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

## Volume 2 | Climate Smart Agriculture Practices

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## ABOUT THE STUDY

The United Nations (UN) Environment under its SWITCH AFRICA GREEN (SAG) programme funded by the European Union (EU) commissioned the study for the Department of Environment, Forestry and Fisheries (DEFF) in South Africa.

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## EXECUTIVE SUMMARY

Agriculture contributes only about 2% to the Growth Domestic Product (GDP) of South Africa but it is considered an important engine for the growth of the rest of the economy because of its backward and forward linkages to the economy. It has thus been identified as one of the key sectors that could contribute towards the greening of the South African economy. The realization of this potential is, however, threatened by changing climatic conditions caused by the global climate change.

The climate change is believed to be anthropogenically forced through increases in atmospheric greenhouse gas (GHGs) concentrations to which agriculture is a contributor. 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. Since agriculture is both a culprit and victim of climate change efforts to green the economy through this sector must address both aspects. Climate smart agriculture (CSA) is ideal in this regard because it embraces both mitigation and adaptation interventions.

The report summarized here describes actionable guidelines for CSA practices for use in the implementation of CSA in South Africa, to support the country's transition to an all-inclusive green economy. The CSA practices include soil and water management, crop production, urban agriculture, rangeland management and agro-processing.

***Soil Management***

Maintaining or improving soil health is essential for sustainable and productive agriculture. The use of mineral fertilizers as a source of nutrients for plant growth is critical for increasing productivity though their production contributes to $CO_2$ emissions and the field application of nitrogen contributes to nitrous oxide emissions and adversely affects the health of soil micro-organisms. A guide is described on the 4Rs (Right fertilizer source, used at the Right rate, at the Right time and in the Right place) nutrient management stewardship approach whose implementation will help to improve fertilization efficiency and limit the economic costs and GHG emissions at the same time. Since the long-term goal is to discourage the use chemical fertilizers alone, guidelines are described on integrated soil fertility management (ISFM) approaches that combine optimally applied fertilizers with organic resources for maintaining and restoring soil fertility.

The combination of conservation agriculture (CA) and ISFM is the prime example of this approach due to its effectiveness in the restoration of soil health and productivity whilst mitigating the emissions of GHGs. It is strongly recommended for widespread promotion and adoption across all farming sectors in South Africa. Guidelines on organic soil fertility management are also described due to the superior soil regeneration potential of organic farming while adapting to and mitigating climate change.

***Soil water Management***

The challenge faced by farmers in the context of the projected climate change scenarios will be to make more efficient use of water resources (rainfall or irrigation) to maintain or improve crop productivity, particularly in those parts of the country where rainfall is expected to decrease in quantity and increase in its variability, both inter and intra-seasonal. Guidelines are described on different climate smart agricultural water management practices for increasing infiltration capacity through improving the physical quality of soil.

These include the in-field rainwater harvesting (IRWH) practices of no-till, minimum tillage, mulching, contour farming, raised beds, ridges, basin tillage, and use of terraces whose implementation will help to increase rainwater productivity. Guidelines are also described on the ex-field rainwater harvesting practices such as cisterns, ponds, liman and stone dams which can be used to trap rainwater that is lost in the form of runoff. Guidelines on smart irrigation approaches are described that can minimize inefficient crop watering practices by ensuring greater water use efficiency. Where feasible, drip irrigation systems are recommended as they have the highest irrigation efficiency (>90%) compared to surface irrigation which has an irrigation efficiency of less than 65%.

### *Cereal Based cropping systems*

In addition to the practices for increasing soil and irrigation water productivity summarized above, guidelines are described that will help farmers: (i) be able to choose climate smart crops. This includes how to switch from maize to sorghum and millet which are more drought tolerant as well as to choose cultivars that are tolerant to diseases and pests; (ii) implement crop rotations, intercropping and cover cropping; and (iii) be able to use climate information in climate smart decision-making.

The guidelines, though comprehensive, do not replace expert advice from soil scientists, agronomists, and extension officers. The guidelines should be used together with practical experience and expert advice by farmers practising or wishing to practice climate smart cereal-legume based agriculture.

### *Sugar cane production*

The sugar industry has been actively involved in responding to the climate change challenge by developing and perfecting of several CSA practices through its research arm, the South African Sugar Research Institute (SASRI). Practices developed include variety improvement, crop protection, crop performance and management, as well as systems design and optimization. The research outputs are transformed into practical knowledge and technology products in the form of better management practices (BMPs).

These BMPs are recommended through the Sustainable Sugar Cane Farm Management System (SUSFARMS®) to encourage their adoption. Implementation of the SUSFARMS® concept has been expanding steadily in recent years.

The concept is enabling the industry to comply with international sustainability standards, such as the Better Sugar Cane Initiative (Bonsucro).

Practical guidelines on implementation of the SUSFARMS® concept are described to facilitate adoption by sugarcane growers and sugar millers in South Africa.  The SUSFARMS® farming model is recognised internationally, and it recently won an international Bunscoro benchmarking award.

### *Fruit and wine Industries*

The fruit and wine industries have adopted numerous adaptation and mitigation strategies that are relevant to the industries. The adaptation strategies include the use of an open web portal called FruitLook to improve water management, shifting to drip irrigation instead of using sprinkler irrigation, use of shed nets, appropriate choice of cultivars for changing growing conditions, and use of windbreaks. Mitigation against GHG emissions is enhanced through widespread use of the carbon calculator tool developed through the confronting climate change (CCC) project.

Use of non-renewable energy in the form of solar and wind farms for minimising emission of GHGs is also being implemented. 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 relevant for products destined for the export market. Assurance of compliance with fair labour practices and use 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 Good Agricultural Practice (GAP). Farmers with SIZA certification are therefore recognised globally. A case study in Ethiopia illustrated how a Union of Cooperatives managed to obtain GlobalG.A.P. certification that paved the way for them to have access to the lucrative EU markets. Wine and fruit farmers in South Africa are encouraged to be members of SIZA to facilitate adoption of CSA practices for environmental sustainability as well as compliance with global standards. Guidelines are provided on how farmers can be compliant with the SIZA Environmental and Social Standards.

### *Urban Agriculture*

Approximately, 60% of the South African population reside in urban and peri-urban environments, and this has created 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, however, faces problems of open land shortage and inadequate water for irrigation. Guidelines are described on environmentally friendly technologies that can be used to address the water and space challenges. These include the use of rooftop farming, vertical farming, greenhouse production systems, hydroponic techniques, greywater recycling, composting, and use of renewable energy (solar and wind power).

***Rangelands management***

Rangelands cover approximately 72% of the total land area of South Africa (Tainton 1999) making them the largest single land use, and thus their proper management could have a huge impact on the greening of the country.

Areas under commercial ranch and wild life production systems have low levels of vulnerability to climate change but areas under communal land use have relatively high levels of vulnerability. Guidelines are described on the implementation of the holistic range management system as a CSA practice for the South African rangelands, especially in the communal rangeland areas.

***Agro-processing***

Agri-Parks are being introduced in South Africa to catalyse development in rural areas by bringing agro-processing closer to production areas. This together with use of cold storage facilities within the Agri-Parks will bring about reduction in post-harvest losses, transport costs and GHGs emissions associated with transport.

Since not all food produced in rural areas can be preserved or processed at the Agri-Parks, home preservation of food needs to be encouraged as well as a strategy for improving household food security.

Guidelines are described for the preservation of fruits and vegetables by solar drying at household level with a view to reduce post-harvest losses and to increase availability and diversity of diets in rural areas throughout the year.

## Conclusions

The development of practical guidelines for the CSA practices summarized above and described in detail in this report has paved the way for the rollout of CSA in South Africa. It should, however, be noted that most of the CSA practices are knowledge intensive so the guides described should be viewed as work in progress to be improved upon as more academic and experiential knowledge is generated. The successful rollout of CSA in the country will ultimately be dependent upon a conducive enabling policy environment. This aspect is the subject of Volume 3 of this report.

## Contributing Authors of the CSA Practices Guideline Report

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# Acronyms

| | |
|---|---|
| **AATF** | African Agricultural Technology Foundation |
| **ACDI** | African Climate & Development Institute |
| **ACRE** | Agriculture and Climate Risk Enterprise |
| **AFIS** | Advanced Fires Information System |
| **AFOLU** | Agriculture, Forestry and Other Land Use |
| **AGRA** | Alliance for a Green Revolution in Africa |
| **ARC** | Agricultural 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 |
| **ARMT** | Agricultural Risk Management Team (World Bank) |
| **ASAR** | Adjusted Sodium Adsorption Ratio |
| **BBF** | Broad Bed and Furrow |
| **BMPs** | Better Management Practices |
| **BONSUCRO** | Better Sugar Cane Initiative |
| **CA** | Conservation Agriculture |
| **CA-FIP** | Conservation Agriculture-Farmer Innovation Programme |
| **CARWG** | Conservation Agriculture Regional Working Group |
| **CCAFS** | CGIAR Research Program on Climate Change, Agriculture and Food Security |
| **CEEPA** | Centre for Environmental Economics & Policy in Africa |
| **CGIAR** | Consultative Group on International Agricultural Research |
| **CIAT** | International Centre for Tropical Agriculture |
| **CIMMYT** | International Wheat & Maize Improvement Centre |
| **CIS** | Climate Information Services |
| **CLIP** | Crop Livestock Intensification Project |
| **CPSI** | Centre for Public Service Innovation |
| **CS** | Climate Smart |
| **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 |
| DRDLR | Department of Rural Development and Land Reform |
| DTMA | Drought Tolerant Maize for Africa |
| EC | Electrical Conductivity |
| EWS | Early Warning System |
| ERWH | Ex-field rainwater harvesting |
| FAO | Food and Agriculture Organization |
| Fertasa | Fertilizer Association of Southern Africa |
| FIP | Farmer Innovation Platform |
| FSA | Farm Sustainability Assessment |
| FSSA | Fertilizer Society of South Africa |
| FPSU | Farmer Production Support Unit |
| GAP | Good Agricultural Practice |
| GDP | Gross Domestic Product |
| GEF | Global Environment Facility |
| GFCS | Global Framework for Climate Services |
| GHG | Green House Gas |
| GrainSA | Grain South Africa |
| IBRD | International Bank for Reconstruction and Development |
| ICARDA | International Centre for Agricultural Research in the Dry Areas |
| ICRISAT | International Crops Research Institute for the Semi-Arid Tropics |
| IFAD | International Fund for Agricultural Development |
| ICT | Information Communication Technology |
| INDC | Intended Nationally Determined Contribution |
| IMAS | Improved Maize for African Soils |
| IPCC | Intergovernmental Panel for Climate Change |
| IRWH | In-field rainwater harvesting |
| ISA | International Society of Arboriculture |
| ISFM | Integrated foil fertility management |
| KARI | Kenya Agricultural Research Institute |
| KSA | Key Strategic Area |
| KZN | KwaZulu-Natal |
| LCR | Low Carbon, Climate Resilient |

| | |
|---|---|
| LDC | Less Developed Countries |
| LTAS | Long Term Adaptation Scenario |
| MFP | Mahlatini Development Foundation |
| MWP | Mondi Wetlands Programme |
| NAMC | National Agricultural Marketing Council |
| NCATF | National Conservation Agriculture Task Force-Malawi |
| NCCRP | National Climate Change Response Policy |
| NDP | National Development Plan |
| NEMA | National Environmental Management Act |
| NGO | Non-Governmental Organization |
| NLP | National LandCare Programme |
| OPV | Open Pollinated Variety |
| PICSA | Participatory Integrated Climate Services for Agriculture |
| PRA | Participatory Rural Appraisal |
| RAM | Resource Allocation Map |
| RRWH | Rooftop rainwater Harvesting |
| R&D | Research and Development |
| 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 system |
| SAI | Sustainable Agriculture Initiative |
| SAIA | South African Insurance Association |
| SANSOR | South African National Seed Organisation |
| SAQ | Self-Assessment Questionnaire |
| SAR | Sodium Adsorption Ratio |
| SASA | South African Sugar Association |
| SASRI | South African Sugar Research Institute |
| SAWS | South African Weather Services |
| SDC | South African Sandy Soils Development Committee |
| SGP | Small Grants Programme |
| SIZA | The Sustainability Initiative of South Africa |
| SPIS | Solar powered irrigation systems |

| | |
|---|---|
| **SSA** | Sub-Saharan Africa |
| **SSDC** | Sandy Soils Development Committee |
| **STATS SA** | Statistics South Africa |
| **SUSFARMS®** | Sustainable Sugarcane Farms Management System |
| **SUSTAINET** | Sustainable Agriculture Initiative |
| **TAW** | Total available water |
| **TVET** | Technical and Vocational Education Training Institute |
| **UCT** | University of Cape Town |
| **UNFCCC** | United Nations Framework Convention for Climate Change |
| **US** | United States |
| **USA** | United States of America |
| **USAID** | United States Agency for International Development |
| **VCF** | Value Chain Financing |
| **WEMA** | Water Efficient maize |
| **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 South Africa |
| **WFP** | World Food Programme |
| **WII** | Weather Index-based Insurance |
| **WMO** | World Meteorological Organization |
| **WPS** | Wind-powered systems |
| **WRC** | Water Research Commission |
| **WRMF** | Weather Risk Management Facility |
| **WRSI** | Water requirement satisfaction index |
| **WUE** | Water Use Efficiency |
| **WWF** | World Wide Fund for Nature |
| **WWF SA** | World Wide Fund for Nature South Africa |

## Chemical Elements/ Compounds

| | |
|---|---|
| Al | Aluminium |
| B | Boron |
| Ca | Calcium |
| Cl | Chlorine |
| Cu | Copper |
| K | Potassium |
| Mg | Magnesium |
| N | Nitrogen |
| P | Phosphorus |
| S | Sulphur |
| Fe | Iron |
| Mo | Molybdenum |
| Ni | Nickel |
| Zn | Zinc |
| Mn | Manganese |
| $NO_3$ | Nitrate |
| KCl - | Potassium Chloride |
| $(NH_4)_2SO_4$ - | Ammonium Sulphate |
| $PO_4^{-3}$ | Phosphate |
| $CaCO_3$ | Calcium carbonate |
| $C_2H_5OH^-$ | Ethanol |
| $N_2O$ | Nitrous oxide |
| $CO_2$ | Carbon dioxide |
| $NH_3$ | Ammonia |

## Definitions

| | |
|---|---|
| **Acidic soils** | Soils with a pH below 7. |
| **Alkaline soils** | Soils with a pH above 7. |
| **Agroforestry** | A land use management system in which trees or shrubs are grown around or among crops or pastureland. This intentional combination of agri-culture and forestry has varied benefits, including increased biodiversity and reduced erosion. |
| **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. |
| **Bioinformatics** | is an interdisciplinary field that develops methods and software tools for understanding biological data. As an interdisciplinary field of science, bioinformatics combines biology, computer science, information engineering, mathematics and statistics to analyze and interpret biological data. |
| **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. |
| **Basis insurance risk** | Basis risk in index insurance arises when the index measurements do not match an individual insured's actual losses. There are two major sources of basis risk in index insurance. One source of basis risk stems from poorly designed products and the other from geographical elements. |
| **Biosecurity** | Procedures or measures designed to protect the population against harmful biological or biochemical substances. |
| **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. |
| **Composting** | The biological decomposition of organic waste such as food or plant material by bacteria, fungi, worms and other organisms under controlled aerobic (occurring in the presence of oxygen) conditions. The end result of composting is an accumulation of partially decayed organic matter called humus. |
| **Ecology** | Interaction of living and non-living organisms within an environment. |
| **Evapotranspiration** | it is the sum of evaporation and plant transpiration from the Earth's land and ocean surface to the atmosphere. Evaporation accounts for the movement of water to the air from sources such as the soil, canopy interception, and waterbodies. |
| **Fertilizer** | Any natural or manufactured material, which contains at least 5% of one or more of nitrogen, phosphorus and potassium. |
| **Blanket fertilizer recommendation** | Generally applicable fertilizer use rates that do not consider variability in soils, farm management and climate. |
| **Blue water** | Is the fresh surface or ground water. |
| **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 orcharacteristic, the crosses are specific and controlled. |
| **Harvest index** | The ratio of grain/tuber to total biomass production. |
| **Genomics** | it is an interdisciplinary field of biology focusing on the structure, function, evolution, mapping, and editing of genomes. A genome is an organism's complete set of deoxyribonucleic acid (DNA), including all of its genes. Genomics aims at the collective characterization and quantification of genes, which direct the production of proteins with the assistance of enzymes and messenger molecules. |
| **Germplasm** | Living genetic resources such as seeds or tissues that are maintained for the purpose of animal and plant breeding, preservation, and other research uses. |
| **Green manure** | A green manure crop is grown for a specific period, and then ploughed under and incorporated into the soil when still green. |
| **Green water** | Is the soil moisture from precipitation, used by plants via transpiration. It is part of the evapotranspiration flux in the hydrologic cycle. |
| **Inoculum (plural inocula)** | A substance used for inoculation. |

| | |
|---|---|
| **Integrated Plant Nutrition** | Combined use of mineral and organic fertilizers to address site- and soil specific deficiencies for improved crop productivity. |
| **Inter-seasonal variability** | Variations that occur between growing seasons, usually over multiple years. |
| **Intra -seasonal variability** | Variations that occur within growing seasons, usually over a single year. |
| **Landrace** | A local crop cultivar that has been improved by traditional agricultural methods. |
| **Leaf architecture** | The design and structure of plant leaves. |
| **Limiting nutrient** | Single nutrient that is in short supply that limits crop growth. |
| **Mutagenesis** | Treating a biological material with a mutagen in order to induce mutations is known as mutagenesis. Agents that induce mutations are known as mutagens, and these include: physical mutagens such as X-rays, neutrons, gamma rays and ultraviolet light; chemical mutagens such as ethylme-thane sulphonate (EMS), ethylene imine (EI) and sodium azide. |
| **Mycorrhiza** | Is a symbiotic association between a fungus and the roots of a vascular host plant. The term mycorrhiza refers to the role of the fungus in the plant's rhizosphere, its root system. |
| **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** | 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. |
| **Orthophoto** | 'ortho-rectified' such that the scale of the photograph is uniform and utilised in the same manner as a map. An ortho-photograph can be used to measure true distances of features within the photograph. |
| **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 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. |
| ***Striga* / Witchweed** | A group of seed plants living as root parasites especially on corn, sugarcane, and other grasses. |
| **Yield potential** | The yield obtainable on a given soil over several seasons with optimum utilization of all inputs. |
| **Transgenic** | A transgenic plant or animal contains one or more genes that have been added from another type of plant or animal. |
| **Vermicomposting** | Is a method of using earthworms to transform organic waste into a nutrient-rich fertilizer. |
| **Weather-index insurance** | A class of insurance products that can allow weather-related risk to be insured in developing countries where traditional agricultural insurance may not always be feasible, thereby helping to increase farmers' ability (and willingness) to invest in measures that might increase their productivity. |

# 1. Introduction

Agriculture contributed 2% to South Africa's Gross Domestic Product (GDP) in 2015 (DAFF, 2016a). Despite its relatively small share of the total GDP it is considered an important sector in the South African economy because of its backward and forward linkages to other sectors. Purchases of goods such as fertilisers, chemicals and implements, for example, form backward linkages with the manufacturing sector, while forward linkages are established through the supply of raw materials to the manufacturing industry. Agriculture is, therefore, a crucial sector and an important engine of growth for the rest of the economy (DAFF, 2016a). It is for this reason that it has been identified as one of the key sectors that will contribute towards the greening of the South African economy (CSIR, 2014).

Crop production and rangeland management in particular, have the greatest potential to contribute towards a green economy for South Africa, although, the realization of this potential is threatened by changing climatic conditions caused by the global climate change. The climate change is believed to be anthropogenically forced through increases in atmospheric greenhouse gas (GHG) concentrations that are believed to be largely responsible for global warming. Agriculture contributes about 14% to GHG emissions (DEA, 2013) and is thus one of the culprits of 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, Kohler, 2016, Bell *et al*. 2018). The projected temperature and rainfall changes are expected to adversely affect a wide range of agricultural activities over the next few decades. The expected reduction in rainfall would have a significant impact on South Africa's agriculture because nearly 91 % of the country is arid, semi-arid or dry sub-humid (Hoffman and Todd, 1999) and experiences varying and low mean rainfall of 464 millimetres annually, relative to the world average of 857 millimetres (BFAP, 2007, Kohler, 2016).

Major impacts will include 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. One anticipated impact involves some spatial shifts in the optimum growing regions. For instance, maize production areas towards the west would become less suitable for maize production. DEA, (2013) projected a range of possible impacts on yields of rain-fed crops including a -25% to +10% change in maize yield under unconstrained scenarios which could be reduced to a -10% to +5% change in yields under constrained scenarios.

Since agriculture is both a culprit and victim of climate change, interventions aimed at greening the economy must address both aspects. Climate Smart Agriculture (CSA) is now widely promoted as the best approach for addressing both the causes and effects of climate change. 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.

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 SWITCH Africa Green (SAG) programme in its efforts to support South Africa's efforts to move towards an inclusive green economy supported the development of detailed guidelines that will contribute to the implementation of CSA in South Africa.

A number of possible entry points for initiating CSA programmes or enhancing existing ongoing activities were identified under the thematic areas of (i) CSA practices, and (ii) Enabling environments for CSA. The CSA practices are soil management, soil water management, crop production (cereal production, sugar production, fruit and viticulture production), urban agriculture, rangeland management, and agro-processing.

The CSA enabling environments are inclusive of agriculture marketing, climate information services, indexed-based insurance, CSA knowledge dissemination, gender and social inclusion. A detailed background to the CSA guidelines in the form of a situation analysis is given in Volume 1 of this report. It provided a basis for the development of the actionable CSA guidelines.

The actionable guidelines for these CSA practices are presented in this report and their implementation should facilitate the country's transition to a green economy. These actionable CSA practices guidelines are targeting Extension Officers and other stakeholders who are involved in the dissemination of agricultural technologies to farmers.

Information on enabling environments for CSA is given in Volume 3 of the guideline report. It is targeting policy makers responsible for formulating policies that will create a conducive and supportive environment for the speedy implementation of CSA in South Africa and thus accelerate the greening of the country.

# 2. Climate Smart Soil Management

## 2.1 Introduction

In South Africa, crop production systems based on intensive and continuous soil tillage have led to excessively high soil erosion rates. Lal (2001) defines soil erosion as a multi-stage process involving the detachment, redistribution, and deposition of soil in depressions and finally in aquatic ecosystems. Chapters 3 and 4 of this Guideline provides a number of selected infield measures describing ways to minimize soil degradation. These measures include reduced tillage, crop rotations, mulching and residue management.

Poor nutrient supply in arable lands, especially among smallholder farmers in South Africa, is a critical factor limiting crop yields (Mandiringana *et al*. 2005). The poor nutrient supply is attributed to nutrient mining because of continuous cropping without appropriate nutrient replenishment. A review of possible soil fertility management strategies revealed that the use of mineral fertilizers as a source of nutrients for plant growth is still critical for increasing productivity (Stewart and Roberts, 2012). However, chemical fertilizers adversely affect soil health (Stapper, 2006). Therefore, their use needs to be progressively replaced with integrated soil fertility management (ISFM) approaches that combine optimally applied fertilizers with organic resources. The combination of conservation agriculture (CA) and ISFM was found to be especially effective in the restoration of soil health and productivity whilst mitigating the emissions of GHGs (Smith and Trytsman, 2017). Conversion to organic farming, where possible, is recommended, as it has superior soil regeneration potential while adapting to and mitigating climate change. Actionable guidelines are described herein for the optimized use of fertilizers, organic manures and ISFM for soil regeneration and soil fertility restoration.

## 2.2 Guidelines on soil fertility management

Nutrients are the primary building blocks for plant growth, and each nutrient fulfils one or more functions in a plant's growth and development. When a nutrient is lacking, plants will display symptoms of stress or defi-ciency. Soil nutrients that are found in the largest amounts in plants are nitrogen (N), potassium (K), phosphorus (P), calcium (Ca), magnesium (Mg), and sulphur (S), and are called **macronutrients.** Plant **micronutrients** are nutrients found in smaller amounts in plants, but are still essential. These micronutrients include chlorine (Cl), iron (Fe), boron (B), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), and nickel (Ni). Soil is considered fertile if it can supply adequate amounts of these nutrients for plant growth. Guidelines are described below on how the fertility can be maintained to support optimum plant growth with minimum negative impact on the environment.

### 2.2.1 Use of Fertilizers

Good nutrient management practices are based on the principles of 4R nutrient Stewardship reported by Fairhurst (2012) and Zingore *et al*. (2014). This approach ensures that the **Right fertilizer source** is used at the **Right rate**, at the **Right time** and in the **Right place**. The correct application of these 4R management practices will result in increased crop yields, as well as mitigate the depletion of soil nutrients. However, in order to maximize the nutrient management benefits through the implementation of the 4R nutrient stewardship approach, good agronomic practices must also be employed. These practices include good land preparation, use of improved crop varieties, planting population, and weed, pest and disease management. These are further described in Chapters 4, 5, 6 and 8 of this Guideline for selected crops.

The four "rights" provide a simple checklist to assess whether a crop has been fertilized properly.

*2.2.1.1 Right fertilizer source*

The right fertilizer source implies matching the fertilizer source to the crop needs and the properties of the soil to which it is applied. The following may be considered:

⇒ Need to understand the nutrients that limit specific crops in the area.

⇒ The chosen fertilizer must supply the required nutrients in plant-available forms.

⇒ It must suit the soil physical and chemical properties to ensure efficiency (e.g. avoiding nitrate application to flooded soils, surface applications of urea on high pH soils, ammonium sulphate to sandy soils with low buffering capacity, and avoiding nitrate based fertilizers in areas with heavy rainfall because they are prone to leaching).

⇒ Recognition of compatibility when mixing fertilizers – For example certain combinations of sources attract moisture when mixed, limiting uniformity of application of the blended material; fertilizer particle sizes should be similar to enable uniform application of fertilizer in the field.

