reassessment, which is why the FFS approach emphasises the nurturing of farmers' skills in these areas, rather than merely adopting new techniques or technologies. For a similar reason, the Conservation Agriculture Academy has proposed that for South Africa, conservation agriculture could serve as the focus for FFSs (CAA, 2013), i.e. because conservation agriculture is a knowledge- and adaptation-intensive strategy rather than a given set of techniques that can be taught, learned and adopted. Kassam, Friedrich, Shaxson and Pretty (2009), and Smith et al. (2016), have made precisely the same point regarding CSA/CA. Farmer Field Schools could thus involve farmers directly in context-appropriate innovation towards the establishment of locally-workable CSA systems.

6. Even outside of Farmer Field Schools, the principles of experiential learning are being increasingly recognised by extensionists, and not only in developing countries. In a study of extension among beef and sheep farmers in New Zealand, it was concluded that, "The affordances for learning and practice change include belonging to a learning community, enhancing self-efficacy, engaging with scientists, seeing relative advantage, reinforcing and validating learning, supporting system's integration and developing an identity as learners" (Sewell, Hartnett, Gray, Blair, Kemp, Kenyon, Morris and Wood, 2017: 313).

However, the FFS approach has been little tried in South African conditions, and even less studied. In the mid-1990s, the then Northern Province's provincial agriculture department experimented with a kindred approach called 'participatory extension,' with support from GTZ (now GIZ) (Hagmann and Chuma, 1999). However, the pilots only lasted a few years and the approach was not sustained. In the late 1990s, the Agricultural Research Council initiated a pilot near Bergville, KwaZulu-Natal using an 'experiential learning' approach modelled loosely on Farmer Field Schools, and discovered that, although time consuming initially, the process was far more effective than conventional extension, both from the perspective of improving productivity, and of natural resource management (Smith, 2006).

However, it can also be argued that in South African conditions the potential of FFSs as a vehicle for promoting small-scale farmers, faces limits. An important issue here is the 'density' of farmers. The frequency and regularity of meetings is part of what makes the FFS effective, however it also means that the approach is most likely to work where at least a few dozen farmers live close to one another. This is why Fort Hare found it easy to establish FFS-style study groups of home gardeners, but would have struggled to do so for field crop farmers, given that in most of the former Ciskei, field crop farmers are relatively few and far between. Having said that, Grain SA's Farmer Development Programme also makes use of study groups, seemingly by means of focusing on parts of the country where small-scale grain farmers are more prevalent.

DAFF's draft policy on CA makes numerous references to the FFS approach, for instance:

Government should invest in CA capacity by supporting short to long-term innovation processes and events, which will include farmer-led experimentation, learning workshops, conferences and farmers' days, study groups, farmer field schools and farmer-to-farmer mentorship. These activities are vital in ensuring participation and innovation that compliment research and extension and promote collaboration and information flow between stakeholders. Using farmers' fields for experimentation and demonstration as part of participatory learning and action research is suggested, as this is where innovation typically takes place. (DAFF, 2017b: 12)

The language strongly echoes what is happening already thanks to 'CA Farmer Innovation Programme for Smallholders' (see below). The question is whether government will be able to live up to this vision, or whether it will rather remain a relatively confined activity undertaken by civil society. Certainly, it will require a giant leap from what exists now, namely a brief short-course on conservation agriculture.

13.5 Case studies

This section presents two rather dissimilar case studies. The first is of the 'CA Farmer Innovation Programme for Smallholders' undertaken by the Mahlathini Development Foundation in collaboration with Grain SA. And the second is based on an article by Bellotti and Rochecouste (2014) regarding the uptake of CA by commercial farmers in Australia. The commonality between these two cases is the importance of interaction of farmers in pursuit of local innovation.

Box 13. 1: Case study 13 1: The CA Farmer Innovation Programme for Smallholders

The CA Farmer Innovation Programme for Smallholders began in 2013 with financial support from the Maize Trust. It operates in three main areas, namely the Bergville region of KwaZulu-Natal, north-eastern Eastern Cape and southern KwaZulu-Natal, and the KwaZulu-Natal Midlands. Within each of these areas, the programme was initiated in multiple sites, and over time has 'scaled out' to additional sites. Presently, there are several dozen villages involved in all, and collectively in the order of 400 to 500 active farmers. The annual costs are in the order of R1.5 million.

The overall purpose of the programme is to develop and refine an approach to promoting local innovation systems in CA that has the potential to both deepen and spread. The programme is based on the Farmer Field School approach but with a particularly strong approach on innovation, as the name of the programme implies. The central elements of the programme are 'farmer learning groups' supported by local facilitators:

> *Within the learning groups farmer innovators volunteer to set up and manage farmer-managed adaptive trials as the 'learning venues' for the whole learning group. Farmer Field School (FFS) methodologies are used within the group to focus the learning on the actual growth and development of the crops throughout the season. New ideas are tested against the 'normal' practise in the area as the controls. Farmers observe, analyse and assess what is happening in the trials and discuss appropriate decisions and management practices. Small information provision and discovery-learning (training) sessions are included in these workshops/ processes. These are based also on the seasonality of the crop and the specific requests and questions from farmer learning group participants. (Kruger and Smith, 2017: 5)*

As is type of the FFS approach, the programme seeks to use the learning groups to raise awareness of and encourage interest in CA more broadly in the community, for instance through "local learning events and farmers' days". However, the programme also includes important embellishments to the basic FFS approach:

> *As learning groups mature they engage in a number of additional processes within the value chain that build social capital and cohesion. VSLAs (Village savings and loan associations) are set up to provide a mechanism for payment for inputs and for setting up bulk buying groups for production inputs. Farmer centres are set up and managed locally (at village and nodal level) to provide for local access to inputs through negotiated agreements with local suppliers and agribusiness, management of shared tools and advice and mentoring in CA. Learning group members also negotiate joint decisions around their crop production planning and marketing and engage with stakeholders and support organisations. To support this process a social compact agreement has been designed to outline roles and responsibilities of the various role players in these forums. (Kruger and Smith, 2017: 6)*

Because the emphasis is on learning-by-doing and innovation, the field trials are diverse (e.g. intercropping patterns, use of cover crops, planting dates, crop varieties, lime application methods, etc.), and the different sites generate a great deal of data. The annual reports put out by Mahlatini and Grain SA reveal the trends in considerable detail, both in terms of yields, soil organic carbon, soil nitrogen, liming requirements, various measures of soil fertility, etc. There are various indications of improvement over time, however, because CA is not a 'quick fix', as of now the results are not unequivocal. On the other hand, there is some suggestion that the benefits of the programme are greater than the data suggest: "For this year the comparable yields are probably due to the fact that quite a number of the longer term participants are now planting their control plots under CA as well," meaning that there is no longer such a clear distinction between CA and non-CA plots.

Not everything is perfect or easy. For the north-eastern Eastern Cape and southern KwaZulu-Natal part of the programme, it appears that the KZN part is progressing well, whereas in some of the communities in Eastern Cape there is "waning interest". In the KZN part, there is a clear distinction between the homestead plots and outlying fields, and for the most part participating farmers only practice CA in the former, because they lack assistance with mechanisation with which to manage the latter. At the same time, government provides some tractor services in these areas, but promotes a very different technological package, perhaps contributing to a confusing picture. However, the candour of the reports serve to make the reported accomplishments that much more believable, and these appear to be considerable, not least as indicated by discernible improvements in soil health and the rapidly growing number of participants. Having said that, one wonders what the growth potential of the initiative is, or should be. As some of the implementers of the programme have themselves acknowledged in their academic writing, uptake of CSA happens while funded projects remain funded, following a large share of these gains are lost. This is why the transition from temporal projects to mainstream (i.e. government-led) programmes is so essential, but in South African and elsewhere – and whether one is talking about CSA or some other important, challenging area of change – said transition often fails to happen to the desired degree, or at all.

Box 13. 2: Case study 13 2: Seemingly spontaneous uptake of CSA/CA among commercial farmers in Australia

Turning now to the Australian case study, the rich article by Bellotti and Rochecouste attempts to show the intricate ways in which different role players interact: "The process of farmer innovation is characterised by a complex web of influences that evolve with time" (Bellotti and Rochecouste, 2014: 27). Moreover:

> *Typically, farmers are influenced by extension agronomists, but agronomists are also strongly influenced by innovative farmers who in turn influence other farmers…. Farmers may adopt a research concept, test and refine it in the field to find in-situ solutions that are passed on to others to do likewise, which in turn may influence other actors to extend the process…. Although simple in concept, it is a complex human process and it is difficult to attribute direct influence. Farmers often obtain information from various sources before making a decision, and the adaptation process often occurs over many cropping seasons. Furthermore, there are often generational influences and a family context in the process. (Bellotti and Rochecouste, 2014: 26)*

The article describes how the processes of CA experimentation and uptake have evolved in five areas, namely Queensland, New South Wales, Western Australia, South Australia, and Victoria. Although the vignettes are brief, they reveal the diverse ways in which the process of CA uptake has unfolded in different places, for example in terms of who the main actors and interactions were, and how exactly production processes were adapted over time. In Victoria, for instance, it was the drought of 1982 that galvanised a core group of farmers to begin experimenting with no-till. Although the process took many years, "A common theme is that farmers are not waiting passively for solutions to be offered; rather, they see a need for change and go looking for answers" (Bellotti and Rochecouste, 2014: 28) which they did in a variety of ways, whether by conducting their own experiments or visiting one another. In New South Wales, some of the early adopters immersed themselves in soil science; then, when the greater dependence on pesticides due to CA resulted in herbicide-resistant weeds, they needed to master IPM as well. Queensland farmers eventually began experimenting with Global Navigation Satellite Systems in order to seek efficiencies (e.g. in input use) through pursuit of Precision Agriculture. However, despite these differences, the different regions have experienced remarkably similar patterns up uptake over time, from less than 10% as of 1980, to not less than 80% in 2008.

