Deliverable

6

Water Research Commission

Project Number: **K5/2719/4**

Project Title: Collaborative knowledge creation and mediation strategies for the dissemination of Water and Soil Conservation practices and Climate Smart Agriculture in smallholder farming systems.

Deliverable No.6: Interim report: Results of pilots; Season 1
Date: January 2019

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Interim report: Refined decision support system for CSA in smallholder farming

1 OVERVIEW OF PROJECT AND DELIVERABLE

Contract Summary

Project objectives

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

Deliverables

Table 1: Deliverables for the research period; completed

No	Deliverable	Description	Target date
FINANCIAL YEAR 2017/2018			
1	Report: Desktop review of CSA and WSC	Desktop review of current science, indigenous and traditional knowledge, and best practice in relation to CSA and WSC in the South African context	1 June 2017
2	Report on stakeholder engagement and case study development and site identification	Identifying and engaging with projects and stakeholders implementing CSA and WSC processes and capturing case studies applicable to prioritized bioclimatic regions Identification of pilot research sites	1 September 2017
3	Decision support system for CSA in smallholder farming developed (Report)	Decision support system for prioritization of best bet CSA options in a particular locality; initial database and models. Review existing models, in conjunction with stakeholder discussions for initial criteria	15 January 2018
FINANCIAL YEAR: 2018/2019			
4	CoPs and demonstration sites established (report)	Establish communities of practice (CoP)s including stakeholders and smallholder farmers in each bioclimatic region.5. With each CoP, identify and select demonstration sites in each bioclimatic region and pilot chosen collaborative strategies for introduction of a range of CSA and WSC strategies in homestead farming systems (gardens and fields)	1 May 2018
5	Interim report: Refined decision support system for CSA in smallholder farming (report)	Refinement of criteria and practices, introduction of new ideas and innovations, updating of decision support system	1 October 2018
6	Interim report: Results of pilots, season 1	Pilot chosen collaborative strategies for introduction of a range of CSA and WSC strategies, working with the CoPs in each site and the decisions support system. Create knowledge mediation productions,	31 January 2019

		manuals, handouts and other resources necessary for learning and implementation.	
FINANCIAL YEAR 2019/2020			
7	Report: Appropriate quantitative measurement procedures for verification of the visual indicators.	Set up farmer and researcher level experimentation	1 May 2019
8	Interim report: Development of indicators, proxies and benchmarks and knowledge mediation processes	Document and record appropriate visual indicators and proxies for community level assessment, work with CoPs to implement and refine indicators. Link proxies and benchmarks to quantitative research to verify and formalise. Explore potential incentive schemes and financing mechanisms. Analysis of contemporary approaches to collaborative knowledge creation within the agricultural sector. Conduct survey of present knowledge mediation processes in community and smallholder settings. Develop appropriate knowledge mediation processes for each CoP. Develop CoP decision support systems	1 August 2019
9	Interim report: results of pilots, season 2	Pilot chosen collaborative strategies for introduction of a range of CSA and WSC strategies, working with the CoPs in each site and the decisions support system. Create knowledge mediation productions, manuals, handouts and other resources necessary for learning and implementation.	31 January 2020
FINANCIAL YEAR 2020/2021			
10	Final report: Results of pilots, season	Pilot chosen collaborative strategies for introduction of a range of CSA and WSC strategies , working with the CoPs in each site and the decisions support system. Create knowledge mediation productions, manuals, handouts and other resources necessary for learning and implementation.	1 May 2020
11	Final Report: Consolidation and finalisation of decision support system	Finalisation of criteria and practices, introduction of new ideas and innovations, updating of decision support system	3 July 2020
12	Final report - Summarise and disseminate recommendations for best practice options.	Summarise and disseminate recommendations for best practice options for knowledge mediation and CSA and SWC techniques for prioritized bioclimatic regions	7 August 2020

Overview of Deliverable 6

This report deals with the piloting of the collaborative strategies across the three sites in Limpopo, KZN and EC. Progress with the decision support system is also detailed. It also includes some of the quantitative measurement procedures and some work on visual indicators, as well as farmer level experimentation. Some of these results cover the requirements of Deliverable 7. In the next 5 months the manuals, handouts and resources will be given more attention to bring these products to a level of quality that can be presented and published. Work on these is presently ongoing and not reported here.

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

- **Practices:** Collation, review, testing, and finalisation of those CSA practices to be included. Allows for new ideas and local practices to be included over time. This also includes linkages and reference to external sources of technical information around climate change, soils, water management etc and how this will be done, as well as modelling of the DSS;
- **Process:** Through which climate smart agricultural practices are implemented at smallholder farmer level. This also includes the facilitation component, communities of practice (CoPs), communication strategies and capacity building and
- **Monitoring and evaluation:** local and visual assessment protocols for assessing implementation and impact of practices as well as processes used. This also includes site

selection and quantitative measurements undertaken to support the visual assessment protocols and development of visual and proxy indicators for future use in inactive based support schemes for smallholder farmers.

Activities in this four- month period have included:

- **Practices activities**: continue modelling of the DSS and run the model for 26 households across three provinces.
- **Process activities**: Conduct CCA workshops 2 and 3 in Swayimane (KZN), CCA workshops 1 and 2 in Madzikane (KZN), as well as training and implementation (Workshop 4) in the EC (3 villages), and monitoring of implementation in Bergville and Ntabamhlophe in KZN. CoP engagement has consisted of presentations at the 2nd African Conference on Conservation Agriculture (2ACCA), the NCCC and a CSA best practice session for the Agroecology network.
- **Monitoring and evaluation:** First round of quantitative measurement of indicators (weather stations, run-off plots, gravimetric soil sampling, soil health sampling, soil fertility sampling, chameleon water sensors) for conservation agriculture (CA) and intensive gardening activities in one site; Bergville, redesign of methodology for visual soil assessments and redesign of garden monitoring process

A chronology of activities undertaken is presented in the table below.

Date	Activity	Description	Team
2018/09/18-19	CCA workshop 1	Initiation of process in Madzikane - SKZN	Mazwi, Samukhelisiwe, Khethiwe
2018/10/02-03	Presentations and attendance	2nd African Conference in Conservation Agriculture – Gauteng	Erna, Phumzile, Tema, Khethiwe, Samukhelisiwe
2018/10/04	CCA W/s 5 – Limpopo	Review and re-planning workshop for village clusters in Limpopo	Erna, Sylvester, Betty
2018/11/07,15	CCA Ws 2 and 3 – Swayimane	Continuation of the CCA process in Gobizembe- Swayimane – SKZN	Tema, Samukhelisiwe
2018/11/11	Presentation	NCCC stakeholder w/s- Gauteng	Erna
2018/11/14-15	CCA Ws 4 Ntabamhlophe – KZN	Review of implementation in gardening practices and tunnels	Samukhelisiwe, Khethiwe and Lindelwa (Lima-RDF)
2018/11/20-21	Training and mentoring	Traditional and local poultry production systems in a changing environment – Limpopo (5 villages)	Erna, Mazwi, Sylvester, Nonkhanyiso, Betty, Andries
2018/11/22	Organise and present	2nd Agroecology network meeting; Best practice in CSA – Nelspruit, Limpopo	Erna, Catherine van den Hoof, Lawrence, Betty
2018/12/04-07	CCA W/s 4 EC	Implementation and monitoring workshops for 3 villages in the EC	Mazwi, Khethiwe, Lawrence
2018/12/04-07	CCA W/s 5 and monitoring Bergville KZN	Implementation monitoring and sharing events in Eizbomvini and Eqeleni	Samkhe, Phumzile
2018/12/12	CCA W/s 5 Ntabamhlophe-KZN	Demonstration of CA with new experimentation cycle	Samukhelisiwe, Khethiwe and Lindelwa (Lima-RDF)

Capacity building and publications:

- Research presentations and chapters:
  - Mazwi Dlamini – M Phil (PLAAS UWC-yr 2); Completed research tools and started on field work
  - Samukelisiwe Mkhize
- Publications: -
- Cross visits:
  - INR_ Agroforestry implementation and progress
- Attendance: -
- Conference papers and presentations:
  - 2ACCA: *Learning Conservation Agriculture the Innovation Systems way* _E Kruger (2 October 2018) and *Soil Health improvements in smallholder CA systems* _E Kruger (3 October 2018)
  - Agroecology Network: *Decision Support System for CSA for smallholder farmers in SA* _Catherine van den Hoof (22 November 2018) and *Best practices in community based climate change adaptation* _E Kruger (22 November 2018)
  - National Climate change Committee Stakeholder Meeting: *Community based climate smart agriculture* _E Kruger (11 November 2018)
  - Farmers Days: Joint open day events for Conservation Agriculture with LandCare and KZNDARD in Nokweja (SKZN), Stulwane- Bergville (KZN), Swayimane and Appelbosch (Midlands-KZN)
- Awards:
  - 2ACCA conference; Conservation Agriculture Champion award
  - LandCare; Best Civil Society Organisation in LandCare award.

2 COPS AND DEMONSTRATION SITES CONTINUED

The work with the CoPs and in the demonstration sites is ongoing. The table below summarises the progress to date.

Table 2: CoPs' established in three provinces (October 2018-January 2019)

Province	Site/Area; villages	Demonstration sites	CoPs	Collaborative strategies
KZN	Ntabamhlophe	- CCA workshop 1 - CCA workshop 2 -CCA workshop 3 -**CCA workshop 4** -**CCA workshop 5**	-Farmers w NGO support (Lima RDF)	- Tunnels and drip kits - Individual experimentation with basket of options
	Ezibomvini/ , Eqeleni	- CCA workshop 1 - CCA workshop 2 - CCA workshop 3 - CCA workshop 4 (training) - Water issues workshops 1,2 -**Water issues follow-up** **-CCA workshop 5**	-CA open days, cross visits (LandCare, DARD, ARC, GrainSA), LM Agric forums, ….	- Tunnels (Quantitative measurements - CA farmer experimentation (Quantitative measurements) – case studies -Individual experimentation with basket of options; monitoring review and re-planning
	Swayimane	- CCA workshop 1 **-CCA workshops 2 and 3**	-CA open days -Umgungundlovu DM agriculture forum	-CA farmer experimentation - gardening level experimentation; tunnel, trench beds drip kits etc.
	Madzikane	**-CCA workshop 1**	-CA open days - Madzikane stakeholder forum	-CA farmer experimentation - gardening level experimentation; tunnel, trench beds drip kits etc
Limpopo	Mametja (Sedawa, Turkey)	- CCA workshop 1 - CCA workshop 2 - CCA workshop 3 - CCA workshop 4 -Water issues workshops 1-2 -**Water issues follow-up** - **CCA workshop 5** **- Poultry production learning and mentoring**	-Agroecology network (AWARD/MDF) -Maruleng DM	-Review of CSA implementation and re-planning for next season Tunnels (Quantitative measurements - CA farmer experimentation (Quantitative measurements) – case studies - Individual experimentation with basket of options -water committee, plan for agric water provision
	Lepelle	Water issues workshops 1-2	-	-water committee, plan for agric water provision
	Tzaneen (Sekororo-Lourene)	- CCA workshop 1 - CCA workshop 2 - Assessment of farmer experimentation	Farmers learning group	-Tunnels and drip kits
EC	Alice/Middledrift area	- CCA workshop 1 - CCA workshop 2 - CCA workshop 3 **-CCA workshop 4 and 5**	Imvotho Bubomi Learning Network (IBLN) - ERLC, Fort Cox, Farmers, Agric Extension services, NGOs	- Monitoring and review of implementation of CSA practices and experimentation - Training and mentoring _CA, furrow irrigation, …. -Planning for further implementation and experimentation and quantitative measurements

*Note: Activities in bold under Demonstration Sites, were conducted during this time frame

2.1 CCA workshop 1

The idea is both to continue the implementation and experimentation with a basket of CSA options in the existing seven (7) villages and to introduce the process in new villages, to practice and refine the decision support methodology being used in different contexts.

The climate change adaptation process was expanded into one more village, in Southern KZN during this period -Southern KZN – Madzikane (Creighton).

In accordance with the capacity development process for staff and interns, these workshops are now facilitated and recorded entirely by the teams themselves. They have made a few interesting adaptations to the facilitation process, which will be incorporated into the overall methodology. Reports are included here with minimal editing, to showcase their work and progress.

2.1.1 CCA workshop 1 summary – Madzikane _SKZN

Written by Mazwi Dlamini and Samukelisiwe Mkhize

On the 18th September 2018 the Mahlathini Development Foundation team (*Mazwi Dlamini, Zanani Mzila and Samukelisiwe Mkhize*) held a workshop with fifteen participants (12 women and 3 men). On day two of the workshop, this team (along with *Temakholo Mathebula and Sandile Madlala*) returned to find twenty participants (16 women and 4 men). According to the participants, the new participants heard about the workshop and decided to join to learn about climate change and its effects on their future farming practices and possible adaptation practices.

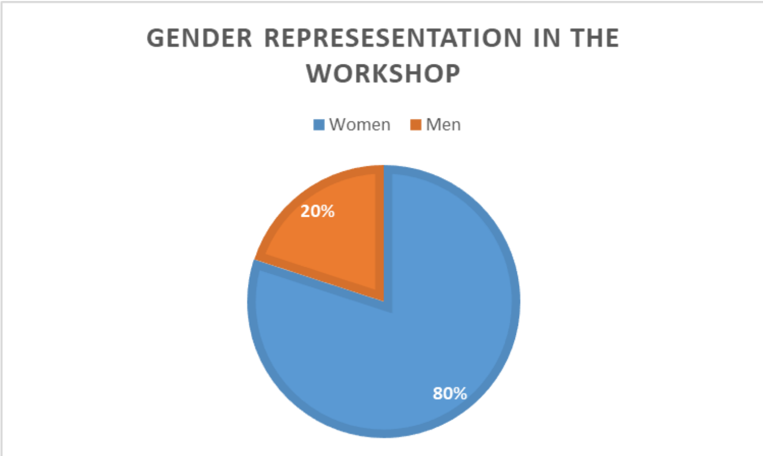


Figure 1: The pie chart shows the participation disparity between men and women on day 1 & 2 of the workshop.

Day One – 18th September 2018

(a) Farmers understanding of climate change and its effect on their farming activities and livelihoods.

Participants' understanding of climate change is related to their experiences of increasing climate extremities and variability. According to participants there have been several incidents of climatic changes and variability that have been taking place over the years in Madzikane. During the discussion, participants mentioned that they have witnessed and experienced the following changes in climate over the years that have 'confirmed' to them that climate change is indeed taking place:

- Change in rainfall patterns (rain coming later than expected) leading to shifting of planting dates
- Shorter but heavy rainfall periods leading to soil erosion

- Increasingly hot temperatures
- Stronger winds breaking maize stalks
- Frosting in September

To broaden participants understanding of how climate change and variability affect their farming practices and livelihoods participants were asked to pick the most important component between soil, sun and rain, related to their farming practices. This led to an interesting debate amongst participants, where some agreed that the most important component is the soil with others insisting that all are important because all three components contribute equally to good crop growth. One of the participants explained that too much rain will result in stunted plants, fungus growth and poor crop growth and too much sunlight/heat dries up vegetable plants. Therefore, they all later agreed that all three are equally important and work together to ensure good crop growth, including the wind (see **Figure 2** below). Mr Xaba (one of the participants) clarified that the customary understanding that soil is the most important component stems from the idea that participants believe and pray to God that they will receive enough rainfall and sunlight from the Creator, so they focus on soil as the only component they can 'fix'.

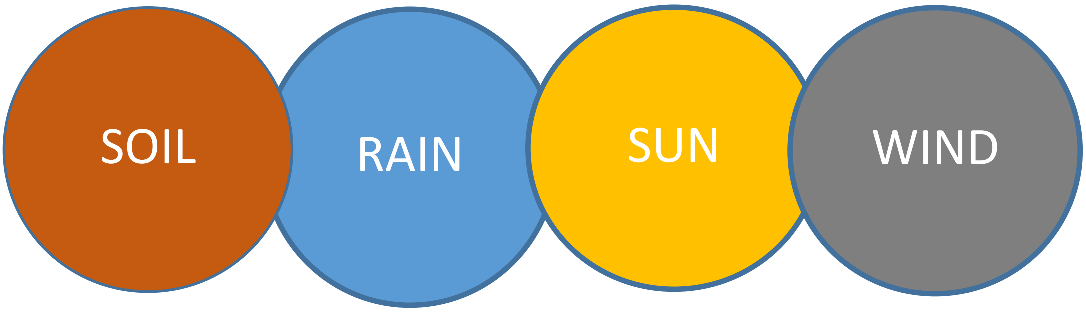


Figure 2: An understanding of how soil, rain, heat and wind affect crop production is required to understand how climate change impacts on current and future farming practices.

(b) Challenges to farmers' livelihoods:

Participants identified the following impacts and challenges on their livelihoods as a consequence of climate variability and changes overtime:

- Degrading veld for grazing
- Drought (erratic rainfall patterns)
- Water scarcity
- Veld fires
- Erosion
- Pest and diseases
- Flooding

Above and Right: Participants discussing their experiences of climate change.

(c) Past, Present and Future livelihoods and farming situations in relation to climate change

This part of the workshop focused on participants' experiences and perceptions on past livelihoods and farming situations, how these situations have changed in relation to climate change and what the future situation will be, looking at current effects of climate change. Mazwi Dlamini illustrated the difference between weather and the climate to participants, by posing this question to participants, ''if a relative called to visit your home and asked what the weather will be like that weekend, what would your response be and why?" None of the participants could respond. He then explained that, weather conditions are predictable unlike climate change and variabilities, weather stations predict future weather conditions by looking at current and past weather patterns. Weather conditions can change throughout the day/week, but climatic changes occur over a longer period of time. This understanding enabled participants to recall cases of extreme climate variabilities that have taken place in the community over the years and effects to their farming practices:

- **2016 - 2017** – Drought – Farmers achieved low yields during this period
- **1993** – Drought – Farmers couldn't plant during this period because of the extensive drought and dry soils.
- **1987** – Flooding
- **1959** – Flooding – Bridges washed away by floods

Right: Mazwi showing participants illustrations of past extreme climate variability and outcomes in the Drakensberg

The participants mentioned the following past, present and future conditions; summarised below.

Table 3: Past, present and future farming situations for the Madzikane farmers' group

PAST CONDITIONS	PRESENT CONDITIONS	FUTURE CONDITIONS
Hot temperatures	Increasingly hot temperatures during summer months	Temperatures will continue to increase drying out vegetable plants (tomatoes, green peppers)
Longer rain season	Shorter rainfall season and frequent droughts	Less rain & no rain fall in some seasons
Strong winds	Frequent and stronger winds that wreck peoples' homes	Less water infiltration in soil
Low yields	Increased yields as a result of sustainable agriculture practices	Yields will decrease if farmers do not act against climate change
Tillage	No tillage and less use of tractors	No tillage and hand planting
Livestock controlled and regulated	No livestock control and regulation	Fencing of farm fields to control livestock grazing
Mix cropping	Single cropping	Mixed cropping and intercropping
Hand weeding	Use of pesticides and herbicides	Increased use of pesticides and herbicides
Soil erosion due to flooding	Increasing incidences of floods that lead to washing away of seeds	Vast and increasing soil erosion that may lead to farmers' inability to farm
Large farm fields	Smaller farm fields	Even smaller farm fields

(d) Climate change predictions

After the discussion on weather vs climate change, participants were equipped with the basic understanding of climatic change and predictions, thereafter, participants were divided into two groups to create maps of current rainfall and temperature patterns. This exercise is designed to give farmers a possible idea of how climate change will effect temperatures and rainfall patterns.