⇒ Need to know the benefits and harmful effects of nutrients that may be supplied together by one fertilizer to the crop of interest. For example, muriate of potash (potassium chloride, KCl) fertilizer supplies the nutrients chloride (Cl-) and potassium (K) that are both good for maize, but chloride can be harmful to the quality of tobacco and some fruits.

⇒ Know the composition of the fertilizers and their effect on plants. Some sources of phosphorus fertilizer, such as single super phosphate, contain plant-available calcium and sulphur, and small amounts of magnesium and micronutrients.

#### *2.2.1.2 Right fertilizer rate*

Ensuring the right rate of fertilizer application is important as under- or over-application of a particular nutrient may affect crop production, and the health of the soil. All essential nutrients must be present in quantities sufficient to meet the requirements of the growing crop. However, the yield of a crop will be mainly determined by the nutrient present in the most limiting quantity.

The right fertilizer rate is site and crop system specific and is estimated taking into consideration the following:

⇒ The nutrient requirements of the crop;

⇒ The soil's capacity to supply nutrients usually measured by soil analysis;

⇒ The amount of nutrients supplied by crop residues and farmyard manure;

⇒ The amount of nutrients applied to previous crops;

⇒ The target yield;

⇒ The attainable or potential yield under local climatic conditions; and

⇒ The cost of fertilizers and the value of crop products.

The Fertilizer Society of South Africa (Fertasa) has championed the development of fertilization guidelines for different crops in South Africa over the years and these are published in the Fertilizer handbook (FSSA 1989 and 2007). The fertilization guidelines are based on the crop yield potential and soil status of phosphorus (P) and potassium (K) as determined by soil analysis.

Yield potential is the yield obtainable on a given soil over several seasons with optimum utilization of all inputs (FSSA, 1989). Its determination is, thus, the ideal starting point for fertilization planning and should take into consideration climate, soil depth, and soil type, planting time, cultivar, irrigation or dry land. Guidelines for N, P, and K fertilization of maize are provided in Annexure 2.1 as adapted from FSSA (2007).

*Accurate fertilizer application*

After choosing the correct rate of application, the next step is to ensure that it is accurately applied. This is usually not a problem for mechanized application but it is for smallholder farmers, who apply their fertilizers manually. In this situation, it is suggested that a calibrated measure such as a soft-drink bottle cap be used.

#### *2.2.1.3 Right time for fertilizer application*

The timing for fertilizer application is chosen such that nutrients become available when the crop needs them. Applicable timing for a nutrient application must take into account the following:

⇒ Nutrients should be applied to match the seasonal crop nutrient demand, which depends on planting date and crop growth characteristics. Basal fertilizer application should ideally be done at, or just after planting, to supply N, P, K and other nutrients required for early crop growth.

⇒ Mineralization of soil organic matter supplies some nutrients, but the crop's uptake needs are not matched with the release of the nutrients for the crop to benefit.

⇒ The dynamics of soil nutrient loss. For example, nitrogen is easily lost especially in sandy soils and should be applied in 2-3 splits during season when growing cereal crops. The split applications should be done at key stages during the crop development, usually when the crop is growing fastest.

#### *2.2.1.4 Right placement of fertilizer*

Applying nutrients at the right place means adding nutrients to the soil at a place where the crops can easily access them. The right placement of the fertilizer is influenced by the type of crop, tillage practices, plant spacing, crop growth stage, crop rotation or intercropping, and weather variability.

The main guidelines for right placement of nutrients are the following:

⇒ Basal fertilizers are best incorporated in the soil at or before planting in order to achieve efficient fertilizer use.

⇒ Nutrients need to be placed where they can be taken up by growing roots when needed. Nutrients that move little in the soil, such as phosphorus, should be concentrated in bands or holes close to the plants to improve availability.

⇒ Placement must suit the tillage system under practice. For example, special equipment is needed to apply fertilizer under the soil while maintaining crop residue cover in conservation tillage systems.

There are four main fertilizer placement methods:

⇒ **Broadcasting** - Fertilizers are applied uniformly to the soil surface either before sowing or in the standing crop. It is easy to implement and has low labour requirements.

⇒ **Banding** - Fertilizers are placed in a band at a depth of 5–8 cm below the soil surface and covered by the soil. Seeds are then planted above the covered fertilizer. It is mostly used for basal fertilizer applications.

⇒ **Spot application** - Fertilizers are applied in small amounts either during planting in each plant hill together with the seed or close to each plant station during the crop growing season. Spot application is preferred where:

- very low rates of fertilizer are used,
- crops are widely spaced, and
- when the risk for nutrient losses through leaching is high.

⇒ **Deep placement –** this is mostly used for the placement of slow-release N fertilizers in flooded fields.

### 2.2.2 Guidelines for fertilization with animal manures

Before the introduction of chemical fertilisers, farmers all over the world, including those in South Africa, used manure to restore the fertility of their lands. 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 (FSSA, 1989). Subsequently, however, a swing occurred towards synthetic fertilizers due to the ease of application and the unavailability of sufficient organic residues to meet demand.

Synthetic fertilizers are, however, not readily available in rural areas and when available they are too expensive for many households. Fortunately, many rural households have access to kraal manure.

#### *Guidelines on fertilization with kraal manure*

Manure contains all the nutrients that a plant needs, but not in the desired proportions. For example, it tends to be quite high in

K and relatively low in P and N. This problem can be addressed by undertaking the following:

⇒ Applying enough manure to meet the nitrogen and phosphorus needs of the crops. This, however, means that the soil will receive an excess amount of potassium, but no harm to the crop is expected from doing this.

⇒ Combining manure with mineral fertilisers. By doing so, the rates at which manure needs to be applied per unit of land, is reduced. The details for this are described in section 2.2.3 on Integrated Soil Fertility Management (ISFM).

The nutrient concentration in kraal manure depends on several factors but the most important is the amount of soil in the manure. The more soil in the manure, the lower its nutrient concentration, and the more manure has to be applied. The average N, P, and K formula for kraal manure is estimated to be 3:1:4 (3) (Van Averbeke and Yoganathan, 1997). The nutrients in kraal manure are therefore one-tenth of the concentration of the chemical fertiliser mixture 3:2:1 (30). This means that 1 000kg of kraal manure has to be applied to provide the same amount of nutrients found in 100kg of chemical fertiliser.

Crops differ in the amount of nutrients they extract from the soil. The higher the yield of the crop, the more nutrients it removes from the soil. Recommended application rates for kraal manure for certain frequently planted field and garden crops are given in Annexure Tables 2. 5 and 2.6, respectively.

### 2.2.3 Guidelines on Integrated Soil Fertility Management

Integrated soil fertility management (ISFM) is a set of agricultural practices adapted to local conditions to maximize the efficiency of nutrient and water use and improve agricultural productivity. ISFM strategies centre on the combined use of mineral fertilizers and locally available soil amendments (such as lime and phosphate rock) and organic matter (kraal manure, crop residues, compost and green manure) to replenish lost soil nutrients. This improves both soil quality and the efficiency of fertilizers and other agro-inputs. In addition, ISFM promotes improved germplasm, agroforestry and the use of crop rotation and/or intercropping with legumes (a crop which also improves soil fertility). The concept acknowledges that neither practices based solely on mineral fertilisers nor solely on appropriate soil intervention such as the use of organic materials or conservation agriculture are sufficient for sustainable crop production on degraded soils.

Figure 2.1 shows the three entry points of ISFM (Vanlauwe *et al*. 2014) that are to guide the practical implementation of ISFM.

1. The first entry point of ISFM focusses on the agronomy of crops and inorganic fertilizers. Germplasm interventions involve the selection of appropriate varieties, spacing and planting date for an area. Interventions on fertilizer use are guided by the 4Rs nutrients stewardship approach targeting the formulation, placement, rate and timing of inorganic nutrient inputs described in section 2.2.1.

2. The second entry point of ISFM targets interventions on organic resource management, including the return of crop residues, manure, compost and other types of organic wastes, next to rotation or intercropping with legumes and use of plant growth promoting micro-organisms. In addition to supplying nutrients, organic inputs contribute to crop growth by:

    - increasing the crop response to mineral fertilizer;
    - improving the soil's capacity to store moisture;
    - regulating soil chemical and physical properties that affect nutrient storage and availability as well as root growth;
    - adding nutrients not contained in mineral fertilizers;
    - creating a better rooting environment;
    - improving the availability of phosphorus for plant uptake;
    - ameliorating problems such as soil acidity; and
    - replenishing soil organic matter.

    The combination of kraal manure and or crop residues with fertilizers, is a practice that smallholder farmers can implement. The results highlighted in Case Study 1 (Annexure 2.8) show that the combination of organic materials and fertilizers has long-term positive impact on crop productivity, resilience to weather impacts and carbon sequestration. Smith and Trytsman (2017) report that many producers world-wide have achieved large improvements in soil health in a relatively short time when conservation (CA) principles and practices and ISFM are used simultaneously.

3. The third and last entry point of ISFM deals with any other amendments or local adaptation that may be needed to alleviate limitations to productivity such as soil acidity, micronutrient deficiency, erosion, soil compaction or pests and diseases.

Some examples of measures that may need alleviation include:

- **Soil acidity**. Some soils are very acidic, either due to of inherent soil properties or due to long term acidity-inducing management practices e.g. the long-term use of ammonium-based fertilizers. When this is the case lime application rates should be calculated to reduce exchangeable Al (to approximately 15%) rather than just increasing soil pH.

- **Micronutrient deficiencies**. Deficiencies to particular micronutrients (e.g. Zn, B) may be observed. Zinc deficiencies were observed in South Africa in the late sixties and were corrected through fertilization with fertilizer blends containing zinc. Since the deficiencies have largely disappeared (FSSA, 1989).

- **Breaking hardpans**. If a sub-surface soil barrier to crop root growth is detected in a farm, breaking such hardpans by deep ploughing or chisel ploughing to a depth of up to 30 cm is recommended, to allow for roots to penetrate the hardpan and access more nutrients and water.

Figure 2.1 provides a conceptual illustration of the responses in crop production and input use efficiency to different interventions for soils with contrasting fertility status. Pathway A on the graph represents healthy soils where interventions on germplasm and fertilizer immediately cause the agronomic efficiency to increase. Pathway B, on the other hand, serves as example for degraded soils where organic resource management and other amendments or practices are required before production can be intensified.

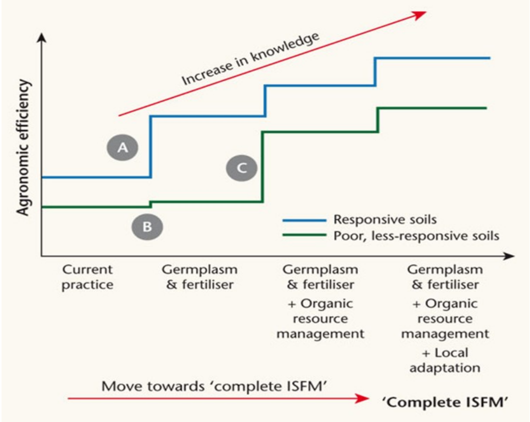


**Figure 2.1: ISFM framework with entry points of interventions and benefits on the efficiency of crop production according to soil health status.**

*Source: Vanlauwe et al. (2014).*

The different fertilizer practices in the ISFM strategy described above enhance nutrient uptake and productivity of crops and thus 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.

### 2.2.4 Nutrient Management in organic farming

#### 2.2.4.1 Introduction

Organic agriculture shares many techniques used by other sustainable agricultural approaches such as intercropping, crop rotation, mulching, integration of crops and livestock. However, what makes organic agriculture a unique agricultural management system is the use of natural (non - synthetic) inputs (INFOAM, 2009).

Generally, organic production systems are designed to:

⇒ enhance biological diversity within the whole system;

⇒ increase soil biological activity;

⇒ maintain long-term soil fertility;
⇒ recycle wastes of plant and animal origin in order to return nutrients to the land, thus minimizing the use of non-renewable resources;
⇒ rely on renewable resources in locally organized agricultural systems; and
⇒ promote the healthy use of soil, water, and air, as well as minimize all forms of pollution thereto that may result from agricultural practices.

This Guideline will focus on nutrient management in organic agriculture and it is prepared with the assumption that the user is familiar with organic agriculture.

Users that are uninitiated in organic agriculture are referred to the additional sources of information in the annexure section this report.

Organic farming systems rely on the management of soil organic matter for soil fertility maintenance because it imparts numerous benefits to the soil that can be grouped into three categories, as follows:

⇒ **Physical benefits:** Soil organic matter enhances aggregate stability, improves water infiltration and soil aeration, reduces runoff; improves water-holding capacity; reduces the stickiness of clay soils making them easier to till; reduces surface crusting, and facilitates seedbed preparation.

⇒ **Chemical benefits:** Soil organic matter increases the ability of the soil to hold onto and supply over time essential nutrients such as calcium, magnesium and potassium; it improves the ability of a soil to resist pH change; accelerates decomposition of soil minerals over time, making the nutrients in the minerals available for plant uptake.

⇒ **Biological benefits:** Soil organic matter provides food for living organisms in the soil; it enhances soil microbial biodiversity and activity, which can help in the suppression of crop diseases and pests; and enhances pore space through the actions of soil microorganisms. This helps to increase infiltration and reduce runoff.

#### 2.2.4.2 Organic agriculture approach to soil fertility management

Organic soil fertility management follows a three-step approach that uses a range of tools to manage soil fertility and plant nutrition.

***Step 1:*** *Soil and water conservation*

The first step practices aim at protecting precious soil and water from being lost. This provides a good foundation for building fertile soil. Soil conservation can be achieved through the following practices:

- Preventing soil erosion by reducing the movement of water with contour ridges and bunds, grass strips and terraces, and application of mulch to the soil surface;
- Protecting the soil with mulch and cover crops;
- Harvesting water with pits and water catchments; and
- Application of reduced tillage to minimize soil disturbance.

***Step 2:*** *Improvement of soil organic matter*

These practices aim at enhancing the organic matter content of the soil as the basis of soil fertility and for efficient management of plant nutrients and water. The practices related to it include:

- Producing own compost or supplying compost or other organic materials from outside the farm to supply stable humus substances to the soil and thus improve its structure and water holding capacity as well as contributing to improvement of soil organic matter content on a long term (i.e., carbon sequestration).

- Growing green manures to produce large quantities of fresh plant material, which are incorporated into the soil, feed the soil organisms and mineralize rapidly to provide nutrients to the crop that follows.

- Recycling of valuable animal manures for composting or fertilization of the crops.

When plant material and manure are mixed into the soil, they are decomposed and partly transformed into humus that serves many purposes in the soil, for example:

- It acts as a reservoir of nutrients. The nutrients are released to the plants in a balanced way, which contributes to good plant health. Soil organic matter is the main nutrient pool for the plants beside nitrogen from symbiotic fixation.

- It increases the water holding capacity of the soil as it acts like a sponge with the ability to absorb and hold up to 90 % of its weight in water.

- It causes the soil to form strong complexes with clay particles, which improve soil structure and thus increase water infiltration, making the soil more resistant to erosion. Better soil structure also enhances root growth.

- Humus improves the exchange capacity for nutrients and avoids soil acidity.

- Soil biological activity is enhanced, which improves nutrient mobilisation from organic and mineral sources and the decomposition of toxic substances.

- Mycorrhizal colonisation is enhanced, which improves phosphorus supply.

- Potential to suppress soil borne pathogens, when compost is applied to the soil.

**Sources of biomass**

*Green manuring*

Green manuring means growing plants with the primary purpose of incorporating their biomass into the soil to supply "organic food" to the soil to improve its nutrient content and thus its fertility. Cover crops and green manures are near synonyms. The main purpose of growing cover crops is to cover the soil with a low vegetation cover to protect it from exposure to sun and rain as well as to suppress weeds but green manures are grown with the main purpose to build maximum biomass. Green manures play a key role in organic farming. They are an invaluable source of food for soil organisms and thus of nutrients for the following crop. They are a farm-grown fertilizer and, therefore, are a cheap alternative to purchased fertilizers. Green manures complement animal manures well and are of high value on farms where animal manure is scarce.

*Composting*

Compost is a common name used for plant and animal material (mainly animal manure) that has been fully decomposed. Compared with uncontrolled decomposition of organic material as it naturally occurs, decomposition in the composting process occurs at a faster rate, reaches higher temperatures and results in a product of higher quality. The practical implementation of composting is provided in Chapter 10 of this guideline.

*Vermicomposting*

Vermicomposting is the method where compost is prepared using specially introduced earthworms, Red Wigglers (*Lumbricus rubellus* or *Eisenia fetida*), as agents for decomposition. In contrast to ordinary composting, vermicomposting is mainly based on the activity of worms and does not go through a heating phase. Vermicomposting is a good technique for recycling food waste and crop residues from vegetable gardens in the proximity of the house. It creates small volumes of very rich manure. Though vermicompost is very good manure, it requires more investment (a tank and worms), labour and more permanent care compared to ordinary composting. On the other hand, letting worms recycle farm or household waste saves time and labour input as no turning is required to keep the compost aerated. Its practical implementation is provided in Chapter 7 of the guideline.

*Microbial Fertilizers*

The microbial fertilizers mostly consist of organic material and some source of sugar or starch, which are fermented together with specific species of microorganisms. The products are living organisms and need to be applied cautiously. Most of the bacteria and fungi present in the purchased products are generally present in soil. Microbial inocula, therefore, enhance the presence of the specific organisms.

Some microbes add nutrients to the soil through mineralisation while others add nitrogen by fixing it from the atmosphere. These include Rhizobium and Azotobacter. Other microbes, such as Mycorrhizal fungi, help to supply plants with phosphorus. Azospirillum and Azotobacter are bacteria that can fix nitrogen. Pseudomonas species are a diverse group of bacteria that can use a wide range of compounds that plants give off when their roots leak or die. They are able to solubilize phosphorus and may help to suppress soil borne plant diseases.

***Step 3:*** *Soil fertility supplements*

In spite of proper soil organic matter management, application of farm-made or commercial organic or mineral fertilizers may be recommended to overcome distinct nutrient deficiencies. Deficiency may be due to unbalanced soil pH or slow release of nutrients from an organic source. Dry soil conditions or cold soils in high altitude may intensify the problem. Before choosing a specific fertilizer, farmers should know the reason for the problem.

Examples include seed oil cakes (soybean, sunflower, neem, peanut), pelleted chicken manure, and agro-processing by-products such as brewery, fruit peels, coffee husks, wood shav-

**Table 2.1: Mineral fertilizers allowed in organic farming**

| Fertilizer | Origin | Characteristics | Application |
|---|---|---|---|
| **Plant ashes** | Burned organic material | • Mineral composition similar to plants<br>• Easy uptake of the minerals<br>• Wood ashes rich in K and Ca | • To compost (best)<br>• Around base of plants |
| **Lime** | Ground limestone<br>Algae | • Buffers low pH (content of Ca and Mg secondary) | • Every two to three years when pH is low (Excessive use should be avoided as it may lead to reduction of P availability and micro-nutrient deficiencies) |
| **Stone powder** | Pulverized rock | • Trace elements depending on the composition of the source<br>• The finer the grinding the better the absorbance | • To farm yard manure (it reduces volatilization of N and encourages the rotting process) |
| **Rock phosphate** | Pulverized rock containing P | • Easily adsorbed to soil minerals<br>• Weakly adsorbed to soil organic matter<br>• Slow reaction | • To compost<br>• Not to reddish soils due to irreversible adsorption |

*Source: Training manual for organic agriculture (http://www.fao.org/fileadmin/templates/nr/sustainability_pathways/docs/Compilation_techniques_organic_agriculture_rev.pdf )* ings and dust, rice husks and plant ashes. Others include bone meal, feather meal, fish meal, horn and hoof meal, as well as commercially produced composts.

*Mineral fertilizers*

The mineral fertilizers, which are allowed in organic agriculture, are based on ground natural rock. However, they may only be used as a supplement to organic manures. If they contain easily soluble nutrients, they can disturb soil life and result in unbalanced plant nutrition. A basic overview of these supplements is given in Table 2.1.

## 2.3 Performance monitoring of the impact of soil management practices in relation to CSA

Productivity is substantially enhanced when: (i) fertilizers are applied following the 4Rs nutrient management approach that ensures minimum loss of applied nutrients, (ii) IFSM is practised through a positive synergistic effect between organic and inorganic inputs. The efficiency of rainfall-use is furthermore greatly enhanced resulting in low crop yield variability over seasons (resilience).

The strategic timing and placement when using inorganic nitrogenous fertilizers under ISFM, results in rates of N application that are much lower than recommendations based on the sole use of inorganic fertilizers. This contributes to mitigation through reduced nitrous oxide emissions. Likewise, organic agriculture is also a good mitigation strategy as 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. The performance of CSA soil management interventions can, therefore, be monitored using the CSA technical indicators shown in Table 2.2.

**Table 2.2: Climate Smart Agriculture technical indicators**

| Theme/Pillar | Sub-theme | Farm level Indicator |
|---|---|---|
| **Productivity** | Crop system | • Increase in crop yield (ton/ha) |
| | Water use | • Increase in green water use efficiency |
| | Input use efficiency | • Increase in input use efficiency<br>• lower rates of fertilizer application |
| **Resilience** | Robustness | • Increases stability of production<br>• Improved economic resilience through improved profitability of the farming enterprise over time |
| | Cropping system | • Increases resilience to drought |
| **Mitigation** | Emissions intensity | • Reduction GHG emissions |
| | Carbon sequestration | • Increases carbon sequestration |

*Source: Adapted from The World Bank Group (2016)*

## 2.4 Conclusions

Maintaining or improving soil health is essential for sustainable and productive agriculture. The use of mineral fertilizers as a source of nutrients for plant growth is still critical for increasing productivity although it has a negative impact on the environment. The adoption of the 4Rs nutrient stewardship approach described in this guideline should help to minimize the environmental impact of the continued use of mineral fertilizers. However, the long-term goal should be the universal adoption of environmentally friendly strategies of soil fertility management such as ISFM and organic farming. The actionable initiatives described in this guideline should contribute to this process.

# 3. Climate smart agricultural water management

## 3.1 Introduction

Climate change will aggravate the scarcity of water for agriculture and human use, especially in the semi-arid and arid areas of South Africa (SA). The Western Cape (amongst other provinces in SA) has faced serious agricultural water scarcity for three consecutive years (2015-2017). Water scarcity can be defined as a lack of sufficient water, or not having access to safe water supplies. Water is a pressing need in many areas of the world. That scarcity is spreading as water is needed to grow and process food, create energy, and serve industry for a continually growing population.

The greatest potential increases in crop yield are in rain-fed areas wherein many of the world's poor live and where managing water is the key to such increases (Molden, 2007). Rainwater harvesting (RWH) practices have been demonstrated to increase agricultural production and sustainability. Rainwater harvesting is based on the principle of depriving (naturally or artificially) section of the land of its share of rainfall (which is usually not used productively) and adding it to another section, where it can be used beneficially. Therefore, rainwater harvesting is the process of concentrating rainfall as runoff from a larger area for its productive use in a smaller target area (Oweis *et al.,* 2001). 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. Rainwater harvesting can be classified as: (1) Macro-catchment (ex-field rainwater harvesting, ERWH), (2) Micro-catchment (in-field rainwater harvesting, IRWH) and (3) Roof-top micro-catchment (non-field rainwater harvesting).

The aim of water harvesting in this case is to collect runoff from areas of surplus or where it is not used, store it and make it available, where and when there is water shortage. This results in an increase in water availability by either (a) impeding and trapping surface runoff, and (b) maximising water runoff storage or (c) trapping and harvesting sub-surface water (groundwater harvesting).

The guideline aims to give the user basic management practices useful for RWH. The application of best management practices should be monitored frequently to allow for flexibility and adjustment. The utmost importance of seeking additional technical assistance to these guidelines, must be emphasized. Land managers, farmers and villagers should consult the appropriate experts for relevant information on cropland production. The scope of these guidelines includes soil water management and the use of stored rain water for agricultural uses as a strategy to adapt and mitigate climate change.

## 3.2 Site and technique selection for Rain Water Harvesting

Rainwater harvesting will only be sustainable if it fits into the socio-economic context of the area and also fulfils a number of basic technical criteria.

Figure 3.1 contains a flowchart with the basic technical selection criteria for the different rainwater harvesting techniques. The major limiting factors to adopt RWH are as follows:

⇒ The ground slope is a key limiting factor to water harvesting. Water harvesting is not recommended for areas where slopes are greater than 5% due to uneven distribution of runoff and large quantities of earthwork required which is not economical.

⇒ Soils should have the main attributes of soils which are suitable for irrigation: they should be deep, not be saline or sodic and ideally possess inherent fertility. A serious limitation for the application of water harvesting are soils with a sandy texture. If the infiltration rate is higher than the rainfall intensity, no runoff will occur.

⇒ The quantities of earth/stonework involved in construction directly affects the cost of a scheme or, if it is implemented on a self-help basis, indicates how labour-intensive its construction will be.