As much as the Australian case resonates with the CA Farmer Innovation Programme for Smallholders discussed above, insofar as they both are steeped in farmer-centred experiential learning, the differences are also stark, and revealing. The critical difference is that the resources available to the Australian farmers are vastly superior to those available to the South African smallholders, even taking into account the support the latter receive from the programme. For instance, the Australian farmers have the capital with which to purchase CA-appropriate equipment, indeed they even constitute such a meaningful market that "Local machinery manufacturers realised the business opportunity and were keen to support this change by demonstrating their own modified machinery; the development of no-till seeding machinery was principally driven by farmers and manufacturers" (Bellotti and Rochecouste, 2014: 25). Moreover, some commercial farmers hired their own consulting agronomists, while other farmers had their own agronomy qualifications. Finally, the various no-till clubs were able to run a variety of research and development projects thanks to funding from government and industry sources.

13.6 Conclusions and recommendations

Even while CSA/CA has been taken up by large-scale commercial farmers at a rapid pace, uptake among small-scale farmers has been slow and sometimes halting. Large-scale commercial farmers have shown their ability to adopt and adapt CSA/CA spontaneously, but have also benefitted from support from industry bodies and government. Meanwhile, there is little evidence of spontaneous uptake of CSA/CA among small-scale farmers, and even where there has been relatively copious, government and donor partner support for CSA/CA, limited results have been seen to date. This is perhaps surprising given the apparently huge advantages that CA has to offer. In South Africa, very little attention to promoting uptake of CSA has been exerted to date; as the country gears up to increase its focus on promoting uptake, it must consider lessons from elsewhere.

It would appear that large-scale farmers have a number of advantages over small-scale farmers when it comes to considering whether or not to take up CSA, but arguably the largest is the capacity and inclination to experiment, learn and adapt. It therefore stands to reason that assisting small-scale farmers to do the same might be strategic. This in effect is what the Farmer Field School approach seeks to do, and the example of the CA Farmer Innovation Programme for Smallholders described above would appear to be best practice. However, it is very clearly not a 'quick fix' approach. To the extent there will be attempts to promote uptake of CSA/CA by means of training extension officers, it must bear these lessons in mind; CSA/CA is not a set of techniques that can simply be taught, it is a 'mind-set' to be cultivated and nourished over a sustained period. Neither conventional T&V extension, nor a lead farmer approach that merely extends T&V, are capable of doing this.[7] The question is whether South African extension officers can be genuinely equipped to do this. The recommendation is that the CA Farmer Innovation Programme for Smallholders be used as a model on the basis of which a core of government extension officers could be empowered to promote CSA/CA in the same fashion, perhaps starting with pilots in a number of provinces.

7. A distinction is in order: the CA Farmer Innovation Programme for Smallholders also uses a lead farmer approach, the difference is that these lead farmers are embedded in a participatory/experiential co-learning environment, and are supported by the programme to perform their role in that spirit.

14.1 Introduction: gender and agriculture in Africa

It has long been recognised that women and men farmers in Africa tend to perform different roles, bear distinct responsibilities, have access to different resources, and enjoy different degrees of autonomy with regard to their farming (FAO, 2011; O'Sullivan, Rao, Raka, Kajal and Margaux, 2014; Quisumbing, Rubin, Manfre, Waithanji, van den Bold, Olney and Meinzen-Dick, 2014; World Bank, 2008). Much of these differences can be ascribed to the fact that women and men farmers farm within different social and familial contexts, with women seeking to balance farming with other tasks, and often bearing primary responsibility for feeding and caring for children (Quisumbing *et al.,* 2014).

The situation is complex because both cultures and agricultural systems across the continent are of course diverse. But it must also be borne in mind that women may occupy different positions in the household; for example, they may be actual or effective household heads, or they may be spouses (usually in male-headed households), or they may be adult children within either male or female-headed households.

The cumulative effect of these disadvantages is that, hectare for hectare, women are estimated to be less productive than men from 8% to 40% depending on the country and crop (Thiessen, 2016). The underlying consideration is women's welfare, with a number of considerations coming to the fore such as women's right to make decisions or participate meaningfully in decision-making, labour allocation, benefit sharing, etc. For those not acquainted with the literature on African farming systems or the literature on intra-household welfare dynamics, one perhaps surprising reality is that the classical 'Beckerian household' whereby household members behave as though there is no real distinction between what is in their individual interest and what is in the interest of the household, cannot be assumed to prevail, as will be illustrated.

To the extent women bear a large share of the burden of farming while appropriating relatively little of the benefits[8], one would anticipate that this will change over time as patriarchy more broadly is challenged. Notwithstanding change over time, in broad terms the distinctions remain in place: "Although gender roles and responsibilities are undergoing significant change in different parts of the continent, African farming systems and the wider policy environment generally remain strongly gendered" (Farnworth, Baudron, Andersson, Misiko, Badstue and Stirling, 2016: 143). Signs of improvement are perhaps more evident in domains where legislation may lead the way, for example in the Ugandan parliament's decision some years ago to allow for 'family title' to land as a means of breaking with the tradition of vesting land rights in the male household head.

Climate change has tended to affect women farmers disproportionately, because they start from a position of relative weakness and have limited resources with which to adapt:

Linked farm household-, intra-household-, community-, and institutional-level data highlight significant and nuanced gender differences in adaptive capacity of individuals and communities to respond to climate change.

The gender gap is also substantial in exposure to climate change and its impacts, and uptake of new practices that lower vulnerability. Women in agriculture will remain

8. It is often stated that in Africa women contribute 60% to 80% of agricultural labour, e.g. FAO, 1995. However, it seems this figure can be traced back to a single 1972 United Nations report which itself depended on guesswork. A more recent, authoritative estimate, based on a number of national household surveys, is that women contribute roughly 20% to 50% of all agricultural labour in Africa, with no consistent distinction between staple and cash crops (Palacios-Lopez, Christiaensen and Kilic, 2018).

largely neglected by information and service providers unless their differing needs, access to, and control over resources are considered at policy and project design stage. Yet clear guidelines for addressing the needs of both men and women in different environments and agricultural systems are still lacking. (Kristjanson, Bryan, Bernier, Twyman, Meinzen-Dick, Kieran, Ringler, Jost and Doss, 2017)

To the extent technologies may exist that mitigate the impact of climate change – e.g. CSA/CA, as discussed more below – women are less likely to know about them, to receive support to take advantage of them, or to have the resources with which to take advantage of them.

Behrman et al. (2014) present a graphic that, despite its apparent simplicity, captures some of the real-life complexity. In the first place, the "vulnerability context" in which farmers find themselves has a number of discernible dimensions, in respect of which women farmers tend

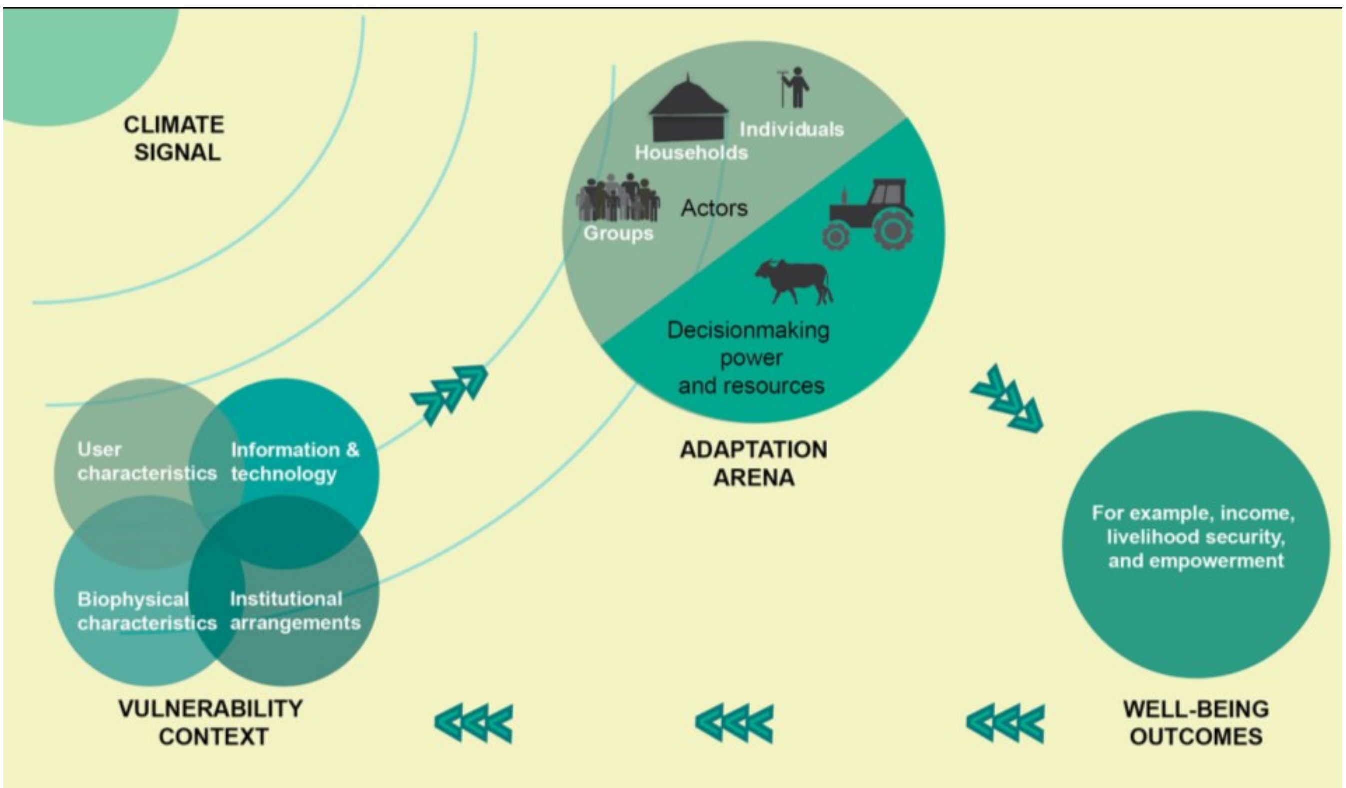


Figure 14.1: Framework on gender, agricultural development, and climate change
Source: *Behrman et al. (2014), reproduced in Kristjanson et al., 2017, p.486*

to be at a disadvantage relative to men farmers.