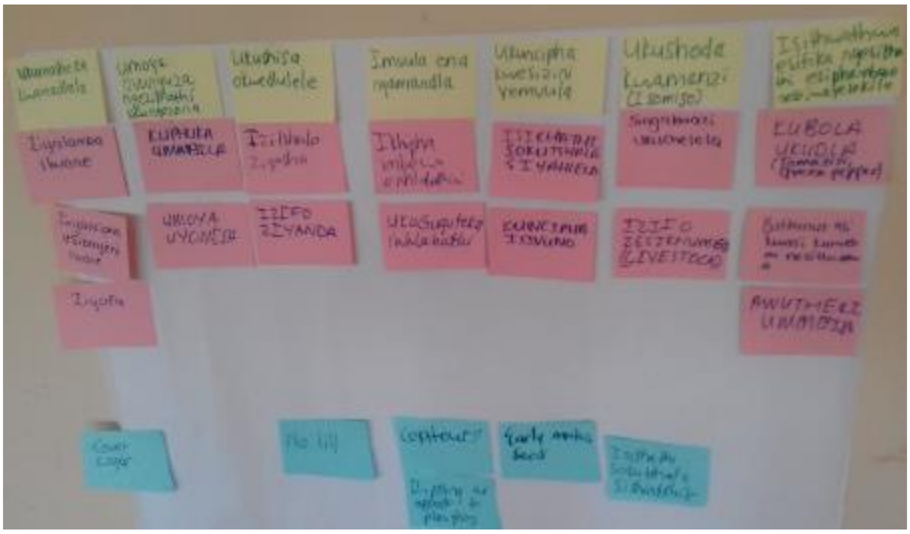
Above left and right: One of the participants explaining rainfall patterns in Madzikane and a small group of participants creating their rainfall and temperature charts

Table 4: The following temperature and rainfall predictions were recorded by participants:

Month	Rainfall pattern	Temperature	Farming practices
January	Low rainfall	Very hot	Vegetables dried out due to droughts
February	Low rainfall	Hot	Beans
March	A partially rainy time of the year but this has increased over the years, leading to spoilt maize before harvesting	Hot	A lot of rain during this month affects maize growth. But it's a good time to plant imfino and cabbage
April	Partial rainfall	Warm, not too hot	Raddish
May	No rain	Cold	Too cold to plant
June	No rain		Too cold to plant
July	No rain	Very cold	Too cold to plant
August	Some rain but relatively low	Very cold and windy	Plant potatoes till December
September	Rainfall gradually increases during this time but still relatively low	Cold and some cases of frosting	Some vegetable plants grown during this time get frost bitten
October	Rainy time of the year	Hot	Potatoes
November	Rainfall increases during this month of this time of the year	Hot	Maize & potatoes
December	High rainfall	Very hot	Maize & potatoes

(e) Reality Maps

This part of the workshop was designed for participants to discuss and create mind maps of social, environmental and economic impacts climate change will have on farmers' livelihoods and farming. The participants discussed and drew up reality impact maps on how the above mentioned issues and problems impact their farming as well as their livelihoods.



Right: Reality Map created by participants

Table 5: Points mentioned on the reality impact map by participants

Economic/Environmental/Social problem	Economic/Environmental/Social Impact	Solutions or adaptations
Degrading veld	- Less fertile veld areas for livestock grazing, - Starvation and dying of livestock - Forced selling of livestock - Increase need to supply feed to livestock	Cover crops

Strong winds, at inappropriate times (no longer in July)	- Breaking of maize stalks - Increased evaporation that leads to drying soils	No adaptation/solution identified
Very hot temperatures	- Dried up vegetable plants - Increase in diseases - Livestock skin diseases	No-till
Heavy rain at inappropriate times	- Increased soil erosion - Seeds get washed away - Less yields - Stunted plants and fungus growth on crops and poor crop growth	Contours, Ripping as opposed to ploughing
Less rain during the planting season	- Changing of planting seasons - Less yields - Stunted	Changing of planting dates
Drought	- Can't irrigate fields and livestock suffers from skin diseases	Drip kits
Untimely frosting	-Frost bitten tomatoes and green peppers, butternut and -Maize does not germinate in this condition	No adaptation/solution mentioned
Livestock invasion into farmers to graze	- Livestock invasion into farming fields grazing on mulch, vegetables and crops	- Fencing farm fields and gardens - Regulation of livestock grazing
Scarcity of water	- No water to irrigate home vegetable gardens	- Installation of jojo tanks

(f) Household visits

Household visits are undertaken to assess the present situation, undertake the baseline interviews and look at local adaptations in the farming system

Right and Far right: Mam' Thengani Shozi explaining to farmers what was planted in her garden and Her garden (100m2) where she had previously planted different vegetables and potatoes.

The team visited Mama Thengani Shozi a 46-year-old farmer from Madzikane to see her vegetable garden (100m^2) and field (0.2 ha), discuss current practices and challenges in relation to climate change. She had previously planted all kinds of vegetables in her garden including carrots, spinach, cabbages, beetroot etc. planting them as seedlings. She produced her own seedlings. Currently, no

vegetables have been planted due to lack of access to water to irrigate her plants, she has to walk a very long distance to fetch water from the river. Her garden is divided into two sections, (1) vegetable section planted in raised soil beds, (2) potatoes section planted in rows with fertilizer to speed up plant growth. According Mam' Shozi, she no longer uses fertilizer because she buys seedlings from 'Sutherlands Nursery' in Ixopo produced with a slow release fertilizer.
The farmers had established a co-operative in order to open up a nursery within Madzikane community to assist local farmers to access seedlings close within the community instead of travel to the Sutherlands Nursery which is very far from eMadzikane.

Right and far right: Participants taking part in the household visit

During the discussion, other participants shared that they prefer to use kraal manure instead of using fertilizers through a process of digging holes, placing seedling(s) then applying micro doses of kraal manure. Once the crop or plant begins to show signs of vigorous growth, she adds liquid manure around the plant.

Practices farmers have experimented with in their vegetable gardens:

- Liquid manure (made from Chicken and cow dung)
- Compost making
- Trench beds preparation
- Seedling production and transplantation

Baba Xaba, one of the learning group participants, shared he prefers to use fertilizers, because fertilizer helps the crops to grow faster and grow bigger since he plants with the purpose of selling his produce. He also experimented with trench beds in his garden which improved soil fertility and harvest. But, due to lack of access to water to irrigate and low rainfall in the community he did not manage to continue planting vegetables. There was a project that was willing to assist them with the construction of tunnels and irrigation systems but all that was not successful due to changing of management in that programme but they still willing to start. The elderly farmers revealed that while they love farming, especially vegetable gardening they don't have enough energy to attend to farming like they used to. But they are also still willing to do something that requires less labour, to which Mazwi advised that tower gardens would be a suitable practice for them, as it is not labour intensive and uses grey water for irrigation.

(g) Introduction of practices

This segment of the workshop introduced practices the farmers could try out immediately or in the near future to solve some of the current issues discussed and to discuss the current adaptation measures they are practicing to solve these challenges. Some of the participants who are participating in the Conservation Agriculture programme were familiar with mulching, no-till and intercropping practices. So, before introducing CSA practices to the farmers it was important to explain that most of the practices can be implemented using materials at home and low external inputs such as, construction of trench beds, ridges and furrows, no-till, mulching and tower gardens etc.

Above left & right: Mazwi Dlamini introducing and explaining the water, soil and crop management CSA practices to participants.

The practices are categorized in four different groups; water management, soil management, crop management, livestock, and natural resources. The following practices were explained to participants:

Water management

- Run-off and contours
- Diversion ditches
- Bucket Drip kits
- Mulching
- Rain water harvesting storage (including jojo tanks)
- Tower garden
- Tied ridges

Soil management

- Ridges and farrows
- Contours
- Cut off drains/swales

Crop management

- Trench beds
- Mulching
- CA (No-till)
- Tunnels
- Inter cropping & crop rotation

(h) Way Forward

Criteria used to select practices

Participants selected a list of criteria to assist them to evaluate and select the practices they would like to adopt. These criteria are used to guide participants on which practices will be best suited for their locality and socio-economic conditions. There are 'standard' criteria used to select CSA practices such as, water availability, soil fertility, cost and labour but participants also thought that fencing and motivation are important criteria they consider when selecting practices:

a) **Water availability:** The water use requirement for each practice
b) **Soil fertility:** The contribution of each practice to soil fertility
c) **Cost:** The affordability of the tools required to construct structures and/or sustain practices
d) **Fencing:** This relates to whether the practice/structure is secure, does not need fencing to protect it from livestock invasion.
e) **Labour:** This relates to the labour intensity and time required to construct structures and sustain practice(s).
f) **Motivation:** This relates to the willingness to commit time and energy to upkeep the practice

<u>Practices to be introduced:</u>

These criteria are used to complete a matrix table that would assist the participants to select prioritized practices. In their respective groups, participants selected 5 possible CSA practices to be introduced. The scale (0,1,2) is used to determine the most suitable practices decided by all participants and to evaluate the different practices to be introduced.

Right and Far right: Tema and Zanani assisting farmers with completing the matrix table

Group One:

Scale: 0-low/easy/cheap**;** 1-medium/average**;** 2-difficult/high/expensive

Table 6: Group 1 Matrix Table (Madzikane)

Adaptations	Labour	Cost	Soil fertility	Water avail	Fencing	Motivation	TOTAL
Tunnels	1	1	1	2	2	2	9
Tank	2	0	0	2	2	2	8
Tower Garden	2	2	2	1	1	2	10
Mulching	2	2	2	2	0	1	9
Drip kits	1	2	1	2	2	2	10

Group Two:

Scale: 0-low/easy/cheap; 1-medium/average**;** 2-difficult/high/expensive

Table 7: Group 2 Matrix Table (Madzikane)

Adaptations	Cost	Soil fertility	Water avail	Fencing	Motivation	Labour	TOTAL
Drip kits	1	1	2	0	2	1	7
Terraces	1	1	2	0	1	0	5
Ridges and furrows	2	2	2	0	2	1	9
Tunnel	1	1	2	0	2	1	7
Tower Garden	1	2	2	0	2	1	8

The next workshop was planned for January 2019, to finalise prioritization of practices and start on the experimentation cycle.

2.2 CCA Workshop 2 and 3 – Swayimane_SKZN

Written by Temakholo Mathebula and Khethiwe Mthethwa

These workshops focused on planning and prioritization of practices and the first round of experimentation and implementation of prioritized practices in Gobizembe (Swayimane).
Practices initially prioritized in the 1st workshop are listed below for continuity sake:

1. Mix cropping
2. Drip kits
3. CA
4. Trenches
5. Cover crops
6. Tower gardens
7. Tunnels

2.2.1 SWAYIMANE-GOBIZEMBE WRC WORKSHOP 2: PLANNING AND PRIORITIZATION OF PRACTICES AND WORKSHOP 3: EXPIRIMENTATION

(a) Introduction

This report is based on the WRC workshop 2- Planning and prioritisation of practices which took place on the 07th of November 2018 and workshop 3: Experimentation, which took place on the 15th of November 2018 in Swayimane-Gobizembe. Workshop 2 focused on a review of the previous workshop discussions, Climate Smart Agriculture as a concept, SCA practices and practices that farmers selected on the previous workshop, pest and disease control, practices video, five categories of practices, group prioritization and the individual prioritisation. Workshop 3 was a practical demonstration workshop to further introduce some of the practices chosen by farmers. The tower gardening and eco-circle implementation process will be discussed and lastly a short section is included for the progress of tunnel trench bed preparation.

2.2.2 SECTION 1: WORKSHOP 2: PLANNING AND PRIORITISATION OF PRACTICES

(a) Review of the previous workshop discussions

In this session farmers briefly reviewed their understanding of climate change, including that farmers seeing changes in the climate. It was said that these changes are due to harmful gases produced by industries which affect the ozone layer.

The impact of climate change that has been noticed is that the soil is now much drier. Crops are not growing so well and yields have decreased. Previously people were harvesting and they could even have a surplus to share with neighbours. There is a decrease in soil fertility and increased outbreaks of pests such as mosquitos, aphids, snails, cutworms. Farmers were informed that ladybirds are insects that cause no harm to the crops. Farmers have noticed that the change in climate leads to change in planting dates.

Adaptive measures that farmers are considering are raised beds, more reliance on compost than fertilisers, making of contours and pest and disease control such as the use of ash. It was mentioned that one of the challenges with using ash is that it is scarce because farmers do not use fires anymore. Chillies mixed with paraffin is also use to control pests and diseases. Also, farmers plant onions in between other crops to control pests and diseases.
Mama Xasibe shared that she mixes cow manure with soil, she opens tram lines, makes swales and contours and she also plants marigold flowers around the beds to control pests.

Furthermore, farmers discussed that there is a need to look at how we can change the way people do things. Farmers rely more on GMO food. The passion for farming is decreasing and youth involvement in agriculture is less.

Above: Temakholo facilitating the introductory discussion with the small group of farmers from Swayimane.

(b) Climate Smart Agriculture as a concept

Temakholo the facilitator explained Climate Smart Agriculture as a concept. The three principles of Climate Smart Agriculture were explained to be the following:

1. Increase yields

2. Sustainability and Increased adaptation and resilience.
3. Decrease greenhouse gas emissions. (industrial effect, fertilisers, carbon monoxide from cars etc)

It was further explained that we are trying to integrate different practices because we believe one solution cannot solve everything.

(c) CSA Practices

Practices that farmers selected on the previous workshop

Farmers mentioned that on the previous meeting they said they would like to try out a tower gardens, trench beds, tunnels and drip kits. The new idea that came up on the day was planting on a cylindrical fence, and about two farmers were interested to try it out. Farmers also asked how to plant or grow cucumber it was then suggested that cucumber should be included on the seeds list to be purchased.

Pest and disease control

Pests and diseases are one of the challenges farmers are facing and they would like to try more options to control pests and diseases. A few methods that were suggested included using Amaranthus, (1 mug Boxer(ugwayi)+ 4L water +plus grated green bar soup), Worm wood leaves (mix with water and sunlight soap), liquid manure and planting garlic chives (*ishaladi lezinyoka).* It was further explained that artificial chemicals are not the same as homemade remedies that are more environmentally friendly – but may not be as fast acting.

Practices video

A composting and Manure Utilization to Promote Organic Growing: Natural Methods for Improving Soil Health and Fertility training DVD (Produced by MDf and KZNDARD in 2011), was used to explain practices instead of presenting the practices using a PowerPoint presentation. It was observed that farmers learn better using graphics and visual aids. Farmers were able to recognise all the practices of their interest after playing the video. The video is very clear, it is communicated in IsiZulu and it kept the farmers well concentrated and well-motivated.

Five categories of practices

It was emphasised to farmers that the practices are categorised into five categories, and this is done to allow farmers to try out a wide range of practices without being tempted to only focus on the gardening practices. It was observed that farmers are not paying much attention in trying out livestock practices. It is assumed that farmers have good vegetation, their livestock is not struggling with feed that is why they were not mentioning livestock in their options. It is suggested that in the next season we can see how livestock integration will be incorporated in this village.

Below is a small table outlining the practices prioritized by this farmer group

Table 8:CSA practices prioritized by the Swayimane farmers group, according to the 5 resource management categories

Practices	Water	Soil	Crops	livestock	Natural resources
1.Tower garden	✓	✓	✓		✓
2.Trench bed	✓	✓	✓		✓
3.New idea- Worm farming		✓	✓		✓

4.Drip kit	✓		✓		
5.Pest and disease control					
6. Manure	✓	✓			
7.Mixed Cropping	✓	✓	✓	✓	

(d) Group Prioritization

Below is the final list of practices prioritized by the group

1. Tower Garden
2. Tunnel
3. Trenched bed/shallow trench
4. Drip bucket
5. Mixed Cropping
6. Manure
7. Pest and disease
8. Cylinder fence garden
9. Worm Farming
10. Mushroom production
11. Eco circle

(e) Individual Prioritisation

75% of farmers want to try out the tower gardens and 86% want to try the eco circle. The tunnel appeared as a second priority in the group prioritisation. Regarding the tunnel, it was emphasised to farmers that for a tunnel to be installed three trenches must be dug and at least one trench outside the tunnel for making comparisons and that only one tunnel could be installed as an initial demonstration. Farmers requested that the bucket drip kits go to those where the tunnel has not been installed and this was agreed to.

All farmers were happy about the tunnel being installed in Mama Ngobese's garden and also farmers availed themselves to assist her with digging the trenches. Mama Lindiwe Zondi volunteered to do trench beds with no expectation of getting a tunnel and she also wants to try the shallow trench beds (30 cm). All the participants with a trench bed will have a bucket- drip. The mixed cropping, manure and disease control will be standard for all the participants- All participants will try out these practices. The cylindrical fenced garden, worm farming and mushrooms were other new proposed practices. The table below shows the list of practices chosen and the names of the participants.

Table 9: Individual practices as chosen by Swayimane farmer

	Lindiwe Zondi	Thandazile Mathonsi	Constance Mcanyana	Mthephi Chonco	Ritha Ngobese	Khanyisile Xasibe	Busisiwe Khoza
1.Tower Garden		✓	✓			✓	✓
2.Tunnel					✓		
3.Trenched	✓				✓		
4. shallow trench	✓						
5.Drip bucket	✓				✓		
6. Mixed Cropping	✓	✓	✓	✓	✓	✓	✓

7. Manure	✓	✓	✓	✓	✓	✓	✓
8. Pest and disease	✓	✓	✓	✓	✓	✓	✓
9. Eco circle	✓	✓	✓		✓	✓	✓
Other proposed practices							
10. Cylinder fence garden			✓				✓
11. Worm Farming					✓		
12. Mushroom production		✓					
Total	**7**	**6**	**6**	**3**	**8**	**5**	**6**

(f) Plan for Experimentation (workshop 3)

The planning for the next workshop went well. The next workshop date was set to be on the 15th of November 2018. A tower garden and an eco-circle were the two practices that were identified to be carried out on the day of the experimentation. Mama Xasibe volunteered that by the 15th of November she will have all the material required in her homestead. Mama Rita Ngobese who volunteered to do the tunnel as well as other members in the learning group who committed to help her dig out trench beds for the tunnel said it will be too much labour required for them to prepare 4 trench beds ready by the 15th of November, however the farmers promised to start the digging of the trench as from the 8th of November (the next day).

2.2.3 SECTION 2: WORKSHOP 3: EXPERIMENTATION

This section contains the discussion about the demonstration of the tower garden and eco-circle which took place on Thursday the 15th of November 2018 at Mama Xasibe homestead garden as agreed on the previous workshop. All the farmers were ready at the venue of the demonstration at 09HOOam.

(a) Tower Garden and Eco-cycle

The farmer had a well fenced vegetable garden. She is using a hose pipe to water her garden. There was plenty of water available during the demonstration. The materials for experimentation were accessible also. The tower garden and the Eco circle were made 1.2 m away from each other.

Tower Garden

A diameter of one meter was measured between the poles of a tower garden. A sewed 3m by 1.5m shade net was fitted onto the poles very gently. A mixture of soil, manure and ash (growing medium) was used to fill the tower. A cylinder (made form a bottomless bucket) was used to fill up the gravel stones at the centre of the growing medium. Spinach was planted along the outside of the tower using a spacing of 15cm between crops. Additionally, 20cm spacing was used to plant Chinese cabbage. During the planning and the prioritisation meeting only four farmers were interested to carry out the tower garden, after the experimentation workshop almost all the farmers wanted to try out the tower garden.