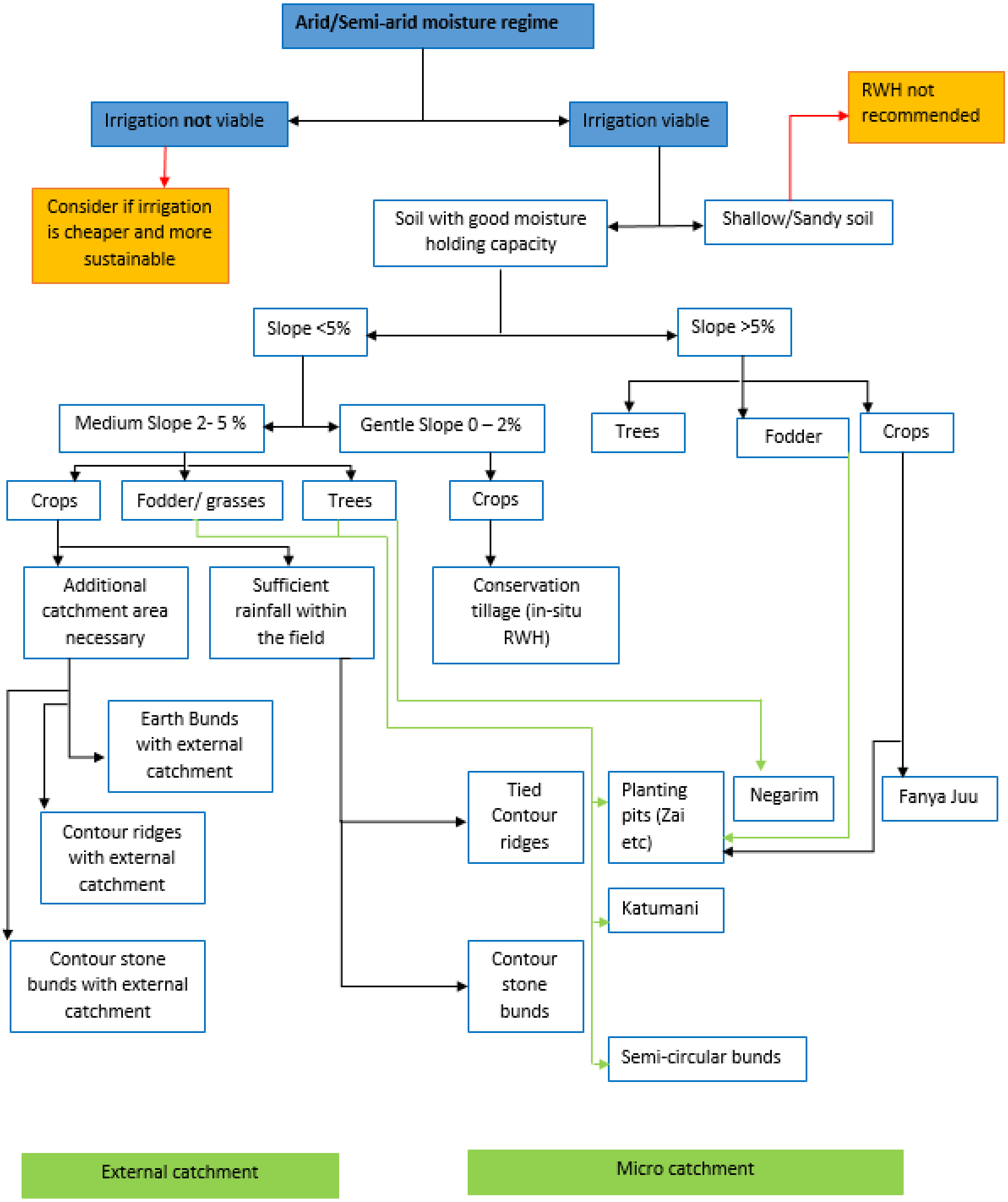


**Figure 3.1: Decision tree on rainwater harvesting in agriculture.**

*Source: Handbook (2001)*

## 3.3 In-field rainwater harvesting measures

In-field rainwater harvesting is a method of collecting surface runoff from small catchments of short length. Runoff water is concentrated in an adjacent application area and stored in the root zone for direct use by plants. Catchment and application areas alternate within the same field. Thus rainwater is concentrated within a confined area where plants are grown. Hence, the system is replicated many times in an identical pattern.

**Why is IRWH a climate smart practice?**

-Avoids risks linked to erratic and declining rainfall

-Reduces run off and soil erosion

-Stores rainwater for longer periods against long midseason dry spells

-Maximizes the use efficiency of water and plant nutrient

-Increase plant root biomass that can crease soil organic carbon

### 3.3.1 Negarim micro-catchments

Negarim microcatchments is one of the water -harvesting schemes for tree production and diamond-shaped basins surrounded by small earth bunds with an infiltration pit in the lowest corner of each. Runoff is collected from within the basin and stored in the infiltration pit. Each micro catchment consists of a catchment area and an infiltration pit (cultivated area). The shape of each unit is normally square, but the appearance from above is of a network of diamond shapes with infiltration pits in the lowest corners. Runoff is collected from within the basin and stored in the infiltration pit. Negarim microcatchments are neat and precise, and relatively easy to construct.

Manure or compost should be applied to the planting pit to improve fertility and water- holding capacity. If grasses and herbs are allowed to develop in the catchment area, the runoff will be reduced to some extent. However, the fodder obtained gives a rapid return to the investment in construction. Regular weeding is necessary in the vicinity of the planting pit.

***Suitability***

Negarim microcatchments are mainly used for fruit crops or nut trees and bushes for fodder growing in arid and semi-arid areas. This technique is appropriate for small-scale tree planting in any area which has a moisture deficit. Negarim micro-catchments have been developed in Israel for the production of fruit trees and widely used in other semi-arid and arid areas, especially in North and Sub-Saharan Africa.

⇒ **Rainfall**: can be as low as 150 mm per annum.

⇒ **Soils**: should be at least 1.5 m but preferably 2 m deep in order to ensure adequate root development and storage of the water harvested.

⇒ **Slopes**: from flat up to 5.0%.

⇒ **Topography**: need not be even - if uneven a block of micro-catchments should be subdivided.

### 3.3.2 Planting Pits (Zai)

Zai or Tassa is a farming technique to dig pits (20-30 cm long and deep and 90 cm apart) in the soil during the pre-season to catch water and concentrate compost. The technique is traditionally used in western Sahel (Burkina Faso, Niger, Mali) to restore degraded drylands. In, Burkina Faso, the adoption of the Zai pits led to the rehabilitation of between 200 000 and 300 000 ha of land, which was formerly degraded and abandoned (Meyer, 2010). This practice can be introduced to the semi-arid and arid parts of South Africa to increase moisture availability. Optimal conditions for the system has been observed in areas that receive 400–800 mm of rainfall in Burkina Faso (Roose *et al*., 1999). In the small pit, organic matter and manure are added to the cultivated area, to improve the soil structure (Renner and Frasier, 1995). Zai pits can fit about 10–15 seeds of sorghum or millet and are usually dug during the dry season. The sowing is done at the beginning of the rainy season or during the dry season (Sedibe, 2005). The pits are dug in an alternate pattern that are more or less a meter apart, with basins that are 30–50 cm wide and with a depth of 10–20 cm (Renner and Frasier, 2005; Sedibe, 2005). Zai pits are potentially useful for adaptation to climate change and variability. According to Roose *et al.* (1999), the challenges in using the zai system are the intensive labour input and manure availability.

The planting pit system is a Micro-catchment technique. Planting pits are made on land which low permeability to allow for run-off collection. Planting pits are holes dug to catch runoff and allow time for infiltration and they are usually fertilised with organic matter in the form of plant debris or compost.

***Suitability***

The planting pits are suitable for semi-arid area to enable crops to survive dry spells. They are used on a wide variety soil types but most suitable on silt and clay soils where runoff can be generated due to limited permeability. The technique works on sloping land from 1-15%.

Pits can be used to grow annual and perennial crops for example sorghum, maize, millet, cowpeas, sweet potatoes, groundnuts and bananas.

### 3.3.3 Tied Contour Ridges (furrows or bunds)

Ridging is a soil and water conservation practice characterized by individual earth blocks built along furrows (Nuti et al., 2009). 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. Tied ridging could reduce runoff and enhance infiltration, increase rainfall use efficiency and soil water storage, and improve crop yield (Tesfahunegn *et al.,* 2008). Tied ridging involves creating ridges that are 20–30 cm high with a spacing of 75 cm wide. The ties can be prepared either before, during or after planting. Tied ridges have been found to be effective and feasible for diverse situations. However, in certain instances, it has led to waterlogging, excessive nutrient leaching and ridge destruction in wet areas. The system is simple to construct by hand or by machine and can be even less labour intensive than the conventional tilling of a plot.

***Suitability***

The tied contour ridging system is used for crop production (crops are planted on the ridges as well as in the furrows) and tree planting (with a wider distance between ridges). This technology has been used to grow crops such as millet, cowpeas and sorghum.

Contour ridges are small earthen ridges, 15 to 20 cm high, with an upslope furrow which accommodates runoff from a catchment strip between the ridges. Ridges may be from 1.5 to 10 m apart, but, as this is a micro-catchment system and the catchment is a function of the distance between ridges, the precise distance should be calculated for the expected rainfall of the region.

Contour ridges for crop production can be used under the following conditions:

- ⇒ **Rainfall**: 350 - 750 mm. (and down to 200 mm for trees)
- ⇒ **Soils**: all soils which are suitable for agriculture. Heavy and compacted soils may be a constraint to construction of ridges by hand.
- ⇒ **Slopes**: from flat up to 5.0%.
- ⇒ **Topography**: must be even - areas with rills or undulations should be avoided.

The technology is being used in a variety of climatic and soil conditions and can be adapted to rainfall by adjusting the distance between contours and also the area of cropping.

Water harvesting potential is reduced or lost if the catchment area is planted.

### 3.3.4 Fanya-juu Terracing

The structure is called Fanya juu (juu is Swahili word for 'up') because during construction, the soil is thrown up-slope to make an embankment which forms a runoff barrier leaving a trench (canal) which is used for retaining or collecting runoff. Fanya-juu terraces are constructed by throwing soil up slope from a ditch to form a bund along a contour. The trench is 60 cm wide by 60 cm deep, and the bund 50 cm high by 150 cm across at the base. Enlarged fanya juus are about 1.5 m deep and one metre wide.

Through gradual erosion and redistribution of soils within the enclosed fields, the terraced lands level off, forming the terraces. Soil and rainwater are conserved within the bunds, and the bunds are usually stabilised with planted fodder grasses. Cut-off drains may be installed in order to protect the terraces from surplus runoff. If stones are available, stone terrace walls are appropriate, as they allow surplus water to pass between the stones and overtop the walls.

Distance between bunds depends upon the slope (5m on steeply sloping lands to 20m on more gently sloping lands) often, runoff from external catchments (roads, homestead compounds or grazing land) is led into the canals which act as retention ditches allowing water more time to infiltrate the soil.

***Suitability***

Crops such as bananas, pawpaws, citrus and guava are grown in the ditches. Fodder grasses or scrubs are planted on the bunds. The technology is known from the Machakos District of Kenya.

## Other in-field water harvesting practices

**Table 3. 1: Guideline in brief for selected in-field rainwater harvesting practices**

| Name of practice | Guideline on the practice | Suitability | Reference |
|---|---|---|---|
| **Grass strips** | • It is a cheap alternative to terracing.<br>• Planted in dense strips, up to a meter wide, along the contour as a barrier to minimize soil erosion and runoff.<br>• Silt builds up in front of the strip, and within time benches are formed.<br>• The spacing of the strips depends on the slope of the land.<br>• Examples include Vetiver grass, Napier, Guinea, Guatemala grass, local Veld grass. | • Where there is a need of fodder or mulch<br>• Not applicable on steep slopes and in very dry (drought) areas | • Duveskog *et al.* 2003 |
| **Contour farming** | • It refers to farming along the lines of equal contour.<br>• Require systematic tillage at the beginning to be applied.<br>• The soil preparation and terracing should be established along the lines of the contours.<br>• Mainly important to reduce runoff and increase infiltration rate and soil water storage. | • Implemented in areas with a slope that is not too long | • FAO 1998<br>• FAO 1997 |
| **Micro-basins** | • Constructed along the retention ditches for tree planting, and they are roughly 1.0 m long and less than 50 cm deep.<br>• Aims to retain water *in situ* or to slow down the runoff water velocity.<br>• The basins are dug during the dry season, to allow planting at the onset of the rainy season and the precise application of fertilizer and manure.<br>• The disadvantage of micro-basin use is the labour required to construct them. | • Used to rehabilitate degraded land by water erosion and increased yields have been reported for crops planted on these basins | • Thiefelder *et al.* 2012<br>• Ngigi 2003<br>• Previati *et al.* 2009 |
| **Earth basins** | • Square or diamond shaped micro-catchments, intended to capture and hold all rainwater that falls on a specific area on the field.<br>• Constructed by making low earth ridges on all sides of the basins.<br>• Runoff water is channelled to the lowest point in the basin and stored in an infiltration pit. | • Rainfall > 150 mm)<br>• Soils should be deep (> 1.5 m)<br>• Slope < 5%<br>• fruit crops | • Duveskog *et al.* 2003 |
| **Stone bunds** | • stones installed along the contour lines.<br>• Sediment that accumulates behind the semi-permeable stones.<br>• Construction starts by placing large rock fragments along the contour followed by medium-size rock fragments that have a diameter of 5-10 cm as backfill and the backfill is topped by small rock fragments with a diameter of 2 cm that serve as a filter and also retain sediment.<br>• The benefits of stone bunds include increased soil water status and crop yields. | • Rainfall: 200 mm - 750 mm<br>• Soils: agricultural soils.<br>• Slopes: preferably below 2%.<br>• must be good local supply of stone. | • Vancampenhout et al. 2006<br>• Nyssen et al. 2007<br>• Zougmore et al., 2000 |
| **Trapezoidal bunds** | • used to enclose larger areas (up to 1 ha) and to impound larger quantities of runoff.<br>• has a base bund connected to two side bunds or wing walls (at an angle at about 135$^{o}$).<br>• Crops are planted within the enclosed area.<br>• Overflow discharges around the tips of the wing walls. | • For growing crops, trees and grass.<br>• Rainfall: 250 mm - 500 mm;<br>• Soils: non-cracking clay content<br>• Slopes: 0.25% - 1.5% | • Critchley et al. 1991 |

## 3.4 Guidelines for ex-field rainwater harvesting measures

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.

### 3.4.1 Earth dams and water ponds

Earth dams are semi-circular or curved banks of earth, 3-4 meters high and 100 meters in length. Water ponds or pans are naturally occurring or excavated water storage structures (called charcos in Tanzania) without a constructed wall/dam.

The reservoir should have a high depth to surface ratio to store maximum water behind the smallest possible dam. The best catchment area would be a relatively steep and rocky landscape with no erosion – and the dam should be placed in gentle sloping land in a wide shallow channel or broad depression. It is preferred that these can be built by using manual labour and animal tracking.

***Suitability***

Primarily used for small scale irrigation schemes in arid and semi regions with limited water resources.

## 3.5 Guidelines to rooftop water harvesting

Collecting water from roofs for household and garden use is widely practised across South Africa. Tanks and containers of all types, from large brick reservoirs to makeshift drums and buckets are a common sight in rural areas.

**Advantages of collecting water from roofs are:**

- ⇒ Roofs are physically in place and runoff is immediately accessible;
- ⇒ For small scale irrigation;
- ⇒ Water collected from roofs is much cleaner than from land runoff; and
- ⇒ Most of the rainwater falling on the roof can be collected, as there is little absorption or infiltration on the roof surface.

Figure 3.2 indicates the three main components to roof water harvesting: the roof, the gutter and the storage tank.

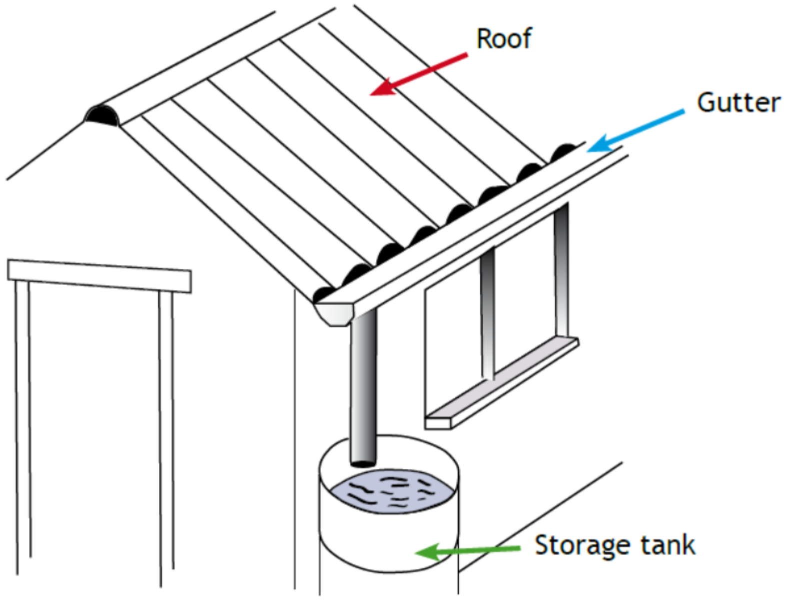


**Figure 3.2: Water harvested from roofs used for drinking, domestic purposes and irrigation of kitchen gardens**

**Rooftop WH:** Harvesting of rainwater can be from roofs of private, public or commercial buildings (e.g. greenhouses, schools). The effective area of the roof and local annual rainfall will determine the volume of the rainwater that can be captured. According to Oweis *et al.* (2012), between 80 – 85 percent of rainfall can be collected and stored.

### 3.5.1 General guidelines for collecting rain water

⇒ **Roof:** 10 mm of rainfall on a surface area of 100 $m^2$ will yield 1 000 litres of rain water.

⇒ **Gutter & downpipe:** Essential for capturing and guiding rainwater into tank.

⇒ **Tank:** Use a good quality tank, preferably with black lining, to prevent growth of algae.

⇒ **Tank stand:** A correctly constructed base provides stable support; allow sufficient height so that a bucket can be placed under the tap.

⇒ **Tap:** use plastic irrigation tap; include fitting to attach hosepipe, if required.

⇒ **Overflow:** Attach a thick black pipe to overflow outlet, use an adaptor to connect it to hose-pipe (guided to any part of garden as desired).

## 3.6 Drainage of excess water for high rainfall areas with clayey soils

Climate change can aggravate the problems of waterlogging in clay soils. A system used at planting time in order to drain excess water away from crops such as the Broad Bed and Furrow (BBF) Maker and raised bed planting systems can be used.

### 3.6.1 Broad Bed and Furrow

The 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. Two, three, or four rows of crop can be grown on the broad bed, and the bed width and crop geometry can be varied to suit the cultivation and planting equipment. In India and Ethiopia, BBF has been used mainly on deep poorly drained soils such as vertisols; wide beds are used on a gentle grade and they are formed by ox-drawn wheeled tool carriers. The purpose of BBF has the following objectives:

1. To encourage moisture storage in the soil profile in the drylands.

2. To safely dispose or remove excess water on the soil surface without causing erosion.

3. 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.

4. The possibility of the re-use of runoff 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 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.

### 3.6.2 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 (Sayre 2004). *In-situ* conservation means 'on site'. When we conserve one or more species in their habitat (where they naturally occur) we call it *in-situ* conservation. For example, conserving tigers in tiger reserves or rhinos in the habitat where they are found. This is the most cost effective way of conserving threatened species in the wild. *Ex-situ* conservation is when a species is taken out from its habitat and conserved (usually multiplied) in an outside facility like a zoo or a captive breeding centre or a botanical garden. *Ex-situ* conservation is important for critically endangered species which may or have lost the conditions to multiply naturally in the wild. *Ex-situ* conservation is costly. The origin and use of raised-bed cultivation systems have traditionally been associated with water management issues. 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 (Sayre 2004).

Bed and furrow structures help hold rainfall, prevent runoff, and promote water infiltration (Araya *et al*. 2015a). Studies conducted in Ethiopia with a modification of the existing traditional IRWH tillage practices, *derdero* and *terwah* with CA practices using mahresha ard plow reduced runoff and increased soil water storage (Araya *et al.* 2012). *Derdero* is a local soil and water soil conservation practices with furrow and resided bed (35 cm wide bed) planting systems in Vertisols in Ethiopia.

Similarly, *terwah* is a local soil and water conservation tillage practiced only on teff planting in Ethiopia. No-till approaches improve the soil's physical condition, leading to enhanced water infiltration and reduced runoff during each rainfall event (Araya *et al.* 2011). Generally, bed planting has advantages over flat planting for the reasons that bed planting is more water efficient, easier for weeds control and has a lesser seed rate requirement for seeding.

## 3.7 Irrigation water use efficiency

Smart irrigation approaches can address the inefficient watering irrigation of crops and land productivity, by ensuring greater water use efficiency. 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 have highest irrigation efficiency among all irrigation methods.

Water in surface irrigation flows by gravity while it requires pressure for water to flow in sprinkler and drip. Sprinkler irrigation needs higher pressure as compared to drip irrigation systems.

### 3.7.1 Drip irrigation

The principle of drip irrigation is very simple: water seeps slowly out of small holes in a pipe on the soil surface. Holes are normally located close to plants so that the water is targeted directly to the root zone.

Drip irrigation comes in many forms, but at its simplest, can be constructed by puncturing a piece of garden hose at intervals and connecting this to a water supply. The end furthest from the header tank should be closed off.

For smaller areas, the pressure from a header tank should be more than adequate to operate the system. Larger areas that require a longer length of tubing may need to be divided into sections and irrigated at different times. Separate sets of tubes with a different hole spacing may be needed to match different crop spacing.

The system should include a simple wire mesh filter between the storage tank and the drip irrigation pipes. This mesh requires regular cleaning as it may get clogged up with algae. A small petrol pump can be used for larger areas. The key advantage of a drip irrigation system is that water is targeted directly to the root zone to allow for applications to be closely monitored.

This considerably reduces the amount of water lost through evaporation compared to sprinkler systems. It also avoids problems of disease encountered from wetting the surface of the leaves and, because only a small area of the soil is watered, the area for weed control is far less than with sprinkler systems.

The system requires considerable work to set up, but once this is done, irrigation is relatively easy. Therefore, it is more likely to be used on smaller areas of high value crops that require regular watering.

**Suitability of drip irrigation**

⇒ **Slope:** Needs fairly level ground

⇒ **Soil**: Not so important

⇒ **Rainfall:** Depends on storage capacity

⇒ **Labour:** High to set up, thereafter low

⇒ **Crops:** Likely to be restricted to higher value horticultural crops

### 3.7.2 Wetting front detector

Wetting front detector (WF) monitors the moisture level in the soil at appropriate locations and depths which useful for irrigation scheduling (Stirzaker 2003; Stirzaker and Hutchinson 2005; Stirzaker *et al.* 2004). The WFD works on the principle of flow line convergence. Irrigation water or rain moving downwards through the soil is concentrated when the water molecules enter the wide end of the funnel. The soil in the funnel becomes wetter as the funnel narrows and the funnel shape has been designed so that the soil at its base reaches saturation when the wetting front outside is at a similar depth. Once saturation has occurred, free water flows through a filter into a small reservoir and activates a float.

The WFD can be used to schedule irrigation, because the time it takes for water to reach a certain depth depends on the initial water content of the particular soil. If the soil is dry before irrigation, the wetting front moves slowly because the water must fill the soil pores on its way down. Therefore, a certain quantity water is needed before the detector will respond. If the soil is quite wet before irrigation, then the wetting front will move quickly through the soil. This is because the soil pores are already mostly filled with water so there is little space for additional water to be stored. Thus, a short irrigation will cause the detector to respond.

The float in the detector is activated when free water is produced at the base of the funnel. Water is withdrawn from the funnel by capillary action after the wetting front dissipates. Depending on the version used, capillary action can be used to “reset” the detector automatically, or water can be removed via a syringe. The water sample can be used for routine salt and fertilizer monitoring.

### 3.7.3 Chameleon sensor system

The Chameleon sensor system is a prototype sensor designed to increase water management techniques for smallholder irrigators on their farms. Applications of the Chameleon sensor 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 (Stirzaker *et al.* 2007). 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. The sensor includes a field reader, sensor array, connector, and battery charging cable.

## 3.8 Use of renewable energy in irrigation systems

Water for irrigation purposes can either be drawn from surface reservoirs (e.g. canals, streams, lakes) or from aquifers. Energy needs can vary depending on the vertical and horizontal distances the water travels.

Options for powered irrigation include:

⇒ **Conventional:** Electricity grid-connection, diesel or petrol-based;

⇒ **Renewable:** Solar, wind, biogas, or small hydropower schemes; and

⇒ **Hybrid:** Grid with diesel/solar/biogas, or diesel with solar/wind

### 3.8.1 Solar-Powered Irrigation Systems

Powering irrigation systems with solar energy is a reliable and environmentally sustainable option in a growing number of contexts. Solar-based irrigation systems can be scaled to meet diverse energy demands and can contribute to a decoupling of growth in irrigated land areas from fossil fuel use, while improving livelihoods. The environmental advantages of using solar and wind energy pumps in irrigated agriculture include:

⇒ Does not produce any GHG emissions after the solar-powered irrigation systems is manufactured which crucial as a mitigation to climate change.

⇒ Potential for adaptation to climate change by mobilizing groundwater resources when rains fail 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).

## 3.9 Monitoring and evaluation of performance of climate smart agriculture water management

In order to determine whether a new technology tested in an on-farm trial is better than the conventional method, it is important to monitor and observe differences between the two technologies.

### Case study 3.1: Basin tillage using mechanization

Basin tillage is a soil and water conservation practice that increases surface depression storage of precipitation, thereby potentially reducing storm runoff and increasing soil water storage and availability to crops. Basin tillage can be constructed using mechanization or manually. The mechanized basin (MB) plough was originally developed by Mr. Jurie Serfontein near Kroonstad for the creation of basins to rehabilitate degraded veld. Dagga & Macartney (1969) reported that the system of cultivation based on ripping, ridging and tieing proved to be an adequate alternative to ploughing and harrowing for seedbed preparation, and a much more efficient method of water conservation. The MB plough was modified to incorporate a small tine to rip the bottom of the basins to improve infiltration (Van der Merwe, 2005).

Van der Merwe (2005) tested the MB plough on a clay soil at the Springbok flats and found that it increased maize and sunflower yield as compared to conventional tillage due to its better water conservation ability. Small basins in rows conserve the rainwater that falls into the basins, where the water in the basins can infiltrate deeper into the soil, below the evaporation layer (Figure 3.3). The MB plough has a basin attachment (small sharp scraper blade) which pivots on the rear of a three-point hitched ripper. The ripper tine operates directly in front of the attachment to break up compacted soil. The scraper at the rear of the attachment creates the basins. The diamond shaped wheel controls the movement of the scraper blade, resulting in a row of basins being created.

The distance between basin rows is versatile and depends on the planter and maintenance considerations. A 1 m spacing is recommended. With a tractor wheel width of 480 mm it implies that during implementation the tractor returns on its tracks when implementing a new row, but the return trip must start about 50 mm away from the initial wheel tracks.