The scope for adaption (conceptualised as taking place in the 'adaptation arena') (Figure 14.1) can be understood as involving a range of tiers of agency and influence, in relation to which the farmer may or may not have the resources with which to effect adaptive changes:

Women often have less bargaining power and fewer assets and other resources identified as essential for adaptation. Moreover, given gender differences in resources, assets, decision-making authority, and roles within the household and community, we would expect that men and women have different preferences, needs, and priorities for adaptation. (Kristjanson et al., 2017: 485).

It is therefore incumbent on development authorities and practitioners to design and promote "gender-responsive climate-smart agricultural practices." Without this, interventions to promote CSA/CA may pass women by, or even threaten to further disadvantage them (Beuchelt and Badstue, 2013). According to Bryan, Bernier, Espinal and Ringler (2017), challenges include,

Lack of staff capacity on gender, lack of funding to support gender integration, and socio-cultural constraints [are] barriers to gender integration..., particularly from government agencies. Enabling organizations to pay greater attention to the gender dimensions of their programmes is possible through greater collaboration across different types of organizations in order to share knowledge and best practices and strengthen the integration of research into adaptation programmes. (Bryan *et al*., 2017: 417)

However, according to various analyses, the reality is that the gender gap is rarely taken into account when new policy and programmes are being designed (Farnworth *et al*., 2016). Even when policies are designed that are sensitive to the needs and circumstances of women farmers, the implementation tends to be done in such a way that the women-specific considerations are neglected (Ampaire, Acosta, Kigonya, Kyomugisha, Muchunguzi and Jassogne, 2016). Even a function as routine and mundane as agricultural extension has been shown to put women farmers at a disadvantage, in that in some countries the extension support women receive has been shown to be inferior in quantity and quality to that offered to men farmers (Lamontagne-Godwin, Williams, Palitha, Bandara and Appiah-Kubi, 2017), despite no doubt a pledge to gender equity in that regard.

14.2 Small-scale women farmers in South Africa

Before proceeding with the discussion of gender and CSA, it is worthwhile to pause to glance briefly at what the survey data reveal about small-scale, black women farmers in South Africa. Unfortunately, the recent survey data are only at household level, which only allows one to distinguish female-headed from male-headed households. Based on data from Statistics South Africa's General Household Survey, Table 14.1 summarises, averaging over the past three years.

Table 14.1: Female-headed and male-headed farming and non-farming households, 2015-2017

	Female-headed	Male-headed	Total
Farming	777 603	599 860	1 377 462
Not farming	1 055 678	1 147 776	2 203 455
Column sums	1 833 281	1 747 636	3 580 917

Source: *Stats SA, various and own calculations*

Note: 'Farming' is taken to mean any involvement in garden/crop/livestock production, regardless how large or small

Based on the above, some simple percentages can be derived:

⇒ Share of rural households that are female-headed = 51%.

⇒ Share of rural households that are farming = 38%.

⇒ Share of rural farming households that are female-headed = 56%.

⇒ Share of female-headed households that are farming = 42%.

⇒ Share of male-headed households that are farming = 34%.

In other words, in rural areas, male-headed households are slightly outnumbered by female-headed households, which in turn are quite a bit more likely than their male-headed counterparts to be involved in farming.

Tables 14.2 and14.3 seek to go a bit further by looking at numbers of households involved in grain and livestock production, respectively. Both tables disaggregate in three ways: according to the gender of the household head, according to whether the household qualifies as a subsistence producer or smallholder household, and according to 'geotype'.

The distinction between 'subsistence' and 'smallholder' is based on the South African government's usage of the terms, whereby 'subsistence' producers are those who farm mainly for the purpose of producing food for own consumption, and 'smallholders' are those who farm mainly for the purpose of deriving an income, even if it is often not the household's main source of income.

The threefold 'geotype' variable refers to the type of area in which the respondent household resides: 'urban' households include those who live in cities and towns; 'traditional' refers to the rural parts of the former homeland areas (i.e. excluding the towns, which count as 'urban'); and 'farms' refer to the rural parts of commercial farming areas. By way of clarifying, it should be pointed out that households of the 'farms' geotype are not mainly land reform beneficiaries as one might have assumed.

In terms of grain production, the majority of households involved are female-headed subsistence producers within the former homelands; and the next most populous group are male-headed subsistence producers within the former homelands households.

Smallholders and households residing in urban areas or commercial farming areas account for relatively small shares of households involved in grain production, though it is possible that they account for a larger share of area planted or grain harvested. Among the relatively small numbers of smallholder households, male-headed households tend to dominate, but not by a vast margin.

Table 14.2: Estimated numbers of black households involved in grain farming, 2015-2017

	'Urban'	'Traditional'	'Farms'	Totals
Female-headed HHs, subsistence	35 894	637 244	22 908	696 046
Female-headed HHs, smallholders	1 075	13 951	844	15 871
Male-headed HHs, subsistence	31 692	431 646	18 725	482 063
Male-headed HHs, smallholders	2 898	16 333	4 467	23 698
Totals	71 560	1 099 175	46 945	1 217 679

Source: *Stats SA, various and own calculations*

Note: 'subsistence' is taken to mean households who indicated that their main reason for farming was to produce food; and 'smallholders' is taken to those who indicated that their main reason for farming was to derive an income.

In respect of black households involved in livestock production – which, incidentally, excludes poultry – the pattern is roughly the same as for grain production, although the gap between the numbers of subsistence producers and smallholders is not as extreme. The figures also belie the stereotype that men are more likely to own livestock than women.

Table 14.3: Estimated numbers of black households involved in livestock farming, 2015-2017

	'Urban'	Traditional	Farms	Totals
Female-headed HHs,	11 205	365 639	24 606	401 450
Female-headed HHs,	3 071	43 283	1 872	48 226
Male-headed HHs, subsist-	24 708	297 917	25 512	348 137
Male-headed HHs, small-holders	8 006	50 998	9 838	68 842
Totals	46 991	757 837	61 827	866 655

Source: *Stats SA, various and own calculations*

Note: 'subsistence' is taken to mean households who indicated that their main reason for farming was to produce food; and 'smallholders' is taken to those who indicated that their main reason for farming was to derive an income.

Tables 4 and 5 explore the issue of land size, specifically the size of land on which households engage in grain production. Table14.4 shows the disaggregation by geotype. As one might expect, those households residing in commercial farming areas are more likely to have larger plots that households in traditional areas, which in turn tend to have larger plots than those accessed by households in urban areas. On the whole, however, it is striking how the vast majority of households' access very small amounts of land for grain farming.

Table 14.4: Land sizes of black households involved in grain farming by 'geotype', 2015-2017

	Urban	Traditional	Farms
< 0.5 hectare	95.5%	84.6%	77.9%
≥ 0.5 and < 1 hectare	3.4%	12.6%	12.7%
≥ 1 and < 2 hectares	0.0%	1.7%	3.0%
≥ 2 hectares	1.1%	1.1%	6.4%
All	100.0%	100.0%	100.0%

Source: *Stats SA, various and own calculations*

Table 14.5 shows the disaggregation by gender of the household head. Women appear to have a disadvantage, in that a higher proportion are confined to less than half a hectare, however the difference is not stark.

Table 14.5: Land sizes of black households involved in grain farming by gender of the household head, 2015-2017

	Female-headed households	Male-headed households
< 0.5 hectare	86.4%	83.0%
≥ 0.5 and < 1 hectare	11.5%	12.8%
≥ 1 and < 2 hectares	1.3%	2.2%
≥ 2 hectares	0.8%	1.9%
All	100.0%	100.0%

Source: *Stats SA, various and own calculations*

Finally, in order to get more detail on the involvement of South African women in agriculture, one has to go back to 2007.

Table 14.6 provides some idea of the participation of women and men in agriculture at that time, in terms of their place in the household, i.e. distinguishing between those who were active in farming who were themselves household heads, versus those non-household heads who were active in farming within male-headed and female-headed households.

While women agriculturalists outnumbered male agriculturalists across the board, the fact that in aggregate there were many more women than men involved in farming is largely due to the much larger number of non-household head women relative to men who farmed within male-headed households (954 000 vs 315 000).

While these women were still outnumbered by women household heads who farmed, it still means that a major and arguably under-recognised clientele for agricultural support services are women agriculturalists within male-headed households.