Above Left to Right; Completed demonstrations of a tower garden and eco-circle. Filling the tower garden with the central column of stones and putting up the poles and shade-cloth tower.

Eco-circle

This is a small raised circular garden. A circle was marked on the ground by attaching a 50cm long string to draw a circular line on the ground. 30cm of top soil was removed separately and another 30 cm of sub soil was also put aside, this made up a total of 60cm deep trench which is likely to be a knee height. An empty 2L bottle was used to distribute water evenly by burning it with an electric driller to open holes, alternatively a wire/nail can be heat up to burn holes. The bottle is placed in the centre of the circle while the pit is being filled. It is filled with layers of sub soil, organic matter, cow manure, dry grass and top soil. Seedlings were then planted and the garden was mulched to retain soil moisture. The garden was made to be basin so that it can also collect and retain water from the rain. Lastly, stones were loosely packed around the garden to control soil erosion and for decoration purposes.

Right and Far-right: Digging out the eco-circle bed and the final bed with seedlings planted, mulching and the 2litre watering bottle in the centre

(b) Farmer led experimentation

A discussion was then held on farmer led experimentation where the objectives of project were explained. The main points emphasized were that research is a process of inquiry and often begins with a question or a problem that requires a solution. In the context of climate change, the objective is to come up with a decision support system that allows the farmer to explore a basket of practices based on certain criteria.

Practices were divided into five categories namely water, soil, crop, livestock and natural resources and criteria were developed to measure which of these categories do the practices fit into the most. Climate smart agriculture is about increased productivity, adaptation and mitigation. In light of those three, what changes have the farmers observed due to climate change? How can these be addressed? What informs those decisions?

The facilitator explained that whenever a new practice is introduced it must be measured against what is already being done in order to assess whether it brings about any change or not. An example was made comparing the tower garden to normal planting practices, whereby the farmer planted spinach on both at similar times. The farmer would therefore need to look at and record how often she irrigates on both, how much she irrigates, crop colour, quality and final yield. Another example that was made was about comparing shallow trenches and deep trenches against normal planting (on level/ flat ground) practice in terms of effect on crop growth, quality and final yield. Consistency is important when taking records as it allows us to not only keep track of the progress but to also identify trends. The agreement was that a monitoring template will be used for recording purposes.

2.3 **CCA workshop 4 and 5**

2.3.1 **Ntabamhlophe (Estcourt-KZN)**

Written by Samukelisiwe Mkhize and Khethiwe Mthethwa

(a) Introduction

On the 14th November three homesteads were visited to assess the experimentation of CSA garden practices implemented in two villages; De Klerk and Enkunzini. The purpose of the visit was to track progress of the practices being implemented, use of the five finger management practices, recording their experiences, and understanding including challenges and successes during the experimentation process in order to use the information to improve the process and ensure successful implementation of practices. The participants are part of the WRC Climate-smart agriculture programme in collaboration with LIMA-RDF and Mahlathini Development foundation.

(b) De Klerk (Learning site and participants case studies)

Mama Claudia Ntuli

Mama Nto Ntuli is a 56 year old, unemployed woman and household head with a family of 2 children. She is a member of the De Klerk learning group, her home garden is used by 8 female participants in the learning group as a collective learning site. The women work and learn together how to construct and manage the tunnel and tower gardens. Some of the women have tried to model the construction of the practices and structures implemented in the learning group, namely Sthembile Hadebe and Tholani Xulu used as case studies in this report. The women share the responsibility of monitoring plant growth, weeding and general maintenance of the practices including joint purchase of seedlings and other inputs required.

So far, they have contributed R20 each twice to buy 40 heads of cabbage, spinach, onions, green pepper and beetroot seedlings planted in the tunnel. 40 Harvested cabbages at R10 each were sold locally to neighbours, the money was used to buy more seedlings planted in the trench beds. Most of the other vegetable crops planted in the tunnel did not survive the very cold winter months, plants were frost bitten.


Above left: Tunnel (collective learning site) Above right: Tower garden in Mama Ntuli's home

The drippers attached to the drip system were 30 cm apart instead of 15 cm (recommended distance), which caused the drippers not to irrigate directly into the crops. Also, the drip pipes were located on the perimeter of the trench bed instead of being placed in between the crops. This led the farmers to believe that the system was ineffective and crops were not receiving enough water. They are now using 20l watering cans to irrigate the trench beds twice daily, working against the purpose of saving water by using less water. The farmers were asked to correct the spacing 15cm instead of the 20l watering cans and to check the distribution of the water below the surface of the soil, before deciding to abandon the practice.


Above left: Dry drip bucket (not being used) Above right: Keyhole garden constructed by the participants

Sthembile Hadebe

Right and far right: Mama Sthembile Hadebe and her fenced vegetable garden


She is one of the farmers in the De Klerk community learning group. Her 10m*8m garden is still under construction, she has started fencing the garden to prevent livestock from feeding on her crops. She has also started implementing practices learnt with the learning group, two trench beds, mixed cropping cabbages and brinjal with mulch on one bed and mono- cropped carrots with mulch on the second bed. Mama Hadebe stated she is very happy with the practices, the intercropping on the first bed has helped to control the pest and diseases affecting growing crops. While, the mulch in the second bed has vastly increased the carrot yields harvested. Before experimenting with the trench beds and mulching the carrots were stunted, fewer and smaller in size. She testified that, 'I have never harvested so many carrots before'. A third bed is still under construction, after seeing the growth potential of her vegetables and greater yields grown in the other two trenches she has decided to dig a 60cm deep hole where she plans on planting more vegetables. Each trench bed is irrigated once a day using 20l bucket of water, she has observed that sometimes the 20l is not enough because of high temperature in the summer months, low rainfall in the winter months the soil gets dry. She has a community tap that is close to her homestead but water does not always come out so she does not get enough water to irrigate sufficiently.

Right: Trench beds) intercropped and Far right: Marigold seedling production

She tried to construct a tower garden but it collapsed because the poles used were too thin to hold up the structure. She had no-one to help her to gather poles big enough to hold the structure together and the sacks were too big, but she still plans on trying to build a new tower garden with help. She believes that with her childrens' help and the proper materials (measurement of poles & sacks) she can rebuild it because she received good training during the workshops and learnt with the learning how to build one properly.

Tholani Xulu

Right: Mama Tholani Xulu in her garden Far right: intercrop of onions and spinach

She is 67 years old, unemployed and living with four grandchildren of whom one receives child grant. She is an active member of the De Klerk community learning group. Besides the social grant payments (child and old age grant), she relies on her farming activities to provide for food for her family; 15 indigenous chickens, 2 goats, peach trees, a 7m*5m garden size where she mixes crops such as onions, spinach, potatoes, parsley and tomatoes. So far, she is only experimenting with trench beds, after witnessing the vigorous growth of the cabbages planted in the tunnel (collective learning site). Her vegetables are growing well on the beds, her biggest problem is cutworms. She has tried to use salt to reduce the number of cutworms and number of the pests in the garden.

She wants to start experimenting with keyhole gardening because she has limited space and to see how it will improve her crop growth in the dry and hot months. Time and materials are the factors that hinder the famer from implementing all the practice she has learnt. She explained that while she wants to start keyhole gardening, she has to travel far to carry large river stones. Also, livestock trampling is a problem. People in the community do not manage their livestock, cows and goats enter into her field and garden when she is not around. During the trainings she also learnt about mulching and compost making and she has started sharing the knowledge with other farmers in the community. She also shares her harvest with her neighbours, recently she harvested 10 cabbages, and shared some of the harvest (2 cabbages) with her neighbour and the rest were eaten with her four grandchildren. She eats one cabbage per week with family. She cooks it once a week as a stew and make salads occasionally with any left overs. The farmer waters her garden once a day because, her water tap does not provide water throughout the day.

Above left: Ma Xulu's garden crops and each tree. Above right: yellow colour on carrot leaves (nutrient deficient-not planted on trench bed).

Enkunzini
Zanele Ngobese

Right: Mama Zanele Ngobese
Far right: Intercropped Lettuce and cabbages

She is a 48 years old housewife and passionate farmer living with her husband and three children. Her husband, a police officer, is very supportive of her farming activities. He assists her with purchasing almost all the materials and inputs she needs for her garden. The dedicated farmer attended CSA workshops, she gained knowledge and skills and she was able to implement the knowledge she has obtained to construct her trench beds and she switched from mono cropping to intercropping on all her beds.

She is also one of the farmers who has a tunnel experiment in her garden used as a learning site for other participants in the Enkunzini community. But she has the sole responsibility of maintaining the structure, monitoring plant growth, practices and watering with a bucket drip. She frequently thins her vegetable leaves and uses the residue as compost. She has not been using the drip system to irrigate her plants, she explained that the buckets often topple over due to heavy winds and do not water the crops sufficiently. Instead she uses a hose pipe to water her plants daily. This seems to be a misguided belief amongst participants that drip kits do not provide plants with enough water, which leads them to opt to over watering their beds with hose pipes and buckets. The soil was slippery and very wet, indicating that too much water was being used on a daily basis instead of saving water through the use of drip irrigation. She was advised to secure the buckets with stones, start using the bucket system and observe the growth of her crops.

Table 10: Tunnel data (crop rotation) in Enkunzinin (Ntabamhlophe):

Bed no	1st round	2nd round	3rd Round
Trench bed 1	Cauliflower, spinach, lettuce, green pepper, cabbage.	Lettuce, beetroot, cauliflower, broccoli.	Chillies, broccoli, cauliflower, carrot, onions.
Trench bed 2	Beetroot, cabbage, pepper	Spinach, red cabbage, cauliflower, carrot, onions, Lettuce	Spinach, green pepper and beetroot.
Trench bed 3	Spinach, cabbage, green pepper, parsley herbs.	Spinach, cabbage, red cabbage, Lettuce.	Cabbage, cauliflower, spinach, green pepper, beetroot.

The tunnel has three trench beds, it has been harvested and replanted three times. The table above shows what has been planted in the first second and third rounds.

The plot had a lot of weeds because has been attending church events regularly so she couldn’t weed the tunnel garden but her vegetables and herbs showed vigorous growth. She was advised to add some mulch to her beds to manage the weeds growing in her garden. The farmer has increased the quality and quantity of her yields since she started growing her crops in the tunnel. She has observed that she is harvesting more in her garden now, the tunnel protects the crops from harsh weather conditions and birds which used to affect her crops growth before harvesting. Also, livestock trampling is a problem in her community, neighbours do not manage their livestock but the crops planted in the tunnel are now protected from livestock. She is able to sell surplus produce and give some fresh vegetables away to sick and poor neighbours. Spinach is sold at R10 per bunch and cabbages R10 each. Peppers are value added by canning. Intercropping with pepper has helped to reduce the presence of pests and diseases on crops. Beetroot and cabbages were infested by aphids and she used blue death to deal with the problem.

She has another 8m by 8m organic garden covered with a black shade net. The shaded garden has four small beds with mixed crops of onions, cabbage, green pepper, beetroot, spinach, and pepper. She uses a 25L bucket for irrigating in the morning and in the afternoon. Temperatures are very high during the day, plants are wilting if not thoroughly irrigated. She also has an 8m*8m tilled field plot where she wants to plant spinach. Last year she planted potatoes, beans and maize (crop rotating). She has expressed an interest in Conservation Agriculture (no-till) farming because she wants to reduce erosion in her field. A one meter diameter area has been demarcated for the Eco circle to be constructed.

(c) Conservation Agriculture Demonstration in Ntabamhlophe

On the 12th December 2018 a group of 23 farmers (4 male & 19 female) from three villages eNkunzini, Emdwebu and De Klerk in Ntabamhlophe joined Samukelisiwe Mkhize and Khethiwe for a small introductory meeting and Conservation Agriculture demonstration planting. Some of the farmers came to the Stulwane MDF-SFIP farmers CA awareness day. The farmers were given the opportunity to listen to the testimonies of 4th and 5th year Bergville CA participants who have been part of the programme from the beginning and demonstration of the MBLI, Haraka, 2 row, animal drawn and tractor drawn planters. The participants were eager to test out the MBLI planters and planting under the three CA principles. We were expecting to plant 1*(400msq) + 4/5 * (100msq) trials with a maximum of 10 farmers instead 23 farmers from the three villages showed up on the day, all ready to learn about CA and start demo planting with their hand hoes. The farmers who went to the Stulwane Awareness Day spread the word to other farmers in the villages, that Mahlathini Development Foundation would come to start CA farming in Ntabamhlophe and it was a great opportunity to learn how to practise sustainable agricultural practices in their fields

One demo plot (200msq of a maize and bean intercrop) was planted after a brief introduction into CA, its relevance and importance. The farmers were each provided with 2kg MAP fertilizer, 0.5 kg maize and beans seed and 2 bags of lime per village to share. The farmers were encouraged to work together and assist each other through the planting process in their homesteads. A week later, all the farmers had planted (some used the MBLI planter, other farmers opted to use their hand-hoes) their 100msq plots and looking forward to seeing the results. The team will be visiting the farmers periodically to monitor the progress.

Right and far right: Farmers digging basins and furrows planting maize and beans

Right and Far right: Farmers helping each other to calibrate the MBLI planter.

2.3.2 **Alice/King Williams Town- EC**

Written by Mazwi Dlamini and Khethiwe Mthethwa

The site visits to the Eastern Cape were held from the 4th to the 6th of December 2018. The main aim of the visits was to monitor, review and re-plan the CSA Practices that were implemented in the beginning of August. The CSA practices implemented were: a shade cloth tunnel with two trench beds, a trench bed without a tunnel, a bucket drip irrigation system, and the installation of 3 chameleons in Berlin, as well as a tower garden and eco-circle in Eqhuzini and short furrow irrigation and CA in Mxumbhu. The second objective of the visit was to facilitate the implementation of other CSA practices identified and prioritised by the EC farmers during the previous workshop. It came to our attention that farmers had already copied some of the practices they were interested in trying out individually. Monitoring of the adopted practices was also conducted. The WRC CSA team members present were Khethiwe, Mazwi and Lawrence.

(a) Day 1| Berlin and Quzuni|04/12/2018

<u>Berlin: Monitoring, reviewing and planning of CSA Practices</u>

The purpose of the activity here was to monitor, review and plan for the next season. The table below compares spinach being grown under three different regimes: An intercropped trench bed inside the tunnel; a trench bed outside the tunnel; and the bucket drip irrigation system. The monitoring was focused on the yields obtained, looking at the number of times in which harvesting took place, the spinach stalk size and the spinach leaf colour. It further looks at the insects, disease, soil moisture and water use. All the crops were planted on the 3rd of August 2018.

This experiment was managed and monitored by an Agriculture student from Fort Hare University. He was unable to provide the focus required and thus the results here are a little confusing.

The results show that the yields in terms of bunches harvested has not been too different. All practices have been harvested five times. The difference comes with the quality of spinach being produced. The results show that the spinach grown in the tunnel has thin and longer stalks while the spinach grown on the trench bed outside the tunnel and the on the drip irrigation system is bigger. The colour of the spinach in the tunnel is pale green while the colour of the spinach on the on the trench bed outside the tunnel and the on the drip irrigation system is darker green in colour. The pale green symbolises lack of chlorophyll due to reduced fertility and or sunlight. In the tunnel there has apparently been fewer pest and disease problems, which may be due to the shade cloth preventing insects from reaching the plants, and perhaps also due to some extent to the intercropping that was only done in the tunnel. The farmers observed that intercropping has a very positive impact in reducing the amount of pests and diseases. Regarding soil moisture: there is more retention of soil moisture in the tunnel because the net provides shade. There is less soil moisture retained in the trench bed outside the tunnel indicated by the spinach leaves wilting during high temperatures. There is more soil moisture retained on the bed where there is a bucket drip since the drops are constantly supplied to the soil. In terms of water use, it has been very inconsistent for all the practices, a hosepipe is used for irrigation therefore it is not easy to determine the amount of water used. Irrigation takes place roughly three times a week. Farmers were encouraged to make use of a watering can with a known volume in order to keep track of the amount of water use. The Drip kit was recognised to have less labour as far as irrigation is concerned, while watering using cans takes a lot of time and energy.

Table 11:Compare experiment in the tunnel, outside the tunnel and bucket drip system

Practice	Crops grown	Harvest times	Stalk size	Leaf colour	Insects	Diseases	Soil moisture
Tunnel, Trench bed (5mx1m and 2mx1m)	Spinach, onions, tomatoes	*Harvested five times	spinach stalks are thin and longer	Pale green	**Fewer**	**Fewer**	The net provides shade therefore soil moisture is retained
Trench bed outside the tunnel	Spinach only	*Harvested five times	Spinach stalks are bigger	Darker green	More	More	Spinach wilts during high temperature, therefore less moisture retained
Bucket Drip (trench bed outside the tunnel)	Spinach only	*Harvested five times	Spinach stalks are bigger.	Darker green	More	More	Water moisture is retained for a longer time since the drip is constantly supplying water

Figure 3: Shows spinach grown inside the tunnel and the spinach grown under drip irrigation system

Chameleons

There is a chameleon installed for each of the practices listed above. The data has been collected by Siyabonga Hafe, and intern at the Zingisa project in Berlin, from the University of Fort Hare. He explained how the chameleon operates. The chameleon is a tool used by farmers to help them make decisions on when to water, and the amount of water to be used for irrigation. The tool has a sensor which demonstrates three colours; green means there is still water in the soil, blue means there is water but the farmer should irrigate and red means the soil is too dry. The data presented by the sensors is automatically uploaded onto the Virtual Irrigation Academy (VIA) chameleon website. There has been a challenge with getting the data uploaded online, and this was apparently due to the type of cell phone Siya was using for monitoring the chameleons. At the day of the visit a different phone was being used and the data was uploaded on the system immediately. One of the farmers asked "…how can chameleons be applied in a big piece of land?" The response was that these practices are intended to provide options for farmers to make decisions regarding their crops, with different options being appropriate for different scales of farming. However, the chameleon can be used at larger scales, but more of them will be required. Some handouts on mixed cropping were left with the farmers, and the lead trainer with the Zingisa project was provided with an electronic version of the CSA practices document.

Figure 4:Siya explains the use of the chameleon to the farmers

Website

name: https://via.farm/myfarms/
User name: sselala
Password: dgen3090

Sensor:

User name starts withAndriod1< = > 87654321, password 123445678 When the reader is trying to change the user name to Andriod1

Below are the Chameleon print outs for the entire season for the three beds

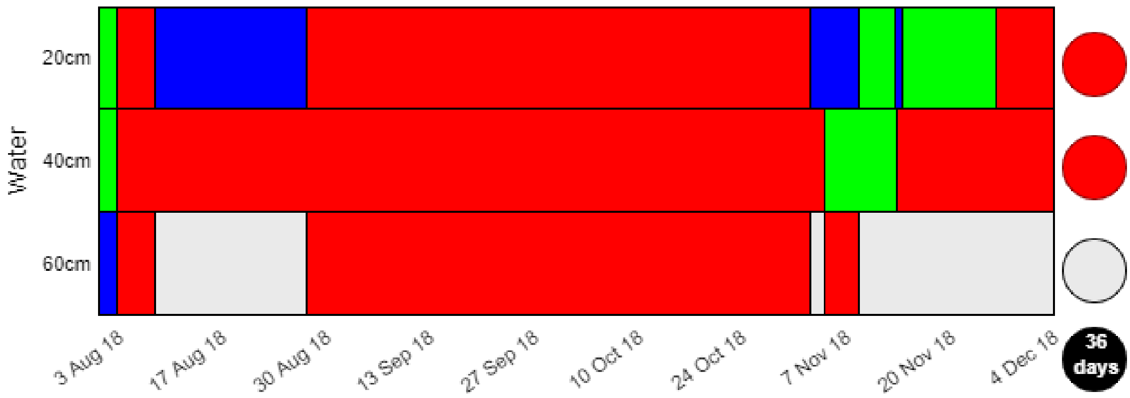


Figure 5: Chameleon readings for the trench bed inside the tunnel

From the above diagram, it is clear that the trench bed inside the tunnel was extremely dry for almost the entire season. Watering only provided some moisture in the shallower depths of the soil. As a consequence, the stress experienced by the crops planted is understandable- as is the reduced yield.