**Figure 3.3: Basin tillage using mechanization**

According to Botha *et al.,* (2014), this innovative IRWH technique has the potential to reduce total runoff and minimize surface evaporation considerably when implemented correctly. The result is increased plant-available water and thus increased yields.

An indicator is a measurement that allows one to track changes. Indicators related to adaptation and mitigation to climate change to be monitored during an on-farm trial might include productivity, yields, resilience, runoff, soil erosion, soil organic matter, improved soil characteristics, input requirements, levels of technology and whether tested solutions were able to solve farmers' problems. Indicators provide a standard against which one can measure, assess or show progress.

The actual selection of indicators depends on the kind of information the group desires and how they want to measure change. Selecting good indicators requires experience and skill. It may be useful to seek help from an extension worker to select appropriate indicators.

The following are some of the measurements that can be used as indicators in monitoring and evaluation of Climate Smart Agriculture (productivity and income, adaptation, mitigation) to assess the impacts of agricultural water management practice.

I. Productivity and income:

⇒ grain yield per unit area;
⇒ lower repairing costs;
⇒ longer life span of the equipment;
⇒ Lower costs due to reduced operations and external inputs; and
⇒ Reduced input requirements.

I. Adaptation to climate change:

⇒ reduce water loss in the form of runoff, deep drainage and evaporation;
⇒ reduce soil water erosion;
⇒ avoids risks linked to erratic and declining rainfall;
⇒ stores rainwater for longer periods against long midseason dry spells; and
⇒ maximizes the use efficiency of water and plant nutrient.

I. Mitigation to climate change:

⇒ Increase soil organic carbon;
⇒ Increase carbon sequestration;
⇒ Reduce fuel consumption; and
⇒ Increase plant root biomass that can increase soil organic carbon.

Some examples of indicators used by farmer groups to measure impacts of IRWH includes yield per hectare parameters such as number and size of fruit, plant height, colour of leaves, number of leaves, number and size of maize cobs, survival rate of seedlings, days spent working on the trial, cost of labour, income from selling plot produce, temperature of the soil, signs of erosion, soil moisture, root penetration in the soil and soil resistance to penetration by a knife or stick.

# 4. Climate Smart Cereal Crops Production

## 4.1 Introduction

Climate smart strategies of growing cereal crops in South Africa (SA) are discussed in the context of projections of climate change scenarios developed by various researchers for SA.

The low average annual rainfall of 450 mm compared to a global average of 860 mm points to challenge of water scarcity for both rain-fed and irrigated production of cereals that face SA as a water scarce country (Kohler, 2016). Climate change will make the situation more difficult. In parts of SA it will alter rainfall amount and distribution, evaporation, runoff, and soil-moisture storage. Higher temperatures, for example, will lead to an increase in evaporation and crop water requirements.

The challenge faced by farmers will be to make more efficient use of water resources (rainfall or irrigation) particularly in those parts of the country where rainfall is expected to decrease in quantity and increase in its variability, both inter and intra-seasonal to maintain or improve crop productivity.

According to Bell *et al.* (2018), it is important to measure contribution to all three criteria but it is rare for a technology to meet all three criteria. For a technology to respond to climate change and be climate smart the productivity objective must be combined with the mitigation or resilience objectives.

## 4.2 Switching from maize to sorghum and millets

Switching crops is an adaptation strategy that is justified if rainfall is expected to reduce to levels where the risk of producing maize becomes unacceptable from a financial viability or food security perspective, depending on the scale of production. Alternatives to maize that can be considered by farmers are sorghum; (*Sorghum bicolor*) and pearl millet (*Pennisetum glaucum*).

### 4.2.1 Practical guidelines to switching to sorghum

Climate and ecology related guidelines for switching to sorghum:

⇒ Under expectations of mild to semi-extreme drought (200-400 mm of rainfall), farmers should consider periodically shifting to sorghum to reduce chances of crop failure.

⇒ Farmers in semi-arid/ extremely high summers/ low and highly irregular rainfall conditions are advised to consider permanent shifts sorghum as a drought, heat, flooding tolerant alternative to improve and sustain crop yields.

⇒ Farmers in marginal systems (low soil fertility, low use of fertilisers) are advised to shift to sorghum as yield declined is moderated under low fertility.

It is important to note the following with respect to sorghum production:

⇒ Choose cultivar with wide adaptability when starting out in sorghum production and thereafter as more experience is gained, results of multi-seasonal testing can be used select cultivar that is more suitable for the farm's yield potential.

⇒ Weed control during the first 6-8 weeks is crucial for achieving good yields, so farmers should ensure good weed control during the early stages.

⇒ In places where temperatures are too hot, farmers are advised to plant photoperiod sensitive cultivars, as they are more resilient to counteracting the temperature effect of shortening growth duration.

⇒ Landraces generally perform better when planting late and under low rainfall (<350 mm), thus farmers can use this alternative to sustain yields under water limited conditions. Important to note is that landraces usually have high tannins therefore not accepted by the formal market for food or brewing.

### 4.2.2 Pearl millet

Climate and ecology related guidelines for switching to pearl millet:

⇒ Pearl millet cropping is recommended for similar ecologies (see above) to sorghum production (rainfall and heat), except where there is regular storms and floods as it is not flood tolerant.

⇒ Where sub-soils are acidic (pH of 4 and above) and/ or have high aluminium content, pearl millet production is recommended over sorghum as it is acid and aluminium tolerant.

The following points are important to note:

⇒ There is no commercial market for pearl millet in SA and any trade is local in production areas.

⇒ Birds readily consume pearl millet seed and losses can be high in small isolated fields. Organise as a community to grow a larger area of pearl millet.

## 4.3 Guidelines for using improved cultivars

Smallholder cropping systems in SA are largely low input because of a number of socio-economic constraints. The climate risk analysis performed by Bell *et al.* (2018) shows that varieties developed for stress (water and low nitrogen) make a positive impact with regards to intra-seasonal droughts and a shortening of growing season. This translates to increased productivity and resilience of cropping systems with incorporation of these varieties.

### 4.3.1 Disease and pest tolerance

Low input vs high input systems

⇒ Landraces generally provide wide-ranging tolerance to pests and diseases recommended for cultivation under low input systems.

⇒ Improved varieties are generally excellent choices for tolerance/ resistance to specific pests and diseases and are therefore recommended for high input systems.

Guidelines to improved cultivars selection for pest and disease tolerance in cereals

⇒ For stem borer infestations, various insect pest protected (Bt) cultivars are available for major cereals. These can be cultivated to curb stalk borer infestations.

⇒ To control *Striga* or witchweed infestations in prone areas, Imazapyr-Resistant (IR)-cereal seed technology cultivars are suggested for production to reduce its impact on yield.

### 4.3.2 Drought tolerance

Drought tolerant cultivars are available for most cereals. The WEMA project implemented by the ARC has released ten Drought*TEGO*™ WEMA maize varieties with predominant characteristics of drought tolerance and high yield potential under optimal moisture. Further details are available in ARC documentation (ARC, 2017a; ARC, 2017b).

## 4.4 Better use of short term and seasonal climate forecasts

The SA climate is highly variable and the daily as well as intra- and inter-seasonal variability are likely to increase with climate change (Lumsden and Schulze, 2012). Short term and seasonal climate affect a wide range of climate smart agriculture related management practices. These include from time of planting, irrigation scheduling, crop and cultivar choices, soil management, choice of intercropping, mulching, fertility strategies, and market -related decisions (FAO, 2013).

Decision-making informed by a sound weather and climate system with good interpretation of forecasts is going to be key in improving timeliness of operations and efficiency of resource utilisation to support increased crop productivity and resilience of cropping systems.

Guidelines for using climate forecasts in climate smart agriculture:

⇒ Consult various sources, such as South African Weather Service (SAWS), extension services to get a good interpretation of advisories given so that these can be translated into sound decisions regarding the management of crop enterprises.

⇒ Even where farmers use traditional indicators, use these in conjunction with scientific methods.

⇒ Forecasting is not very accurate, and it is important to work with information that reflects higher chances of success when making forecast based decisions.

⇒ Short-term forecasts are generally more accurate than longer term forecast. Decide with this in mind.

## 4.5 Intercropping

Intercropping is a multiple cropping practice that involves the growing of two or more crops in the same field. One of the benefits of intercropping is an increase in crop productivity. Cropping systems are more resilient with intercropping even under conditions of low soil fertility and moisture. Commonly planted food legumes include beans, pigeon pea, cowpea, groundnuts and soybeans. Non-edible legumes such as velvet beans can be used as a climate mitigation measure by farmers intending to produce feed for livestock. Velvet beans have a high carbon sequestration potential because of high levels of biomass that is achieved.

There are different approaches that can be used when intercropping such as the following:

⇒ **Mixed intercropping:** in this system, two or more crops are planted in a mixture without a distinct row arrangement.

⇒ **Row intercropping:** two or more crops are planted in distinct rows.

⇒ **Relay intercropping:** two or more crops are grown at the same time and their life cycles overlap i.e. a second crop is sown after the first crop has been well established but before it reaches harvesting stage.

⇒ **Strip intercropping:** is the growing of two or more crops at the same time in separate strips wide enough apart for independent cultivation.

According to GrainSA (2018), the main motivation for intercropping by smallholder farmers is to improve output per hectare. In a commercial enterprise, intercropping can be used to address the need for animal feed, particularly during the dry season. The nutrition value of maize stover that is grazed after harvest can be improved upon by relaying a legume before the maize is harvested.

Success of intercropping can only be achieved by careful crop selection to minimise competition and to enhance facilitation. Here are key points to keep in mind:

⇒ Not all varieties of maize are tolerant to intercropping. Attention must be given to selecting the maize variety/ies leaf architecture that allows more light to reach the bottom of the canopy.

⇒ Where the association is with a climbing legume, a strong stalk will be required to withstand the weight of the climber

⇒ The two crops must not compete. If planted together, the legume must be slower growing at the beginning to allow the maize to establish with little competition. The root systems must work in different layers of the soil horizon to avoid competition for water and nutrients.

⇒ Climbing legumes tend to be more aggressive and reduce maize yields in comparison to bush types.

⇒ Good planning is important (spatial arrangement, crop and cultivar choices, etc.), and

⇒ With proper planning, though usually maize-legume systems produce less maize than the monoculture but provide higher economic returns, the depression in maize yield might not be observed with yields similar to the monoculture and in some instances, higher.

## 4.6 Crop rotation

Crop rotation is a planned succession of crops (cash and cover) chosen to sustain a farm's economic and environmental health. Usually a rotation contains at least one 'money crop' (which in this case is a cereal crop of choice) that finds a direct and ready market; one clean tilled crop; one hay or straw crop; one leguminous crop. The starting point for the design of a rotation should be the capabilities of the farm and the land in terms of soil type, soil texture, and climatic conditions. Crop rotations should consider suitability of individual crops with respect to climate and soil, balance between cash and forage crops, seasonal labour requirements and availability, and cultivation and tillage operations.

The type of crop rotation will depend on the objectives of the farm. Examples of objectives farmers may have for their farm is wide but may include:

⇒ better moisture conservation;

⇒ reduced financial risk;

⇒ reduce mechanisation costs; and

⇒ weed, disease and insect control.

Since no single rotation can be regarded as ideal, a broad set of guidelines can be used for each farmer to arrive at what will work for them.

**Table 4. 1: Guidelines for crop rotation**

| Item | Guidelines |
|---|---|
| **Pre-planning the rotation** | ⇒ The rotation must adapt itself to the farmers' business.<br>⇒ It must adapt itself to the soil and fertility problem.<br>⇒ The fertilizer question often modifies the rotation.<br>⇒ The kind of soil and the climate may dictate the rotation.<br>⇒ The labour supply has an important bearing on the character of the rotation course.<br>⇒ The size of the farm and whether land can be used for pasturage are also determinants.<br>⇒ The rotation must be planned with reference to the species of plants that will best serve one another, or produce the best interrelationship possible.<br>⇒ The rotation must consider in what condition one crop will leave the soil for the succeeding crop, and how one crop can be seeded with another crop. |
| **Basic guidelines of cereal-legume based crop rotations** | ⇒ Deep rooting crops should follow shallow rooting crops.<br>⇒ Alternate between crops with high and low root biomass.<br>⇒ Nitrogen fixing crops should alternate with nitrogen demanding crops.<br>⇒ Wherever possible, catch crops, green manures, and undersowing techniques should be used to keep the soil covered. Crops which develop slowly and are therefore susceptible to weeds should follow weed suppressing crops.<br>⇒ Alternate between leaf and straw crops.<br>⇒ Where a risk of disease or soil borne pest problems exists, potential host crops should only occur in the rotation at appropriate time intervals.<br>⇒ Use variety and crop mixtures when possible.<br>⇒ Alternate between autumn and spring sown crops. For example, winter wheat and dry beans, maize and cowpea, sorghum and bambara, millet and lentils. |
| **General Principles of cereal-legume based crop rotations** | ⇒ Follow a legume crop, with a high nitrogen demanding crop which is usually a cereal.<br>⇒ Grow less nitrogen demanding crops, in the second or third year after a legume sod.<br>⇒ Grow the same annual crop for only one year.<br>⇒ Don't follow one crop with another closely related species.<br>⇒ Use crop sequences that promote healthier crops.<br>⇒ Use crop sequences that aid in controlling weeds.<br>⇒ Use longer periods of perennial crops on sloping land.<br>⇒ Try to grow a deep-rooted crop as part of the rotation.<br>⇒ Grow some crops that will leave a significant amount of residue.<br>⇒ When growing a wide mix of crops try grouping into blocks according to plant family, timing of crops, (all early season crops together, for example), type of crop (root vs. fruit vs. leaf), or crops with similar cultural practices. |

### 4.6.1 Practical guidelines based on farm size

**Farmers with limited land area (< 2 ha)**

⇒ Rotation is challenging and should be avoided where possible. Rather, intercropping should be used to introduce diversity in the cropping system.

⇒ Farmers are advised to use mulch, compost, and short-term winter cover crops in place of multi-season cover crops and hay rotations.

**Farmers with large land area (> 2 ha)**

⇒ Large farms have a large cover crop dependency, and are recommended to use cover cropping and crop rotation.

## 4.7 Converting from conventional cereal monoculture to conservation intercrop farming

To convert from conventional to conservation agriculture, may be a challenging phenomenon and should be done gradually, beginning on a small-scale and gradually, expanding area under conservation agriculture. However, the conversion falls into three steps:

### 4.7.1 Basics guidelines to converting from conventional to conservation agriculture

**1. Before starting**

⇒ Choose the field - Start with a field with good potential.

⇒ Start small - Start with one field, observe and learn.

⇒ Get support - Learn from neighbours and friends. Seek advice from extension service providers use animal/tractor - drawn sub-soiler or ripper to remove hardpan. Remove rocks or tree stumps. For acidic soils, add lime.

**2. First season**

⇒ Cover the soil - use mulch plant cover crops such as lablab, cowpeas or other cover crop legumes.

⇒ Control weeds – use hand-pulling, slashing or use herbicides to control weeds.

⇒ Do not plough direct - plant the cereal crop through the mulch, or dig planting basins on which crops are sown.

⇒ Grow crops - Grow the cereal crop and an intercrop e.g. maize and beans or other legumes. For spreading architecture legumes e.g. spreading cowpea, plant them once the cereal crop has emerged to avoid suffocation. For erect and semi-erect architecture legumes e.g. beans, bambara groundnuts, peas, lentils, jugo beans, they can be planted at the same time as the cereal crop.

⇒ Leave the soil covered - At harvest leave the crop residues on the field. Leave the cover crop growing.

**3. Second and following seasons**

⇒ Control the weeds - Hand-pull, slash or use of herbicides.

⇒ Crop Residues - Ensure there is enough crop residues in the field.

## 4.8 Practical guidelines to minimum tillage

⇒ Where possible, disturb soil only where seeds will be planted. Apply minimum soil disturbance without soil inversion.

⇒ Use hands or specialised equipment for seeding and placing fertilizers.

⇒ Allow permanent soil cover with living crops or crop residues. Residues can be both standing stubble or loose residues.

⇒ Use crop rotations to reduce crop diseases and increase diversity, resilience, and soil health.

## 4.9 Cover cropping

A number of legumes are recommended for cover cropping various cereals in both winter and summer.

⇒ Examples of legume cover crops that can be planted in summer (warm seasons) include: dolichos, sunnhemp, cowpea and lucerne, velvet beans, soybean and mung bean.

⇒ Examples of legume cover crops that can be planted in winter (cool seasons) include: hairy vetch, forage pea, lurcene and red clover.

## 4.10 Basic practical guidelines to mulching

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.

### 4.10.1 Choosing types of Mulch

Mulches are available in many forms. The two major types of mulch are inorganic and organic.

*1. Inorganic mulches include various types of stone, lava rock, pulverized rubber, geotextile fabrics, and other materials.*

⇒ Do not replenish inorganic mulches often as they decompose extremely slowly.

⇒ Use them with the understanding that they do not improve soil structure, add organic materials, or provide nutrients.

*2. Organic mulches include wood chips, pine needles, hardwood and softwood bark, cocoa hulls, leaves, compost mixes, and a variety of other products usually derived from plants. Organic mulches decompose in the landscape at different rates depending on the material, climate, and soil microorganisms present.*

⇒ Since the decomposition process improves soil quality and fertility, those that decompose faster must be replenished more often.

### 4.10.2 Practical guidelines to mulching

The choice of mulch and the method of application can be important to the health of landscape plants. The following are some guidelines to use when applying mulch:

⇒ Determine whether soil drainage is adequate and if plants may be affected by the choice of mulch. The majority of commonly available mulches work well in most landscapes. A select number of plants may benefit from the use of slightly acidifying mulch, such as pine bark.

⇒ For well-drained sites, apply a 5 to 10 cm layer of mulch (less if poorly drained). Coarse mulches can be applied slightly deeper without harm. Place mulch out to the edge of a plants stem or beyond.

⇒ If mulch is already present, check the depth. If sufficient mulch is present, break up any matted layers and refresh the appearance with a rake. Some landscape maintenance companies spray mulch which is water-soluble, and vegetable based.

### 4.10.3 Planting density and mulching guidelines

⇒ Mulching works well with a high population of maize crops (plants in excess of 45 000 plants/ha), in higher rainfall areas.

⇒ Where there is a lower plant population (20 000 plants/ha), additional mulch is required. Cover left after harvesting is not sufficient to actually achieve the type of mulch needed to accomplish the positive attributes.

## 4.11 Monitoring performance of the intervention in terms of the CSA pillars (adaptation, resilience, and mitigation)

Table 4.2 provides a summary of performance indicators that

Table 4. 2: Performance indicators of cereal based climate smart agriculture monitoring and evaluation at farm and community/ provincial/ catchment/ governmental level.

| | Farm level | Administrative |
|---|---|---|
| **Adaptation** | ⇒ Area under improved/ tolerant cultivars.<br>⇒ Area under intercropping. | ⇒ Area under improved/ tolerant cultivars.<br>⇒ Area under intercropping. |
| **Mitigation** | ⇒ Number of crops per plot.<br>⇒ Area with crop residue/ mulch.<br>⇒ Reduced soil moisture fluctuations. | ⇒ CSA friendly policy.<br>⇒ Cohesive CSA decision making at government level.<br>⇒ Cleaner water due to less erosion and reduced sedimentation of water bodies.<br>⇒ Lower municipal and urban water treatment costs.<br>⇒ Less flooding due to increased infiltration; less damage from droughts and storms. |
| **Resilience** | ⇒ Yield per unit area.<br>⇒ Soil organic matter levels over time.<br>⇒ Reduced input requirements.<br>⇒ Improved microbial activity in soil.<br>⇒ Lower repair costs, longer life span of equipment, and less fuel consumption.<br>⇒ Lower costs due to reduced operations and external inputs. | ⇒ Sustained yields under harsh environmental/ pests/ disease conditions.<br>⇒ Relief funds availability. |

can be used at various levels to monitor and evaluate CSA. These indicators are not specific to cereal-legume based production systems but apply to CSA, in general.

## 4.12 Key challenges that face climate smart agriculture and solution suggestions

**Change of mind-set**

⇒ Farmers must drop their traditional practice of preparing the land with a hoe or plough, and instead rely on biological tillage by the plant roots and earthworms.

⇒ The switch also encourages subsistence farmers to see their farms as a business rather than merely a way to feed their families.

**Limited crop residues**

⇒ Keeping the soil covered is important in conservation agriculture, but it can be difficult. Farmers have many uses for crop residues: as fodder, fencing, roofing and fuel. Livestock keepers let their animals graze on stubble.

⇒ In drier areas, it is impossible to grow a cover crop in the dry season, and crop residues are a vital source of animal feed. Farmers need to explore strategies of relay cropping cover crops into standing maize at 6-8 weeks after planting. Research is needed to support farmers to find the best species to use, time and density of seeding.

## 4.13 Conclusions

The practical guidelines were developed as basic guides for farmers practising climate smart agriculture in cereal-legume based systems. Guidelines compiled include: (i) basic principles of choosing climate smart crops, (ii) guidelines to crop rotations, mulching, tillage, intercropping and cover cropping, (iii) and guidelines to using climate information in climate smart decision making.

Contacts and resources for additional information have been included in this guideline to provide users with additional climate smart agriculture resources. The guidelines do not replace expert advice (e.g. soil scientist, agronomists, extension officers). These guidelines should be used together with practical experience and expert advice, by farmers practising or wishing to practice climate smart cereal-legume based agriculture.

# 5. Sugar Industry

## 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). Sugar contributes 6% of South Africa's total agricultural output on 2.2% of South Africa's arable land area, generating R14 billion in income and R2.5 billion per annum in export earnings, with the animal feeds component contributing billions in value towards livestock. Sugar, indeed, generates more than twice the average level of economic output as the average output from arable land in South Africa, and nearly twenty times the economic output of land in general in SA (McCarthy, 2007). Therefore, the sugar industry is a significant contributor to the South African economy.

Recommendation of better management practices (BMPs) for sugarcane growers and sugar millers are made through the Sustainable SugarCane Farm Management System (SUSFARMS®). This Chapter will first present CSA practices that are recommended in the sugar industry, and environmental standards/ systems that the sugar industry complies with. Secondly, the Chapter will also direct readers to guidelines on BMPs that are elaborated in the SUSFARMS® Manual. These guidelines were specifically developed for the sugar industry and compliance with these guidelines enables sugarcane producers and millers to acquire the certification requirements of consumers and large scale buyers who are concerned with sustainable sourcing of sugar. Only those who can demonstrate their commitment to utilisation of sustainable farming practices, including adoption of ethical labour practices, can access the export market.

## 5.2 Climate-smart agriculture practices in the South African sugar industries

Numerous CSA practices are being researched and implemented in the sugarcane industry. The South African Sugar Research Institute (SASRI) is conducting most of the research into adaptation and mitigation strategies that are subsequently adopted by sugarcane growers. SASRI also jointly does research with other institutions such as the University of KwaZulu Natal and Free State University. 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. This research is continuously undertaken through SASRI and its collaborators.

Research at SASRI is clustered within four multi-disciplinary programmes including variety improvement, crop protection, crop performance and management, and a systems design and optimisation 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 namely: breeding and selection, variety characterisation, novel and improved traits, and, genomics and bioinformatics. The novel and improved traits sub-programme involves use of mutagenesis, and research into production of transgenic sugarcane varieties. The recently initiated transgenic sugarcane programme is presently working on developing drought tolerant and mealybug resistant varieties.

The goal of 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 continuously undertaken in five key areas namely: 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 research is to develop models and better management practices to enable stakeholders to enhance sustainable crop production. Research is undertaken in six key areas namely: 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.

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 namely: production sustainability, water management, and technology development.

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.

## 5.3 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.

The main global voluntary sustainability organisation operating in the sugar industry in South Africa is Bonsucro (Better Sugar Cane Initiative). Bonsucro 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. Examples of such large scale buyers include Coca Cola, Nestle, Unilever and Kraft Foods.

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

The SUSFARMS® is used as a farmer-extension tool to facilitate adoption of better management practices (BMPs). It is a management tool to facilitate production of sugarcane in a profitable, sustainable and environmentally responsible manner (Maher, 2007). The BMPs reduce negative impacts on the environment, comply with legislation, maintain a high level of social responsibility and assist in ensuring financial sustainability. Implementation of the SUSFARMS® concept has been steadily expanding over the years. The concept is enabling the industry to comply with international sustainability standards, such as Bonsucro. This is important because globally, there is growing consumer concern about 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 meets 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.

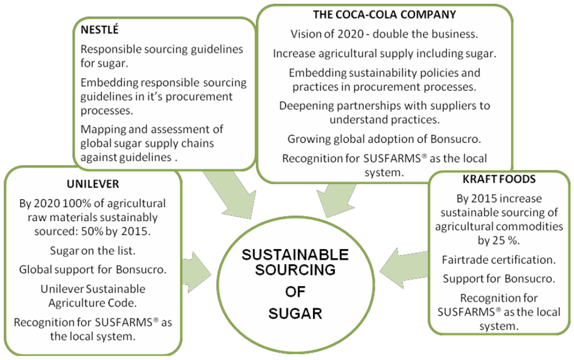


**Figure 5.1: Specific targets for sustainable sourcing of sugar by some major sugar purchasers**.

*Source: Govender (2013)*

Implementation of SUSFARMS® and better management practices in the sugarcane growing regions is continuous. New research findings are used to update existing recommendations. The SUSFARMS® farming model recently won an international Bunscoro benchmarking award (Edmonds, 2018).

### 5.4.1 Conceptual Framework

The SUSFARMS® conceptual framework described herein was derived from the 2014 Draft Edition of the SUSFARMS® Manual. The framework provides a mechanism for the articulation and acknowledgement of relevant international and South African legislation as well as sugar industry standards. Compliance is achieved by means of implementing BMPs. The three main principles that make up the main framework of the SUSFARMS® system are:

i) **Prosperity** - this embodies the economic principle whereby economically viable sugarcane production is maintained or enhanced.

ii) **People** - this embodies the social principle whereby the rights of employees, suppliers/contractors and the local community are upheld and promoted.

iii) **Planet** - this embodies the environmental principle whereby natural assets are conserved, critical ecosystem services are maintained, and agricultural resources are sustainably used.