Their agricultural roles and responsibilities may well be different, since women are generally responsible for food supply, irrespective of the gender of the household head. Underlining this point is the fact that of these women agriculturalists within male-headed households, in about 40% of the cases the male household head was not himself active in agriculture (not shown in table).

Table 14.6: Involvement of women and men in agriculture according to position in household

	Women engaged in agriculture		Men engaged in agriculture	
	Number	Share	Number	Share
Household heads	1 164 380	43%	964 827	55%
Reside in male-headed households	954 383	35%	314 756	18%
Reside in female-headed households	571 823	21%	486 825	28%
Total	2 690 586	100%	1 766 408	100%

Source: *Hart and Aliber, 2010: 80; based on data from Stats SA, 2007*

14.3 Potential of CSA to contribute to gender equality and women empowerment

There are numerous claims to the effect that CSA has particular potential to uplift women in Africa, and that in fact it is already doing do. There are also claims that CSA is spreading very slowly in Africa, and also that CSA packages often fail to take women's circumstances into account, which is why women are especially unlikely to take up CSA, or are especially likely to 'dis-adopt' where they did take it up. Some of these differences could be ascribed to the fact that these studies cover a wide range of African countries; on the other hand, a large share of the research literature focuses on Zambia, wherein one also finds both these claims and counter-claims.

Before beginning to present some of the evidence, it is worth quoting a very thorough and reasonably recent review article on precisely the question of women benefitting from CSA/CA:

The costs and benefits of CA adoption to women themselves – in terms of income, labour deployment, contributions to food and nutrition security, relative decision-*making power at household and community level, and potential deepening and widening of their integration into value chains and extension networks – remain largely unknown. Even less is known about whether CA provides an opportunity for women to alter existing gender relations in their favour, and, if so, under which conditions. (Farnworth et al., 2016: 143)*

In other words, as of now there are no hard and fast answers to the question whether in general CSA benefits women farmers, although there is certainly some evidence to suggest that CSA at least *sometimes* benefits women. Examining the evidence reveals how complex the question actually is.

Based on their study of CSA uptake in Zambia, Umar and Nyanga (2014) state that:

The results show that CA improved crop yields, and nutrient use efficiency; gave more stable yields during periods *of moisture stress, and above normal rainfall; resulted in more diversified crop combinations; and was welcomed by women farmers as it encouraged the production of food legumes. CA adoption was also associated with a reduction in the use of purchased inputs and more use of locally available resources. CA is thus a sustainable intensification agricultural system that could help the many women farmers in Zambia that currently face low crop productivity due to unreliable access to agricultural inputs. (Umar and Nyanga, 2014: 69).*

The importance of increasing and stabilising yields is perhaps self-evident, but it should be stressed that stability in particular is especially a virtue for vulnerable individuals or households who have minimal capacity to self-insure against downside risk. The point about reducing the reliance on purchased inputs is a bit more obscure since the study quoted above does not indicate what these might have been, and this issue in fact is central to why the reality of CSA seems to be so heterogeneous.

On close inspection, there is a large number of variables and issues at play, however, the most commonly cited factor that appears to be central to this apparently contradictory picture is the role of labour requirements. The agreed point of departure is that, more so than men, women are time-constrained by virtue of the gendered division of labour, which among other things means that women bear primary responsibility for childcare and food preparation, and – what gets mentioned less often – care for the elderly and infirm, responsibility for husband's fields, etc. In addition, the gender division of labour within agriculture is often such that women's farm-related tasks are especially time-consuming, such as manual land preparation (where alternative forms of land preparation are absent) and weeding (Farnworth et al., 2016). Thus, there is little dispute that in order for women to take up a potentially advantageous innovative practice, it cannot add significantly to women's labour burden, and should preferably reduce it. On the other hand, according to some research, women household heads are at a greater disadvantage than married women (Namonje-Kapembwa and Chapoto, 2016).

Land preparation is one area where CSA/CA appears to offer major labour-time savings. According to a study of farmers in Malawi, "throughout the year the labour requirement for conventional agriculture was consistently higher; Conservation Agriculture reduced the labour demand by an average of 34-35 days compared to conventional agriculture (Maher, Wagstaff and O'Brien, 2015: 232)." In addition:

Conservation Agriculture presented a less intensive labour calendar; the cultivation period extended from June to May, compared to October to May under conventional agriculture. This is due to land preparation beginning earlier under Conservation Agriculture as fields can be prepared during the dry season, whereas under conventional agriculture ploughing is only possible once the soil has been softened by the rains. (Maher et al., 2015: 233)

Umar and Nyanga's study of Zambia also found "significant savings in labour" associated with ripping or traction CSA/CA as compared to conventional ploughing (Umar and Nyanga, 2014: 72).

But it is important to be clear about what comparisons are being drawn, as well as about the further implications of the approach to land preparation. Umar and Nyanga were comparing animal or tractor-powered minimum tillage to conventional animal or tractor-powered ploughing, but this shift would tend to be to the direct advantage mainly of men. Women benefit indirectly, in the sense that the use of any kind of powered tillage or planting tends to mean less manual labour on their part; but this advantage is independent of the shift from powered conventional tillage to powered minimum tillage.

For much of Sub-Saharan Africa, most CSA/CA-based land preparation consists of neither animal or tractor-powered direct seeding nor ripping, but rather of the formation of small 'planting basins'. Planting basins seemingly are the most common form of 'manual CA', the others being the use of the jab planter or dibble sticks. Relative to ploughing or hoe-based ridge planting, these basins involve relatively little soil disturbance, and also serve as a form of water harvesting. However, the initial establishment of the basins requires a great deal of time and strength. Umar and Nyanga note that, "An average of 34 person-days ha-1 for land preparation was reported under manual CA compared to 7.8 person-days ha-1 under traction CA; planting basins or manual CA was reported to be very labour demanding and characterized by drudgery" (Umar and Nyanga, 2014: 72). Farnworth et al. note that preparing basins is less labour-intensive "compared to hand-hoe tillage of complete fields, which is common in some parts of the region", while also acknowledging that it is quite onerous relative to conventional ploughing (Farnworth et al., 2016: 150); while this latter comparison might seem inappropriate, in fact some research finds that uptake of CSA is lower in the presence of animal traction or tractor services because these latter are more commonly geared to perform conventional tillage than minimum tillage (Umar and Nyanga, 2014). In a recent research project conducted in Ghana, Uganda and Bangladesh, it was also found that "adaptation strategies tend to create higher labour loads for women" (Josta, Kyazze, Naab, Neelormi, Kinyangi, Zougmore, Aggarwal, Bhatta, Chaudhury, Tapio-Bistrom, Nelson and Kristjanson, 2016: 133).

Research is divided on how farmers perceive the net labour-related advantages of basins as a form of CSA. As noted by Maher et al. above, even if the work-hours of digging the basins is very large, it has a relatively benign impact because the work can be spread over a longer period of time, specifically because it can begin well before the first rains. "On the other hand, preparing basins is laborious and difficult since this off-season activity coincides with maximum soil hardness; in Zambia, female-headed households argued they had particular difficulty in digging sufficient basins due to the need for them to perform many other competing tasks, including domestic and care tasks, with little adult help" (Farnworth et al., 2016: 152). Umar and Nyanga concur that many farmers do not take advantage of the possibility of preparing land during the dry season:

CA promoters advise that ripping and digging of planting basins be performed during the dry season. They contend that, this helps labour constrained households, the most severely affected of whom are women-headed households. However, tillage during the dry season seemed to be a big challenge for most households as they preferred to engage themselves in non-farming activities during this period. Most waited until the beginning of the rainy season before starting to till their land, contrary to instructions given by CA promoters. (Umar and Nyanga, 2014: 72)

Moreover, the physical strength required to form the basins, which are typically about 20 cm in depth, can be considerable. In Zambia, where CSA is being promoted very actively, the common tool for basin digging is a 'chaka', which is a long-handled hoe with a particularly heavy head, which Nyanga, Johnsen and Kalinda (2012) found to be problematic for many women farmers. Farnworth et al. (2016) indicate that the use of heavy hoes such as the chaka may be limited by many women's poor health; as indicated by Howson, Harrison and Law (1996), across Sub-Saharan Africa, 10% to 40% of women suffer from chronic energy deficiency (CED).

Farnworth *et al.* summarise by noting as follows:

"Access to, the deployment of, and benefit from productive assets are critical for effective participation in CA initiatives as with other technological innovations. Both women and men smallholders, for instance, generally lack appropriate implements to seed through an organic mulch. This is one of the major constraints faced by Afri-

can smallholders wanting to adopt CA. Further time-saving investments include the acquisition of machinery such as rippers and direct seeders, herbicides, and hired labour. The widespread unavailability, or expense, of such technologies leads many smallholder farmers to select manual CA systems (such as planting basins), which are often labour-intensive." (Farnworth et al., 2016: 146)

And, it so happens, the burden of manual CA systems tends to fall to women, and the poor[9].

But while land preparation is an important consideration, weeding is at least as important. In many CSA practices, the burden of weeds is potentially greater because of the absence of ploughing, although some researchers have pointed out that "the relationship between tillage and mulching practices, agro-ecological conditions, herbicide use, health, and weed pressures, remains poorly understood" (Whitfield, Dougill, Dyer, Kalaba, Leventon and Stringer, 2015: 15).

In their study of CA in Zambia, Umar and Nyanga noted the "increase in weed burden under CA," which was "exacerbated by the seeming inability of households to weed as frequently and as timely as recommended so as to prevent the formation and dispersal of weed seeds; the high labour demand under manual CA is a major bottleneck considering the severe labour shortage that characterizes smallholder households at critical periods of the farming season…" (Umar and Nyanga, 2014: 72).