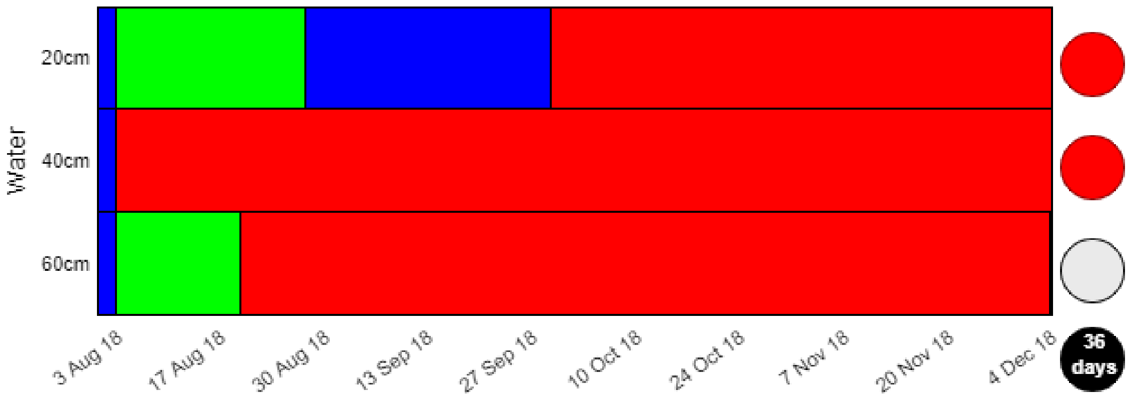


Figure 6:Chameleon readings for the trench bed outside the tunnel

For this trench bed the lack of water in the soil is even more obvious and underwatering was done throughout the season.

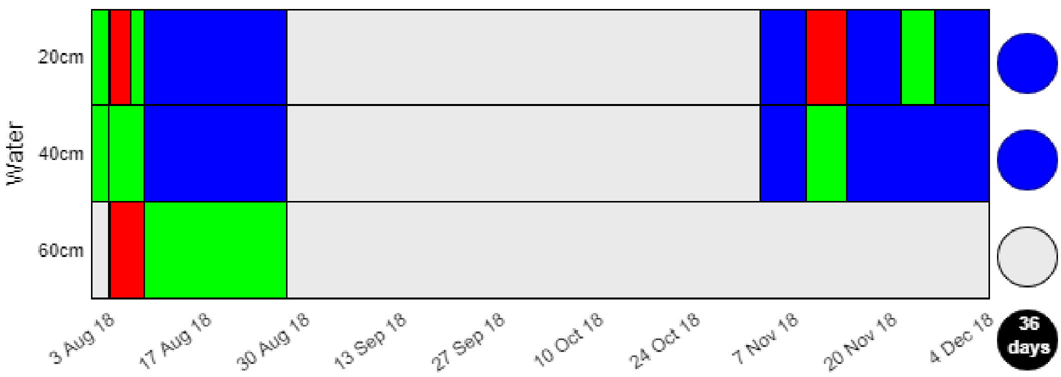


Figure 7: Chameleon readings for the trench bed with the bucket drip irrigation system

For this trench bed, the presence of the bucket drip system provided a means of ensuring regular and sufficient watering of the bed, although the complete lack of watering between September and November is still visible. The grey areas indicate extremely high water tension and thus very dry soil.

Suggestions and recommendations

MDF is to organise a Samsung phone that will be specifically used for the chameleons. This will play a huge role in preventing the challenges with hot spot settings that were experienced this season and will allow for better management of the mobile data. The tool was regarded as being very effective provided there is technical support to the user.

It was also decided that the manager of the centre, Eddie would take over the management of the experiment and the reading of the chameleons.

eQuzini- Eco-circle

This activity was carried out in the homestead garden of Mrs Phindiwe Msesiwe, who is a champion farmer in her village, who has already progressed well in developing a varied demonstration garden, including trench beds and a tower garden, constructed during the previous workshop with the CSA team. She has also constructed a small pond, fed by a diversion furrow. During this visit she was sharing information with her neighbours on all the various practices she is experimenting with, particularly the tower garden.

Right: Phindiwe explaining the tower garden to her neighbours

The focus of this visit was the construction of an eco-circle (or fertility pit, banana pit, infiltration pit, circular swale). This is a small raised circular garden. A circle was marked on the ground by attaching a 50cm long string to draw a circular line on the ground. 30cm of top soil was removed separately,

Above left and right: Shows a complete eco-circle as well as the eQuzini farmers

the soil was too shallow and dry that it couldn’t be dug any deeper than 40cm instead of 60cm. An empty 2L bottle was heated up to burn holes to distribute water evenly in the ground. The bottle was placed in the centre of the circle on the bottom of the pit. The pit was then refilled with layers of subsoil, organic matter, cow manure, dry grass and topsoil. Seedlings were then planted and the garden was mulched to retain soil moisture. The garden was made to be basin like so that it can also collect and retain water from the rain. The stones and excesse soil were loosely packed around the garden to control soil erosion since the site was on a gentle slope and also a small diversion furrow was designed and made to channel rain water runoff to the eco-cycle. Handouts on fertility pits and diversion furrows were left with the farmers. Mrs Msesiwe was asked to take photos of the pit every 2 weeks and send them via WhatsApp to the CSA team.

(b) Day 2|Umxumbu|05/12/2018

(i) Mxumbu: Monitoring of CSA Practices and CA demonstration

The plan of the day was to conduct a CA demonstration in Mxumbu location with the Mxumbu Youth Group farmers. It was a great to hear from the farmers that they have implemented some of the practices that were discussed and demonstrated during the previous workshop. It is motivating to see that farmers are putting the knowledge they have gained into practice. Furthermore, the farmers explained that they had travelled to neighbouring communities to conduct workshops on some practices such as CA and tower gardens and also trained farmers from another area, Macubeni near Lady Frere, who are involved in a GEF funded Sustainable Land Management project, supported by the Department of Environmental Science (DES) at Rhodes University.

Table 12: Practices being implemented in Mxumbu

Practice	Picture
***Trench bed Intercropping and mulching** A trench bed of 1m deep. An intercropping of spinach, beans, carrot and potatoes had been done. The idea was to intercrop root crops with leaf crops. Some of the heavy mulch which had been applied had been removed, following advice from a CSA team member, as it was suppressing the growth of the carrot seedlings.	 **Mixed cropping**

***Raised beds** **Round -** This is a round bed supported by 2l empty 2l bottles to give it shape and to control erosion. Unfortunately, the seedlings are dying because the farmers were attending a workshop at the critical time, and could not water them, and chickens are eating because there is no proper fencing. They are planning to collect sacks so that they can close the garden tightly, and make sure there is always someone available to irrigate the beds. **Rectangle** - It is 2. 5 by 1m, and is planted as a mixed cropping area. It was constructed from the leftover soil from the tower garden	 **Round raised bed**
***Tower garden** They used different layers of soil, manure, and mulch. The top layer is a mixture. They use all locally available materials to build the tower i.e. sticks from the bush, a large fertiliser sack, and normal stones (rather than gravel).	 **Tower garden**

***Furrow irrigation** After they had been taught about furrow irrigation they conducted their own experiment. The plot which is 22m by 12m was prepared with 14 furrows. Along the furrow ridges they planted black maize, pumpkin, water melon, Bambara nuts, sunflower, pearl millet, sorghum, and popcorn maize. They planed beans on the furrow slopes. They realised that it is difficult to get the bottom of the furrows level over a long distance, so, following advice, had halved the lengths. They are planning to add manure onto the furrows after harvesting. They like the open furrows because they depend much on rain water.	 **Furrow irrigation**
***Seed saving** The farmers had planted onions before the winter, then they attended a conference in Johannesburg where they learnt about keeping onion seeds. They came back home and make a decision not to harvest the onions so that they can produce and collect seeds. They had to stick to the decision even when customers want to buy the onions. They are planning instead to sell onion seeds so that others can grow their own crops.	 **Onions seed saving**
Planting of herbs On the first of November they made a raised bed where they planted different herbs. i.e. common mint, catmint, marigold, nasturtium, garlic, and white clover. The idea is to multiply these herbs and transplant them among crops throughout the garden to help control pests and diseases. They want to get more advice and do more research on which vegetables should be planted together. Handouts on mixed cropping was left with the farmers.	 **Herbs**

(ii) Enterprise and market

- **Spinach**

The farmers here view farming as a business and they are selling spinach and other vegetables to support their livelihoods. The spinach in the pictures show the crops grown in the tunnel and in trench beds with bucket drip irrigation. These were planted in the first week of October and participants have now sold more than 100 bunches, at R10 per bunch (27leaves).

Below Left to right: Showing the size of a bunch of spinach ,being sold to a neighbour



- **Cabbage**

The farmers are also selling cabbage, but the biggest challenge that they are facing with cabbage is pests and disease. Last year there were no pests on their produce because they sprayed with chemicals to control pests. This season no chemicals were used because they believe it is not good for human health, but this has led to considerable damage to the crop, although the use of an aloe/soap mix has helped to some extent. However, this was applied when the plants were already well grown, and the control was limited. The farmers have observed that while some people who understand the organic and agroecological approaches value cabbage that has symptoms of pests and diseases, such as holes in the leaves and some discoloration, because they can see it was produced organically. However, most others reject the produce infected by pest and disease because they think it is not good quality. Farmers think the cabbages are mostly affected by pests because it has been mono-cropped. It was suggested to farmers that they should also try crop rotation to break the lifecycle of pests and diseases. Rotten, surplus and residue cabbages is served as feed to a pig.


Above Left and Right; Feeding the pig with cabbage leaves, harvested form the plot

- **Poultry**

On the last visit farmers were producing broilers, but due to high cost of feed, the farmers have switched to a more free range system with layers; feeding the chickens crushed maize instead of poultry rations to reduce costs. However, the layers do not produce eggs every day in this system. They are thinking of selling the chicks from these fertilized eggs.

(iii) CA Demonstration

From the initial demonstration conducted in August, the farmers have conducted trainings to teach other groups about Conservation Agriculture (CA); they have also already planted a 9m by 18m plot of CA in their small garden. They have however already tilled the plot originally demarcated for the CA demo. A small 5m by 5m demonstration was set up in one of the household gardens, although no planting of seeds was done since the soil was too dry. The sowing process was explained in detail by a member of the CSA team, and the seeds and other materials were handed out to the farmers to conduct their experimentation after the rains arrive.

Above left and Right: the CA demonstration explained and demonstrated

(c) Day 3|Dimbaza|06/12/2018|

(i) Dimbaza- Infiltration pit and Diversion furrow

The site for this visit was the garden of Ms Aviwe Biko, another champion farmer experimenting with a range of CSA practices and sharing her experiences with other farmers who are managing land in the area. She has already constructed a range of differently shaped raised beds, trench beds and a tower garden, and was keen to install the infiltration pit.

The purpose of the site visit was to make an infiltration pit and a diversion furrow. An infiltration pit is another name for an eco-circle or fertility pit. The workshop started with an explanation of the WRC CSA project, and then the purposes of the pit and furrow were explained. The same procedure that was used to make an Eco-circle at EQuzini was followed (see EQuzini, above). The following section will give details on how the diversion furrow was made.

It was important that the furrow was positioned on a slight slope leading down to the infiltration pit. In order to make sure that the slope was reasonable, and heading in the right direction, a line level was constructed. However, the small spirit level, usually used to indicate the slope, was missing, so a level was improvised out of a 300mm water bottle, half filled with water, and marked on either side with a line indicting the line of the surface of the water when the line was level (horizontal). This kind of level is not as precise as a spirit level, and is probably not accurate enough to be able to calculate the angle of a slope with any degree of certainty, but it can indicate when the line is level (such as along a contour), or which direction the ground is sloping, and whether the slope is gentle or steep. It is therefore adequate for aligning diversion furrows. It is also something the farmers can easily make for themselves. This makeshift line level was then used to identify the best line for the diversion furrow to follow, to bring water into the infiltration pit, and the furrow was constructed by the farmers with the support of the CSA team.

After completion of the task, in very hot weather with the temperature reaching 36°C, a plan was agreed for a follow-up visit in 2019, and a range of handouts on infiltration pits, furrows, mixed cropping and other practices was left with the farmers. Ms Biko was asked to take photos of the infiltration pit every 2 weeks and send them through on WhatsApp to the CSA.

Above Left to Right; diversion furrow and infiltration pit implementation process

(d) Conclusion and suggestions

In conclusion, the field visit went well. Farmers are passionate and they are looking forward to take the CSA practices to a larger scale. It is suggested to facilitate localised workshops rather than choosing central places where people find it far to attend trainings and follow up meetings. Among local communities where workshops will be conducted, it will work best to form solid CSA groups to avoid always meeting new faces for every field visit taking place. As mentioned, farmers were encouraged to keep forwarding photographs of practices on WhatsApp every two weeks to CSA team members.

A field visit will be carried out next year in 2019 to monitor and implement more practices. One of the practices that was suggested as the first priority for the next visit was the roof top rain water harvesting practice which will be implemented at Dimbaza. This practice however needs capital investment and more research in terms of measurements in order to ensure accuracy. Lawrence (CSA team member) is familiar with the practice, it has been implemented in the Amanzi for food project, he will assist in facilitating the implementation of the practice. In the next visit we will also look at other practices from the livestock and natural resources categories of the five fingers.

2.3.3 **Eqeleni and Ezibomvini – Bergville- KZN**

Written by Samukelisiwe Mkhize

Workshops were conducted in two villages (CCA workshops 1-4), Eqeleni and Ezibomvini where local farmers were introduced to a range of CSA practices, including seedling production, eco-circles, trench

bed preparations, mulching, intercropping and natural pest and disease control practices. Farmers decided on their own which practices to experiment with from the above-mentioned practices, they have observed the performance of the practices and provided some evaluation on crop quality, water usage and saving qualities and management of the practices.
The farmers are able to self-assess the performance of these practices and make informed decisions on which practices they would prioritize over others based on their experiential learning experiences, and the performance of the practices. The graph and table below represent the most and least prioritized garden practices and the combination of practices implemented by participants in Eqeleni and Ezibomvini. Monitoring was conducted for 12 participants who implemented these practices after the workshops.

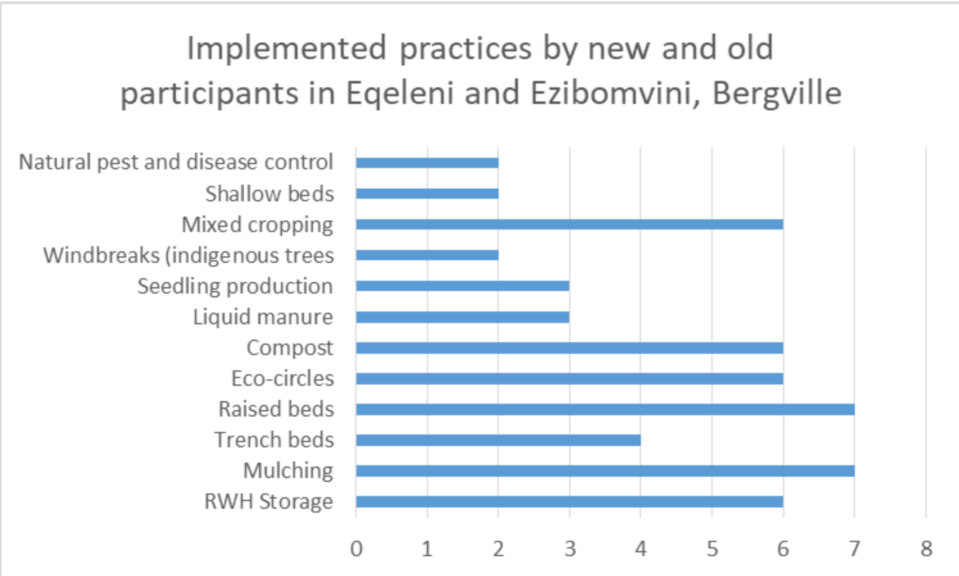


Figure 8: Implementation of CSA practices in gardening in the Bergville area- July-November 2018

The graph shows a high percentage of participants experimenting with raised beds, a local practice, as compared to trench beds. Farmers expressed that while they are aware of the differences in crop quality and yield using the different practices, digging deep trenches is too laborious for some of them to do alone. It was suggested to the participants that they should use the learning group as a resource to find other participants who want to construct trench beds and work together. There are a relatively high number of participants who have added mulch on their trench beds but some participants expressed that while mulching has increased soil moisture on their raised beds and reduced the need to irrigate too often, the practice requires regular maintenance and thatch attracts termites which eat the crops. The participants have also stressed the issue of pests and diseases that infect their green pepper, spinach and cabbages. Some of the have tried using insect repellents such as, Blue Death and Bulala Zonke with varying results. The participants are struggling with a host of pests, the most common being:

- Molerats
- Cutworms
- Birds
- Termites
- Diamond back moths (eats cabbages) and
- Snails

Right above: cabbage eaten by birds

Right below; green peppers showing insect feeding damage and subsequent bacterial infections

Participants requested assistance with appropriate natural remedies and also with identification of different pests and disease. Not a lot of emphasis is given to diseases in crops and participants are not familiar with the different diseases common in their crops

Table 13: Shows the combination of practices implemented by participants in Bergville

	Trench beds	Shallow beds	Raised beds	Mixed cropping	Windbreaks	Seedling production	Liquid manure	Eco-circle	RWH Storage	Tunnel	Pest and disease	Mulch
Phumelele Hlongwane	✓	✓	✓	✓	✓				✓	✓	✓	✓
Zodwa Zikode	✓	✓	✓							✓		
Nombono Zikode	✓			✓						✓		✓
Nonhlanhla Zikode	✓	✓	✓	✓		✓	✓					✓
Ntombakhe Zikode	✓		✓	✓			✓			✓	✓	
Sdudla Sibiya	✓					✓					✓	
Fikile Zikode			✓		✓							
Sizeni Dlamini	✓	✓					✓					✓
Nomalanga Khumalo			✓				✓				✓	
Thulile Zikode	✓		✓					✓	✓		✓	
Sibongile Zikode	✓	✓	✓	✓		✓		✓	✓			
Gcinekile Zikode			✓									

The farmers were provided with Chinese cabbage, mustard spinach, kale, rape, spring onions, and coriander, parsley and lavender seeds for seedling production to be later transplanted. This was a way of introducing a number of new crops to the farmers and for them to assess these crops in terms of growth and food value. During the monitoring process, we found that most of the farmers had not harvested their produce, not transplanted the seedlings, and received low yields. The farmers had mainly two issues, many of their vegetable gardens were poorly fenced or unfenced. Chickens had invaded the gardens and ate the seeds, or they did not have enough water to irrigate their gardens. These are common issues, but the underlying issue is that they are unfamiliar with are unfamiliar with the crops and especially the herbs (coriander, parsley and lavender).
Harvested crops were mainly Chinese cabbage, mustard spinach, kale and spring onions. The spring onions were mainly harvested because the farmers cooked it with '*isijabane*' (see picture below) a cultural maize meal and spinach dish made locally. Their choice of vegetable production crop varieties is mainly influenced by their ability to sell these locally and use them for household consumption.