The SUSFARMS® Manual categorises the three main sections of people, prosperity and planet under two main headings, namely “A statement of intent” and “measures”.

The Statement of Intent is a broad statement that indicates the overall objective (or desired outcome) from implementation of BMPs or being legally compliant. Measures on the other hand, are the ‘auditable’ elements of a SUSFARMS® system and form an integral part of the SUSFARMS® Progress Tracker.

The measures are fair to both small and large farms, they can be adapted and applied to all regions in the sugar industry and relate to operational aspects of sugarcane production. For each practice that is required, there is a related ‘measure’ that serves to ‘check’ whether legal requirements have been implemented or BMPs are in place (SUSFARMS®, 2014).

### 5.4.2 The SUSFARMS® Progress Tracker

Since each legal requirement or BMP has a measure associated with it, it is possible to assess progress with regard to implementation of sustainability practices at one point in time, or over a longer period of time.

The “SUSFARMS Progress Tracker” is a checklist of each measure, against which one can indicate full achievement, partial achievement or non-achievement of a legal requirement or BMP.

Once completed, the Progress Tracker provides a progress report. This report can be used to develop an action plan that can serve to plan the way forward towards the implementation and achievement of new measures.

The Progress Tracker can be used to conduct a Self-Assessment, Internal Assessment or External Party Assessment, depending on the purpose of the assessment and who conducts it (SUSFARMS®, 2014). This 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.

## 5.5 Practical implementation of the SUSFARMS®

A self, internal or external assessment procedure consists five steps involving the grower and assessor. The steps are namely: i) a pre-assessment stage; ii) an interview with the grower; iii) field visit; iv) scoring against the progress tracker checklist, and; iv) development of a corrective action plan (SUSFARMS® 2014). These steps are shown in Figure 5.2.

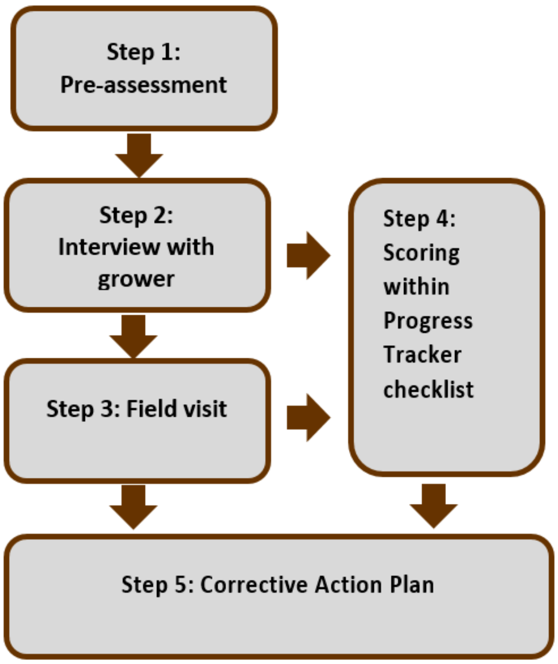


**Figure 5.2: Steps involved in conducting an internal or external assessment.**
*Source: SUSFARMS® (2014)*

**Step 1: Pre-assessment**

In the case of an external assessment, a grower is notified of the upcoming assessment. The notification must remind the grower to have the following documents on the day of the assessment: i) copy of the previous assessment and action plan; ii) copies of the Land Use Plan and all other relevant maps.

**Step 2 and Step 3: Interview with the grower and field visit**

Steps 2 and 3 consist of an interview with the grower, followed by a field visit to gain an understanding of the layout and operations of the farm. The following information is captured in the Progress Tracker Report (SUSFARMS® 2014):

⇒ Grower's name, mill group, farm name and grower code.
⇒ The major and minor river catchments in the area.
⇒ The name of the Local Environment/Conservation Committee.
⇒ The eco-zone/ward and relevant 1:10 000 orthophotos.
⇒ Cane area and total farm area.
⇒ Topography and average slope %.
⇒ Soil parent materials and forms.

The farm maps/ land use plan should reflect the following information:

⇒ Conservation and extraction layout.
⇒ Fields, field number and size.
⇒ Soil types, both parent material and soil forms.
⇒ Sensitive areas highlighted.
⇒ Wetlands, rivers and streams.
⇒ Quarries.
⇒ Staff/labour housing and workshop.
⇒ Rubbish dumps.

Key items to note during the field visit would be inclusive of:

⇒ Land use plan.
⇒ Financial plan.
⇒ Copy of Occupational Health and Safety Act (OHSA) 85 of 1993 Safe working conditions.
⇒ Contracts with employees.
⇒ Copy of basic conditions of employment sectoral determinations (farm worker sector).
⇒ Evidence of Unemployment Insurance fund (UIF) and skill development levies contributions.
⇒ Evidence of only labour tenants claims.
⇒ Protection of any areas or objects under the national heritage resources act and/or similar provincial legislation.
⇒ Alien plant control programmes.
⇒ Protection/management of any natural ecosystems.
⇒ Pollution and waste management systems.
⇒ Change of land use and dam construction has been authorized.
⇒ Condition and position of waterways, roads and construction terraces.
⇒ Quarries – siting and condition.
⇒ Crossings – position, type and condition.
⇒ Water use registration and/or authorization.

⇒ Use of agricultural remedies and fertilizers

⇒ Fire management.

The Progress Tracker checklist follows the SUSFARMS® manual and all measures can be cross-checked to the manual for further details.

**Step 4: Scoring**

The objectives of scoring are to:

⇒ determine the current performance of the grower in relation to the requirements of SUSFARMS®;

⇒ highlight strengths and weaknesses; and

⇒ develop an action plan for corrective action where this is required.

Scoring is based on the recording of actual observations/ discussion with the grower by the assessor as to which of the proposed measures have been addressed on the farm – be they legislative requirements, BMPs or higher level practices.

**Step 5: Development of a corrective action plan (CAP)**

A corrective action plan (CAP) can follow either a self, internal or external party assessment. The CAP suggests corrective actions to be taken to reach achievement of all SUSFARMS® measures. If necessary, corrective actions can be given priority ratings of 1 to 3.

Priority 1 is the most urgent and corrective action must be accomplished within six months to a year depending on the extent of non-achievement. Priority 2 and Priority 3 time frames can, for example, be within a period of 6 – 12 months and longer than 12 months respectively.

When giving a priority rating, financial constraints, legal implications and practicalities must be taken into consideration as they influence time needed to accomplish the CAP. All CAP's and time frames should be mutually agreeable between the assessor and the farmer. In subsequent assessments, the CAP report will be used to determine whether or not the farmer has complied with the previously suggested course of action (SUSFARMS® 2014).

## 5.6 Monitoring performance of the intervention in terms of the CSA pillars

In general, farmers will conduct self-assessments, internal or external assessments and generate reports using the SUSFARMS® Progress Tracker. Overtime, there must be evidence of increasing and sustainable utilisation of BMPs, and compliance to labour and environmental legislation. Examples of farm level and administrative indicators that can be used are shown in Table 5.1.

**Table 5.1: CSA farm level technical indicators**

| Theme/Pillar | Sub-theme | Farm level indicators |
|---|---|---|
| Productivity | Crop system | Increase in sugarcane yields (ton/ha) |
| | Water use | ⇒ Increase in irrigated land area, reduction in total water withdrawal;<br>⇒ maintenance of irrigation system in accordance with a predetermined schedule;<br>⇒ increase in water productivity; and<br>⇒ Increase in use of waste water for irrigation in compliance with the National Water Act. |
| | Energy | ⇒ Reduction in agricultural energy use, such as during irrigation; and<br>⇒ increase in use of renewable energy (e.g. bioethanol). |
| Resilience | Robustness | ⇒ Increases stability of production, promotes income diversification, incorporate site-specific knowledge; and<br>⇒ Improved economic resilience through improved profitability over time. |
| | Cropping system | ⇒ Increases resilience to drought, such as through using drought tolerant sugarcane varieties emanating from conventional and molecular breeding, as well as genetic modification programme. |
| Mitigation | Emissions intensity | ⇒ Reduces GHG emissions. |
| | Sequesters carbon | ⇒ Increases carbon sequestration. |

*Source: Adapted from The World Bank Group, 2016)*

## 5.7 Case studies

Two case studies are presented, one being on BONSUCRO certification in Honduras (Box 5.1), while the other is on smallholder women sugarcane farmers in South Africa (Box 5.2). The Honduras example shows how a company called Azunosa had to make significant changes to its business practices to obtain BONSUCRO certification after a five-year period. The painstaking process the company went through in obtaining the certification subsequently resulted in multiple benefits. The cost of obtaining certification was therefore far outweighed by the benefits. The South African example shows that interactions between smallholder and commercial farmers can be beneficial with respect to adoption of BMPs in sugarcane farming.

### Case study 5.1: Assessing the business case for BONSUCRO certification for Azunosa in Honduras

**Background information on Azunosa**

Azunosa is the third largest sugar manufacturer in Honduras. Honduras is the second poorest country in Central America, with nearly two thirds of its citizens living in poverty. SABMiller acquired Azunosa as part of its Honduran business in 2001. SABMiller is Azunosa's largest customer, purchasing 80% of the company's sugar. Azunosa generates energy from sugarcane mash during the production season, 50% of which it uses to power its own operations and 50% of which it sells to the national grid. The company owns 46% land while local farmers own the remaining 54% in its supply base. Some farmers manage their lands independently, to Azunosa's technical specifications, while others manage their lands jointly with Azunosa or allow Azunosa to do it on their behalf.

**Azunosa's Investment in Bonsucro Certification**

The company achieved Bonsucro certification in November 2014. This was preceded by significant changes to business practices over a course of approximately five years. The most significant change had to do with process management and documentation, enabling the company to generate the information needed to demonstrate compliance. For example, Azunosa instituted a voucher system to measure the time cutters spend working in the fields, allowing the company to control their working hours. The company has also had to learn new ways to measure and report on fertilizer usage, workplace accidents, and research and development expenditures. Additional changes the company made are detailed in Jenkins *et al.,* (2015).

**Azunosa's Return on Investment in Bonsucro Certification**

There are prospects for cost savings as a result of changes implemented to achieve Bonsucro certification, including greater operational efficiency and reduced use of inputs such as fertilizers and pesticides. Improved documentation and controls are also revealing opportunities for continuous progress in many aspects, such as piloting drip irrigation that would further reduce fertilizer, labor, and fuel costs. The time voucher system has reduced conflicts with workers through improved legal compliance. The changes implemented for Bonsucro are also helping the company to comply with the ISO 9000 standard for quality. Investment in Bonsucro certification should help keep the company competitive in the long run. This will continue to align it with the evolution in values and procurement policies underway in the sugar market today.

**Case study 5.2: A story of women in South Africa excelling in sugarcane production (derived from Solidaridad, 2018)**

Sugarcane production is generally perceived to be a male dominated sector. In South Africa, women are much more involved in horticulture, soy and cotton. However, there are also women thriving in smallholder sugarcane farms. Since 2016, Solidaridad in collaboration with the Illovo sugar mill, has supported smallholder sugarcane farmers in Noodsberg, South Africa. The support has been focused on leadership, business and financial management, and good corporate governance.

Typically, farmers work in cooperatives such as the Gqugquma grower cooperative. In this cooperative, the increase in women participating in sugarcane production is evident. Following this, Solidaridad conducted gender inclusivity dialogues to help break down gender stereotypes. The Gqugquma grower co-operative has 80 active farmers and it is headed by a female.

Much of the cooperative's success can be attributed to multi-stakeholder engagement and network relations. For example, Gqugquma receives mentoring from commercial farmers operating within the Noodsberg area. Agronomic support that is given includes guidance on planting methods and plant treatments that help the crop stay healthy.

## 5.8 Conclusions

Some of the CSA practices being implemented in the sugarcane industry were presented. Adoption of these CSA practices, or BMPs, is through the SUSFARMS® farming model. Implementation of the SUSFARMS® concept has been growing steadily over the years, and it is enabling the sugarcane industry to comply with international sustainability standards. Guidelines for implementing the SUSFARMS® concept were provided in this Chapter. One case study revealed that the benefits of obtaining certification far outweigh the costs (time and financial) of investment that may be needed. Sugarcane farmers are therefore encouraged to adopt CSA BMPs as part of the SUSFARMS® farming model.

# 6. Fruit and wine industries

## 6.1 Introduction

This Chapter will focus on climate smart agriculture (CSA) practices for the table and wine grape (viticulture) production, as well as subtropical (banana and citrus) fruit production. This provides examples of practices being implemented to deal with the adverse effects of climate change in the fruit industry. Implementation of CSA practices in the fruit industry is strongly aligned with the Sustainability Initiative of South Africa (SIZA). The SIZA contains guidelines that are essential for the wine and fruit industry to comply with fair labour practices and use of sustainable farming practices. These two aspects are important for producers to be able to meet sustainable sourcing requirements of their major clients.

The fruit and wine industries make substantial contributions to the South African economy. South Africa is the world's 8th largest wine producer and it contributes approximately 3.6% of the total global volume. 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 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.

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).

## 6.2 Adaptation and mitigation strategies that are being implemented in the fruit and wine industries

### 6.2.1 Adaptation options

Adaptation in the fruit and wine industry can be fostered through strategies such as:

⇒ Identification of new optimum growing areas to suit the changing climates.

⇒ Shifting to use of stress (e.g. heat, drought) tolerant cultivars.

⇒ Use of cultivars and rootstocks best suited to local soil and climatic conditions. The deciduous fruit sector could, for example, move towards the choice of lower chill cultivars in areas which do not receive sufficient chilling.

⇒ Protecting honeybees that perform a critical pollination service to farming in this region. Current disease pressures on hives and insufficient forage sources could become worse and adversely affect bees under the additional stress of climate change (www.greenagri.org.za).

⇒ Use of shade netting to protect crops from either excessive solar radiation, environmental hazards (e.g. hail, strong winds, sand storms), or flying pests (birds, fruit-bats, insects).

⇒ Use of FruitLook to improve water management.

⇒ Other irrigation related adaptations include - switching to more effective irrigation such as drip irrigation; irrigating at night to save water through reduced wind drift and evaporative losses, and to enhance the plant's resistance to heat waves during day-time; and irrigating optimally through use moisture probes for irrigation scheduling (Schulze and Schütte 2016a).

⇒ Soil water management such as through application of mulch and plastic liners to retain soil moisture.

⇒ Integrated pest management.

### 6.2.2 Mitigation options

Mitigation of greenhouse gas (GHG) emissions can be enhanced through:

- ⇒ Widespread use of non-renewable energy in the form of solar and wind farms.
- ⇒ Reduction in use of synthetic nitrogen fertiliser, which can be achieved through application that is more precise as and when the plant needs it (www.greenagri.org.za). Nitrogenous fertilisers release nitrous oxide ($N_2O$) into the atmosphere, which is one of the GHGs.
- ⇒ The carbon calculator tool is recommended for use to facilitate gradual reduction in GHG emissions over time. The tool was developed by the Confronting Climate Change (CCC) initiative (http://www.climatefruitandwine.co.za/About.aspx ).

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. The rest of the chapter presents guidelines that can be followed by fruit farmers to comply with sustainable sourcing requirements.

## 6.3 The Sustainability Initiative of South Africa (SIZA)

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, 2018c). 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. South Africa has endorsed major International Labour Organisation (ILO) conventions and most of these requirements are included in its labour laws which are included in the SIZA Standard (SIZA, 2016). 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, 2018c). Various retailers, including Tesco, Walmart, Ahold, Migros, COOP Switzerland, Delhaize, Carrefour and local retailers such as Pick ’n Pay (SIZA, 2018b), support sustainable sourcing requirements.

The goal of the Environmental Standard is to assist the South African fruit industry with an approach to measuring and reporting against sustainability criteria, specifically those that are relevant for on-farm activities within the South African context.

The structure was designed to establish a starting point (baseline) and then measure against and report based on continuous improvement against that baseline and identified risks. Development of the Environmental Standard was preceded by pressure from international markets such as the European Union (EU) and United Kingdom (UK), who were setting new requirements for environmental compliance in 2017.

The UK market required its global supply base to complete the Self-Assessment Questionnaire (SAQ) on Sedex or via SAI FSA. Avocado growers were asked for a full audit on the Rainforest Alliance Standard (SIZA, 2017). Compliance to SIZA now enables producers to be compliant with these other global sustainability systems.

The SIZA has two main focus areas, namely:

⇒ monitoring and verification of compliance and best practices on farms which takes place through self-assessments and third party social audits conducted by independent audit bodies; and

⇒ facilitation of capacity building initiatives to support growers, smallholders and workers with the implementation of ethical and environmental standard requirements through promoting awareness and understanding of the ethical and environmental standards as well as building practical and social skills to enhance productivity and well-being on farms.

The SIZA environmental and social standards provide a principle statement for each code principle. Each code principle has a list of code requirements. Each code requirement has:

i) a benchmark which refers to evidence required to indicate compliance and identifies the applicable South African legislation; and

ii) guidance notes to provide practical information on implementation of the requirement.

Monitoring and verification of compliance with legislation and adoption of best practices on farms takes place through self-assessments and third party social audits conducted by independent audit bodies.

To this end, farmers answer a series of questions to determine their baseline performance scores. From then on, they will have to improve their sustainability standards. For example, the sustainable farming practices section contains questions relating to water, soil, biodiversity and energy/materials/waste. The questions become deeper in scope per criteria, and progress from basic (level 1) to advanced level (level 3), as depicted in Figure 6.1.

Four different compliance levels are recognised for the environmental standard, namely basic, essential, intermediate and advanced.  The Basic and Essential cover record keeping and minimum legal compliance issues, and the Intermediate and Advanced levels allow the user to assess where they are in the journey of environmental sustainability.

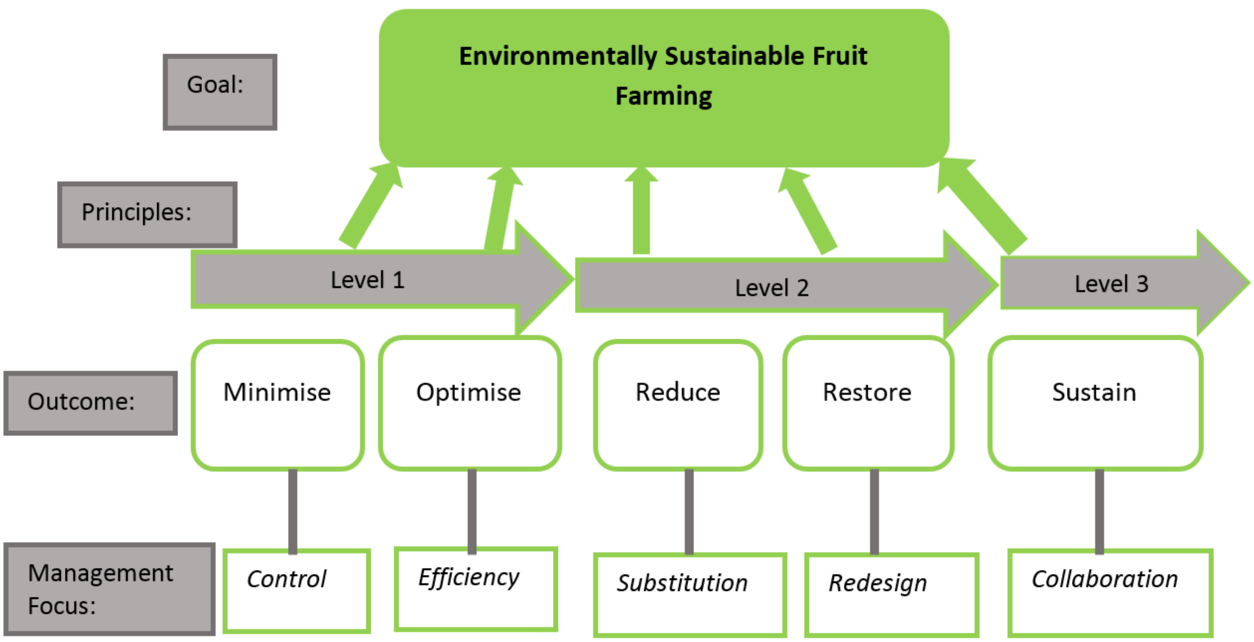


**Figure 6.1: Different levels of compliance to environmental standard for sustainable fruit farming**

*Source: SIZA (2018a).*

#### 6.3.1 SIZA / Confronting Climate Change (CCC)

When completing the SIZA Environmental SAQ, one is required to report on their energy use and emissions and how these are monitored. A hyperlink is provided to the CCC website (www.climatefruitandwine.co.za), where the carbon calculator tool can be used to report on energy use and emissions (SIZA, 2018c). The carbon calculator tool enables growers and service providers to measure their carbon footprint, identify 'carbon hotspots', and develop creative solutions to reduce $CO_2$ emissions. Guidelines on the type of data requirements necessary to complete the CCC carbon calculator for fruit and wine are available from the following link www.climatefruitandwine.co.za/Support.aspx. Four different types of workshops are also conducted to assist users of the carbon calculator tool. These are namely: carbon foot print workshops, train-the-trainer workshops, emerging farmer workshops and what-next workshops.

#### 6.3.2 SIZA / FruitLook

The SIZA Environmental Standard also encourages improvement in water management through use of FruitLook. FruitLook has been reported to lead up to 30% more efficient use of water (https://www.fruitlook.co.za/). FruitLook is an open access online platform used to monitor vineyards and orchards using satellite imagery and weather information. The online platform 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. The FruitLook website (https://www.fruitlook.co.za/) has a manual with guidance notes on how to use the online platform. Training of users and would be users is conducted on a regular basis in different parts of the country. The training sessions are widely publicised and the schedules can also be obtained from the FruitLook website.

### 6.4 Practical implementation of the SIZA

As noted earlier, monitoring and verification of compliance with legislation and adoption of best practices on farms takes place through self-assessments and third party social audits conducted by independent audit bodies. To achieve this, one needs to use the Self-Assessment Questionnaires (SAQs) provided by SIZA in conjunction with the Environmental and Social Standards.

⇒ **Step 1 – Completing the general data section**

Firstly, one provides answers to general questions about the farm, most of which have open answers. Guidance notes in the Social and Environmental Standards are used to learn more about the background of any of the questions so that appropriate answers can be provided.

⇒ **Step 2 – Assessment of compliance to environmental sustainability and ethical labour practices**

After the general section, one proceeds to complete questions that seek to establish environmental sustainability of farming practices, and compliance to labour regulations. It is emphasized again that Guidance notes in the SIZA Environmental and Social standards should be consulted for more background information on relevant legislation specific to South Africa. All applicable questions should be answered. Once completed, this information is used to calculate a performance score.

⇒ **Step 3 - Improvement Potential**

An improvement plan can be created for topics in which current farming practices fall below expectation. Adaptation and mitigation practices that can be considered for implementation in the wine and fruit industries were illustrated in Section 6.2 of this Chapter.

⇒ **Step 4 – Adapting farming practices**

After identifying farming practices that should be changed and new ones to be used, the farmer then effects these changes on the farm. After some period of implementing the new practices, the farmer can redo the SAQ to see how these changes would have improved the overall score. See Figure 6.2 for summarization of the steps involved in practical implementation of the tool.


**Figure 6.2: The four steps involved in practical implementation of the SIZA standards**
*Source: Adapted from the SAI Platform (2018)*

## 6.5 Capacity building for implementation of the Environmental Standard

A number of training workshops are held throughout South Africa on an annual basis. They are designed to assist producers with a better understanding of the Environmental Standard, to explain the process and to provide guidance on how to complete the SAQ. Information on where and when training workshops will be held is available on the SIZA website. Training include the following:

⇒ Training for those who implement the SIZA Environmental Standard (consultants, extension officers, technical advisors and potential verification partners);

⇒ Training for producers who use the results to better manage their environmental risk and reports to markets; and

⇒ Upliftment training on base-level environmental practices to train employees on environmental stewardship and the importance thereof in a farming environment.

## 6.6 Other details important for successful implementation

Smart Agriculture for Climate Resilience (SmartAgri), a two-year project by the Western Cape Department of Agriculture and the Western Cape Department of Environmental Affairs and Development Planning, was launched in August 2014. SmartAgri responds to the need for a practical and relevant climate change response plan specifically for the agricultural sector of the Western Cape Province (www.greenagri.org.za). They conducted status quo reviews of climate change and the agricultural sector of the Western Cape Province. They developed briefs with practical tips for farmers for the citrus, table grape, wine and deciduous fruit sectors. These briefs can be downloaded from their website (www.greenagri.org.za).

## 6.7 Monitoring performance of the intervention in terms of the CSA pillars

In general, the farmer must be able to monitor their increasing and sustainable use of recommended practices and compliance with legislation by continuous use of the SAQ. Once the baseline or starting point has been identified, the farmer should aim to progress from basic (level 1) to advanced level (level 3), as shown in Figure 6.1. Self-assessments are complimented with external audits of all participating farmers to monitor progress at national level. It is important to remember that SIZA audit results also reflect on the GlobalG.A.P database. International buyers therefore monitor their suppliers social and environmental compliance to sustainable sourcing requirements. Some of the general indicators at farm level are shown in Table 6.1.

## 6.8 Case studies

Two case studies are presented. One looks at some of the benefits of using FruitLook as determined from a survey of farmers who were using the tool (Box 6.1). The second case study explains how a Union of Cooperatives in Ethiopia was able to obtain GlobalG.A.P certification, which then enabled them to have access to European Union (EU) markets (Box 6.2).