The solution is to apply herbicides. The potential of herbicides to free up valuable labour time goes well beyond CSA/CA. In their study of the benefits of herbicide-tolerant GM maize by small-scale women and men farmers in KwaZulu-Natal, Gouse and Louw (2013) observed that:

"[E]ven though female farmers tend to be slow to adopt new technologies, female farmers can possibly benefit more from the introduction of GM technologies than their male counterparts due to their specific roles in the smallholder production system. Farmers seem to value the weed control benefit of HT maize higher than the borer control benefit of Bt maize. In a community where the majority of farmers are elderly and HIV/Aids and out-migration limit household labour, and profit driven surplus production is generally not the main objective, the convenience of the production seems to be more important." (Gouse and Louw, 2013: 19)

But poorer farmers – disproportionately women – are less able to afford pesticides; or, returning to the point made about the sometimes disharmony with intra-household decision-making, men may choose to not spend money on herbicides even if/though the failure to do so leads to a significant additional burden on women. (In this latter example, CSA is still evidently adopted, but it is ambiguous whether or not it is to the benefit of women.) As stated by Farnworth *et al.:*

"One of the most fundamental misapprehensions of policy-makers and development planners is that increasing household incomes will automatically result in improved food and nutrition security within the household. Countless programmes are built and justified on this premise. Yet, it has been documented for decades that men are less likely than women to spend the money thus gained on

9. South Africa's CA Farmer Innovation Programme for Smallholders (see Chapter 13), has so far benefited little from mechanisation, thus the areas planted are typically very small. Indeed, lack of access to CSA-based mechanisation services was the reason given by the programme implementers for the fact that in the southern KZN sites, farmers only practised CSA on their garden plots, and only used their fields if they were supported in doing so by government's cropping programme, which typically implied conventional tillage (Kruger and Smith, 2017a). On the other hand, it should be pointed out that a number of farmers in the Bergville sites found that an important benefit of CSA was that they could now manage planting their garden plots by hand, whereas prior to participating in the initiative they had to hire tractors at significant expense (e.g. "R15-R20 per metre for ploughing and the same amount for discing"), even for these relatively small areas (Kruger and Smith, 2017b). What is less clear is what have been the implications of CSA for agricultural labour hours, and whether women farmers have been affected disproportionately.

household welfare….

The ability to purchase herbicide is not merely a matter of income, but it is also a matter of intra-household decision-making around how to allocate resources – this encompasses both willingness and ability to pay." (Farnworth et al., 2016: 153)

Another concern is that herbicides might be incompatible with mixed cropping, and with biodiversity more generally. As Umar and Nyanga point out, wild vegetables are often critical to the food security of rural households, including those who are farming. Using a nationally-representative dataset of farmers, they found that the share of CA-practising farmers using herbicides rose from a low base of 1.1% in 2006/07, to 8.2% during the 2009/2010 – quite a significant increase. However, "Incorrect application of herbicides was common as farmers reportedly found the herbicide application instructions too technical and difficult to follow" (Umar and Nyanga, 2014: 72).

As Farnworth *et al.* state:

"The application of herbicides is fundamental to the labour-saving credentials of CA. Minimum soil disturbance is strongly associated with increased weed growth when herbicides are not used. A major cause of dis-adoption of CA is increased labour demand for weeding in situations where herbicides are not used." (Farnworth et al., 2016: 152)

Maher et al. note that herbicides do make a big difference to women's welfare, provided they are used correctly. However, she also notes an important side-effect; the most marginal households in Malawi are those which rely on casual labour, and much of this is of course is on other people's plots. The uptake of herbicides reduces the need for casual workers, whether or not CSA is adopted; this has negative consequences for these already-marginal households (Maher *et al.,* 2015). Meanwhile, Nyanga *et al.* (2012) raise concerns regarding both the sustainability of herbicide use, and the possible risks to human health, especially given that many farmers use herbicides without understanding the instructions or taking necessary precautions.

A further consideration is the supposed benefits of crop rotation and/or inter-planting. The technical rationales for crop rotation and inter-planting include to break the cycle of pest reproduction, enrich the soil through the use of leguminous crops, and enhance the coverage of the soil surface. But in addition, it is claimed that women in particular appreciate the fact that adoption of CSA tends to involve the increase in legume production, which enhances household nutrition and food security (Umar and Nyanga, 2014); indeed, in many areas legumes are seen as 'women's crops' (Baudron, 2014). However, the counter claim is that where men are in control, the interest in legume production tends to be more tepid. The reason appears to be twofold. First, men tend to be more interested in marketable crops (Manjichi and Dias, 2014)[10], and in many rural scenarios the market for legumes (and legume seed) is absent or limited (Umar and Nyanga, 2014). And second, inter-cropping in particular is not always easy to reconcile with mechanised production methods, and certainly not with spraying (Nyanga *et al.,* 2012). This would appear to be why the standard three-pronged CA package of minimum tillage, crop rotation, and maximum soil cover is not taken up in full, rather the focus is particularly on minimum tillage. This has led to a debate as to whether the piecemeal/selective adoption of CA implies an imperfect appreciation of its principles, or what is hopefully the initial stages towards a more complete adoption in the future.

To summarise, the adoption of CSA tends to follow the pattern set by other improved technologies: they tend to be more prominent on plots owned or controlled by men, and even then, may or may not be to the advantage of women. However, because there is no single

CSA/CA technology package, even for grain farming, much depends of the specifics of the household in question together with the particular technology package it is attempting to take up.

14.4 Gender-responsive policymaking to scale up CSA

As stated above, there is a tendency to disregard the specific implications for women when policies or programmes are designed to promote the use of improved technologies; and, even when the implications for women are explicitly considered, there tends to be a gap between the good intentions and the reality of implementation (Ampaire *et al*., 2016; Beuchelt and Badstue, 2013).

There are various reasons why this might be so. One interesting line of inquiry is that of Westengen, Nyanga, Chibamba, Royo and Banik (2018), who undertook a subtle political-economy analysis of the discourse and deeds related to the promotion of CSA/CA in Zambia. While their analysis does not focus on gender, it is not difficult to see the implications for women:

"From its initial focus on CA as soil conservation and sustainable agriculture, the framing of the initiative has evolved to accommodate shifting trends in the policy arena. In tandem with the increased focus on climate adaptation, we see an increased emphasis on private sector-led modernisation. The initiative has shifted its target group from the poorest smallholders to prospective commercial farmers, and has forged connections between its farmer-to-farmer extension network and private input suppliers and service providers. The link between CA and input intensification is reflected in national statistics as a significantly higher usage of herbicides, pesticides and mineral fertilizer on fields under CA tillage compared to other fields. We argue that the environmental and participation agendas are used to buttress CA as an environmentally and socially sustainable agricultural development strategy, while the prevailing practice is the result of a common vision for a private sector-led agricultural development shared between the implementing organisation, the donor and international organisations promoting a new green revolution in Africa" (Westengen et al., 2018: 255).

Such a claim obviously has important implications for the integrity with which CA is being taken up, particularly regarding the observation on the anomalous trends in the increased use of external inputs such as fertiliser. Where women are concerned, the issue is the drift away from "the poorest smallholders", which would tend to include a disproportionate share of vulnerable women.

Whitfield et al. (2015) make a similar argument, but address the gender issue explicitly. Their general concern is that some governments and international donor partners have been inclined to disregard contrary evidence as to the benefits of CSA/CA, while exaggerating 'success stories': "there is a knowledge politics underlying the translation of a weak evidence base around CA into persuasive narratives and financial and political support". It is important to stress that neither Whitfield *et al.* nor Westengen *et al.* are discrediting the science behind CSA/CA, however they are claiming that some actors employ the science selectively and opportunistically, especially regarding the real-world impact beyond controlled field trials. Whitfield et al. further suggest that when CA was initially being promoted in Africa in the 1990s, the expressed rationale was for CA's environmental and productivity benefits. Social empowerment, and in particular the empowerment of women, were only later integrated into "the language of CA programmes", as concern for the marginalised and women became more central to some donor agencies' agendas:

"Non-governmental organisations such as CARE and Con-

10. Although this is disputed by Palacios-Lopez et al. (2018); see footnote above.

cern Worldwide have promoted this narrative, which attempts to link CA to broader notions of human development beyond increasing on-farm production (Concern Worldwide 2013). The NORAD CAP report makes reference to the many benefits [of CA] for women, associated with earlier land preparation and reduced weeding, which are often responsibilities that fall on female members of the household. This appears to be, as a delayed response to the push towards mainstreaming gender and empowerment concerns within the activities of development funders initiated in the 1990s, without a clear reason for its absence from previous discourse around CA, particularly given the explicit commitment towards women's empowerment within the government's Agricultural Sector Investment Programme of the early 1990s as well as in the broader objectives of a number of the organisations and funders engaged in CA in Zambia. As discussed later, a possible explanation for this is the limited and highly context specific nature of evidence in support of this narrative" (Whitfield et al., 2015: 62).

Taken together, the analyses of Whitfield et al. nor Westengen *et al.* suggest the possibility that, even when women's welfare is taken into account in policy and programme development around CSA/CA, it may not be altogether sincere, and may gloss over some of the real challenges and incongruous facts that have begun to manifest in the research literature.