A few participants are starting to use these herbs, adding them to stews and curries because they are aware of the benefits of these herbs; mainly companion planting to control pests and diseases. This presents an opportunity for these participants to share their experiences with new participants who do not know what to do with the herbs or unaware of the benefits. So far, there are a few incidents were farmers are learning or sharing experiences together about challenges they are facing, in terms of implementing the practices, especially amongst those with tunnels and those without. Participants with tunnels have created their own 'learning group' assisting each other with planting, irrigation techniques and harvesting, but those without tunnels often have no recourse to new information.

Above Left: Nonhlanhla Zikode (58yrs) from Ezibomvini has made raised beds and uses thatch grass for mulching. She removes the grass when she sees fungus starting to appear as she believes this affects her crops/ Middle: A mixed crop and mulched bed and Right: Seedling production

2.3.4 **Sedawa, Turkey- Mametja- Limpopo**

(a) Review and re-planning

Written by Erna Kruger and Betty Maimela

Date of workshop: 04 October 2018 (75 participants)

(i) Agenda: Peer review and planning for the CSA innovation development programme – (AgriSI) in the Lower Olifants.

This is a yearly event to review progress, tackle issues and broadly plan for the year going forward for the learning groups involved. It also involves showcasing present successful activities and community level discussion around issues and possible solutions.

TIME	Facilitator	Activity	Resources
9:00-9:30am	ERNA	Introduction; review of five fingers and general comments for this season -	PP: data projector, chords, screen
9:30-10:30	SYLVESTER, BETTY	Small groups to work on practices they are using under each of the five fingers and report back to plenary	Newsprint, kokis
10:30-11:00	ERNA	Compare this to the list of practices introduced in the trainings and add these to the lists	PP presentation
11:00-12:00	ERNA, SYLVESTER	Plenary for traffic lights, no of participants implementing and also comments on these practices (How much do they help)	
12:00-1:00pm	ERNA	Presentation on experimentation and measurements Discussion on herb growers and how that is going	PP presentation
1:00-1:45pm	SYLVESTER, BETTY	Small groups discuss experimentation and practices for the next 6 months (summer season) and make a list (with names of who will do those) and report briefly to plenary Including succession and continuity planning for herb and veg sales. Including new ideas… poultry…	Newsprint, Kokis
		Announcements: Mango production training 29-31 October 2018	
2:00-3:00pm	Christina,…	Visits to households	
3:00pm		LUNCH	

(ii) Report back from Ukuvuna cross visit

15 Participants from these groups attended a 3-day cross visit to the Ukuvuna learning sites in Sekhukhune. Report backs were made by Alex Magopa and Christina Thobejane.

They talked about:

- Tree propagation using cuttings: This method is used if you want a particular tree type and do not have seeds. It works for oranges, naartjies, peaches, grapes and roses. This is an in- situ method where growing medium is tied onto the desired small branch and it is left there for around 3 months until roots are formed, before the branch is cut away from the tree.
- Us of tobacco for pest control: A brew is made from the young leaves only as the older leaves are too strong.
- An easy way to plant and harvest potatoes: Digging a ditch and planting the potatoes in there and then filling this ditch as time goes along. It reduces the need for time consuming ridging activities.
- Youth are involved there, and it would be important to encourage our youth here also to do farming
- We can start having poultry, so that we can use the manure in the garden and for compost and liquid manure instead of having to buy manure

- Many different herbs were shown and are being grown; including yarrow (for stress relief), comfrey (for bones and liquid manure), parsley, coriander, wild mint (Mabele Mabutswa – for pest control), Wild Dagga and geranium
- A lot of different things were learnt as their gardens are full of different kinds of crops. However, we now have a market for our crops, which they do not.
- They build seed houses, that they insulate on the inside using old egg boxes and they place old sugar cane on top of the roof. A gutter is installed and the run-off collected. This sweet water is used as a kind of liquid manure on the gardens. This sugar water will provide for very sweet fruit from fruit trees.
- Mixed cropping; alternate rows of Lucerne and vegetables – this is for soil fertility and also saves water. Lucerne is very deep rooting and thus it can find water in the soil and does not need that much watering.
- Flowers can be planted for pest control in between vegetables; they also attract birds and bees, which are needed for pollinating crops.
- They also shared on the issue of livestock integration – feeding them from the garden and using their manure in the garden- like a cycle. This was a highlight for us.

This visit encouraged us to put more effort into our farming, even if we do not have much water. Some farmers there see farming as a full time job- they are busy in their gardens every day for the whole day. Mr Malatjie asked that these participants try out some of the ideas, so that our learning groups can also learn these techniques in that way and also that they share some of the seeds they were given.

One of the fruit seeds that they brought with, were strawberry seedlings which they bought from one of the farmers they visited who specialises in planting strawberries. Trona Morema, planted them inside her tunnel, where she made a shallow trench bed that she built using cement bricks. See the picture alongside.

(iii) Mango production household visits

A few participants in Lepelle and Sedawa were visited by Jeffery Tshishonga, a farm manager at Landman Group the commercial Mango estates (Bavaria), so that he could give them advice on mango tree management and also check on issues with deficiencies, pests and diseases. This information will also be useful in designing the upcoming Organic Mango Production training, organised through the Hoedspruit Hub for the (29-31 October 2018).

Report backs from the participants visited by Jeffry Tshisonga highlighted input on pruning – both water shoots, and excessive branches to ensure that all flowers have access to sunlight. This increases fruiting substantially. Also, the tips of the branches that bear fruit are pruned in winter to stimulate more fruiting branches. He emphasised that pruning shears should be used for straight clean cuts and not the pangas people have been using. He spoke to irrigation and suggested they build basins around their trees to allow for around 200-400l of irrigation in one go. Watering like this needs to be done once a week or bi-weekly. Also the leaves that fall form the trees should not be swept away but placed around the tree as mulching. Spraying for powdery mildew needs to be done when the trees are flowering. There are fungicides that are not too harmful that can be used as powdery mildew is very common.

(iv) Review of CSA practices

Here small groups made lists of practices falling into the five finger categories (water management, soil management, crops, soil fertility and soil health and natural resources). These practices were then assessed for impact; participants indicting who is using the practice and comments were made.
The traffic light system of assessment of implementation was used (red – none or very little); (yellow- can be improved) and (green- good implementation.)

The table below summarises this exercise

Practice	**Implementation**	**No of people (N=62)**	**Comments**
WATER MANAGEMENT			
Mulching		23	Saves water, suppresses weeds
Furrows and ridges		9	Make sure you allow the grass to grow before you turn the soil. Helps control soil pests
Banana basins		13	Prevents water run-off, provides fertility and water for the trees as you add leaves and compost before planting the trees
Roof water harvesting		50	Tanks for storage not enough, so this does not last long and does not work in the dry season. We use this water for drinking
Underground tanks		2	Very expensive and have now been dry for a long time as there has been no rain. Holds 24 000l, but even that was not enough to use for gardening
Stone bunds		15	Reduces erosion and holds water
Diversion diches		4	This helps to control and increase the amount of water that goes into the garden
Small basins		18	Provides some extra water for the crops planted.
SOIL MANAGEMENT			
Use feedbags to make ridges		2	Control soil erosion
Plant grass on bare soil		0	Good idea, but no-one is implementing this. Can use lemon grass, black oats for example, this planted grass prevents weeds from growing
Contour planting		9	We are more aware of this now and are doing this in the larger fields
Plant trees around the fence and yard		9	For wind protection; Not much planting of trees now, due to drought, but it is known to be a good

			idea. Plant any kind of no fruiting tree to protect the fruit trees in the yard.
CROP MANAGEMENT			
Correct timing of irrigation		7	Early mornings or late afternoons- this reduces stress and wilting
Planting sweet potatoes		15	Works well on ridges and furrows and works even in these hot, dry conditions – but needs some watering
Tunnels (shade houses)		10	These work extremely well and all participants are interested
Bulbinella		3	To trap water and is used for medicinal purposes (introduced by MDF)
Using organic pest control remedies		15	Chilli and aloe and liquid manure works well. Not many pests seen
Liquid manure		10	Use black jack leaves, chicken and goat manure – works well
Keep loosening the soil		27	Traditional practice –(in fact not recommended for soil health and soil structure- causes compaction, and capping)
Drip irrigation		10	Helps to use less water and save the water especially if mulching also used. Plants grow well
Use of herbs in-between veggies		21	This is now becoming common practices. It helps for pest control, water management
Trench beds		28	They make a big difference – good looking crops, big and healthy
Shallow trenches		16	Easier than trenches with a similar result. Can be done on larger areas
Compost		4	Labour intensive, not enough water
Use of manure		62	We all now use manure and understand that the soil needs to be fed
NATURAL RESOURCES			
Less cutting of trees		62	We are all aware and trying to save the trees
Minimising veld fires		62	We are all aware and are not burning veld
Planting of indigenous trees		26	We are all aware and are doing this on a small scale in our yards

(v) Presentation of experimentation results

A power point presentation was given (Attachment 1: AWARD-AgriSI Cluster Review Workshop-October 2018) that outlines the results of the experiments in the tunnels (trench beds inside and outside the tunnel and also furrows and ridges outside the tunnel). It was shown that the water productivity is much higher inside the tunnels and also how this is substantially increased when deep watering and mulching is used. A cost benefit analysis showing the amount of profit possible for a tunnel was also shown (R900 for 3-4 months), using spinach as an example.

A presentation was also done on the organic marketing of vegetables and herbs. Participants explained to the group how the process works and some results of incomes made and specific crops sold were presented. Hoedspruit Hub has tried out a number of different avenues for marketing – each with their own positives and negatives, described briefly in the small table below.

Market	Requirements
Local restaurants and health shop	Small quantities, can deal with some variability of crops, but quality must be good
Veggie boxes; facebook page	Medium quantities; quality must be good, required regular supply and lots of different crops
Supermarkets (Lebamba, PicknPay)	Larger quantities; lower price, continuity of supply is absolutely crucial
Friends and individuals	Small quantities, will more likely take what is available,
Saturday farmers market and boot car sales	Tested dried herbs and pesto as well as vegetables. – Small quantities need good quality and regular supply.

It was discussed that these were all an initial testing of the market in Hoedspruit and that the farmers' desired market of supermarkets could in fact be the most difficult and least rewarding as these buyers want contracts, large and continual supply and pay less. At the moment farmers are getting high prices as produce is sold as organic and directly to consumers.

Crops with a HIGH demand: flat leaf parsley, basil, onions, spinach, beetroot, green beans, sweet potatoes
Crops with GOOD demand (smaller quantities): curly leaf parsley, coriander, fennel, cabbage,
Crops with LOW demand: local tomatoes (the buyers do not like the variability in size and shape of the tomatoes)
New crops to focus on: baby marrows, carrots

Suggestions for more participants to come on board (at the moment 10-15 participants only):

- There has to be quality control at the village (learning group) level before produce is taken to the market.
- Planting intervals are important; so you have to plant regularly and not wait for everything to be harvested before planting again. We need to set up planting calendars for all the groups
- Protect the market by providing good quality and sticking to the requirements (borehole water for washing, correct weights and packaging
- Each village must make a plan -types of herbs and vegetables
- Number of people
    - Sedawa: 13
    - Lepelle: 2
    - Turkey: 9
    - Fenale: 5

  - Mametja: 5
  - Botshabelo: 3
- A contact person was chosen for each village – who will ensure availability lists are made for the village and that the orders are prepared and delivered on time at the right places

Name and Surname	Village	Phone number
Mogofe Mabiletse	Turkey	0724151686
Julia Maneneng		
Patricia Ngobeni	Lepelle	0717006817
Tronah Morema	Mametja	0799107186
Joyce Mafologele	Mametja	0799849098
Lucy Seemole Malepe	Botshabelo	0760158315

(vi) Planning for upcoming year

Below are summarised points related to group discussions for future activities. A general point was made that due to the continued lack of access to water, the groups would focus on small intensive gardening activities. People are focussed on making more trench beds as well as raised beds with organic matter as these are the best practices for now. There was a plea made to not forget about the issue of livestock however.

1. **Water issues**: Turkey also wants to be part of this process and discuss local options and potentials
2. **Underground RWH tanks**: given the difficult conditions there is a large interest in underground tanks; but funding would need to be found to do this. ***24 People made requests***
3. **Conservation Agriculture**: Given the continued dry conditions in the area a group decision was made to focus this activity on the fields of individuals who have some irrigation. Experimentation with diversification of crops (including legumes) as well as some fodder production options are to be considered. There are (9-12 individuals). Crops requested: sorghum, cowpeas, jugo beans and runner beans
4. **Organic herb and vegetable marketing:** This process has now been piloted and is to be expanded into 5 of the 6 villages. Each learning group will set up their own internal process for managing production, orders and deliveries
5. **Indigenous poultry production**: training and support on breeds and local level feed production for indigenous poultry. ***Training set up for 19-20 November***
6. **Lucerne:** introducing mixed cropping with Lucerne into the gardens
7. **Strawberries:** these were seen in Sekhukhune and people would like to try them
8. **Revision workshops:** These are important as new people come on board all the time and older participants can take part to assist in the learning and mentoring.
9. **Handouts:** were again requested.

(b) Local Poultry Production Options

Written by Mazwi Dlamini and Nonkhanyiso Zondi

Two, one day learning workshops were held; one in Turkey (2018/11/20) and one for Sedawa, Mametja, Botshableo, Willows and Fenale (2018/11/21). A total of 86 participants attended these sessions.

Here issues of housing, feeding, poultry health and different breeds were discussed. In addition, the groups went through a budgeting exercise for broilers and layers and different feeding schedules and regimes were presented.
Below small snapshots of the information presented and discussed are outlined.

(i) Feeding Chickens

Chickens are the same as humans; they also need a balanced diet which will allow them to grow to their full potential. Herbs such as Comfrey, Fennel, and Thyme etc play an important role in the diet of the chicken. Grains like sunflower are also needed to balance the diet. But the most important part in chicken feed is the protein which they get from grubs. Grubs are required for body fat and they are a very good source of protein. It's like a full meal e.g. pap, meat and spinach or cabbage.



If hens eat their own eggs, it is a sign that they are not getting the right nutrients, not enough calcium and not enough protein. Although it is recommended that egg shells are crushed and used in the feed, this can actually promote the practices of eating eggs and so grit and seashells are used instead.
Commercial feeds such as grower and finisher are used for broilers and layers. The three- phase feeding that includes post finisher is done to clear out the vaccines and other additives in the feed prior to marketing
For commercial production and working with broilers and layers one has to stick very strictly to the timing and feeding, so that the broilers can be ready after 5 weeks and layers are able to lay on average 1 egg/hen/day. If this is not done, the very small profit margin in poultry production can be lost. It is also advisable to keep at least 100 chickens at a time for commercial production. Working with smaller batches is generally not profitable
Below is a table of costs.

ITEM	COST
100 1st Grade Chicks per box (including ND&IB sprays and chick box)	R 740
2 phase feeding programme 0-21 days starter 22-36 days finisher 37-42 post finisher	R360 x 2=R720 R340 x 5=R1700 R320 x 1=R320
3 phase feeding programme 0-14 days starter 15-36 days grower 37-42 days finisher	R360 x 1=R360 R340 x 3=R1020 R340 x 3=R960 R320 x 1-R320
Drinker	R62 x 3=R186

Feeder Day old	R40 x 3=R120
2 phase feeding	R3046
3 phase feeding	R2966

(ii) Housing

Chickens are very sensitive to diseases. They need to be kept in a clean environment and be provided with clean drinking water daily. They also need to be kept warm/cool depending on weather. So rondavels, or shaded areas are a good place to keep them. It is also possible to keep them in moveable arcs or chicken tractors, as this way they can scratch and feed on bugs and also fertilize the soil for you while being moved regularly to a new area that provides food and a clean environment for them. This dramatically reduces the incidence of mites and ticks on poultry

The groups also built chicken tractors as a part of the learning process

Right and far right; Chicken tractors being constructed in turkey and Sedawa respectively.

Chicken tractors of this size can house around 10 chickens. Take care to only have 1 rooster in any one enclosure. If there are more, they compete and may kill chicks that are born.

(iii) Health

A session was also spent on discussing poultry diseases and how to control these. The main way of controlling diseases is vaccination. In terms of prevention, one needs to remove sick chickens as soon as possible from the rest, as diseases generally are spread between the birds.

Below is a vaccination chart and schedule – so if day olds or other birds are bought one has to ensure that these vaccinations were done. Some vaccines are added to the drinking water to avoid having to inject the chickens. Vaccinations are important for indigenous chickens as well, even though they are hardly ever done.

AGE	VACCINATION	ROUTE
Day 1	Marek IB/ND Hitchner B1	Subcutaneous Spray
Day 7	ND-IB-MG (Mycoplasma) (0.1ml)	Subcutaneous
Week 3	Gumboro Precise	Water
Week 4	IB H120 Gumboro Precise	Water Water
Week 6	ND la Sota	Spray
Week 7	ND-IB-MG (Mycoplasma) (0.1ml)	Subcutaneous
Week 8	Pox Deworm	Wing Web Water
Week 12	ILT	Eye Drop
Week 14	IB/ND Hitchner B1 Deworm	Spray Water

(iv) Breeds

A short discussion on different poultry breeds for different purposes was also held/ The advantage of dual-purpose breeds is that they are good meat and egg producers. They are generally slow growing, similar to indigenous breeds, but produce better and can be a profitable process, especially if feed is produced for them rather than bought

3 NEW EMPHASIS: WATER ISSUES

Some follow-ups have been made during this period, in preparation for the training and implementation around spring protection, and water storage and reticulation for agricultural use in 2019.

3.1 Water issues follow-up- Limpopo

3.1.1 Lepelle

Very little progress has been made in Lepelle, as the water committee has floundered under the political instability caused in the village due to strife caused by lobbying in the area to change the traditional authority and headmen for the area. Community members have not contributed as agreed and thus MDF is unable to take the next step in the process. The agreement was that MDF would match whatever contributions the community made, so that the first steps in renovation of the furrow can be made. No progress has been made in the community to deal with water leakages caused by broken pipes and joins.

3.1.2 Sedawa

Here Raymond Vonk, a hydrological engineer specialising in borehole surveying (geophysical services), was employed by MDF to do a survey of three potential borehole sites for the Sedawa community (2018/10/07). He produced a report clearly indicating three potential sites along the three lines suggested by the community. This will be reported back to the learning group and water interest group so that the next steps can be taken.

Figure 9: Assessment of Line 2 for borehole options. This line is close to the river in Sedawa and thus also has the greatest possibility of finding a strong source without deep drilling

Suitable sites were found along all three of the lines, although the line close to the mountains above the village, likely would need to have a deeper hole drilled. Mr Vonk suggested the community members find out from others the average depth of drilling for the area. He was unable to conduct his usual electromagnetic survey to access this due to the presence of too many fence lines in the vicinity, which interferes with these measurements. Mr Vonk also offers remote assistance when boreholes are drilled to access the condition of the rock and slurry being removed, to be able to advice whether the hole should be drilled deeper or not.

3.1.3 **Turkey**

In this village learning group members have met independently and decided on a process for saving towards drilling of joint boreholes for agricultural water provision. They have suggested that MDF meets with them once they have collected enough funds to assist them with planning and siting of these boreholes. In addition, Chris Stimie produced a more detailed budget for the two water provision options (reticulation from the mountain spring and the boreholes).