**Table 6.1: CSA farm level technical indicators**

| Theme/Pillar | Sub-theme | Farm level Indicators |
|---|---|---|
| Productivity | Crop system | ⇒ Increase in fruit yields (ton/ha). |
| | Water use | ⇒ Increase in irrigated land area, reduction in total water withdrawal.<br>⇒ Use of Fruitlook to prevent over or under-irrigation; maintenance of irrigation system in accordance with a predetermined schedule.<br>⇒ Increase in water productivity. |
| | Energy | ⇒ Reduction in agricultural energy use, such as during irrigation and in packhouses.<br>⇒ Increase in use of renewable energy (wind/solar farms). |
| Resilience | Robustness | ⇒ Increases stability of production, promotes income.<br>⇒ Diversification, incorporate site-specific knowledge.<br>⇒ Improved economic resilience through improved profitability of fruit farming over time. |
| | Cropping system | ⇒ Increases resilience to drought, such as through using drought tolerant fruit varieties.<br>⇒ Changing of varieties to suit changing environments; use of shed netting; etc. |
| Mitigation | Emissions intensity | ⇒ Reduces GHG emissions from continued assessments using the carbon calculator tool. |
| | Sequesters carbon | ⇒ Increases carbon sequestration. |

*Source: Adapted from the World Bank Group (2016)*

## Case study 6.1: FruitLook improves farm water management (derived from Fruitlook News, 2018)

One of the best ways to find out the impact or benefits of using a certain technology is to ask those who are using it. Through surveys, evidence was provided that FruitLook is supporting the agricultural industry in becoming more (water) efficient. From January 2018, a survey was conducted to investigate how users have benefitted from using the FruitLook service (Fruitlook News, 2018).

The results showed that: more than 71% of the respondents had improved their water management; 57% became better aware of crop development throughout the season; more than 35% had detected/solved growth issues in the midst of the season; more than 30% had increased their yields; improved uniformity of their blocks; and they had been able to compare productivity as well as water usage of their blocks.

Additional benefits that farmers derived from using FruitLook are reported in the September edition of FruitLook News (Fruitlook News, 2018). This case study shows that farmers can expect to experience the benefits that Fruitlook was designed to deliver, and even more.

## Case study 6.2: Ethiopian Union of Cooperatives ready for export to Europe (derived from the Import Promotion Desk - https://www.importpromotiondesk.com/en/)

The Import Promotion Desk (IPD) is an initiative established by the Federation of German Wholesale, Foreign Trade and Services (BGA) and sequa gGmbH – the development organisation and partner of the German private sector. They are funded by the Federal Ministry for Economic Cooperation and Development (BMZ) (https://www.importpromotiondesk.com/en/). The IPD provides consulting services to small and medium-sized companies from emerging markets and developing countries with few or no existing contacts to Europe. The IPD can help reduce the costs related to initiation, negotiation and management of an export business.

IPD assisted the Union of Cooperatives Meki Batu from Ethiopia to exhibit for the first time at Berlin's "Fruit Logistica" in February 2017. For two years, IPD worked intensely with the union, which comprises over 8 000 Ethiopian farmers, to prepare them for the exhibition in Germany. Meki Batu Union is an association of farmer cooperatives committed to sustainable farming. Their product includes beans, onions, chilli and paprika sugar snap peas and papayas. Through its export promotion programme, the IPD managed to open the door to the European market for Ethiopian farmers.

The precondition for the export of fresh fruit and vegetables to was certification according to the international standards of GLOBALG.A.P. The IPD assisted to prepare the Meki Batu Union for this certification. The Meki Batu Union first participated in a GLOBALG.A.P. workshop in Ethiopia in July 2015. In a second step, the IPD provided comprehensive advice and prepared a detailed timetable for the certification process in cooperation with the union. IPD also prepared Meki Batu Union for the European market by complementary measures, including a Study Tour to the Fruit Logistica 2016, in Germany.

Finally, in spring 2017 Meki Batu Union received GLOBALG.A.P. certification and thus its ticket to the European market. They are now well prepared for the European market where thousands of top companies, wholesalers and importers are constantly on the lookout for new and exciting products (https://www.importpromotiondesk.com/en/). They now have opportunities for huge forex earnings by having access to the EU market.

## 6.9 Conclusions

Some adaptation and mitigation options that are being used in the fruit and wine industries were identified. Urgency in adoption of these practices is in part being fostered through pressure from consumers and retailers who are concerned about environmental sustainability. In particular, major clients of the fruit and wine industries have put in place sustainable sourcing requirements that necessitate compliance with some global standards. In South Africa, compliance with the SIZA implies compliance with other global standards such GlobalG.A.P. Guidelines were provided on how farmers can be compliant with the SIZA Environmental and Social Standards. One of the case studies illustrated how a Union of Cooperatives in Ethiopia managed to obtain GlobalG.A.P. certification, thus providing them with access to the lucrative EU markets. Wine and fruit farmers in South Africa are encouraged to be members of SIZA to facilitate adoption of CSA practices for environmental sustainability, as well as compliance with global standards.

# 7. Guidelines for Climate Smart Urban Agriculture in South Africa

## 7.1 Introduction

More than 60% of the South African population reside in urban and peri-urban environments (Davis, 2017), which has created a big food security challenge. 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. In addition to contributing to the alleviation of food security, urban agriculture also contributes to climate mitigation through moderating temperature, carbon sequestration and stabilizing soil physical properties (de Zeeuw *et al*., 2011). It, however, faces problems of open land shortage and irrigation water scarcity. Options for addressing these problems include the use of rooftop farming, greenhouse production systems, hydroponic techniques, greywater recycling, composting, and renewable energy (solar and wind power). The objective of this document is to describe guidelines on how some of these techniques can be implemented to support sustainable urban agriculture in South African urban and peri-urban areas.

## 7.2 Greenhouse (controlled climate system) for urban agriculture

A greenhouse is typical adaptation component of climate smart agriculture but the technology needs high initial and maintenance capital. As such, it is used for producing high value horticultural crops that are used for different purposes (food, medicine and ornamental plants). The crops grown in greenhouses are produced outside their natural habitat through manipulating the microclimate inside the greenhouse. The technology was introduced to satisfy demands of local markets.

South African cities are located in diverse climatic zones, mostly tropical and temperate climatic conditions, with warm to hot summer and cool to chilling winter. In winter greenhouses create summer condition because they trap infrared-red light. So the purpose of greenhouse facility is mainly to extend season and protecting from wind. This structure will be very important in cities essentially when rooftop farming, which is high windy area.

Greenhouses include glasshouses and tunnels, which have heat-trapping characteristics. Glasshouses have gas roofs and walls supported with metallic frame. These structures are durable provide that they are kept clean, and the walls are protected with bird nets and the roofs with and hail nets. Depending on the available space and purpose different sizes and shape glasshouses can constrict.

Tunnels, are constructed with half a circle (an arc) frames and are covered with plastic material that may vary transparency, thickness and strength. Compared to glasshouse, tunnels have shorter service life and can easily be damaged by violent winds. Therefore, site selection and windbreak structures are important for plastic tunnels to serve longer.

Both tunnels and glasshouses in South Africa are used for producing high value horticultural crops, the main ones being tomatoes, lettuce, green pepper and cucumber. Under fully controlled or semi-controlled greenhouse, these crops can be produced year round.

## 7.3 Roof top farming

Roof top farming is producing crops on the roofs of houses. It is implemented on underutilized rooftops of buildings and therefore helps to address the problem of space, which was identified in the situation analysis as a constraint for farming in urban environments. In addition to food production, rooftop farming/ greening reduces urban heat because the plants absorb the solar radiation. It also reduces intensity and runoff of torrential rainfall. One must consider the following challenges and possible solutions in rooftop farming:

⇒ Strong wind is common, which can damage the crop, thus needs to be protected with some sort of shelter including shade nets and greenhouse.

⇒ Management is not as simple as back yard garden; unless the proper infrastructure for irrigation system and water reservoir is in place, up and down carrying water and other means of production and produces would be tough.

⇒ The plants should be in pots filled with light density soil. Soilless culture (hydroponics) is the ideal fertilizer and water management technique (See Section 9.4).

⇒ Not all rooftops are readily usable for gardening practice, but with few adjustments, most roofs can be converted to green. By constructing some supporting frames for the plants and provision for the movement of the operator, even corrugated iron (tin) roofs can used for rooftop farming.

⇒ Not all rooftops are accessible; the building owner should be willing to host such a project.

⇒ Need to be a well-drained rooftop. The gardening practice should not be an obstacle for draining water. Otherwise, it can deteriorate the ceiling on the house because of high humidity or leakage. Storing more water could also be above the weight limit that the roof can carry, resulting in clasping of the building.

Depending on the season, site and micro-climate controlling measures, crops like tomato, cucumber, pepper can be produced in rooftop farming practices.

## 7.4 Hydroponics

Hydroponics or soil less culture is the best way of using scarce water and fertilizer resources. This technology enables farmers to grow high quality horticultural crops on marginal land, on rooftop and in greenhouses efficiently using the scarce water resources. Hydroponic systems also enable the production of more plants per given area (hyper density planting) as the only limiting factor is light. Balanced nutrient solution enough for all plants is provided at the root system of the plants. The techniques are usually used for production of vegetables, herbs and fruit-producing herbaceous plants (strawberries and tomatoes, for example).

Hydroponics techniques fall in one of two categories: Open or closed hydroponic system. Closed hydroponics can further be classified into static and continuous flow solution systems. In a static solution system, the plants root system is partly immersed into the solution, (e.g. aquaponics). This technique needs continuous monitoring of pH and electrical conductivity (EC) to determine the concentration of the nutrients in the solution. In the continuously flowing solution technique, the nutrient solution is collected and pumped back (recycled).

In open hydroponic, the nutrient solution is not recycled. Once it passes through the root zone of the plants the nutrient solution is discharged to drainage system or absorbed in the ground, if pots are used, for example. Drip irrigation is a typical example of hydroponics technique where nutrient solution is not recycled. This technique is less efficient in water and nutrient use (compared to the closed hydroponics system), but it has the low risk of disease outbreak.

Several hydroponic techniques are used. These include nutrient film technique (NFT), flood and drain (ebb and drain) technique, wick technique, dripping system, micro-sprinkler, floating technique (aquaponics). Most large-scale indoor farming systems use NFT, drip or micro-sprinkler hydroponic technique.

## 7.5 Vertical farming (hydroponics)

Vertical farming is a type of crop production technique where the farming is vertically expanded instead of horizontally widening the farming area. Under natural condition, in South Africa, walls facing towards north can be used for all types vegetables small horticultural crops. East and west facing walls can be used for plants that may need short light hours. To produce the same amount of food as field-grown plants, in vertical farming the farmer needs 7% of the space in the field and saves up to 93% of the water required (Opperman, 2018).

As an intensive production system, at commercial level, the vertical farming is not limited to walls or widely spaced shelf towers, but also in closely spaced shelves or special pocketed tower can be used to produce horticultural crops (vegetables, herbs and fruits). Such practices further increase the number of plants per unit area, thereby increasing the total biomass produced per area compared to production through the normal (horizontal) hydroponic system. Vertical farming establishment starts with site selection and collecting the necessary materials, which may vary depending on the scale and available initial capital. The materials that is needed during planning period include sheltering structure, supporting frames and fittings for pots, growing media, nutrients and nutrient solution preparation assisting instruments, solution re-cycling pipes and water pump.

## 7.6 Composting and worm composting (vermicomposting)

Composting is the process of transforming organic materials of plant or animal origin into humus in heaps or pits. Compared with uncontrolled decomposition of organic material, decomposition in the composting process occurs at a faster rate, reaches higher temperatures and results in a product of higher quality. The process proceeds through three main phases: the heating phase, the cooling phase and the maturing phase. The phases can, however, not be clearly separated from one another.

Composting procedure may differ depending on the available composting facilities, composting scale, and the objective/purpose composting practices.  Different organic materials such as plant debris, including leaves, chopped straws, stems and paper can be used by incorporating them in different layers. Animal manure facilitates inoculation of the decomposers and used as food/source of energy for the microorganisms (detailed procedure is given in Hadfield, (2016) and other listed references).

Worm composting (vermicomposting) is a composting technique where worms eat the plant materials, digested and passes out as their excreta in a very fine as solution form. Vermicomposting can also be used to reduce the volume of human faecal matter by over 90% and there is a potential of making it safe for farming because the they lower the egg and population of disease causing microorganism (Eastman *et al*., 2001; Atanda *et al.,* 2018). Ravindran and Mnkeni (2017) report that vermicomposting accelerates the breakdown of antibiotics in chicken manures rendering the resulting chicken manure vermicomposts much safer for agronomic use. This could apply to other manures as well which may be contaminated with antibiotics.

The leachate that is produced during vermicomposting (worm wee) is suitable for hydroponic systems because the mineral nutrients dissolved in it are readily available to plants.

For both composting and vermicomposting practice the composting space may not be a problem but continuous supply of sorted compostable material could be a problem. The municipality need to come on board for the improvement of the life of the community and sustainably manage the environment. In this regard, the municipality need to collect decomposable materials separately and put composting bins in strategic areas and take responsibility of making containing the bins aesthetically pleasing and of low odder as possible. This careful management of these compostable organic matter should not be limited at the composting or vermicomposting sites only.  Farmers should also be considerate, thus should run-off of the organic fertilizer into sewage system and choose application time for odorous fertilizers when there will be minimum disturbance to neighbours and by passers or visitors.

## 7.7 Rain water harvesting and greywater recycling in urban agriculture

South Africa is situated in a dry region. The recent severe drought and water scarcity in Western Cape region, particularly Cape Town, is an example that South African cities are facing scarcity of portable water. Using water harvesting and recycled water for crop production could significantly reduce the pressure on the potable water (Dhakal, *et. al.,* 2015).  Rainwater harvesting in urban area also has positive impact on the environment because it keeps storm water which otherwise moves downstream caring waste out of the sewage system.

Rainwater harvesting can be done from catchment of open land areas and from roofs of houses. In urban area the latter is the main catchment for rain water. Normally most houses have gutters that collect and drain rainwater to avoid erosion of the soil around the foundation of the houses in areas with dusty ground. Therefore, it needs a little effort and capital input to direct the water gutters to reservoir. In South Africa the JoJo Plastics water tanks are commonly used for collecting water. There are different sizes of the tanks and they are light and easy to move them when they are empty. In well-planned building, underground rainwater reservoirs maximize utilization of the land allotted for building. Detailed information on rainwater harvesting has been presented in Chapter 3 of this report).

Recycling water used in the kitchen (grey water) is safe for irrigation purposes of plants that are eaten cooked, fruit trees and ornamental plants. This reduces the pressure on the scarce potable water. Large-scale blackwater purification (treatment) is also practiced by municipalities. Such water can be utilized for irrigation of crops and pasture grass in dairy farms.

## 7.8 Case studies

The following two case studies are examples of successful climate smart urban agriculture. Through on or the other way, this urban agriculture successfully achieved sustainable production in urban area in a limited space, saving water and reducing negative contribution of agriculture to the environment. They are also model examples of adaptation and resilience to climate change

### Case study 7.1: Rooftop garden in Johannesburg

A rooftop garden operated by in 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. This farm 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.

The choice of the plant/crop grown in the garden 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*) and uses 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, in this urban agriculture greenhouse is used to grow a summer plant year-round. To mitigate high competition for space and potable water the garden is situated on rooftop and under hydroponic system, respectively. Such a conducive environment, enable sell basil in a cycle of 21 days fresh produce a price.

### Case study 7.2: Eden Green Hydroponics (vertical farming)

Eden Green Hydroponics is an urban farming in Pretoria, South Africa (https://youtu.be/0AyPGYieWpQ). This farm used three of the production technologies suggested for urban agriculture in this guideline: vertical farming, hydroponic (aeroponic) and greenhouse. To create conducive environment, artificial condition is created through greenhouse growing system. Operators of Eden Green Hydroponics confirm that such a facility can be used to produce crops in the middle of a desert because it needs small amount of water for irrigation (fertigation). Vertical farming in Eden Green reduce both land and water use by 90%. Yield in the vertical farming is 20 time of an open land farming and 5 time more than of conventional hydroponic system.

## 7.9 Monitoring urban agriculture practice

This guideline provides urban farming stakeholders with several options of different means of farming in cities with a potential to increases productivity, adaptation and/or mitigate greenhouse gas emission. These methods of farming may perform differently in different situations of the stakeholder and environment or locality. Therefore, carefully choosing one or more of the means or production strategies continuously monitoring is necessary. The purpose of monitoring is to confirm that the introduced technology is a reliable means of production that achieve the expectations of climate smart agriculture.

In monitoring process, it is important to have operationalized indicators that should be used as yardstick to measure the performance and sustainability of the positive contribution of the introduced technology. Indicators for climate smart urban agriculture are the data or information on the impact of the technology on productivity, adaptation and resilience, and reducing emission of greenhouse gases.

The technologies proposed for climate smart urban agriculture in this guideline, greenhouse, vertical farming, rooftop farming, hydroponic, composting and vermicomposting, rainwater harvesting. Each of the production strategy attempts to meet one or two or three (all) of the objectives of climate smart agriculture. Based on the balance outcome the technology can be adopted or be rejected and the monitoring process continues as the situation for a given area is dynamic. List of most of the indicators in smart agriculture have been listed in Section.3.9.

# 8. Climate Smart Range Management: Guidelines for the practical implementation of the Holistic Range Livestock Management

## 8.1 Introduction

About two-thirds of the world's rangelands are now transformed to desert lands (https://www.savory.global ), accelerating climate change on the one hand, and making the lands and land users less resilient to adapt and/or mitigate to climate change effects on the other. Land degradation and climate change are believed to be the main causes that are turning African pastoral societies or communal rangeland users into conflicts, social and ecological crisis (e.g. Solomon *et al.,* 2007; Hoffman and Vogel, 2008; Seymour and Desmet, 2009). Land degradation and signs of desertification are now widespread in many arid and semi-arid rangelands of South Africa (Vetter, 2013; Gxasheka *et al.,* 2017). Therefore, there is an urgent need to apply climate smart practices that will contribute to profitable utilization of the rangelands and restoration of degraded areas to increase their productivity and resilience to climate change effects.

Properly managed livestock are key to restoring the rangeland soils that have the potential to store greater than 10% of terrestrial biomass carbon (C) and 10 to 30% of global soil organic carbon (SOC) (Derner and Schuman, 2007), and to minimizing the most damaging impacts on humans and the natural world. Vast communal lands in South Africa have been continuously grazed without formal grazing planning or well-designed routines. As a result, a greater proportion of the rangelands show signs of deterioration or degradation. Continuous grazing has led to the replacement of native perennial grasses, which dominate in good rangelands, by annuals and forbs that have less forage and ecological values. Continuous grazing has increased the invasion of exotic species, low growing native forbs, prostrated grasses and local woody plant species (Rusch and Oesterheld, 1997). Visual observations in Eastern Cape and North West provinces attested that continuous grazing in vast communal areas has resulted in rangeland degradation with signs of desertification because areas have been selectively, repeatedly and heavily grazed with concomitant effects of lowering biomass and litter cover and exposure of the soil to erosion and impact of heat.

Commercial livestock ranches in South Africa practice rotational grazing and as the result, they are in better condition than the communal grazing lands, with less evidence of attendant degradation. Although rotational grazing systems have allowed improved stocking rates, most available data on their impact on vegetation shows no benefits (Hart *et al.,* 1988; Hickman *et al.,* 2004) or deleterious effects (Taylor *et al.,* 1993; Taylor *et al.*, 1997). However, formal rotational grazing systems are virtually impractical for communally used grazing lands, as it requires higher capital investment in fencing and water supply.

In addition, the maintenance and management of more camps require more attention greater than the management and organisation ability of the communal farmers. If this grazing system is introduced under the prevailing communal condition and negligence, mismanagement will result in faster rangeland deterioration. Fixed grazing systems will not be sustainable in the prevailing unpredictable climatic events. Therefore, a grazing planning practice, that takes account of all factors into the planning, and that allows flexibility depending on circumstances or weather condition and plant growth is desirable. One rangeland management practice that has proven to have overwhelming benefits including the restoration of degraded communal rangelands, is the Holistic Rangeland Livestock Management (HRLM).

## 8.2 Holistic rangeland livestock management as climate smart agriculture

Allan Savory, a Zimbabwean biologist, game ranger, farmer and rancher investigated ways to save southern African semi-arid rangelands from desertification that stemmed from mismanagement, and developed holistic rangeland management about 40 years ago (Savory, 1999). The principles of Holistic Rangeland Management were developed based on the natural relationship between large herds of wild animals and their rangeland ecosystem that has maintained stable ecosystem for decades. Understanding this natural relationship of mimicking nature helped in the development of a plan for managing large livestock herds on rangelands without causing deterioration. Observations suggest that Holistic Planned Grazing (HPG) allows much higher grazing animal density over a short time period, and may result in higher soil-water content through the development of higher levels of ground-surface litter (Savory, 1999). Evidence confirmed that Holistic Management of grasslands has resulted in the regeneration of soils, increased productivity and biological diversity, as well as economic and social well-being. The ability of High Grazing Pressure (HPG) to effect these desirable results is likely to depend on farming goals, proper execution of good land stewardship skills, and application of the correct recovery period (Savory, 1999). Approximately 9 million hectares of land have been holistically managed worldwide, with attendant benefits gained out of the desired effects since the 1980s (https://www.savory.global). Holistic Management can, therefore, be considered climate smart agriculture, as it maintains or restores rangelands leading to maintaining and increasing carbon sequestration, drought resilience, food security, and financially viable communities.

## 8.3 How does holistic management differ from rotational grazing?

Holistic Management Grazing Planning differs from Moderate Intensive Grazing (MIG) or rotational grazing. In MIG and rotational grazing, farmers generally plan grazing periods, plan forward and tend to use a calendar (seasons) in some way but not using a planned grazing chart or other visual aids.

The entire objective of rotational grazing or MIG is to achieve maximum animal weight gain per farm in the shortest amount of time but at the same time minimizing overgrazing. In Holistic planned grazing, recovery periods are planned rather than grazing periods (which are derived from recovery periods). Grazing planning is done long before critical periods, and displayed using charts that show three dimensions—time, area, forage volume and other important variables.

## 8.4 Principles of holistic rangeland land management

The principles of Holistic Management are based on the concept that, to properly manage livestock and rangelands and get the desired effects that sustain human benefits as well as the resources, is fundamental. This entails charting grazing movements that consider the time the plants are grazed, the period animal stays on grazing land, as well as the time the plant is rested for recovery.

Holistic planned grazing takes into consideration, the following:

⇒ the needs of land, plants, animals, and people;
⇒ strategically mimicking nature using thorough planning, monitoring and re-planning;
⇒ grazing planning by taking into account ecological, environmental, and human factors;
⇒ where livestock need to be and when, and for how long;
⇒ promotion of healthy eco-system processes including water and mineral cycling, community dynamics, and energy flow;
⇒ moisture and minerals movements into the soil through agents such as dung beetles and other organisms; and
⇒ the need for adequate trampling of the dung, urine, and dead plants to promote decomposition.

Holistic grazing planning enables to manage land and animals together to:

⇒ produce the maximum amount of high quality forage on an increasing or sustained basis;
⇒ ensure adequate forage reserve and/or cover for livestock and wildlife, in particular during critical periods such as drought;
⇒ meet nutritional requirements of the livestock throughout the seasons;
⇒ minimize stress on the animals from physical handling, as well as on the people; and
⇒ allows flexibility to accommodate other farming activities within a farm such as cropping, wildlife, and other land uses, as well as with the personal schedules of those who will operate the plan.

## 8.5 Practical implementation of holistic livestock rangeland management

Holistic rangeland livestock Management uses a grazing plan aimed at using effectively grazing and other animal impacts (trampling, excretion of dungs and urine) to restore or maintain the health and productivity of private or communally used grazing lands. The central focus of HRLM is to make a farmer or rancher or group of communal farmers who depend on the land, care about the land and be a good land steward while making a decent living without affecting the social interactions in the family and community.

*The following steps are required for practical implementation of HRLM*

## 8.6 Define the communal villages or sets of grazing lands

Conceptually, HRLM can be applied on communal rangeland used by a single community or rangelands used by sets of communities sharing some similar characteristics. It works best on communal rangelands with defined boundaries. This entails choosing communities to participate, conduct resource inventory, determine resource needs including logistics and planning grazing. Another essential pre-requisite is that the rangeland has to be fairly large in size (1 000 ha or more). Working on sets of rangelands used by many communities is preferred because it enables to get the desired land size for practical application of the HRLM; aids to combine resources for effective inventory and monitoring, and implementation of activities.

## 8.7 Community mobilization

Engaging community members is the pivotal activity to introduce HRLM without which it is impossible to implement the practice. Participation of the communities is the most essential component of HRLM because they are the first stakeholders who decide to make a choice to improve the land and natural resources and use productively in order to yield sustainable economic return to the present and future generations.

To get the desired results, the following steps are important practices in community mobilization (Africa Centre for Holistic Management and the Savory Institute, 2013).

***Preparations for community mobilization*** involves the following steps:

⇒ Deciding on a clear, convincing goal to work with communities to improve their lives and the lives of future generations by restoring their land and natural water sources;

⇒ Identifying people who will become part of the team. These will have a number of different roles depending on the existing capacity of the community and the phases of the community action cycle;

⇒ Understanding the situation on the ground: the extent to which land and water have been utilized or degraded, how community members view these problems and what they are currently doing about them;

⇒ Conducting a resource inventory for land management improvement activities (financial, human and material);

⇒ Developing a community plan and strategy to work with communities to restore the land and water;

⇒ Developing a team (s) and their skills to support the community and facilitate the activities throughout the programme until the community has developed its capacity to implement the programme on its own; and

⇒ Conducting a community survey and selecting communities for participation in the programme based on an assessment of the major social, livelihood and environmental characteristics of the community.

***Organising the community for action:*** Here Programme team members must raise community awareness about rangeland management, utilization and rangeland degradation and effects on the community. The Programme team meets and orients the leaders of the community and seeks formal acceptance by the leaders for the community to participate in the programme.

***Exploration of land and water restoration issues with the core group:*** The purpose is to help the core group members and the broader community to explore factors that affect the quality of the land and water including their beliefs and practices and to identify the most important causes of poor land quality that the community would like to work on to improve the situation. This phase provides community members with a common language to talk about these issues and capture understanding of the links between what they do and the impact that their actions have on the land and water. It also provides the programme team with a better understanding of the community's perspectives and practices. It is very important to listen and not judge or try to correct them.