These concerns arguably relate to one of the most obvious scaling up strategies typically proposed for CSA/CA, which is to mainstream CSA/CA into national policies and programmes. In this context, mainstreaming relates not to 'gender mainstreaming' as mentioned above, but 'CSA mainstreaming', so that for instance CSA is integrated into core functions such as extension, input support, technology promotion, etc. Mainstreaming makes eminent sense, but seemingly it is also vulnerable to falling into the trap of paying lip-service to the specific concerns for women and other vulnerable farmers. As a strategy for scaling up CSA, it is also obviously limited by government's capacity.

On a more encouraging note, FAO has explicitly acknowledged the challenges faced by vulnerable individuals and households, and made the case not against mainstreaming, but of making special provision for the vulnerable. The key insight is that, as explained above, the poor typically struggle to take up technologies that would be to their longer-term advantage, both because they cannot accumulate the savings with which invest in them, and because of their natural risk-aversion (FAO, 2013). Thus, mainstreaming is not enough; there must be a deliberate effort to offer additional support to vulnerable groups so that they can get over the hurdle towards adoption that poverty puts in their way. This is the gist of the chapter in FAO's Climate-Smart Sourcebook entitled, "Making climate-smart agriculture work for the most vulnerable: the role of safety nets" (FAO, 2013). As the title suggests, the key idea is to provide some kind of baseline support to vulnerable households so that taking the leap into a new technology is not so daunting. This support can take different forms, such as cash transfers or guaranteed public works-type employment; the key requirements are that it is reliable and sufficient in magnitude. To be clear, the purpose of the safety-net is to create a more conducive situation for vulnerable households to take up CSA/CA; it would need to be complemented by a concerted effort to facilitate uptake of CSA/CA through training or other forms of support.

From a South African perspective, the existing vast social grant system would seem to imply that an adequate safety net has already been established. However, on further reflection, it is not clear how much this is the case; the vast majority of grants go to the elderly, parents of minors, and people with disabilities. Of these three groups, parents of minors would in principle be the most auspicious in terms of taking up CSA, however it is not certain that the grants are enough to allow this; moreover, it possibly misses a more promising demographic in terms of interest in farming, namely somewhat older women. On the other hand, it is certainly far better than nothing.

A second complementary approach to the mainstreaming approach is to single out women to participate in co-ops aiming to assist them to take up CSA/CA. Such an approach has been supported for example by the FAO in Lesotho and Gabon (Thiombiano, 2012). Unfortunately, details regarding these co-ops are very sketchy. On the face of it, the approach would complement the mainstreaming approach in that it would or could offer women members additional attention and support to overcome their specific barriers. Moreover, it has been shown in some country contexts that women who participate in generic programmes to promote CSA fail to get the support they need either because it is socially or logistically difficult for them to interact with those from whom they are supposed to be receiving the support:

Female respondents tended to perceive increased issues with accessing information due to a lack of female lead farmers (e.g. 'I am not a man. I cannot ask another man. And my husband is not around' – Y23). Female-headed households also faced access difficulties due to responsibilities that did not allow for them to engage with learning activities (e.g. 'Sometimes, they invite me when I have not time to attend, because I am the only one at home with the cattle. So I cannot abandon that… I can't leave' – Q22). As such, gender tended to moderate access to informational opportunities due to gender roles that limit the opportunity to attend learning activities. (Brown, Llewellyn and Nuberg, 2018: 200)

Relative to the social safety-net approach mentioned above, it could obviously be targeted at women or other vulnerable people who are already farming and thus have real potential to benefit from CSA. However, one caveat is in order from a South African perspective. The South African government has attempted to promote small-scale farmer development by means of co-ops, but in the views of some has to a large degree assisted in the creation of the wrong kinds of co-ops, namely production co-ops, whereby individuals attempt to collaborate in primary production. This approach tends to be highly problematic, which is why most such registered agricultural co-ops are not operational. A pro-CSA women's co-op would have far more promise if it focused on what co-ops are traditionally good at, namely assisting with cost-effective input acquisition and output marketing, and possibly sharing equipment. In other words, if government or another role-player were to attempt to create or support women's co-ops as a means of promoting CSA, then one would hope that they avoid repeating the all-to-common error of promoting production co-ops.

14.5 Case studies

Of the four case studies offered here, two are adapted from FAO's Climate-Smart Agriculture Sourcebook (FAO, 2013), the third is taken from a CARE report on its 'Pathways Approach' (Njuki, Kruger and Starr, 2013), and the fourth is from Gender in Climate-Smart Agriculture: Module 18 for the Gender in Agriculture Sourcebook (World Bank Group, FAO and IFAD, 2015).

South Africa's CA Farmer Innovation Programme for Smallholders (see Chapter 13), has so far benefited little from mechanisation, thus the areas planted are typically very small. Indeed, lack of access to CSA-based mechanisation services was the reason given by the programme implementers for the fact that in the southern KZN sites, farmers only practised CSA on their garden plots, and only used their fields if they were supported in doing so by government's cropping programme, which typically implied conventional tillage (Kruger and Smith, 2017a). On the other hand, it should be pointed out that a number of farmers in the Bergville sites found that an important benefit of CSA was that they could now manage planting their garden plots by hand, whereas prior to participating in the initiative they had to hire tractors at significant expense (e.g. "R15-R20 per metre for ploughing and the same amount for discing"), even for these relatively small areas (Kruger and Smith, 2017b). What is less clear is what have been the implications of CSA for agricultural labour hours, and whether women farmers have been affected disproportionately.

Although this is disputed by Palacios-Lopez et al. (2018); see footnote above.

Case study 14.1: Ethiopia's Productive Safety Nets Programme

In Ethiopia, land degradation is a major cause of the chronic food insecurity widely experienced by the country's largely rural population. In addition, Ethiopia is ranked the ninth most susceptible country in the world to natural disasters and weather-related shocks, with climate change likely to exacerbate this situation. In 2005, the government of Ethiopia, with the support of WFP and other partners, introduced a new way of supporting vulnerable and chronically food insecure households, replacing continual appeals for emergency food aid and ad hoc responses with a more predictable safety net. The Productive Safety Nets Programme (PSNP) is a social transfer programme in which beneficiaries receive both cash and food support. The PSNP covers several thousand watersheds in 319 chronically food insecure *woredas* (districts) in six regions as well as two urban administrative areas.

With an annual budget of approximately US$ 450 million, the programme targets around 7.8 million people in a normal year (and that rose to around 11.6 million during the regional drought of 2011). It is the largest social protection program in Sub-Saharan Africa outside of South Africa and has reached around 12 percent of the population in Ethiopia. The PSNP delivers 46 000 public works 'projects' every year. The public works are aimed at restoring local environments degraded by years of overuse and poor management, including, for example, the establishment of area enclosures, woodlots, construction of hillside terraces, shallow wells and ponds and stream diversion for irrigation, in accordance with the Ethiopian Ministry of Agriculture and Rural Development procedures on Community-Based Participatory Watershed Development, as well as building social infrastructure such as education and health facilities for the local community. In addition, the PSNP provides the poorest and most vulnerable households, who are unable to contribute to public works due to labour constraints, with regular, predictable support through cash transfers. As such, the PSNP provides a planned systematic approach in addressing chronic and seasonal hunger in Ethiopia. The PSNP is complemented by the Household Asset Building Programme (HABP), which seeks to improve household's income generating and asset holding abilities. While the PSNP is designed to protect existing assets and ensure a basic level of food consumption, the HABP is designed to assist households in increasing incomes generated from agricultural activities and to build up assets so that they will be able to 'graduate' off PSNP. A household has graduated from PSNP when it is deemed to have moved from being dependent on assistance to a 'food sufficient' situation without the need of external support.

A recent impact assessment showed that PSNP public works:

- ⇒ reduced sediment in streams by 40-53 percent in areas closed to grazing and cultivation
- ⇒ increased woody biomass and forage production three to four-fold;
- ⇒ increased water availability and quality;
- ⇒ increased ground water recharge and improved downstream base flow of streams;
- ⇒ lessened damage from seasonal floods (by soaking up rain water in areas closed to grazing and cultivation);
- ⇒ enhanced down-stream crop production through soil and water conservation interventions;
- ⇒ stored carbon (estimates from just two of several thousand watersheds calculated over a million tonnes of carbon dioxide equivalent had been sequestered);
- ⇒ increased biodiversity;
- ⇒ increased social cohesion by improving livelihoods; and
- ⇒ improved access to social services (for example 3 900 schools and 450 health posts have been constructed or refurbished).

More specifically, it was found that in 2010, 70 percent of PSNP households in the survey perceived their overall economic condition as better or the same compared to the previous year, an increase from 41 percent in 2008. The survey also found that from 2004 to 2010, the level of assets had increased, and distress sales had declined, regardless of beneficiary type. Participation in PSNP was found to raise the likelihood of using fertilizer by 19.5 percentage points. Other studies showed that households with access to both PSNP and complementary packages of agricultural support were more likely to borrow for productive purposes, use improved agricultural technologies, and operate their own non-farm business activities.

From a CSA perspective, it can be concluded that PSNP has helped a very large number of Ethiopians cope better with climate-induced risks, although challenges in the implementation of PSNP remain.

Case study 14.3: R4 – Scaling up good practice through partnership and innovation

In 2010, WFP and Oxfam America partnered to scale up an innovative approach to strengthen poor farmers' resilience to climate-related shocks. The Rural Resilience Initiative (R4) combines improved resource management (risk reduction), insurance (risk transfer), microcredit (prudent risk taking), and savings (risk reserves). The initiative builds upon the Horn of Africa Risk Transfer for Adaptation (HARITA) programme, which was successfully implemented in Ethiopia's Tigray region by Oxfam America with funding from the Rockefeller Foundation and Swiss Re. R4 allows poor, food insecure households who already benefit from food-for-asset or public works schemes such as PSNP to pay for insurance with their labour. Through "insurance-for-work" poor farmers work on small-scale, community-identified public projects in return for insurance coverage. Farmers with more cash can also purchase this insurance outright.