3.2 **Water issues follow-up – Bergville**

For both viallges, Ezibomvini and eqlqeni, initial workshops and field assessments have been done to assess the need and potential. Learning groups have undertaken to start collecting contributions from their groups and to plan an implementation process after discussion of the small reports produced by Mr Chris Stimie who attended these processes with a view to proposing the most beneficial and appropriate interventions.

3.2.1 **Ezibomvini**

Written by Chris Stimie

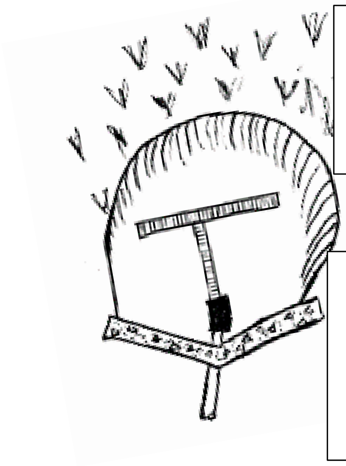
(i) Ezibomini village: Spring development proposal

Figure 10: Springs visited in Ezibomvini

Description:

The Google Earth image above indicates the 4 springs that were visited on 7 August 2018. The red line indicates the possible pipe route from the springs to the indicated household. The distance of the pipe is about 400m, depending on the exact route and the height difference is about 10m.

The cheapest and easiest option for extracting water from the spring is to install a slotted pipe (see photo below) close to the eye of the spring and cover it with gravel and soil. From this slotted pipe a black plastic pipe (HDPE) can be linked to take the water to plastic tank at the selected household. The older, abandoned spring (#4) could be used for that. The spring needs to be excavated to ensure that it will give the best yield possible. The other spring that is used by many villagers will therefore be available as before.
The way the spring is protected means that the spring will be almost invisible after the construction and contamination by cattle will also be eliminated. If there is a need to provide water for cattle that can be done with an outlet from the pipe.



The spring is excavated to expose the eye/s in a round shape. A layer of gravel is placed on the floor. The slotted pipe system is connected to the main pipe to the tank.

The low concrete wall is then constructed as indicated. The pipes are covered by gravel and on top of the gravel a geotextile is placed. The geotextile is covered by topsoil and the spring will be protected against animals and most vandals.

Right: A well manufactured slotted pipe: 63 mm PVC pipe with 1mm slots every 7mm

It is recommended that a 40mm HDPE, Class 6 pipe is used from the spring to the proposed plastic tank (5000 ℓ) This pipe would be able to give about 3000 litres of water per hour with a 10m height difference. The tank should fill up in less than 2h.

The houses on the other side of the hill will also be serviceable with water from the springs. A small tank could be installed to buffer the flow of the spring, or the water could be available at a tap under gravity. The pipe should be fitted with a valve before the inlet to the tank for easy management of the water.

Estimated costs:

The slotted pipe and related fittings: R300 (The slotted pipe itself will be supplied free of charge)
Gravel and geotextile to cover the gravel: R500
Pipe (40mm HDPE/6) 400m @ R14.50/m : R5 800 (Plus another 450m to the other side)
Trench digging and back filling for pipe Installation @ R200/10m: R8 000
Joints for the pipe: R500
Fittings at the tank: R800
Plastic tanks (5000 ℓ & 2000 ℓ) R9 000
Tank platform (built locally with bricks and concrete floor): R2 000

Unforeseen: R3 100
Total: R30 000
If the distribution to the 10 selected Households are added, there will be additional costs. This estimate is based on the assumption that each HH will have a pipe of 300m linked to it in the distribution network from the tank. The cost of a 25mm HDPE pipe (Class 10 – lowest class available) is R8.6 /m. That gives a cost of R26 000. If the installation cost is R10/m the total will be R56 000. Fittings and other costs could be taken as R4 000 which will make the total R60 000. One size could be used for simplicity. This will total to R90 000
Note: From experience management of taps are problematic as people (especially children) tend to leave them open which will empty the tank in a short period of time. The effective management of taps is crucial to the successful use of the system.

3.2.2 **Eqeleni**

Written by Chris Stimie

(a) Eqeleni Village – alternative water supply

Figure 11: Taps and water points in Eqeleni village

(b) Description of problem

This village has a fairly reliable water supply system that was installed more than 10 years ago. The municipal taps are in daily use and are an important source of clean water for the village. These taps are fed from Emmaus where there is a borehole and a pump supplying the villages in the vicinity.

There are a few problems with it. Firstly the taps are sometimes dry when the borehole pump is not working. Secondly the taps are about 400m apart, next to the road only - which makes it quite far for women to cart water for their household. Lastly the areas around the taps are trampled and very muddy which makes it prone to waterborne diseases.

There were plans in the past to do reticulation from the main line to households, but that never came to fruition.

There are also springs in the area. From discussions it became clear that these springs were used as source of water many years ago. At the moment it seems that they are used by cattle mainly. These springs are in the valley and are much lower than the households.

(c) Possible interventions

The need for reticulation of water was strongly expressed by the community and the validity for this need is obvious. This unfortunately is outside the scope of this project.

Intervention 1:

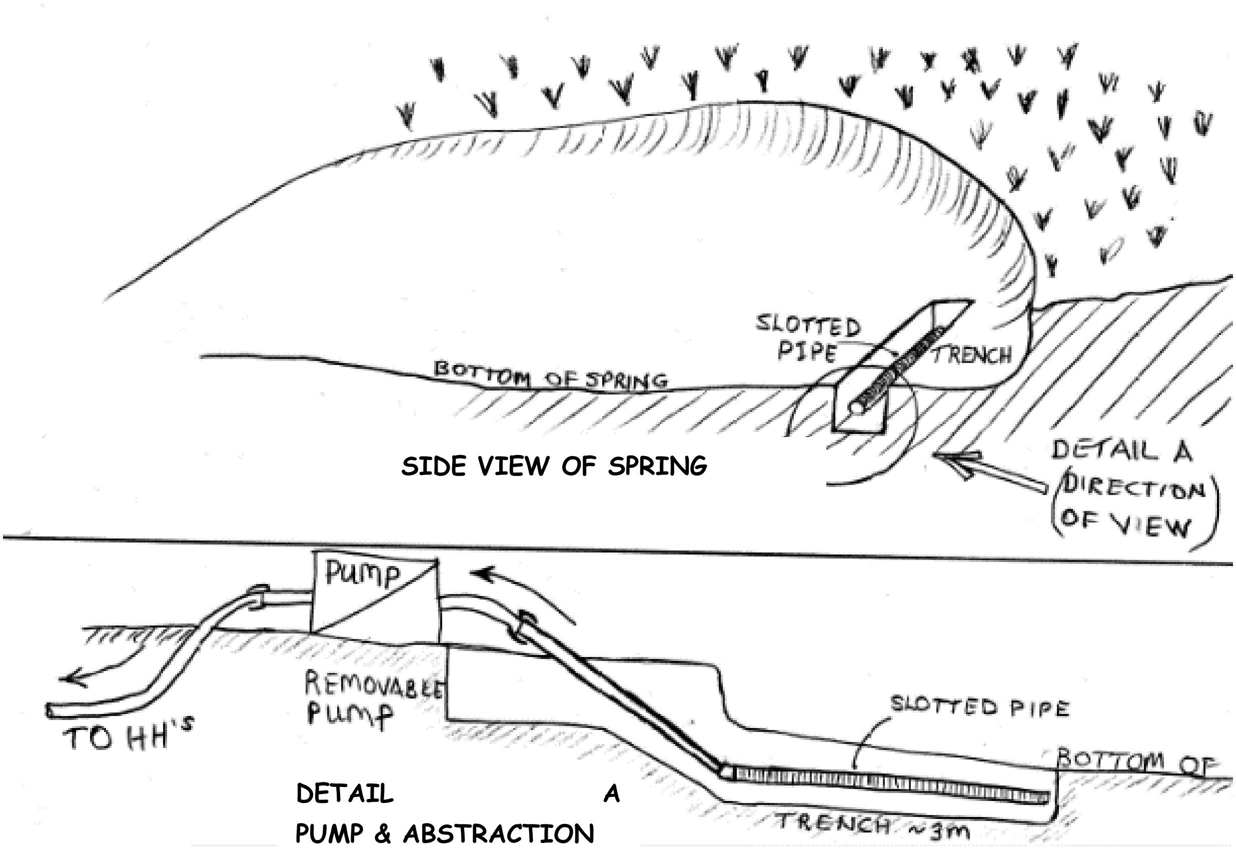
The areas around the taps could be improved by a concrete slab with drains leading excess water away and providing cattle a cleaner facility to drink water.

Cost: About R8 000 per tap for concrete work.

Intervention 2:

The springs could be developed and water could be pumped into a reservoir at a suitable position and elevation. The households are all higher (between 5 and 20 m) than the springs pumping will be needed. As electricity is not available at the springs it will have to be provided or diesel or solar will have to be used as a power source. Apart from the relatively high cost the vulnerability for vandalism or theft is very high. The effective operation and maintenance of these mechanical systems are also of concern.

In terms of pumps a few options do exist. A common approach is to use a portable diesel or petrol pump-unit. These pumps are about R18 000 for a diesel unit and R8 000 for a petrol unit. The flow rates are very high – maximum 30 000 liters per hour and they cost roughly R15 to R25 per h to operate. They can be transported with a wheel barrow. This option is not recommended.



The other option is to use a solar pump. The appropriate unit is about R15 000 to buy and is not really portable. To prevent theft and vandalism it can be mounted on a trolley the total cost would then be at least R25 000. The flow rate would be about 500 liters per hour and that means a 5000 liter tank of R6 000 should be filled in a day.

If a pipe with a diameter of 25mm (HDPE, Class 10) of 270m is installed from the spring to the plastic tank the cost of R2 800 should be added for the pipe and fittings. This pipe should be buried. Cost for that is R10 per m for 270m = R2 700 The total is thus R 5 500

The abstraction works are similar to other springs and is basically a slotted pipe in gravel in a trench. The cost for that would be about R3 000.

Cost: for abstraction, solar pump, pipe & tank. That would be R3 000+R25 000 + R5 500 + R6 000 + R2 500 for contingencies. That totals to R42 000.

Intervention 3:

It is possible to install rainwater tanks at selected households. At least in summer the tanks would be fed by rain and that will reduce carting water. If enough storage is provided the water could be used for production like vegetable growing.

Cost: The estimated cost to provide a 5000 litre rainwater per household is R10 000 and R50 000 to provide 2 x 5000 litre buried rainwater tanks. These tanks will be able to catch stormwater from roads and plots and can be used for irrigation.

These options now need to be further discussed with the community and a plan put in place for implementation.

4 CSA PRACTICES / DECISION SUPPORT SYSTEM

Written By Catherine van den Hoof[1] and Erna Kruger

[1] Post- doctoral fellow at the global change research and sustainability Institute, WITS.

Dr van den Hoof has assisted us in framing the decision support system and developing a model for this process, as the first step towards designing the web- based platform for this process.

Below the updated process and the model building section of her latest report is presented. This is the first round of modelling, which will now be followed by trouble shooting, addition of more information to further test the model and then fine tuning of the model.

4.1 Development of DSS

The development of a DSS requires the identification of a range of technical and social criteria relevant to the context, which decision-makers need to analyse in order to reach their decisions. In our case the set of criteria that helped to make informed decisions on management practices were the current farming systems, the physical environmental conditions, which limit the productivity of the framing systems, and the socio-economic background of the farmer, that together with the farming system and the environmental conditions can limit the capacity of the farmer to adopt specific practices. Each of these above-mentioned factors need to be translated into proxies that can be used as indicators for those complex realities. Besides this, the resources and related management strategies as well as a list of practices need to be provided as input to the system.

All information, except the physical environment; i.e. climate, soil and topography, and the resources and management strategies, were derived through the use of a range of Participatory Rural Appraisal (PRA). The practices were identified by both farmers and experts. Data on the physical environmental conditions are by default taken from datasets freely available online. This information can however be customised by the DSS user, in case more appropriate information is available for the specific farmer concerned.

4.2 Conceptual framework

The input data, the flow of processes and the outputs of the DSS are represented in Figure 1. In a first step the resources to manage and the related strategies are identified based on the physical environment and the farming systems. Based on these, a range of practices are suggested. The socio-economic background of the farmer, as well as the farming system and the physical environment, tend to restrict those suggested practices to a more confined number. In the next step, this confined list of practices is presented to the farmer. Based on its own priorities, capacities and knowledge, the farmer ranks those practices. The aim is for the farmers themselves to be able to decide on the practices in which they are more interested, according to their own context and needs. In parallel to this, the same confined list of relevant practices is presented to a facilitator. He/she is asked to rank according to its own opinion on the amplitude of the positive impact of each practice on the resources to manage as well as on the natural environment as a whole and the ecosystem services that it provides. Both outputs, relevant practices ranked based on facilitator and relevant practices ranked based on farmer input, lay the ground for discussion on the options available to farmers to sustain and improve farm productivity, based on their own aspirations, but also those options seen as more appropriate based on facilitator's experience/knowledge regarding not only the resources to manage but also regarding the natural environment as a whole. The differences between both outputs will also highlight the relevant practices that might need internal or external support for adoption and implementation by farmer.

In the context of climate change, the DSS can provide information on management practices that can be considered appropriate for increasing resilience. Therefore, future projections are needed as climate input in the DSS.

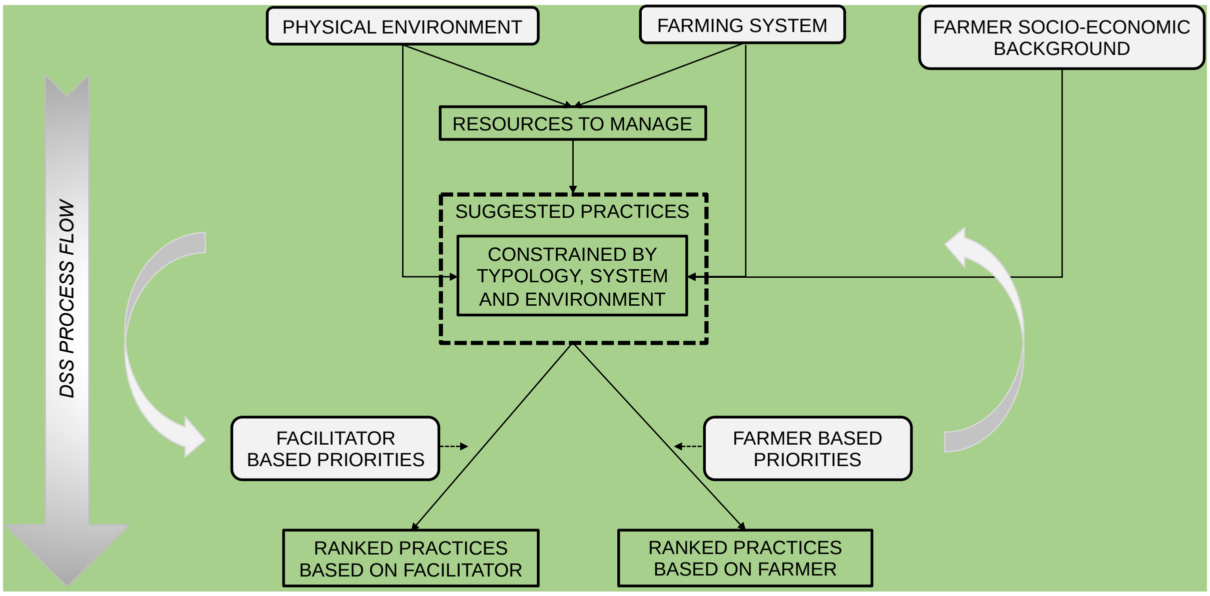


Figure 1: Schematic of the Decision Support System (DSS), with model inputs highlighted in grey.

4.3 DSS inputs

4.3.1 Physical environment

In the DSS, the components of the physical environment; i.e. climate, topography and soil are each represented by the following proxies; Agro-Ecological Zones (AEZ), slope gradient and soil texture class and organic carbon content, as represented in Figure 2. Each component and related proxy are described in more details in the following sections.

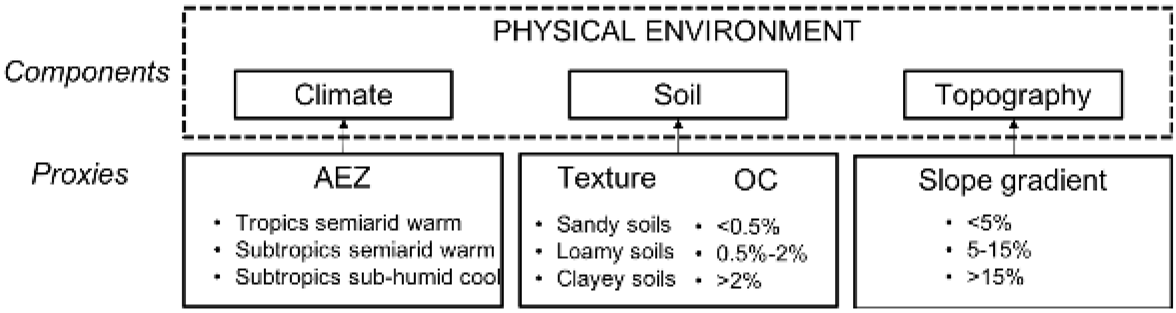


Figure 2: Components, proxies and sub-categories of the physical environment.

(a) Climate

Precipitation and temperature, through evapotranspiration, defines largely the moisture availability. Very high temperatures can cause heat stress to crops and livestock. Crop and livestock diseases and pests are also often related to temperature and humidity. Climate, in particular precipitation, pattern has also an impact on soil health and fertility through soil erosion, weathering, leaching, crust formation etc. Climate also affects weed growth, which can strongly reduce harvest. Many crops will fail almost completely when no weeding is done and labour requirement for weeding is often the factor which limits the cropping area. In many sub-humid areas, the control of weeds, particularly grass weeds, is the most difficult of the farmers' tasks. Climate consists of a variety of variables and can constrain farming productivity in many ways. Climate constraints are often classified according to the length of periods with temperatures and moisture limitations. Temperature constraints are related to the length of the temperature growing period, i.e. the number of days with a mean daily temperature above 5 °C. For example, a temperature growing period shorter than 120 days is considered a severe constraint, while a period shorter than 180 days is considered to pose moderate constraints to crop production. Hyper-arid and arid moisture regimes are considered severe constraints, and dry semi-arid moisture regimes are considered moderate constraints. For example, tropics semiarid – warm climate presents unreliable rainfall, together with its warm climate and high solar radiation levels, creates problems of moisture availability for crops. These climates tend to have hot, sometimes extremely hot, summers and warm to cool winters, with some to minimal precipitation. Hence, more efficient water management systems are needed to sustain productivity. The low rainfall and the long dry season make the semi-arid zone a relatively healthy environment for man and his livestock. Subtropics semiarid – cool usually feature warm to hot dry summers, though their summers are typically not quite as hot as those of hot semi-arid climates. Unlike hot semi-arid climates, areas with cold semi-arid climates tend to have cold winters. The cold semi-arid climate is often located at a higher elevation than the hot semi-arid climates. The cold semi-arid climates are also likely to experience temperature variations between day and night, which is not the case in hot semi-arid regions.