***Planning together:*** The purpose is to help the community describe its common desired future and a Community Land Restoration Action Plan, to establish a community coordinating and monitoring committee that will ensure that the Action Plan is implemented effectively.

***Acting together:*** The purpose of this phase is for the community to implement its Community Action Plan for land and water restoration. Community members carry out planned activities, learn more about the technical aspects of implementation, monitor their progress, and adjust their plans as necessary.

***Developing an evaluation plan and evaluation materials.***

## 8.8 Establishing the existing condition

One of the steps needed to accomplish HRLM is to begin to pull together what is known about the existing conditions of local and natural resources within the area the HRLM hopes to be implemented. This is equivalent to running an inventory of the rangeland resources, logistic, materials and human requirements. An aspect of the inventory work could be done before community mobilization, with the largest part being accomplished after community mobilization.

Relevant information is gathered from secondary sources such as agricultural or development organizations. The existing conditions are captured through a scoping study to deliver total land size, condition of grazing, ascertain livestock numbers/ species, levels of farming infrastructure (roads, water point's fences, dip tanks), household numbers, and human populations.

## 8.9 Practical implementation of planned grazing

Good handling of animal grazing and animal impacts on the soil and plants maintains or improves rainwater use efficiency and solar energy harvesting to maximise plant growth and biomass production. This increases the land and animal performances and profitability of the farming enterprise. The following practical steps are needed to implement planned grazing:

⇒ ***Demarcating grazing lands and paddocks*** (if needed) on the grazing lands;

⇒ ***Establishing method for estimating available grazing forage and forage utilization*** (Animal Days per Acre). This determines the carrying potential (optimum stocking rate) of the rangelands that maintain land productivity and profitability. This information also determines restoration needs of degraded rangelands;

⇒ ***Determining grazing and recovery peri***ods required to sustain the major perennial grass plants in the area. Adequate recovery time is given more weight than grazing periods, to minimize the effects of overgrazing;

⇒ ***Determining the size and number of paddocks*** per herd (if more than one herd is planned). This is planned to provide shortest time possible for plant grazing, soils trampling and adequate recovery periods for the plant re-growth. Animal impact increases with increasing stock density. When paddock numbers increase (through fencing or herding), stock density automatically increases, grazing period decreases and recovery period increases;

⇒ ***Balancing the differing quality and quantity of forage*** with the size of paddocks to determine desired grazing and recovery periods that ensure even grazing to provide adequate and even plane of nutrition for the grazing animals. Provision of uneven supply of forage (both quality and quantity) results in uneven supply of nutrient intake. This condition depresses animal performance (especially during the dry months) and lowers profitability;

⇒ ***Planning for forage reserves during prolonged drought period***. This entails deferring one or two paddocks from grazing. A drought reserve reduces the likelihood of having to buy hay, destock, and overgrazing. When drought happens, it may be necessary to change management of the animals and the grazing depending on the severity of the drought. "The bottom line in this situation is not to worry about overgrazing but to worry about the animas".

⇒ ***Determining Correct Stocking Rates for the land***. This ensures adequate forage supply for the livestock throughout the year and provides desired litter cover for the soil surface. The stocking rate under HRLM also ensures desired animal impact on the soil surface through trampling, dung and urine excretion. These, together, could lead to maximum retention of rain and nutrients in to the soil. To avoid overgrazing, the stocking rate is determined by also taking in to account fluctuations in forage abundance as the result of rainfall variations.

⇒ ***Planning for water development or water points or dams'*** renovations as well as adequate storage (several days' supply) to ensure sustainable supply of water throughout the year. This maximizes herd size without stress at water points and allows uniform utilization of forages at the farm.

⇒ ***Developing a breeding plan*** to match livestock breeding cycles to the environment and forage abundance to enhance reproduction rates.

⇒ ***Planning grazing management*** to help break parasite breeding of flies, liver fluke, ticks and other parasites. This reduces costs related to animal veterinary and maintains healthier animals.

## 8.10 Developing a grazing chart

A grazing chart is a grazing plan displayed graphically on sheets of paper, which takes into account vegetation, soil, social, financial and environmental variables. The following steps are needed to develop a grazing chart:

i) Holding a preplanning session with the farmers who put the plan into effect, to decide on factors to take into consideration in planning;
ii) Setting up one grazing chart per herd;
iii) Recording management concerns affecting the whole herd including issues affecting livestock performance (calving, breeding, weaning etc.);
iv) Recording herd information;
v) Recording livestock exclusion periods;
vi) Checking for unfavourable grazing patterns;
vii) Recording paddocks requiring special attention;
viii) Rating each paddock's quality relative to the others;
ix) Determining the length of recovery periods;
x) Calculating grazing periods;
xi) Assessing forage volume, carrying capacity, and drought reserve;
xii) Plotting the grazing chart;
xiii) Making a final check of the grazing Plan; and
xiv) Implementing and monitoring the plan.

## 8.11 Monitoring and Evaluation of performance CSA intervention

Monitoring entails the collection and analysis of information about the ongoing activities for appraisal of the success, and for helping to 'learn from mistakes'. Monitoring of HRLM intervention must be aimed to:

⇒ Assess the impact that this CSA practice has on the environment and socio-economic situations of the communities;

⇒ Determine the effectiveness of the CSA practice in achieving the holistic goals relevant to adaptation, resilience or mitigation capacity of communities and the environments they live to climate risks;

⇒ Generate notions to improve internal learning to make decisions and make corrections;

⇒ Ensure accountability of key stakeholders; and

⇒ Generate sets of objective data to share with the government to influence policy and share learning with other communities and the wider public.

More specifically, monitoring the HRLM involves the following activities:

***Determining the key issues to monitor*** - The three major subjects that need monitoring to evaluate the ongoing impacts of HRLM interventions are:

⇒ Socio-economic;
⇒ Ecological; and
⇒ Animal performance impacts.

***Selection of variables and information to be collected*** — For each subject, sets of variables are selected and information are gathered to:

⇒ assess the magnitude and direction of changes taking place;
⇒ based on the assessment, to understand the reasons for changes - i.e. what factors/ inputs/ management/ constraints have caused the change; and
⇒ Interpret the changes to draw conclusions and/or recommendations.

***Socio-economic variables***

A) Organisational

⇒ Ability to work together in:

- sharing resources (human, financial, technical);
- supporting leadership and vision
- management (e.g. refining aims, objectives, roles & responsibility)
- doing the job
- ensuring sustainability

⇒ Ability to work jointly with partners and other stake holders;

⇒ Disseminating or sharing good practice and techniques with other communities or individuals; and

⇒ Individual contribution to the outcomes and impacts

B) Economic return

⇒ Income from livestock sale and products
⇒ Net profit
⇒ Contribution to savings

C) Cultural and social benefits

⇒ Roles to food insecurity at times of critical periods
⇒ Inheritance, insurance, prestige, ceremonial roles

***Ecological variables***

A) Vegetation

⇒ Forage biomass.
⇒ Plant community composition.
⇒ Plant basal cover.

B) Soil

⇒ Soil moisture.
⇒ Improvement in litter cover.
⇒ Reduced soil bare patches.
⇒ Reduced soil erosion.
⇒ Soil organic carbon.
⇒ Soil structure.

***Animal performance impacts that needs monitoring include***

⇒ Animal weight gain.
⇒ Animal weight loss.
⇒ Number of animals per household.
⇒ Calving.
⇒ Mortality, etc.

***Analysing the information***

Information is only useful if it is analysed and put to good use. A key purpose of monitoring is to support internal decision making and planning. Therefore, periodic analysis of the data, and interpreting the results is of great importance. Depending on the purpose of monitoring, the data may be shared with the relevant stakeholders and communities. The information could be incorporated into annual reports and provide a useful background document that can be given to people or communities who are interested to know about HRLM.

## 8.12 Ethics and Data Protection

It is very important that no information is gathered or shared without the informed consent of respondents/ participants. Respondents' or participants' anonymity in the communication of data must be respected.

## 8.13 HRLM performance indicators

Identifying the relevant performance indicators are important to successfully examine how well the HRLM performs as CSA practice in fulfilling its objectives in changing climate scenarios. The indicators are selected to objectively assess the performance in terms of productivity, sustainability, resilience and mitigation. Whatever procedures or methods are used, the process should build an agreement among decision makers and stakeholders.

Similar themes (pillars) described by world band groups (2016) as cited in Ngara (2017), for soil and water management in Zimbabwe, are used to measure the performance of HRLM, as a CSA practice. These pillars are productivity (adaptation), resilience and mitigation.

Each pillar is evaluated based on a set of sub-themes and indicators as presented in Table 8.1. The selected performance indicators are not conclusive but subject to change in the future.

**Table 8.1: HRLM indicator pillars**

| Theme (pillar) | Sub-themes | Indicators |
|---|---|---|
| **Productivity** | Pasture | Increase in forage yield and forage quality, improvement in forage species composition, decrease in weeds/poor quality forage species, increase in the amount of forage available in dry period; increase in the amount of lands that is regenerated after degradation. |
| | Soil | Improvement in soil cover and soil fertility, decrease in soil erosion, decrease in bare batches. |
| | Livestock & products | Increase in livestock number, increase in meat production, wool production, low animal mortality, improved in calving & weaning weight, decrease in the incidence of disease outbreak, decrease in the number of sick animals, decrease in expenditure for medicines and veterinary. |
| | Water use | Reduced water runoff, increase in the rate of infiltration, increased rain use efficiency, increase in soil moisture. |
| | Energy use | Increase in quality forage biomass. |
| | Households | Improved income per household, improved food security, increased employment opportunities. |
| Resilience | Pasture | Increase in stability of forage production, forage reserve available during drought, maintain perennial plant cover during drought; lower expenditure to buy additional feed. |
| | Soil | Soil remains stable during drought; less subject to rain or wind erosion. |
| | Livestock | Decrease in the rate of susceptibility to diseases and forage shortage, decrease in the rate of mortality during drought |
| | Households | Capital savings. |
| Mitigation | Pasture and soil | Reduction GHG emissions resulting from restoration of degraded rangelands; |
| | | Increase in soil and biomass carbon & Nitrogen sequestration |
| | Livestock | Reduction in the amount of GHG emitted per LSU resulting from improved forage quality |

*Source: Adopted from The World Bank Group, (2016) as cited in Ngara, (2017).*

## Case study 8.1: Climate Smart Adaptation Strategies (Peel and Stalmans, 2018).

Some farms in South Africa have adopted holistic planned grazing (HPG) as an adaptation or mitigation practice, but there has not been conclusive evidence of a success story to date. However, in Zimbabwe, vegetation monitoring and landscape function analysis showed that the Africa Centre for Holistic Management (ACHM) at Dimbangombe had a significantly higher rangeland condition in terms of composition, cover, standing crop and soil health than the adjacent Sizinda community rangelands (SCR) and Monde communal rangelands (MCR).

Overall grazer density on ACHM was 42% higher than that of SCR (no data for MCR) (Peel and Stalmans, 2018). Finer-scale satellite collar data for ACHM 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 showed that the grazing resource would on average, not be limiting for livestock at the ACHM but limiting on the SCR.

Overall, ACHM showed stable perennial composition with smaller tufts significantly close to each other. This study concluded that HPG yields positive long-term effects on ecosystem services (soils and vegetation), and pointed to the potential of the HPG approach to enhance the sustainability of livestock and wildlife in this environment.

## 8.14 Conclusion

The degraded state of South Africa's communally used rangelands under continuous grazing renders them less resilient and adapted to the impact climate change. The Holistic rangeland livestock management (HRLM) strategy described in this guide is a climate smart agriculture practice whose implementation is likely to result in the regeneration of soils and increase pasture productivity in South Africa communal rangelands. This in turn will render the people who rely on rangeland resources for their livelihoods to be more resilient and adapted to the effects of changing climate. The implementation of HRLM will also increase the mitigation potential of rangelands through enhanced carbon sequestration. It requires community mobilization and their participatory involvement in decision-making and implementation planning.

# 9. Food Preservation and Climate Smart Agriculture

## 9.1 Introduction

Reducing food waste by preserving more of the food being produced, creates an opportunity to increase food security without increasing the environmental burden of production (Cole *et al*., 2018). According to WWF-SA, (2017) out of 31 million tons of food produced in South Africa 10 million tons of food is wasted. Highest losses occur in fruits and vegetables which could be as high as 44% for the smallholder farmers (DAFF, 2016b).

Such losses mean loss of food and income to the farmers as well as creating burden on the environment through the release of carbon dioxide and methane caused by decomposing food waste that increases our carbon footprint. The scarce resources such as water, energy and land that are used in producing the food that is not utilized are also wasted. As a signatory of the United Nations' Sustainable Development Goals, the South African government, represented by the Department of Agriculture, Forestry and Fisheries, has made a global commitment to halve the country's food waste by 2030 (WWF-SA, 2017).

Vegetable and fruit consumption for many of the low-income families is limited especially in winter when these commodities are out of season. Diets are mainly cereal based and monotonous and this can increase the risk of micro-nutrient deficiency. Monotonous diets have been associated with food insecurity (Chakona and Schackleton, 2017).

Home preservation of fruits and vegetables can contribute to dietary diversity and food security. Drying of commodities is one of the cheapest methods of preserving food especially if renewable energy sources are used. Other methods of preservation such as cold storage and canning are expensive and utilize fossil fuel which is not affordable for most small scale farmers and such techniques contribute to the problem of greenhouse gas emissions.

One way of making such technique affordable for smallholder farmers could be installation of centralized facilities, which could be accessed by the targeted communities at a minimal fee.

## 9.2 Background

Agro-processing has been identified as key in reducing post-harvest losses, promoting food security and creating jobs (NGP, 2010; NDP, 2011; IPAP, 2013) especially in rural areas where the 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 Agro-processing industry is well developed but concentrated with a few corporates controlling the value chains and small companies (SMMEs). Small scale farmers are, therefore, disadvantaged in that they cannot enter the chains due to lack of skills, access to finances and understanding legal documentation (e.g. contracts) with the main market players (Louw *et al.,* 2007).

In order to address these challenges and to create a more inclusive economy, the government has identified several strategies to revitalize agriculture and agro-processing value chains. The objective is to develop 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 SMME's into the existing commodity chains. Nine strategic value chains (poultry, soya, red meat, wheat and other crops, fruit, vegetables, sugar and wine) are being targeted (DAFF, 2015, DRDLR, 2015).

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 (DRDLR, 2016).

As a network it enables a market-driven combination and integration of various agricultural activities and rural transformation services (DRDLR, 2016). Some of the objectives of the Agri-Parks are to bring underutilized land especially communal areas and land reform farms into full production leading to significant increase in produce and to improve household food and nutrition security (DRDLR, 2015). Introduction of Agri-Parks close to areas of production will have a positive effect on climate change. The key issues that will be addressed by the Agri-Park are:

- ⇒ Reduction of post-harvest food losses, especially of 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.

It is assumed that most of the produce will be absorbed by the Farmer Production Support Units (FPSU) and the Agri-Hubs in the Agri-Parks but still not everything that is produced will be processed by the Agri-Parks.

Commodities to be processed by the Agri-Parks have to be driven by market intelligence for sustainability. Home preservation will play a critical role in making sure that whatever is not taken in by the FPSU, is not wasted and that people can enjoy the produce of their gardens long after the production season. It is also a good practice to preserve some of the produce for home use.

Food drying as a method of preservation has been used since time immemorial and still in use presently to preserve food. Advantages of drying fruits and vegetables are:

- ⇒ The dried product is lightweight and occupies less space and easier to transport;
- ⇒ Dried products are rich in minerals and some vitamins than products preserved by exposure to very high temperatures;
- ⇒ Drying is cheaper compared to other methods of preservation especially when renewable energy is used; and
- ⇒ Produce does not have to be sold at give-away prices during harvest season but can be easily preserved by drying and made available during off-season periods.

## 9.3 Preservation of fruits and vegetables by drying

### 9.3.1 Drying principle

The basic principle in drying food is to apply enough heat to dry the food as quickly as possible without seriously affecting the flavour, texture and colour of the food (Kendall *et al.* 2017). Maintaining the right temperature with some air circulating is the trick to successful drying. During drying moisture in the food evaporates into the surrounding air. The air around the food becomes moist and it is important for the moist air to be removed so that drying continues. Therefore, ventilation in and around the food is very important.

Drying of fruits and vegetables can be done using different methods employing renewable energy or energy from fossil fuel.

### 9.3.2 Direct sun drying

- ⇒ Drying in the open sun is very simple, requires minimal equipment and is environmental friendly.
- ⇒ A drying tray with the vegetables or fruits to be dried is covered with a mesh/net cloth to prevent flies and other insects from getting in contact with the food.
- ⇒ The tray is placed on a roof or any other place where there is total exposure to the sun and away from animals and left to dry naturally.
- ⇒ Drying can take between 3 to 4 days depending on the outdoor temperature and the kind of fruit or vegetable being dried.

The disadvantage of drying in the open sun is that the final product is of lower quality due to the long exposure to the sun and dust if it is windy. It may also be difficult to dry to low moisture levels that will prevent the growth of moulds especially in humid areas.

**It is important to note that the product still contains many important nutrients especially minerals which are not affected by drying. Therefore, this technique can be practiced by all interested to preserve the surplus from their gardens for future use and improvement of household food security.**

### 9.3.3 Solar drying

Solar drying also utilizes the heat from the sun to dry the produce. There are many types of solar dryers and according to Sivakumar and Rajesh, (2016) they can be divided into three main groups as:

⇒ Direct solar dryers in which air is heated in the drying chamber, and acts as both the solar collector and the dryer.

⇒ Indirect solar dryers that have a solar collector and a drying chamber. Air is heated in the collector chamber and then it rises to the drying chamber.

⇒ Mixed-mode dryers where the temperature in the drying chamber is raised by both direct absorptions of solar radiation and heat transferred from another solar absorber.

The type of dryer to be constructed will depend on availability of materials for construction, affordability (cost of the construction materials), availability of local artisans to build the dryer and amount of fruits and vegetables that is to be dried.

#### *9.3.3.1 Construction of a Simple Solar Dryer*

A basic cabinet type low cost solar dryer as described by Appropedia (2008) can be constructed at home or by village artisans. It is made up of a cabinet raised off the ground using wooden legs and covered with a standard UV stabilized or polyethylene sheet. Inside the cabinet, there is a rack to support plastic mesh trays on a wooden frame on which the fruits/vegetables are placed. One third of the bottom of the cabinet and the top of the door is made of wire mesh to allow for air to get in and out of the cabinet. An example of a small cabinet solar dryer which can be constructed for home use is shown in Figure 9.1

**Figure 9.1: A simple solar dryer for home use.**

*Source: East Africa Energy Technology Development Network- Uganda, (2004).*

###### *9.3.3.2 Advantages of using a solar dryer*

⇒ Drying is faster because inside the dryer it gets warmer than outside.

⇒ Less risk of spoilage because of speed of drying.

⇒ Product is of higher quality than drying in the open sun.

⇒ The product can be left in the dryer overnight or during rain.

At the beginning of the drying stage, if it is very sunny and hot, moisture may condense on the inside of the plastic cover. This can be avoided by opening the loading door slightly to improve air circulation.

The plastic cover outside should be washed regularly to remove dust because a dirty plastic will reduce dryer performance and increase drying time.

## 9.4 Drying fruits and vegetables

**The key to good and safe fruits and vegetables preservation, is cleanliness.** The environment, the equipment and the person doing the preservation must all be clean.

Mnkeni *et al.,* (2001), have described drying of fruit and vegetables including instructions for specific fruits and vegetables.

### 9.4.1 Harvesting, sorting and weighing fruits/vegetables for drying

Only good quality fruits/vegetables should be used. They should be handled carefully during harvesting to avoid damage (FAO, 2008). Harvesting in the morning hours after the dew and gently picking fruits and vegetables that are mature is recommended. The produce should be kept in the shade after harvest and spread out to allow heat to escape. If possible, harvesting and processing should be done on the same day for maximum nutrient retention. If it is not possible, then, the vegetables/fruits must be stored in a cool place where nutrient loss is minimum. The fruit or vegetables to be processed for the day must be weighed and the weight recorded. Recording of activities is important so that one can refer back in case of a problem.

### 9.4.2 Washing of vegetables for drying

The workplace area where processing is taking place, must be cleaned before one commences with any processing. The use of portable water is recommended to clean the vegetables. The water used for washing may be recycled (i.e. can be used for irrigation, flushing toilets, animals drinking water, etc.). The water which is used for rinsing the fruit or vegetables should be treated with a disinfectant or a sterilizing solution, which is consumption safe.  The fruit/vegetables should be soaked in the rinsing solution for up to 10 minutes (especially for vegetables that are going to be dried directly without peeling or heat treatment) before proceeding to the next step. The vegetables must always be washed before cutting. If washed after cutting, this will result in much of the nutrients being lost in the washing process.

### 9.4.3 Peeling of vegetables for drying

Peeling knives and work area should be cleaned with bleach solution before use.  Use of sharp stainless steel knives is recommended. Peeling must be done carefully with minimum removal of flesh. The peelings and seed should be disposed of, as soon as possible.

### 9.4.4 Cutting

Cutting must be done using sharp knives in such a way that the slices are not too thick or too thin and are of uniform size. Thicker slices will dry at a slower rate than thinner slices and may not dry fully and may subsequently deteriorate after packing. Very thin slices, on the other hand, tend to stick to the drying trays and will be difficult to remove.

### 9.4.5 Blanching

Blanching is mainly done for vegetables and not fruit. Blanching is the process of heating vegetables to a temperature high enough to:

⇒ Inactivate enzymes present in the tissue. It stops the enzyme action that causes loss of colour and flavour during drying and storage;

- ⇒ Reduce microbial load on the vegetables;
- ⇒ Set the colour; and
- ⇒ Shortens the drying and rehydration time by relaxing the tissue walls so moisture can escape or re-enter more rapidly.

#### *9.4.5.1 Water-Blanching*

In water blanching, the vegetables are submerged in boiling water. A large pot should be two-thirds filled with water, covered and brought to a rolling boil. The vegetables in a wire basket or a colander should then be submerged in the water. The pot should then be covered and blanching done according to time period for each vegetable as indicated in Annex 11.1. Water blanching usually results in a greater loss of nutrients, but it takes less time than steam blanching.

#### *9.4.5.2 Steam-Blanching*

In steam blanching, the vegetables are suspended above the boiling water and heated only by the steam. A deep pot with a close-fitting lid and a wire basket or a colander or sieve that can allow the steam to circulate freely around the vegetables is recommended. Water in the pot is brought to a rolling boil. The vegetables should be loosely placed in the basket no more than 5 cm deep and placed in the pot. The water should not come in contact with the vegetables. The pot should then be covered and steamed according to the time period for that vegetable as indicated in Annex 11.1

*Note: Not all vegetables require blanching. Onions, green peppers, herbs and mushrooms can be dried without blanching.*

Fruits that turn brown on exposure to air such as apples and bananas may need to be dipped into lemon juice before drying.

### 9.4.6 Spreading on trays

The drying trays should be well cleaned before use. Clean gloves must be used to avoid skin contact with the blanched vegetables. The blanched vegetables should be spread as a thin layer on the trays as evenly as possible. Uneven spreading will cause some parts to dry before others and loss of quality of final product. If fruits are being spread, then the slices should be arranged as a single layer and as close as possible without overlapping.

### 9.4.7 Drying

The interior of the drying cabinet should be swept clean and then wiped out with a clean, damp cloth before loading the dryer. During the first few hours of drying, particularly during very hot and sunny weather, fruit may dry at such a rate that moisture condenses on the inside of the plastic covers. This can be avoided by opening the loading doors slightly (20 mm) to improve air circulation. Under fine and sunny conditions fruit slices should be dry after two full days in the dryer. However, it is essential to test slices. **If the slices are not sufficiently dry, they will become mouldy in a short time**.

### 9.4.8 Unloading the dryer

Hands should be washed with soap and dried thoroughly when handling the dried fruit/vegetables. The best time to unload is during the afternoon and on a sunny day. Trays should be taken from dryer and kept in a clean area for the product to cool down to room temperature. When the product has cooled down it should be removed from trays, weighed and the weight recorded.

### 9.4.9 Packaging and storage of dried vegetables

Packing should be done immediately after unloading and cooling to prevent re-absorption of moisture. Packaging material must protect the product from moisture, air, light, dust, microorganisms, insects and rodents. Product should be stored in small quantities to avoid large scale contamination.

- ⇒ Each storage container should be marked clearly with labels stating the product name and the date it was packaged and the use by date.

⇒ Dried products must be stored in a cool dry and clean area which is secure and protected against rodents and other pests.

Properly stored dried vegetables can keep well for between 6 to 12 months. The dried products should be checked once every month and vegetables/fruit that develop an odour or show any signs of moulding should be discarded.

## 9.5 How to use dried vegetables

Dried vegetables can be used with addition of herbs or butter or any desired spices. They can also be used in soups, stews, sauces and casseroles. Consumption of dried vegetables can be significantly increased if training focuses on methods of cooking/preparation of the dried vegetables. Mnkeni *et al.,* (2001), have reported a variety of recipes using dried fruit and vegetables.

To refresh dried vegetables such as cabbage, spinach or tomatoes they should be covered with hot water and allowed to simmer to the desired tenderness. Root and stem vegetables can be refreshed by covering with enough cold water to keep the vegetables immersed for a minimum of 30 minutes.

After soaking they should be simmered in the same soaking liquid until tender. Dried vegetables are rich in fibre, minerals, and the B vitamins. Vitamin C and Beta Carotene is significantly reduced by the exposure to the sun (Sablani, 2007; Mills-Gray, 2018). Dried fruits contain concentrated fruit sugar which is a good source of quick energy. They also contain a good amount of vitamins and minerals.

## 9.6 Monitoring performance of home preservation of fruits and vegetables in terms of the CSA pillars

Performance indicators that can be used are as indicated in Table 9.1. It is important that research be carried out to establish the baseline for the indicators mentioned in Table 9.1.