The insurance reduces uncertainty from climate variability and allows the poorest and most vulnerable farmers to make investments that increase their productivity. In case of a drought, farmers receive automatic insurance pay-outs if rainfall drops below a predetermined threshold. With the insurance pay-out, the farmers do not have to sell off livestock, tools or other productive assets to survive and will be able to afford the seeds and inputs necessary to plant in the following season.

R4 is now targeting nearly 19 000 households in the Tigray region of Ethiopia. The initiative reached a major milestone in 2012 when more than 12 000 drought-affected households received an insurance pay-out of over US$ 320 000. This is the first time that a weather index insurance programme in Ethiopia has delivered pay-outs at such a large scale directly to small farmers. In addition, farmers received the funds when they needed them the most, thanks to an early warning system based on advanced satellite technology that calculates when the crops begin to suffer and triggers the pay-outs.

The R4 Initiative demonstrated that safety nets can provide an effective and cost-efficient platform to make insurance accessible to the chronically poor. The initiative represents a new kind of partnership, bringing together public and private sector actors in a strategic large-scale initiative to innovate and develop better tools to help the most vulnerable people build resilient livelihoods. It also constitutes a first step towards developing a sustainable insurance market for poor people, an essential factor in ensuring farmers' livelihoods and food security over the long term. In 2012, R4 began expanding to Senegal where it expects to reach 18 000 farmers by 2015. In 2013, R4 is further scaling up in Ethiopia and is expected to be piloted to two additional countries by 2015.

Case study 14.2: The FACASI Project

Cultural norms and gender-biased access to, and control over, productive resources – such as livestock or mechanized farm equipment – affect women's role differently in animal-drawn tillage systems versus mechanized tillage systems. Although women generally do not access or control small-scale farm machinery, when farmers can afford it, women may benefit indirectly in terms of labour savings. The FACASI Project (Farm Power in Conservation Agriculture for Sustainable Intensification) promotes the use of appropriate mechanization in conservation agriculture systems in sub-Saharan Africa by introducing two-wheel tractors to overcome labour shortages and the limited availability of draft animals at crucial moments in the agricultural calendar. Two-wheel tractors allow timely land preparation and planting. Timely planting leads to better crop establishment and fewer weeds - which reduces weeding, a task traditionally designated to women. Two-wheel tractors and other small, mechanized equipment can be used for multiple purposes and ease traditional tasks undertaken by women, such as pumping and transporting water. In Bangladesh, local manufacturers produced self-propelled reapers and then connected them to a two-wheel tractor to harvest. Small, mechanized threshers and shellers are also available; this equipment affects harvesting and postharvest operations, which are often overlooked when conservation agriculture's benefits are evaluated in terms of labour and time. Again, attention should be paid to how mechanization affects women's income-earning opportunities. For example, another conservation agriculture technology, direct rice seeders, eliminated the need to transplant rice (an important source of wage labour and income for women) and affected household incomes in areas where they were introduced.

Case study 14. 4: CARE's 'Pathways Approach'

The virtue of CARE's 'Pathways Approach' is arguably that it attempts to encourage tangible, programmatic expression to the various elements that would appear to be required to enable women to benefit from opportunities such as CSA, in which there is a combination of material and not-so-material factors. The idea is that for change to happen, various issues have to be addressed, thus it seeks to allow less wriggle room to merely pay symbolic attention to seemingly ephemeral issues such as 'empowerment':

> *CARE's 'Pathways Approach' is based on a global theory of change that addresses the underlying causes of poverty and women's exclusion in agriculture through increased productivity and empowerment of women farmers and more equitable agriculture systems at scale. Across each of the implementing countries, CARE has identified five common and closely inter-related change levers that must be impacted to achieve the Pathways goal of more secure and resilient livelihoods. (Njuki, Kruger and Starr, 2013: 5)*

Figure 14.2 below depicts the theory of change and its underlying 'change levers'.

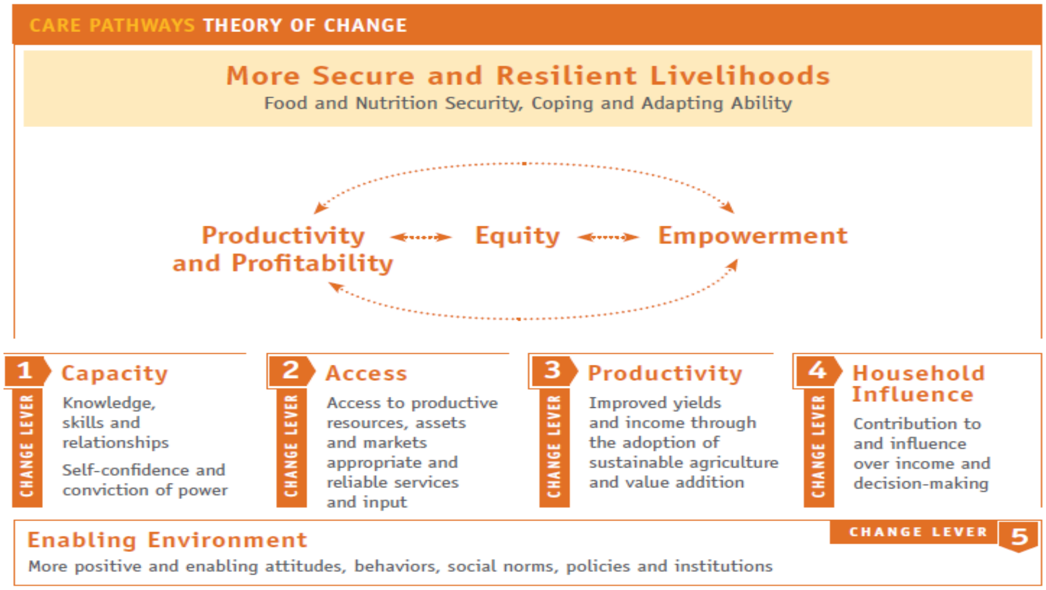


Figure 14. 2: CARE's theory of change for increasing the productivity and empowerment of women smallholder farmers
Source: *Njuki, Kruger and Starr, (2013)*

14.6 Conclusions and recommendations

While there is little doubt that CSA has much to offer women farmers, based on the evidence from Africa, much depends on the specifics and details of the case at hand. This has to do with the circumstances of particular women farmers, as well as the specific elements of the CSA/CA package that they are trying to adopt.

The one over-riding lesson is that whoever is seeking to promote women's uptake of CSA/CA needs to consider the complexities in advance, and then keep a watchful eye as efforts proceed. Particular attention should be paid to the implications of the technology for women's financial and time resources; the same can be said for other vulnerable groups.

Generally speaking, the environment for promoting CSA among women farmers is reasonably conducive in South Africa. The widely accessed social grants go some distance in providing a safety net, in the absence of which, fewer women would probably be willing to venture into CA. Arguably the biggest shortcoming of the South African environment is lack of a functional mechanisation policy, in the absence of which many low-income women farmers would only be able to consider relatively labour-intensive forms of CSA/CA, which would likely limit their willingness to take it on, or the benefits from having done so.

15.1 Introduction

The preceding sections of this report dealt with the various practices that can serve as entry points for CSA in South Africa. A selection of these practices have been developed into actionable CSA guidelines for use in the implementation of ongoing CSA activities or the initiation of new ones. The contribution of the CSA guidelines to the widespread adoption of CSA will, however, depend on the creation and implementation of appropriate policies and an enabling environment. Good CSA policies will facilitate the removal of impediments that act as disincentives for adopting CSA while ensuring the reallocation of resources to programmes that provide incentives for the adoption of CSA. In this section of the report some of the policies/strategies/plans at different levels of governance in the country that have a direct or indirect bearing on CSA are highlighted.

15.2 CSA Policy Framework in South Africa

The CSA policy framework in South Africa is described in detail by Mnkeni and Mutengwa (2014). The aspects of these policies relevant for this report are summarized below.

15.2.1 Policies and Institutions relevant to CSA in South Africa

Institutional Arrangements

The institutional arrangements currently in place are those for responding to climate change in South Africa in general. They consist of the National Committee on Climate Change (NCCC) and the Intergovernmental Committee on Climate Change (IGCCC) chaired by DEA. DAFF is an active member of both committees. Other members of the IGCCC include the Departments of Science and Technology (DST), of Basic Education (DOE), of Trade and Industry (DTI), of Social Development (DSD), of Human Settlements (DHS), of Transport (DoT), of Water Affairs (DWA) and the National Disaster Management Centre (NDMC).

There are no specific institutional arrangements for CSA, but these are expected to be put in place after a CSA policy has been formulated. DAFF, however, is actively promoting conservation agriculture (CA) and in 2009 it established the National Conservation Agriculture Task Force (NCATF) to drive the promotion of CA. The NCATF is one of the national institutions participating in the Conservation Agriculture Regional Working Group (CARWG). DAFF has also indicated its intention to form a national network for climate smart agriculture to facilitate the achievement of its stated objective of enhancing cooperation with all stakeholders involved in agriculture, including organised agriculture, the private sector, research and academic institutions, NGOs, CBOs and others.

Policies

As noted above, the CSA policy in SA is still being formulated by DAFF and good progress has been made in that the CCSP which is the precursor to this policy has been completed consistent with the approach chosen by the South African (SA) government. Therefore, the policies reviewed in this section are those that are directly or indirectly related to CSA.