Currently in the DSS, the climate is defined based on the Agro-Ecological Zones for Africa South of the Sahara (Sebastian, 2014; HarvestChoice, 2011). Agroecological zones are geographical areas sharing similar climate characteristics (e.g., rainfall and temperature) with respect to their potential to support (usually rainfed) farming. Because of the general similarity of production conditions, many agricultural technologies, practices and production systems tend to behave or respond consistently within a specific AEZ. Agro-Ecological Zones for Africa south of the Sahara were developed based on the methodology developed by FAO and IIASA. The dataset includes three classification schemes: 5, 8, and 16 classes, referred to as the AEZ5, AEZ8, and AEZ16, respectively. AEZ 5, 8, and 16 classes are based on the high-resolution agro-ecological data at 10 km resolution. The data can be accessed freely at doi:10.7910/DVN/M7XIUB. In this study the 16 classes dataset was used, as represented in Table 1.

	Subtropics		Tropics	
	warm	cool	warm	cool
Arid				
Semi-arid	Alice/King		Tzaneen	
Sub-humid		Bergville,		

Humid				

Table 1: Agro-Ecological Zones encountered in South-Africa (grey) and location of the closest town of the study sites within these zones.

The different terms in Table 1 are defined as follows:

- Tropics: mean monthly temperature adjusted to sea-level[1] greater than 18ºC for ALL months
- Sub-tropics: mean monthly temperature adjusted to sea-level less than 18ºC for 1 or more months
- Arid: less than 70 days length of growing period (LGP)
- Semi-arid: 70-180 days LGP
- Sub-humid: 180-270 days LGP
- Humid: over 270 days LGP
- Warm: Zones with mean temperatures greater than 20ºC
- Cool: Zones with mean daily temperatures of 5-20ºC during the growing period

The length of growing period (LGP) is defined as the period during the year when average temperatures are greater than or equal to 5ºC (T_{mean} >= 5ºC) and precipitation plus moisture stored in the soil exceed half the potential evapotranspiration (P > 0.5PET). A normal growing period is defined as one when there is an excess of precipitation over PET (i.e. a humid period). Such a period meets the full evapotranspiration demands of crops and replenishes the moisture definite of the soil profile. An intermediate growing period is defined as one in which precipitation does not normally exceed PET but does for part of the year. No growing period is when temperatures are not conducive to crop growth or P never exceeds PET (FAO 1978).

South Africa covers 12 different AEZ. These are highlighted in grey In Table 1. The sites currently covered in this study are located in three of these 12 AEZs: i.e. tropics semi-arid – warm, sub-tropics semi-arid – warm and subtropics sub-humid – cool. Those are also represented in Table 1. Semi-arid regions in South Africa are characterised by mean annual precipitation between 200mm and 400mm, and the sub-humid regions by mean precipitation between 400mm and 1100mm.

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

Concerning future climate projections, various available climate predictions of General Circulation Models (GCM) were used for characterization of future climates. The geographical distribution of the AEZ under future projections are based on four major GCMs and cover a range of IPCC emission scenarios. GCM model outputs for individual climate attributes were applied as follows: deviations of the monthly means of three 30-year periods (the 2020s: years 2011-2040; the 2050s: years 2041-2070; and the 2080s: years 2071-2100) from the GCM 'baseline' climate were calculated for each grid of the respective GCMs, interpolated to 30 arc-minute resolution and subsequently applied to the CRU baseline climatology (1961-1990) to represent respective future climates.

Most scenarios for southern Africa suggest increasing temperatures, and associated increases in evapotranspiration, with less certainty over changes in precipitation (IPCC 2007; Cooper et al. 2008; Bryan et al. 2013). Rainfall is generally expected to become more erratic, with delayed onsets, with increases in both inter- and intra-seasonal droughts, and with more frequent and intense flood events (Cooper et al. 2008; Twomlow et al. 2008; IPCC, 2014). Climate change will amplify existing stress on water availability and on agricultural systems, particularly in semi- arid environments (IPCC, 2014). Given those projected increases in variability, it is suggested not only to account for change in mean but also in interannual variability; increasing variability and unpredictability will increase the vulnerability of the farmers to climate.

(b) Soil

Soil texture and organic matter content are important soil characteristics that influence water quantity and soil fertility and health. Soil organic matter affects the chemical and physical properties of the soil and its overall health by providing nutrients and habitat to organisms living in the soil, its composition and breakdown rate, which affect the soil structure and porosity, the water infiltration rate and moisture holding capacity of soils; the diversity and biological activity of soil organisms; and plant nutrient availability. It reduces compaction and surface crusting and facilitates rooting. The same can be stated for the soil texture.

Based on various proportions of sand, silt, and clay, the soils can be categorized as one of the four major textural classes: sands, silts, loams, and clays (Berry et al. 2007). Sandy soils are referred to as coarse-textured and have the tendency to drain quickly after rainfall or irrigation. Because they drain faster than other soil textures, they are subject to nutrient losses through leaching, and they also warm faster in the spring. Sandy soils tend to have a low pH and very little buffering capacity; hence, are often acidic. Silty soils might be fairly well-drained, but they usually retain more water than sandy soils. These soils have the tendency to compact easily when moist and form crusts when wet. The clayey soils, which are fine-textured soils tend to drain water slowly, can easily be compacted if trampled while wet, and harden when dry. Because of their tendency to hold more water and drain slowly, fine-textured soils also warm up slowly during the spring. Loamy soils have relatively even percentages of sand, silt, and clay separates. Loams are slightly gritty, relatively well-drained, and easy to work with agricultural tools. Loams usually hold water well and drain easily.

The four texture classes have been defined based on the clay silt and sand fraction taken from the AfSoilGrids 250m soil database (Hengl et *al.*, 2017), and grouped according to the textural classes represented in Figure 3, and further regrouped as follows:

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

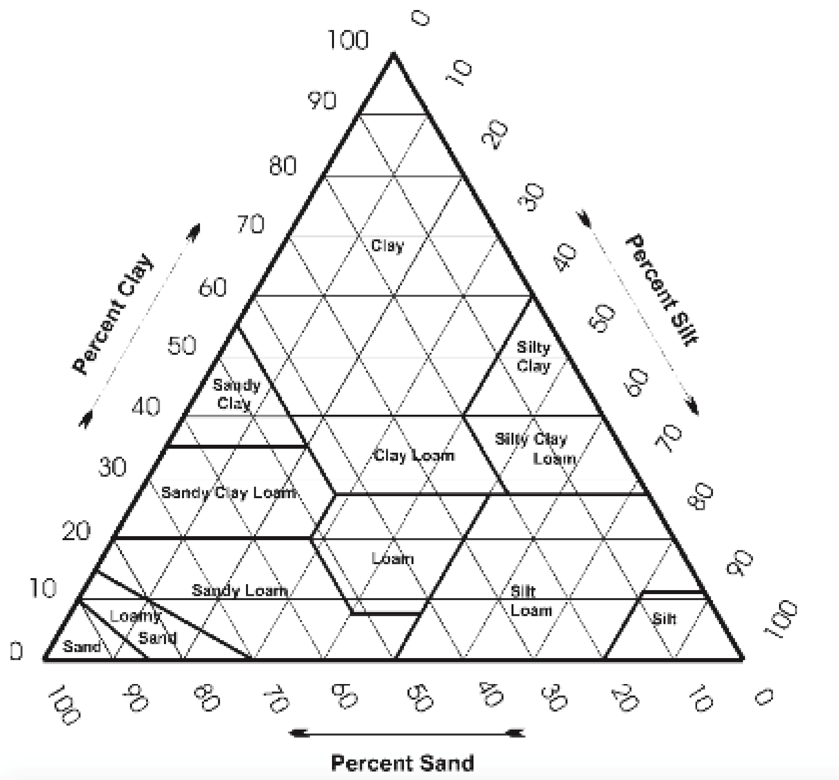


Figure 3: Soil texture triangle.

Soils with higher levels of fine silt and clay usually have higher levels of organic matter than those with a sandier texture. Currently in our DSS, soil fertility is defined based on the percentage in soil organic carbon content, taken from the AfSoilGrids 250m soil database (Hengl et *al.*, 2017). In south Africa, about 58% of soils contain less than 0.5% organic carbon and only 4% contain more than 2% organic carbon (du Preez et *al.*, 2011). Based on this information, three different categories have been created as follows: (1) <0.5%, (2) 0.5% - 2% and (3) >2%.

The AfSoilGrids 250m dataset (Hengl et *al.*, 2017) contains the following soils characteristics for the whole African continent at 250 m spatial resolution at seven standard soil depths (0, 5, 15, 30, 60, 100 and 200 cm).

- soil organic carbon (gC/kg)
- pH (in H_2O)
- fraction of sand (kg/kg)
- fraction of silt (kg/kg) and clay (kg/kg)
- bulk density (kg/m^3)
- cation-exchange capacity (CEC, cmol $^+$/kg)
- depth to bedrock (cm)
- probability of occurrence of R horizon or bedrock within 200cm
- soil classes based on the World Reference Base (WRB) and the United States Department of Agriculture (USDA) classification systems

This dataset can be found at https://www.isric.online/projects/soil-property-maps-africa-250-m-resolution. In case soil texture has been measured locally, this observation can be used as input for the DSS instead of the values taken from the above mentioned AfSoilGrids 250m dataset. The same is valid concerning the soil organic matter content. In the future, additional soil characteristics, from the database or observed, could be used as input for the DSS to better define soil structure, water holding capacity, health and fertility, etc.

(c) Topography

Topography, and in particular the slope grade, enhance erosion and run-off, and by consequence reduces soil fertility and water infiltration. Around up to 5% slope, the conditions for agricultural production are optimal. Between 5 and 15% the conditions are sub-optimal and beyond 15% they are on average not suitable. The slope gradients have therefore been divided in 3 classes: flat to gently sloping (<5%), undulating to rolling (5%-15%) and hilly to very steep land (>15%).

Slope gradient data at around 1km resolution have been made available at the http://gaez.fao.org/ website. These data have been compiled using elevation data from the Shuttle Radar Topography Mission (SRTM). The SRTM data is publicly available at around 100 meters resolution at the equator.

However, in case topographic information has been observed locally, those values can be used as input for the DSS instead of the values taken from the above-mentioned database.

4.3.2 **Farming systems**

The vast majority of South Africa's rural residents derive their livelihoods from a number of diverse on-farm and off-farm sources. The on-farm sources can be divided as follow: crops, livestock and other natural resources. Crops have been divided in field cropping and vegetable gardening, since the management practices differ strongly between both, in particular due to differences in plot size and location; gardens are smaller and generally closer to the house. Vegetable gardening is also often a dry-season activity. The extent of this activity is then largely influenced by availability of a reliable water source. By consequence the DSS differentiates the following farming systems:

- Vegetable gardening
- Field cropping
- Livestock
- Trees and other natural resources

Information on the farming systems has been collected during the field work. It has to be mentioned that a farmer can belong to more than one farming system type.

4.3.3 **Farmer socio-economic background**

Extensive socio-economic and demographic background information from the different farming household (HH) involved in this study has been compiled during the field work. The different themes are listed below:

- Demographic information
    - Gender HH head

    - Age HH head
    - Dependency ratio HH head
- Learning and access to education (level of education)
- Source of income (unemployment vs. external employment, own business, grants, farm, etc.)
- Total income
- Access to services, infrastructure, technology
    - Electricity
    - Water (tap, borehole, rainwater harvesting, etc.)
    - Irrigation (buckets, standpipes, etc.)
    - Fencing
    - Farming tools (hand vs traction/other)
- Social organisation (saving clubs, cooperatives, others)
- Market access (formal vs. informal)
- Farm size
- Farming purpose (food vs. selling)

Based on their vulnerability to shocks and stress, the farming households have been subdivided into three categories. The most vulnerable have been assigned to typology A and the less vulnerable to typology C. Farmer typology is a way of segmenting farmers into groups to assist in developing targeted farm extension programs. Both typologies A and B can be considered to have a high level of vulnerability, but A is more extreme. Typology C indicates a much smaller group of smallholder farmers who have better or more reliable access to infrastructure and support, are generally better educated, have access to larger fields and more livestock and farm primarily for income generation purposes. They fund these farming enterprises primarily through incomes earned from employed members within the household, or a combination of employment and social grants (including pensions). These farmers are also more likely to belong to cooperatives and farmers associations and to have access to formal market linkages.

From this, we can state that the typology of a farming HH can be differentiate by the HH head gender, dependency ratio (ratio of children and pensioners against working aged adults within HH), level of education, employment status, income, access to services and formal market, farming purpose and farm size. The different options of outcome for those 9 socio-economic and demographic characteristics are provided in Table 2, as well as to which typology they belong. An outcome can belong to different typology; for example, typology A as well as typology B are often characterised by a female headed farming HH.

In the DSS, the typology with the most frequent outcome is assigned as mean typology to the farming HH. In case two typologies are equally frequent, the typology with the lowest level is assigned to the HH. This HH typology is further used as proxy for the socio-economic background of the HH. An example of how a specific typology is assigned to a farming HH is provided below and is based on the information provided in Table 2.

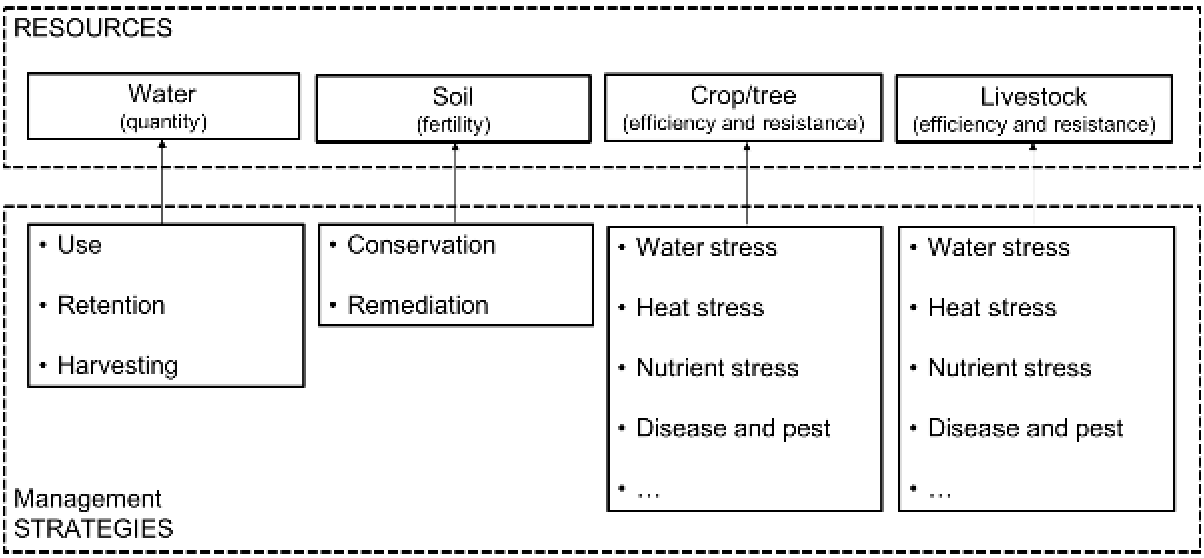
Socio-economic charcateristics	Typology A	Typology B	Typology C
Gender	female	male/female	male
Dependency ratio	>1.25	0.75-1.25	<0.75
Level of education	<grade 10	<grade 10	>grade 10
Unemployement	yes	yes/no	no
Total income	R0-R1999	R2000- R4999	>R5000
Access electricy and tap-water	no access	access to one	access to both
Access to formal market	no access	no access	access
Farming purpose	food	food/market	market
Farm size	0,1- 1ha	1- 2ha	>2ha

Table 2: Socio-economic characteristics and range of values used to define the three typologies.

The farming HH considered in this example is characterised by a male head (typology B or C), with a dependency ratio larger than 1.25 (typology A), which went to school up to grade 9 (typology A or B), is employed with a total income of R1500 (typology B or C), has access to electricity but has no tap-water (typology B), has no access to formal market (typology A or B), with food as the main farming purpose (typology A or B) and with a farm size of around 0.2ha (typology B). The outcome of four out of the nine socio-economic characteristics could be assigned to typology A, seven to typology B and one to typology C. By consequence, this farming HH will be assigned typology B.

4.3.4 Resources and management strategies

The management strategies have been grouped by resources to manage. Four type of resources have been identified: water, and in particular quantity (1), soil, in particular fertility (2), crop (3) and



livestock (4), in particular efficiency and resistance, as represented in Figure 4. Efficiency refers to the conversion of water, nutrients or land into the required output, such as biomass per unit area of land cultivation or seed generation of the plant itself. Resistance relates to crop or livestock that are for example better adapted to drought or heat conditions or better protected against diseases, etc.

Figure 4: Resources and related management strategies.

4.3.5 **Agricultural practices**

Based on farmers and expert knowledge, a list of relevant practices has been set up, including, in case of available information, their beneficial impact on the different resources mentioned in section 3.2.4, the required tools, financial investment and knowledge as well as the limitations set by the physical environment to implement these practices. This list of practices, that can be found in Appendix A, is not exhaustive and can be extended with other practices. All suggested practices are assumed to fit within at least one of the three CSA principles, which are 1) increasing productivity, (2), increasing resilience to climate change, (3) reducing contribution to climate change.

4.4 DSS processes and intermediate steps

4.4.1 **Defining resources to manage based on physical environment and farming systems**

As introduced in section 3.2.1., the resources to manage and the related strategies depend strongly on the physical environment; i.e. climate, soil and topography, and the combination of those three components. For example, in sub-humid environments, biotic factors, such as the amount of vegetation and organic matter, as well as the soil texture play a significant role in maintaining good soil status and preventing erosion; high sand content and low clay content increased the likelihood of erosion. In the semi-arid and arid regions, high levels of sand content also increase the likelihood of erosion but so do high levels of clay; due to lack of vegetation, there will be a crusting of the clay surface which increases erosion. Slope grade has also a variable effect on erosion under different climatic zones, and in particular due to differences in amount of rainfall; severely eroded soils are present in the semi-arid zone with slopes greater than 15%, whereas slightly to moderately eroded soils were found in the sub-humid zone under the same slope classes.

The information provided in this section as well as in section 3.2.1 has been compiled and used to build Table 3. The justification for managing the different resources in our DSS is as follows:

- Semi-arid warm: in this environment water is limited and the temperatures can be hot.
- Sub-humid cool: in a more humid environment, weeds are growing well and can create a competing environment for nutrients. Plants and animals are also more prone to diseases.
- Sandy soils: those soils have poor structures, with low water and nutrient holding capacity. They heat up fast.
- Clayey soils: high level of clay can increase the probability of erosion due to crusting, in particular under a semi-arid environment.
- OC: soils with less than 2% OC are considered to be of low fertility.
- Sloping: above 5% sloping, agricultural production becomes sub-optimal due to erosion and run-off, in particular in semi-arid regions. Sloping above 15%, agricultural production is not suitable under all conditions, due to water and nutrient run-off.

Table 3 allows to identify, for each farming HH, the resources to manage and the related strategies provided the farming system and the environmental conditions.