**Table 9.1: Indicators for monitoring performance of home food preservation of fruits and vegetables**

| CSA Pillar | Indicators at Household level | Indicators at Administrative level |
|---|---|---|
| **Adaptation** | Increase number of food secure days | Number of extension workers trained in home food preservation.<br>Number of households trained in food preservation.<br>Number of households practicing preservation of fruits and vegetables.<br>Number of training centres established. |
| | Increase in the number of households supplementing their diets with fruits and vegetables that they preserved | Number of households consuming locally preserved fruits and vegetables. |
| | Increased quantities of fruits and vegetables preserved | Less fruit and vegetables waste treatment at municipal damp sites. |

## 9.7 Conclusions

Fruit and vegetables can be preserved by solar drying at household level to reduce post-harvest losses and to increase availability and diversity of diets throughout the year. Some communities might have knowledge on sun drying, so research is needed to find out the indigenous knowledge that is available and how it can be improved upon for production of better quality products. There is a need for training of trainers (extension workers, community development workers) as well as households on how to preserve food at household level.

The training centres in the Farmer Production Support Units of the Agri-Parks should have a unit on home food preservation where community members may be trained. Training should also include other simple and affordable methods of preservation that are environmental friendly. Training support can be obtained from Technical and Vocational Education Training Institutes (TVET) in the country.

## 10. General Conclusions

The preceding sections of this report describe various implementation guidelines of practices identified as possible entry points for CSA in South Africa. The Guideline, though comprehensive, do not replace expert advice from professionals in the different fields and that of extension officers. Many aspects of CSA are knowledge intensive and so the guides should be viewed as work in progress to be improved upon with increase in experiential and academic knowledge. More research funds need to be availed by government to support on-going agronomic work, and more especially long-term research. It is proposed that the focal point for support should be at the provincial level. The implementation of these guidelines, where applicable, should help South Africa's transition to an all-inclusive green economy. The contribution of the CSA Guideline to the widespread adoption of CSA will, however, depend on the creation and implementation of appropriate policies and an enabling environment. This latter aspect is the subject of Volume 3 of this guideline report.

## ANNEXURES TO THE DIFFERENT GUIDELINE CHAPTERS

### Chapter 2

**Annexure 2.1 - Table 1: N-Guideline for maize adjusted for texture (FSSA (2007).**

| Clay content (%) | Yield (ton ha$^{-1}$) | | | | |
|---|---|---|---|---|---|
| | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 |
| | kg N ha$^{-1}$ | | | | |
| **5** | 23 | 58 | 92 | 126 | 160 |
| **15** | 10 | 45 | 79 | 113 | 147 |
| **25** | 0 | 33 | 67 | 101 | 135 |
| **40** | 0 | 14 | 48 | 82 | 116 |

*Source: FSSA (2007)*

**Annexure 2.2 - Table 2: Guidelines for P fertilization of maize**

| Soil P (Bray 1 method) mg kg$^{-1}$ | P recommendation for potential yield of (t ha$^{-1}$) | | | | | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
| | kg P ha$^{-1}$ | | | | | | | | | Sub optimum Soil P; P upgrading + maintenance |
| **0-4** | 20 | 42 | 65 | 88 | 109 | 130 | 130 | 130 | 130 | |
| **4-7** | 17 | 31 | 47 | 63 | 67 | 90 | 93 | 95 | 97 | |
| **8-14** | 13 | 19 | 30 | 42 | 50 | 59 | 64 | 67 | 68 | |
| **15-20** | 10 | 13 | 21 | 29 | 36 | 42 | 47 | 50 | 53 | |
| **22-27** | **7** | **10** | **15** | **19** | **26** | **31** | **34** | **38** | **41** | **Optimum soil P** |
| **28-34** | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 27 | 30 | Above optimum soil P; maintenance |

*Source: FSSA (2007)*

**Annexure 2.3 - Table 3: Guideline for K-fertilization of maize on soils with low clay content (< 25%)**

| $NH_4OAc$ extractable soil K at start of season | K recommendation for yield potential of (t $ha^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| mg $kg^{-1}$ | kg K $ha^{-1}$ | | | | | | | | |
| **10** | 10 | 19 | 28 | 37 | 46 | 55 | 64 | 73 | 82 |
| **20** | 0 | 11 | 20 | 29 | 38 | 47 | 56 | 64 | 73 |
| **40** | 0 | 5 | 13 | 22 | 30 | 39 | 47 | 56 | 64 |
| **60** | 0 | 0 | 8 | 16 | 24 | 32 | 40 | 48 | 56 |
| **80** | 0 | 0 | 5 | 12 | 20 | 27 | 35 | 42 | 50 |
| **100** | 0 | 0 | 0 | 10 | 17 | 24 | 31 | 38 | 45 |
| **120** | 0 | 0 | 0 | 3 | 15 | 21 | 28 | 34 | 41 |

*Source: FSSA (2007)*

**Annexure 2.4 - Table 2. 4: Guideline for K-fertilization of maize on soils with high clay content (> 25%)**

| $NH_4OAc$ extractable soil K at start of season | K recommendation for yield potential of (t $ha^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| mg $kg^{-1}$ | kg K $ha^{-1}$ | | | | | | | | |
| **< 40** | 16 | 30 | 44 | 58 | 72 | 86 | 100 | 114 | 128 |
| **40** | 5 | 16 | 27 | 38 | 49 | 60 | 71 | 81 | 93 |
| **60** | 0 | 9 | 19 | 30 | 40 | 49 | 59 | 67 | 78 |
| **80** | 0 | 5 | 13 | 22 | 31 | 40 | 49 | 57 | 67 |
| **100** | 0 | 0 | 9 | 17 | 25 | 33 | 41 | 48 | 57 |
| **120** | 0 | 0 | 6 | 13 | 20 | 27 | 34 | 41 | 48 |
| **140** | 0 | 0 | 5 | 11 | 17 | 23 | 29 | 35 | 41 |
| **160** | 0 | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 |

*Source: FSSA (2007)*

**Annexure 2.5 - Table 5: Land application rates of kraal manure recommended for low and high target yields of selected Crops (Source: Van Averbeke and Yoganathan, 1997).**

| Crop | Target yield (t/ha) | | Application rate of kraal manure (wheelbarrows/ha) |
|---|---|---|---|
| **Maize and sorghum** | 2 | Low | 100 |
| | 5 | High | 200 |
| **Potatoes and Cabbage** | 30 | Low | 300 |
| | 40 | High | 400 |
| **Peas** | 2 | Low | 150 |
| | 3 | High | 200 |
| **Dry beans** | 1 | Low | 100 |
| | 2 | High | 150 |
| **Cucurbits, beetroot, and onion** | 20 | Low | 200 |
| | 30 | High | 300 |
| **Tomatoes** | 30 | Low | 225 |
| | 40 | High | 300 |
| **Spinach** | 10 | Low | 550 |
| | 15 | High | 850 |

*[For each crop, or group of crops, a low and a high target yield is given. The low target yield applies to farming areas of low, unreliable rainfall while high target yields apply to areas of high rainfall or are using irrigation]*

**Annexure 2.7 - Table 6: Area of land to be fertilized with one wheelbarrow load of kraal manure in garden plots (Source: Van Averbeke and Yoganathan, 1997).**

| Crop | Crop area to be fertilized with one wheelbarrow load of kraal manure ($m^2$) | |
|---|---|---|
| | Low target yield | High target yield |
| **Maize, sorghum, peas** | 100 | 50 |
| **Potatoes and cabbage** | 33 | 25 |
| **Dry beans** | 30 | 60 |
| **Cucurbits, beetroot, tomatoes and onion** | 50 | 30 |
| **Spinach** | 15 | 10 |

*[Example: Garden production of cabbage on 20m x 10m plot (area= 200$m^2$)*
*High target yield e.g. when irrigated: Application rate = 200$m^2$ x 1 wheelbarrow load/25$m^2$ = 8 wheelbarrow loads of kraal manure*
*Low target yield e.g. if not irrigated: Application rate = 200$m^2$ x 1 wheelbarrow load/33$m^2$ =6 wheelbarrow loads of kraal manure]*

**Annexure 2. 8 - Case study 1 - ISFM Case study on Productivity of maize grain, variability in maize yield in response to climate impacts and soil organic carbon (SOC) status after 20 years of cultivation for different input practices (Vanlauwe et al. 2005)**

The results of the 20-year study (Figure 2.2 top panel) show that when NPK fertilizers and organic inputs were combined, maize grain yields were between 0.26 and 2.4 ton/ha greater as compared to when the same inputs were applied separately. In the ISFM system maize grain yields remained well above 2 tons/ha after 10 years of cultivation and with a reduced rate of N input whereas the maize productivity dropped to 1 ton/ha in trials where exclusively fertilizers were used.

Figure 2.2 (middle panel) shows that in trials where fertilizers and organic inputs were combined, the production of maize crops were significantly less impacted by changes in weather conditions as compared to when fertilizers were applied exclusively. It is noteworthy that the organic inputs played an important role in reducing the climate sensitivity of maize crops. The higher productivity and yield stability achieved in the ISFM system prove that the practices significantly strengthen the resilience of crops to climate change impacts.

The bottom panel of Figure 2.2 summarizes the content of organic C in the top 5cm of soil at the end of the 20-year trials for different input practices. The dashed line in the graph depicts the soil organic C (SOC) content at the onset of the trials. When fertilizers and organic inputs were combined the SOC content was significantly greater as compared to when fertilizers or organic were applied alone. These results demonstrated that ISFM practices mitigate $CO_2$ emissions from soils thereby making important contributions to diminishing the GHG footprint of agricultural systems.

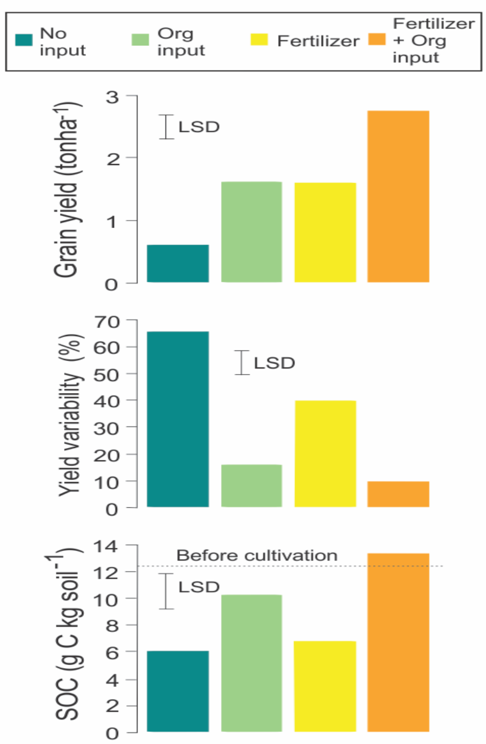


**Figure 2. 2: Productivity of maize grain, variability in maize yield in response to climate impacts and soil organic carbon (SOC) status after 20 years of cultivation for different input practices illustrating contributions of practising ISFM to the three dimensions of CSA. LSD = least significant difference.**

*Source: Adapted from: Vanlauwe et al. (2005) by Roobroeck et al. (2016)]*

# Chapter 4: Actionable Guidelines for Climate Smart Cereal Crops Production

## Annexure 4.1 Selected case studies highlighting application of climate smart agriculture in cereal systems.

### Case study 4.1: Conservation agriculture

For many years, farmers in Malula Village, King'ori Division of Meru District in Tanzania, on the slopes of Mount Meru were practicing conventional agriculture. The grounds were bare and eroded by rain, wind and livestock. This contributed to infertile soils leading to low yields and returns. Farmers would harvest only three bags of maize per hectare and 2 to 4 bags of beans. In 2004, Conservation Agriculture (CA) was introduced, but the uptake was minimal. Only a few farmers responded to the CA technology.

They reaped the benefits of increased yields and informed others. Then about 10 farmer groups were established through the Farmer Field Schools methodology. The groups were introduced to CA equipment such as rippers, knapsack sprayers, sub-soilers amongst others. They were also introduced to cover crops and the practice of crop rotation. During the first two seasons the yields were low, but in subsequent seasons the yields increased from about 30 bags to 50 bags of maize by the third year (2007). After approximately six years the returns stabilized to about 60 bags of maize per hectares and about 20 bags of beans. Farmers have expanded their acreage under crop. The soil fertility has improved, weeds have been suppressed by cover crops (SUSTAINET EA, 2010).

*Citation: Sustainable Agriculture Information Initiative (SUSTAINET EA). 2010. Technical Manual for farmers and Field Extension Service Providers: Conservation Agriculture. Sustainable Agriculture Information Initiative, Nairobi.*

### Case study 4.2: Tillage systems

One of the studies conducted in Bergville, 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.

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 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. These 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).

*Citations:*

*i) Mchunu CN, Lorentz S, Jewitt G, Manson A and Chaplot V (2011) No-Till Impacts on Soil and Soil Organic Carbon Erosion under Crop Residue Scarcity in Africa. Soil Science Society of America Journal **75** 1502–1511.*

*ii) Mchunu CN and Manson A (2015) No-till for Kwazulu-Natal's Small-Scale Farming Systems. Research & Technology BULLETIN. Department of Agriculture and Rural Development, Province of KwaZulu Natal.*

*iii) No-Till Club (July 2018) Bringing You the Facts about No-Till Conservation Agriculture.*

## Case study 4. 3: 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.

*Citation: Arathoon JA (2010) No-Till Crop Production for KwaZulu-Natal. Agri Update (2010/15), Information from the KZN Department of Agriculture, Environmental Affairs and Rural Development.*

## Case study 4. 4: Mulch and residue cropping

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, and maize is also dried and threshed for sale).

*Citation: Dlamini M, Kruger E and Smith H (2014) Promoting Conservation Agriculture to Increase the Sustainability of Smallholders in Matatiele. Grain SA, August 2014. https://www.grainsa.co.za/promoting-conservation-agriculture-to-increase-the-sustainability-of-smallholders-in-matatiele. Accessed 30th August 2018.*

## Case studies 4.5. Climate forecast case studies

Case studies of climate and weather forecasts in Lumsden and Schulze (2012) compared traditional and scientific methods showed that scientific weather/climate information is available to commercial farmers but resource poor farmers largely rely on traditional indicators and have limited access to scientific forecasts. An exercise conducted with 394 participants in the Modder Riet Catchment (Zuma-Netshiukhwi and Walker 2012a) showed that traditional indicators for rainfall and seasonal rainfall seemed to provide predictions for short lead times and did not allow for planning compared to 14-day and seasonal forecast that were issued to farmer groups at least two months in advance. The study by Lumsden and Schulze (2012) notes that the good performance of Free State under challenging rainfall conditions is in part due to good use of forecast data and advisories on planting dates and appropriate management strategies given to the farmers.

Zuma-Netshiukhwi and Walker (2012b) cite the case of the Scott group who manage Rustfontein Farm in the Modder/Riet Catchment to advance a case for seasonal forecasts. In 2009/10, a tailor-made advisory for Rustfontein farm predicted an above-normal rainfall season. The Scott group was advised to plant in late December, to select a short season cultivar and to increase maize population from 15 000 to 30 000 plants/ha. The neighbouring farmer did not receive the same advisory, planted in late November and harvested 0-1 t/ha of maize whilst the Scott group harvested 2-3 t/ha. Analysis of dry spell probabilities was used by the Scott group to manage harvesting and baling of Lucerne as >7 days of dry weather is required.

## Annexure 4.2 Example of a cereal-legume based crop rotation

A crop rotation programme will usually include a plan for top, medium and low potential soils (GrainSA, 2016). Let us take the example of a farm with 300 ha of topsoil that intends to follow a two crop system of maize and soybeans and will include a fallow system. The 300 hectares will be divided into convenient 100 hectare blocks. The rotation for this example would be as shown in Table 4.3.

**Table 4.3: The planting sequence of the first planting programme**

| Production year | Block 1-100 ha | Block 2-100 ha | Block 3-100 ha |
|---|---|---|---|
| **1** | Maize | Soybean | Fallow |
| **2** | Fallow | Maize | Soybean |
| **3** | Soybean | Fallow | Maize |
| **4 Repeat Y1** | Maize | Soybean | Fallow |
| **5 Repeat Y2** | Fallow | Maize | Soybean |
| **6 Repeat Y3** | Soybean | Fallow | Maize |

*Source: GrainSA, 2016*

## Annexure 9. 1: Blanching Periods for different Vegetables

| VEGETABLES | PREPARATION | Blanching Time (minutes) | |
|---|---|---|---|
| | | Steam | Water |
| **Beans, green** | Wash thoroughly. Cut in short pieces or lengthwise. (May freeze for 30 to 40 minutes after blanching for better texture.) | 2 to 2½ | 2 |
| **Beets** | Cook as usual. Cool; peel. Cut into shoestring strips about 3 mm thick. | No further blanching required. | |
| **Broccoli** | Trim and cut as for serving. Wash thoroughly. Quarter stalks lengthwise. | 3 to 3½ | 2 |
| **Cabbage** | Remove outer leaves; quarter and core. Cut into strips about 3 mm thick. | 2½ to 3 until wilted | 1½ to 2 |
| **Carrots** | Use only crisp, tender carrots. Wash thoroughly. Cut off roots and tops; prefer-ably peel, cut in slices or strips about 3 mm thick. | 3 to 3½ | 3½ |
| **Cauliflower** | Prepare as for serving. | 4 to 5 | 3 to 4 |
| **Celery** | Trim stalks. Wash stalks and leaves thoroughly. Slice stalks. | 2 | 2 |
| **Garlic** | Peel and finely chop garlic bulbs. No other pre-treatment is needed. Odour is pungent. | No blanching needed. | |
| **Greens (chard, kale, turnips, spinach)** | Use only young tender leaves. Wash and trim very thoroughly. | 2 to 2½ | 1½ |
| **Okra** | Wash, trim, slice crosswise in 3 mm to 6 mm disks. | None | |
| **Onions** | Wash, remove outer "paper shells." Remove tops and root ends, slice 3 mm to 5 mm thick. | None | |
| **Peppers and pimien-tos** | Wash, stem, core. Remove "partitions.") Cut into disks about 8mm thick | None | |
| **Potatoes** | Wash, peel. Cut into shoestring strips 6 mm thick, or cut in slices 3 mm thick. | 6 to 8 | 5 to 6 |
| **Pumpkin** | Cut or break into pieces. Remove seeds and cavity pulp. Cut into 2.5 cm strips. Peel rind. Cut strips crosswise into pieces about 3 mm thick. | 2½ to 3 | 1 |
| **Squash, summer** | Wash, trim, cut into 5 mm slices. | 2½ to 3 | 1½ |

*Source: Renee Boyer (2009).*

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## Additional information sources

### Chapter 2

Training manual for organic agriculture (http://www.fao.org/fileadmin/templates/nr/sustainability_pathways/docs/Compilation_techniques_organic_agriculture_rev.pdf ).

Organic Africa (https://www.organic-africa.net/fileadmin/documents-africamanual/training-manual/chapter-08/Africa_Pres_M08_Conversion.pdf )

Training manual for extension officers on organic farming technologies for the restoration of degraded lands ( https://boris.unibe.ch/69743/1/TRAINING%20MANUAL%20Dodoma%20DECEMBER%20ENGLISH2009%20_2_.pdf )

### Chapter 4

***Additional information on cultivar selection***

ARC-Small Grain publishes compact manuals annually with the latest cereal production information. The manuals are usually for major cereal crops, thereby sidelining many indigenous crops. They provide guidelines regarding selection of crops and cultivars and related planting periods, plant density and disease resistance, plant nutrition and general production guidelines. Millets and sorghum receive limited attention in the manuals due to limited research on the crops.

The latest reports are listed below and reports for previous years are available in the same format and titles.

Agricultural Research Council (ARC), 2017a. Guideline Production of Small Grains in the Summer Rainfall Area. ARC - Small Grain Institute. Pretoria, South Africa.

Agricultural Research Council (ARC), 2017b. Guideline Production of Small Grains in the Winter Rainfall Area. ARC - Small Grain Institute. Pretoria, South Africa.

Cultivars and population under intercropping

To intercrop maize with beans, maize hybrids (e.g. SNK2147, PAN701, and PAN6804) can be intercropped with determinate (e.g.  PAN127) and indeterminate (e.g. PAN148) cultivars.

Recommended planting population for maize hybrids planted is at 4.4 plants m-2 and 4.2 plants m-2 for bean cultivars in intercropping systems but this will depend on rainfall and soil fertility conditions. Much lower populations should be used as recommended by extension services in dry areas.

***Additional information on sorghum production***

Guidelines for production of sorghum are available from the Department of Agriculture, Forestry and Fisheries (DAFF) https://www.nda.agric.za/docs/brochures/prodguidesorghum.pdf, the Agricultural Research Council (ARC) www.arc.agric.za/arc-gci/Fact%20Sheets%20Library/Sorghum%20Production.pdf, and Pannar Seeds (Pty) Ltd www.pannar.com/assets/documents/grain_sorghum_op.pdf.

Guidelines for the production of pearl millet are available from at https://www.daff.gov.za/.../Brochures%20and%Production%20guidelines/Productio.

***Additional information on crop rotation guidelines is available from the following documentation:***

Mohler CL and Johnson SE (2009) Crop Rotation on Organic Farms: A Planning Manual.  Sustainable Agriculture Research and Education (SARE), Natural Resource, Agriculture, and Engineering Service. New York, USA. pp 1-164.

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Sustainable Agriculture Information Initiative (SUSTAINET EA), (2010) Technical Manual for farmers and Field Extension Service Providers: Conservation Agriculture. Sustainable Agriculture Information Initiative, Nairobi.

***Additional information on minimum tillage guidelines is available from the following documentation:***

Mrabet R and Wall P (2015) Practical Guide to Conservation Agriculture in West Asia and North Africa. International Center for Agricultural Research in the Dry Areas (ICARDA), Beirut, Lebanon.

***Additional information on mulching guidelines is available from the following documentation:***

International Society of Arboriculture (ISA), (2004) Proper Mulching Techniques. Illinois, USA.

## Chapter 5

IFC (International Finance Corporation) 2011. Good management practices manual for the cane sugar industry (Final). https://www.ifc.org/wps/wcm/connect/486cf5004953685e8586b519583b6d16/IFC_GMP_ManualCaneSugarIndustry.pdf?MOD=AJPERES. Accessed 22 November 2018.

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Sugar Research Australia 2014. Irrigation of Sugarcane Manual. Technical publication MN14002. Sugar Research Australia Ltd 2014 edition of the Irrigation of Sugarcane Manual published in 1998 by BSES Limited. ISBN: 978-0-949678-31-7. https://sugarresearch.com.au/wp-content/uploads/2017/02/Irrigation-Manual-F-LowRes2.pdf. Accessed 22 November 2018.

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Cultivation of mangoes – DAFF. https://www.daff.gov.za/daffweb3/Portals/0/InfoPaks/Cultivation%20of%20mangoes.pdf. Accessed 23 November 2018

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http://www.arc.agric.za/arc-itsc/Leaflets%20Library/Cultivating%20Banana%20-%20English.pdf. Accessed 23 November 2018

Mango planting manual. https://www.worldagroforestry.org/sites/default/files/users/admin/mango-planting-manual.pdf. World Agroforestry Centre and IFAD. Accessed 23 November, 2018.11.23

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SIZA, 2018. The Sustainability Initiative of South Africa. https://siza.co.za/. Accessed 20 October 2018.

The World Bank Group, 2016. Climate-Smart Agriculture Indicators: Agriculture Global Practice. World Bank Group Report Number 105162-GLB, Washington.

## Chapter 7

***Greenhouse resources***

Easy Greenhouse: https://easygreenhouses.co.za/; E-mail: Linda@easygreenhouse.co.za Tel: (011) 792 7583.

Greenhouses Tunnels South Africa: http://www.wilsacgreenhousetunnels.co.za/; Tel: 0623927267.

Spectrum Tunnels: http://spektrumtunnels.co.za/ (Phone 071 361 8208; E-mail: spektrumtunnels@gmail.com.

K.R. Manohar and C. Igathinathane. 2007. Greenhouse Technology and management. AS Publications, Hyderabad, India.

***Rooftop farming information resource***

Guide to setting up your own edible rooftop garden. Free download book available at: http://archives.rooftopgardens.ca/files/howto_EN_FINAL_lowres.pdf

Rooftop roots (a rooftop farming inter price in Johannesberg, South Africa http://rooftoproots.co.za/ ; E-Mail: info@rooftops.co.za, Tel: 010 595 2370.

South African urban farmers grow herbs and crops on rooftops (rooftop urban agriculture success story of Mr. Nhlanhla Mpati in South Africa). Available at: http://www.africanews.com/2017/11/21/south-african-urban-farmers-grow-herbs-and-crops-on-rooftops//

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K Robrto. 2006. HowTo Hydroponics: The complete guide to building and operating your own indoor hydroponic gardens. Available at: http://ebooks.bharathuniv.ac.in/gdlc1/gdlc4/Agriculture/HowTo%20Hydroponics%20ver%204.1.pdf

***Source of information for vertical farming***

ARC (Agricultural Research Council) Vegetables and Ornamental Plants Institute (VOPI), Roodeplaat, Pretoria. Website: www.arc.agric.za; Tel: 0128419611.

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***Source of composting and vermicomposting***

J Hadfield. 2016. The A-Z Vegetable gardening in South Africa. Penguin Random House South Africa, Cape Town, South Africa.

The Cornell Small Farms Program. 2012. Guide to urban farming in New York State. Available at: https://cpb-us-e1.wpmucdn.com/blogs.cornell.edu/dist/c/2110/files/2012/03/GuidetoUrbanFarminginNYS-1s2f0rm.pdf

The South African Department of Environmental Affairs. 2013. The national organic waste composting strategy. Available at: http://sawic.environment.gov.za/documents/1825.pdf

***Sources of information for water harvesting and recycling waste water***

Department of water affairs and Forestry. 1996. South African water quality guidelines. Volume 3: Industrial use. Available at: http://www.dwa.gov.za/iwqs/wq_guide/Pol_saWQguideMARINEIndustrialusevol3.pdf

N. Nel, H. E. Jacobs, C. L. and K. Du Plessis. 2017. Supplementary household water sources to augment potable municipal supply in South Africa. Water SA, 43: 553-562.

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