1) Land care programme

The Land Care Programme, which was described earlier, seeks to:

⇒ Conserve natural resources,
⇒ Use them in a sustainable way,
⇒ Create a conservation ethic through education and awareness, and
⇒ Create jobs and address poverty by launching various natural resource rehabilitation, improvement and

conservation projects.

The CRDP and Policy for Recapitalization and Development Programme (RDP) were launched by the Department of Rural Development and Land Reform in 2013 as an update of the Rural Development Framework. The CRDP aligns the RDP to the National Development Program (NDP) vision for 2030 which has three focus areas for Agriculture namely, successful land Reform; employment creation and strong environmental safeguards. This revised policy is guided by several principles including:

⇒ Rapid transfer of agricultural land to blacks without distorting the land market or business confidence.
⇒ Sustainable production based on capacity building prior to transfer through incubator, mentorships and accelerated forms of training.
⇒ Development of sound institutional arrangement to monitor markets against corruption and speculation.
⇒ Alignment of transfer targets with fiscal realities.
⇒ Enhanced opportunities for commercial farmers and organized industry to contribute through mentorships, training, commodity chain integration and preferential procurement.

2) Policy on Agriculture and Sustainable Development

The aim of this policy is to integrate and harmonise the three pillars of sustainable development: social (people), environment (land) and economic (prosperity). Its goal is "to ensure responsible economic development for the benefit of future generations". Tools for achieving sustainable development in the agricultural sector are agrarian reform, participation, income diversification, land conservation and improved management of inputs. The purpose of the policy is "to facilitate a coordinated approach towards achieving economically, socially and environmentally sustainable agricultural sector".

3) National Agriculture Research and Development Strategy

The objective of the National Agriculture Research and Development strategy is to "guide and direct the generation, adaptation and application of knowledge and innovation for sustainable agricultural development to benefit society". The goal of the research strategy is to enhance the contribution of agricultural research towards attaining a 6% economic growth through sustainable agricultural productivity, sustained competitiveness to ensure food security and eradication of poverty in South Africa.

15.2.2 Effectiveness of the Policies and Activities

The policies listed above are robust and comprehensive, but their successful implementation remains to be realized. The LARDP, for example, is not on track in terms of achieving its stated goal of transferring 30% of all agricultural land to black African farmers over a 15-year period. Hope is now pegged on the ongoing engagement on land expropriation without which is aimed at accelerating the transfer of land to blacks.

For those in possession of land, implementation of CSA is also impeded by land tenure arrangements. Most smallholder farmers in South Africa operate on land that is under the communal tenure system where land rights are not secure. A case in point is Zanyokwe Irrigation Scheme in the Eastern Cape (EC) South Africa where insecure land tenure arrangements are limiting access to land and undermining interest and commitment to farming.

A number of DAFF policies effectively conflict each other with respect to CSA. For example, promotion of some aspects Agro-ecological agriculture seem to be in conflict with efforts that are aimed at high productivity and facilitation of smallholder and emerging farmers to be commercially-oriented. One of the aspects of agro-ecological agriculture is minimum reliance on external inputs, such as fertilisers, and new varieties of crops, which is in contrast to promotion of best management practices. Landraces (traditional) varieties that are promoted in agro-ecological agriculture are widely known to be low-yielding, and often unresponsive to high input application.

A policy on organic agriculture is also nearing finalisation. There are dangers that farmers may actually be left confused if these programmes are not properly targeted or co-ordinated. A similar conflict relates to the Mechanization support policy for household food security. This policy regulates the rolling out of mechanization support to some two million deserving households in South Africa. It is, however, in conflict with the promotion of CA which has different machinery requirements compared to conventional farming. It is actually working against CA, by distributing tillage implements to farmers, such as ploughs, discs, etc. The policy needs to be reviewed in order to accommodate the machinery needs of aspiring or practicing CA farmers.

The Land Care programme is implemented by DAFF in response to the Conservation of Agricultural Resource Act (CARA) through the Extended Public Works Programme (EPWP). It is operative in all the nine provinces of South Africa, and has been effective in reversing soil and land degradation through support provided to community initiatives. The main incentive offered by the programme is a Land Care Conditional Grant that is issued to a province that has identified serious land and water degradation problems.

The National Agricultural Research Strategy has been very effective in generating knowledge that is relevant to CSA. Its weakness at this point seems to be lack of coordination among the different role players involved in CSA or CSA related research. This weakness may be overcome through the establishment of the national network for CSA planned by DAFF.

15.3 Impact of Policies and Activities on Gender and Social Equity

Two of the stated objectives of the LARDP policy are: 1. to expand opportunities to women and young people in rural areas with the intention of improving gender equity, and 2. overcoming the legacy of past racial and gender discrimination in ownership of farmland. The pursuit of these objectives will no doubt lead to the achievement of gender and social equity in the ownership and use of land in South Africa. Unfortunately, the planned transfer of the land to victims of past discriminatory laws has not made much progress and only very few women benefitted from the little land that has been transferred so far (Madizwamuse, 2010).

The rollout of the DAFF Land Care programme in all provinces has contributed significantly to green job creation, poverty eradication, food security and a better life for all (South Africa Yearbook 2012/13). The programme has contributed to social and gender equity because most of the beneficiaries from Land Care projects are the previously disadvantaged groups and because as one of its objectives the programme always strives to balance gender when employing local people.

15.4 Agriculture and Green Economy policies

Table 15.1 provides a synopsis of agricultural and green economy issues which are highlighted in the government strategies, plans and programmes discussed in Chapter 1 of CSIR (2014) which focussed on the greening of the South African economy. There is very little common ground between the documents highlighted in the table that connects agriculture to the green economy. Nevertheless, their existence indicates that there is some basis for some activities to take place that will contribute towards the greening of the South African economy.

Table 15.1: Primary issues for agriculture and the Green Economy in various Strategies, Plans and Programmes

	Issues
NSSD (DEA)	-Sustainable Water and Land Resources Management -Protection of agricultural land -Sustained food security -Local economic development
New Growth Path & Green Economy Accord (EDD)	-Addressing unemployment, poverty and inequality -Support for small scale agriculture -Investment in agro-processing chains and expanding trade -Biofuel production
National Development Plan (NPC)	-Land reform and security of tenure -Expansion of agriculture: Promotion of food production and increasing rural income and employment in the large scale and small scale sectors -Development of poor rural inhabitants and emerging farmers -Infrastructure for agriculture and farmer support -Improving efficiency of irrigation
Medium Term Strategic Framework (MTSF) (The Presidency)	-A competitive economy -Decent work opportunities -Growth in core productive sectors including agriculture
National Skills Development Strategy III (DHET)	-Training to enable effective participation in the economy -Training to enable entrance into formal workforce or self-employment and livelihood creation
National Climate Change Response White Paper (DEA)	-The significant impacts of climate change on agriculture -Agriculture has significant potential for adaptation to climate change -The vulnerability of the agricultural sector due to climate change impacts on resources such as water (changes in availability) and soil (increased erosion from more intense rainfall) -Dependence of a climate-resilient agricultural response on recognition that agriculture should provide commodities and a range of other environmental and socio-economic benefits
Strategic Plan for the Department of Agriculture, Forestry and Fisheries	-Subsistence farmers and smallholder producers -Agro-ecological agriculture -Efficient use of natural resources -Protection of indigenous genetic resources -Green jobs to improve livelihoods -Increase investment in agriculture -Increase market access for South African products -Increase production of feedstock for manufacturing -Food security and agrarian reform: improve profitable food production -Integration of the second economy into the mainstream
National sectoral strategy with provisions for agriculture (DRD&LR, DTI, EDD, DOE)	***Department of Rural Development and Land Reform*** -Sustainable livelihoods -Skills, employment and participation of rural people in the mainstream economy -Land reform that ensures food security -Land rehabilitation ***Department of Trade and Industry*** -Support for agro-processing industries -Development of biofuels ***Economic Development Department*** -Employment / green jobs -Lower carbon emissions ***Department of Energy (Biofuel Strategy)*** -Renewable energy development -Uplift agricultural sector -Attract investment to rural areas
Provincial & Local Strategies	***KwaZulu-Natal*** -Green jobs -Self-sufficiency (produce own food, water and energy) -Comprehensive overhaul of the whole economy ***Gauteng*** -Food security -Local organic production -Small scale urban agriculture -Spatial planning and land use – biodiversity and ecosystem services ***Limpopo*** -Methods of production / farming: Organic and local production, companion agriculture, permaculture and urban agriculture -Water efficiency, appropriate crops -Regulation of feedlots -Production of biofuel resources -Seed bank -Food labelling -Food banks ***Western Cape*** -Support for agri-production and expanding value chains and markets -Sustainable farming practices -Energy and water efficiency -Waste beneficiation -Food security ***City of Tshwane*** -Promote sustainable agriculture and agro-ecology -Rehabilitate degraded common-lands and promote their sustainable use -Promote small-scale organic farming and farm-produce, community co-operatives and local food markets, green packing houses and processing facilities -Expand existing feeding schemes and establish community nutrition centres -Promote urban agriculture and establish food gardens at public institutions -Support programmes to ensure protection of agricultural land, sustained food security and local economic development

15.5 General conclusion

The Situation analysis has revealed that information on the different CSA practices is available to feed into the actionable CSA guidelines. The details of these guidelines are given in the executive summary and in the different sections of this report. It should be noted that most of the CSA practices are knowledge intensive so any guide that will be produced should be viewed as work in progress to be improved upon as more academic and experiential knowledge is generated.

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