			Resources and management strategies												
			Water (quantity)			soil (fertility)		crop/tree resistance and efficiency				Livestock resistance and efficiency			
			Harvesting	retention	use efficiency	conservation	improvement	Water	Heat	nutrient	disease	Water	Heat	nutrient	disease
Proxies for physical environment	AEZ	Tropics semiarid warm													
		Subtropics semiarid warm													
		Subtropics sub-humid cool													
	Soil texture	Sandy soils													
		Loamy soils													
		Clayey soils				*									
		Silty soils													
	Soil OC	<0.5%													
		0.5-2%													
		>2%													
	Slope	<5%													
		5-15%	*	*	*	*									
		>15%													
Farming	system	Field cropping													
		vegetatble gardening													
		Livestock													
		Tree and other nat. resources													

Table 3: Criteria for defining the resources to manage and related strategies, based on the physical environment and farming system (grey boxes) (: solely if semiarid zone).*

A farming HH is defined by one of the options within each component of the physical environmental categories (see Figure 2); i.e. AEZ, soil textures, OC and slope. If one of these options vs. resources and management strategies box in Table 3 is highlighted in grey, it suggests that the specific resource needs to be managed by mean of the provided strategy but solely if the farming system, at the bottom of this Table 3, suggests to do so (if those boxes are highlighted in grey as well). In case of field cropping, vegetable gardening and others such as trees, the resources to manage are restricted to water quantity, soil fertility and crop, while for livestock farming system, it is restricted to livestock, water quantity and soil fertility. The boxes highlighted with an asterisk (*) suggest a conditional criterion; i.e. farming on a clayey soil only need soil conservation if it is located in a semi-arid region.

For example, a farming HH in Tzaneen (tropic semi-arid warm climate according to Table 1), which main farming systems are crop field and gardening on sandy soils with less than 0.5% soil organic carbon (OC) and located in an undulating landscape (slope between 5% and 15%), would need, according to Table 3, to manage the water quantity through water harvesting, increasing water use efficiency and retention as well as increase the resistance to drought and the water use efficiency of crops and vegetable, to conserve and improve soil fertility, to increase the heat resistance of crop/vegetable and the efficiency of nutrient uptake by the crop/vegetable.

4.4.2 Suggesting management practices based on resources to manage

Based on the information provided in section 3.2.5 and Appendix A, Table 4 has been built. This Table 4 associates the practices to the resources and the management strategies that they cover. It can be seen that a practice can be beneficial to different resources through different mechanisms and strategies. This Table 4 allows to select the practices that could be used to manage the resources, through specific strategies, that were identified in section 3.3.1.

	Resources and management strategies												
	Water (quantity)			soil (fertility)		crop resistance and efficiency				Livestock resistance and efficiency			
Practices	Harvesting	retention	use efficiency	conservation	improvement	Water	Heat	nutrient	disease and pest	Water	Heat	nutrient	disease
Drip irrigation			■			■							
Bucket drip kits			■			■							
Furrows and ridges/ furrow irrigation			■	■		■							
Greywater management			■			■							
Shade cloth tunnels		■	■			■	■		■		■		■
Mulching		■		■	■	■	■	■					
Improved organic matter (manure and crop residues)		■	■		■	■	■	■	■				
Diversion ditches	■			■									
Grass water ways	■			■									
Infiltration pits / banana circles (with OM)	■	■		■	■		■						
Zai pits (with OM)	■	■		■	■		■						
Rain water harvesting storage	■												
Tied ridges	■	■		■		■							
Half moon basins	■	■		■		■							
Small dams	■												
Contours; ploughing and planting	■			■		■							
Gabions	■			■									
Stone bunds	■			■									
Check dams	■			■									
Cut off drains / swales	■			■									
Terraces	■			■									
Stone packs	■			■									
Strip cropping	■			■									
Pitting	■			■									
Woodlots for soil reclamation		■		■	■								
Targeted application of small quantities of fertilizer, lime etc					■			■					
Liquid manures					■	■		■	■				
Woody hedgerows for browse, mulch, green manure, soil conservation			■	■	■	■	■	■	■			■	
Conservation Agriculture		■	■	■	■	■	■	■	■			■	
Planting legumes, manure, green manures					■			■	■				
Mixed cropping				■	■			■	■				
Planting herbs and multifunctional plants				■	■			■	■				
Agroforestry (trees + agriculture)		■		■	■	■	■	■	■		■	■	
Trench beds/ ecocircles		■			■	■	■	■	■				
push-pull technology									■				
Natural pest and disease control									■				
Integrated weed management						■		■					
Breeding improved varieties (early maturing, drought tolerant, improved nutrients),						■	■	■	■	■	■	■	■
Seed production / saving / storing						■	■	■	■				
Crop rotation			■		■	■		■	■				
Stall feeding and haymaking										■		■	
Creep feeding and supplementation												■	■
Rotational grazing				■	■							■	■
Debushing and oversowing				■	■							■	■
Rangeland reinforcement				■	■							■	■
Bioturbation				■	■							■	■
Tower garden			■		■	■		■	■				
Keyhole beds			■		■	■		■	■				

Table 4: Criteria for selecting practices based on the resources to manage and related strategies (grey boxes).

4.4.3 Confining suggested practice based on restrictions set by the farmer's socio-economic background, the farming system and the environmental conditions

Practices that have been suggested in section 3.3.2 to manage specific resources might not be appropriate under specific environmental conditions, farming systems and socio-economic conditions. Environmental conditions such as steep slopes, too hard or too soft soils, too much or not enough rain might limit the implementation of certain practices. Farming systems might also restrict the choice of practices; for example, practices that require a significant area or mechanisation, are solely appropriate to fields, since they are much larger than gardens. Finally, farmer socio-economic background also limits the implementation of certain practices; for example, practices that are labour intensive, costly, requiring significant mechanisation, input or skills, might not be appropriate for farmers of typology A or B. Farmer typology, as defined in section 3.2.3, has been proven to be a good indicator for the adoption or not of a practice by a farmer. Those restrictions for practice implementation due to physical environment, farming system or farmer's typology are represented in Table 5, which has been built based on the information provided in Appendix A.

This Table 5 highlights in grey the suitability of the practices under the different physical environmental conditions, farming systems and farmer's socio-economic background. In case the practice in not suitable for one of these categories or sub-categories characterising the farming HH, the practice is rejected from the list of suggested practices.

	Proxies for physical environment													Farming system				Typology		
	AEZ			Soil texture				Soil OC			Slope									
Practices	Tropics semiarid warm	Subtropics semiarid warm	Subtropics sub-humid cool	Sandy soils	Loamy soils	Clayey soils	Silty soils	<0.5%	0.5-2%	>2%	<5%	5-15%	>15%	Field cropping	vegetable gardening	Livestock	Tree and other nat. resources	A	B	C
Drip irrigation																				
Bucket drip kits																				
Furrows and ridges/ furrow irrigation																				
Greywater management																				
Shade cloth tunnels																				
Mulching																				
Improved organic matter (manure and crop residues)																				
Diversion ditches																				
Grass water ways																				
Infiltration pits / banana circles																				
Zai pits																				
Rain water harvesting storage																				
Tied ridges																				
Half moon basins																				
Small dams																				
Contours; ploughing and planting																				
Gabions																				
Stone bunds																				
Check dams																				
Cut off drains / swales																				
Terraces																				
Stone packs																				
Strip cropping																				
Pitting																				
Woodlots for soil reclamation																				
Targeted application of small quantities of fertilizer, lime etc																				
Liquid manures																				
Woody hedgerows for browse, mulch, green manure, soil conservation																				
Conservation Agriculture																				
Planting legumes, manure, green manures																				
Mixed cropping																				
Herbs and multifunctional plants																				
Agroforestry																				
Trench beds/ ecocircles																				
push-pull technology																				
Natural pest and disease control																				
Integrated weed management																				
Breeding improved varieties (early maturing, drought tolerant, improved nutrients),																				
Seed saving/ production/ storing																				
Crop rotation																				
Stall feeding and haymaking																				
Creep feeding and supplementation																				
Rotational grazing																				
Debushing and oversowing																				
Rangeland reinforcement																				
Bioturbation																				
Tower garden																				
Keyhole beds																				

Table 5: Criteria for confining the selected practices based on farmer's typology, physical environment and farming system (grey boxes).

4.4.4 **Ranking relevant practices based on farmer and facilitator input**

(a) Ranking based on facilitator input

The facilitators are asked to assign per resource for each practice a value between 0 and 3, according to what the facilitator think to be the level of beneficial impact, direct or indirect, of the practice to improve or sustain the specific resource, with 0 as no beneficial impact, 1 as low, 2 as medium and 3 as high beneficial impact on the specific resource. Besides the impact on the four resources mentioned earlier; i.e. water, soil, crop and livestock, a score has to be assigned to the beneficial impact of the practice on the natural environment with regard to the ecosystem services it provides. An example of scores given by a facilitator of Mahlathini Development Foundation is shown in Table 6.

The relevant practices that were selected in section 3.3.3 based on the physical environment, the farmer system and typology are ranked by summing the different scores assigned to each practice for the five different resources. The practices with the highest total score are assumed to contribute the most, based on the facilitator knowledge/experience, to improve or to sustain the different resources. A separate ranking can be made for the contribution to the natural resources only.

	Resources					
Practices	water	soil	crop	livestock	CSA	total
Drip irrigation	3	0	2	0	0	5
Bucket drip kits	3	0	2	0	1	6
Furrows and ridges/ furrow irrigation	3	2	2	0	0	7
Greywater management	3	0	2	0	0	5
Shade cloth tunnels	3	1	2	1	1	8
Mulching	2	2	3	1	1	9
Improved organic matter (manure and crop residues)	3	3	3	1	1	11
Diversion ditches	3	2	2	1	1	9
Grass water ways	3	2	2	1	1	9
Infiltration pits / banana circles	3	2	3	1	1	10
Zai pits	3	2	3	1	1	10
Rain water harvesting storage	3	2	2	1	1	9
Tied ridges	3	2	2	1	1	9
Half moon basins	3	2	2	1	1	9
Small dams	3	2	2	1	1	9
Contours; ploughing and planting	2	3	2	1	1	9
Gabions	2	3	2	1	3	11
Stone bunds	2	3	2	1	1	9
Check dams	2	3	2	1	1	9
Cut off drains / swales	2	3	3	1	1	10
Terraces	2	3	2	1	1	9
Stone packs	2	3	2	1	1	9
Strip cropping	2	3	3	2	1	11
Pitting	2	3	2	2	2	11
Woodlots for soil reclamation	1	3	1	1	3	9
Targeted application of small quantities of fertilizer, lime etc	2	1	3	1	1	8
Liquid manures	1	1	3	1	1	7
Woody hedgerows for browse, mulch, green manure,	1	2	3	2	2	10
Conservation Agriculture	2	2	3	2	2	11
Planting legumes, manure, green manures	1	2	3	1	1	8
Mixed cropping	1	2	3	2	1	9
Herbs and multifunctional plants	1	2	3	2	1	9
Agroforestry	2	2	3	3	1	11
Trench beds/ ecocircles	2	2	3	1	1	9
push-pull technology	1	1	3	1	1	7
Natural pest and disease control	1	1	3	1	1	7
Integrated weed management	1	1	3	1	1	7
Breeding improved varieties (early maturing, drought tolerant, improved nutrients),	1	1	3	1	1	7
Seed saving/ production/ storing	1	1	2	1	1	6
Crop rotation	1	2	3	2	1	9
Stall feeding and haymaking	1	1	1	3	1	7
Creep feeding and supplementation	1	1	1	3	1	7
Rotational grazing	1	1	1	3	3	9
Debushing and oversowing	1	1	1	3	3	9
Rangeland reinforcement	1	1	1	3	3	9
Bioturbation	1	1	1	3	3	9
Tower garden						
Keyhole beds						

Table 6: Scores, between 0 and 3, assigned by a facilitator to each resource and per practice based on the estimated beneficial impact of the practice on the specific resource.

(b) Ranking based on farmer input

The relevant practices that were selected based on the physical environment, the farming system and typology are presented to the farmer. The farmer is then asked to assign a value between 1 and 3, per practice, to each of the following themes: (1) intensity of labour, (2) of investment and (3) of required skills, with score 1 being high intensity or requirement level and score 3 low intensity and requirement level, as well as the (4) beneficial impact on its farm productivity and (5) on water savings, with score

1 being no or very low impact and score 3 being high impact. All scores are summed per practice to get a total score and to allow for the practices to be ranked, according to the farmer's aspirations and abilities. The practice with the highest score gets the highest ranking.

4.5 **Implementation of DSS in Excel**

The above-mentioned flow of processes has been implemented as routines and tabulars in Excel in the file named "DSS_model_v2.xls". The implementation steps and rules are provided and described in this section. The DSS_model_v2.xls file consists of 8 work sheets:

- DSS_input
- Typology
- Resources to manage
- Tab pract. vs res.
- Tab pract. vs constrains
- Tab score facilitator
- Tab score farmers
- Example for HH1

4.5.1 **"DSS_input" sheet**

The input data, as described in section 3.2, has been imported into sheet "DSS_input" for the 26 farming HH. The content of this sheet is provided in Appendix B, where it has been split-up in two tables; i.e. Table B.1, with the physical environment input data, and Table B.2, with the socio-economic background and farming system input data. A description of each variable in those tables are provided below:

- HH - no. of participant: number, from 1 to 26, assigned to each farming HH interviewed during the field survey
- Location:
  - Name & Surname: name and surname of the HH head of the farming HH.
  - Village: name of the village where the farming HH is located.
  - Town: closest town to the farming HH.
  - Province: province where the farming HH is located.
  - Longitude: approximate longitude where the farming HH is located.
  - Latitude: approximate latitude where the farming HH is located.
- Climate – AEZ: this is the name of the agro-ecological zone (Sebastian, 2014; HarvestChoice, 2011) where the farming HH is located", as described in section 3.2.1.1. The GIS file of the AEZ dataset (Sebastian, 2014; HarvestChoice, 2011), as well as the related legend, are provided in the compressed folder "input_datasets.zip.
- Soil: information on soil texture and soil organic carbon content, based on the AfSoilGrids 250m soil database (Hengl et *al.*, 2017), as described in section 3.2.1.2. The GIS file of the soil datasets as well as the related legend, are provided in the compressed folder "input_datasets.zip"
  - Texture adapted: the soil texture can be either sand, clay, loam, silt, and is based on the AfSoilGrids 250m soil database (Hengl et *al.*, 2017), and the soil texture triangle, as described

in section 3.2.1.2, but adapted, if required, based on the soil samples taken during the field survey. This column is used as input for the DSS.
- Texture AfSoilGrids: the soil texture can be either sand, clay, loam, silt, and is based on the AfSoilGrids 250m soil database (Hengl et *al.*, 2017), and the soil texture triangle, as described in section 3.2.1.2. This column is not used as input in the DSS.
- OC AfSoilGrids: % of soil organic matter taken from the AfSoilGrids 250m soil database (Hengl et *al.*, 2017).

- Topography: average slopes of the terrain where the farming HH is located, as described in section 3.2.1.3. The GIS file of the slope dataset as well as the related legend, is provided in the compressed folder "input_datasets.zip"
  - slope: this column translates the codes provided in the GIS file into the slope % categories, as defined in the legend file. These categories are further adapted to the categories used in this study, as defined in section 3.2.1.3. Since the used categories differ from the dataset categories, a farming HH may fall in more than one slope category, and a value 1 is assigned to each of them;
  - slope 0-5%
  - slope 5-15%
  - slope >15%
- Gender HH: the value of 1 means that HH head is a female and a value of 0 a male.
- Dependency ratio: ratio of children and pensioners against working aged adults within HH
- Education: highest level of education of the HH head, expressed in the school grade achieved. A value of 99 means that the HH head has obtained a higher degree than grade 12.
- employment satus: the employment status of the household head is expressed as 1 for unemployed and 0 for employed.
- Income: total income of the HH, including social grants, employment and selling of farm products, etc.
- Access electricity and tap water: a value of 1 in the column "tap water" means that the HH has access to tap water and a value of 0 means there is no access. The same is valid for the column "electricity" in the context of access to electricity.
- Market access: a value of 1 represents HH that have access to formal markets while 0 means that the HH has no access.
- Farming purpose: a value of 1 means that the main purpose of farming is to sell the products at the market, while a value of 0 means that the main purpose is own consumption.
- Farm size: the total size of the farm fits within one of the following categories; i.e. 0,1-1 ha, 1-2 ha, >2ha, by assigning the value 1. The other two categories will be assigned the value 0.
- Farming systems: the farming HH belongs to at least one of the following 4 categories; i.e. gardens, field, livestock/chickens, trees/natural, by assigning the value 1. If the HH does not practice a specific farming system, the value 0 is assigned to that category.

The source data for the climate (AEZ), soil (texture and organic carbon) and topography (slope), as mentioned in section 3.2 are provided in the folder zipped "input_datasets". These datasets are either georeferenced tiff files or GIS shapefiles that can be imported as such in a GIS such as the open source software QGIS. The related legends are provided as well.

4.5.2 **“Typology” sheet**

This sheet computes the HH typology based on the input dataset “socio economic background”, as described in section 3.2.3 , and the rules defined in Table 2 of section 3.2.3. The typology has been computed in 4 consecutive steps, represented by 4 consecutive tables within this sheet:

- A. Socio-economic characteristic of HH that fits within specific typology receives value 1:

In this table, for each typology, the 9 socio-economic characteristics are assigned value 1, if the characteristic, provided in the DSS_input sheet, fits the specific typology, according to the rules defined in Table 2. In case it does not fit, the value 0 is assigned.

- B. Total score/typology:

The sum of the values, 1 or 0, assigned to the 9 characteristics are provided per typology. The maximum value out of the 3 total scores for the different typologies is provided in the last column of this table.

- C. Typology with max score (=1):

The typology with the maximum score is assigned value 1. More than one typology can have a same maximum score

- D. If 2 typologies have same max score then lowest typology is assigned to HH:

If more than one typology has the same maximum score, then the HH is assigned the lowest typology (lowest is typology A and highest is typology C).

4.5.3 **“Resources to manage” sheet**

This sheet computes the resources to manage based on the input dataset “physical environment”, as described in section 3.2.1 , the input dataset “farming system” as described in section 3.2.2, as well as on the rules defined in Table 3 of section 3.3.1. The typology has been computed in 2 consecutive steps, represented by 2 consecutive tables within this sheet:

- A. Resources to manage based on physical properties (=1):

In case the resource needs to be managed based on the physical environment , as described in Table 3, it is assigned the value 1. Otherwise it is assigned the value 0. The rules of Table 3, as implemented in Excel are provided below:

- water (quantity)
    - harvesting: =IF(OR(AEZ="tropic warm semi-arid",AEZ="sub-tropic warm semi-arid", AND(AEZ="tropic warm semi-arid",slope 5-15%=1),AND(AEZ="sub-tropic warm semi-arid", slope 5-15%=1),slope >15%=1,soil texture="sand"),1,0)
    - retention: =IF(OR(AEZ="tropic warm semi-arid",AEZ="sub-tropic warm semi-arid", AND(AEZ="tropic warm semi-arid",slope 5-15%=1),AND(AEZ="sub-tropic warm semi-arid", slope 5-15%=1), slope >15%=1, soil texture ="sand"),1,0)
    - use efficiency: =IF(OR(AEZ="tropic warm semi-arid",AEZ="sub-tropic warm semi-arid", AND(AEZ="tropic warm semi-arid", slope 5-15%=1),AND(AEZ="sub-tropic warm semi-arid", slope 5-15%=1), slope >15%=1,soil texture="sand"),1,0)

a. soil (fertility)

- conservation: =IF(OR(soil texture="sand", soil texture ="silt", slope >15%=1,AND(AEZ="tropic warm semi-arid",soil texture="clayey"),AND(AEZ ="sub-

tropic warm semi-arid",soil texture="clay")*AND(AEZ="tropic warm semi-arid", slope 5-15%=1)*AND(AEZ="sub-tropic warm semi-arid", slope 5-15%=1)),1,0)
- improvement: =IF(OR(soil texture="sand",soil OC<2),1,0)

a. crop/tree resistance and efficiency
- water: =IF(OR(AEZ ="tropic warm semi-arid", AEZ ="sub-tropic warm semi-arid", soil texture ="sand", slope >15%=1),1,0)
- heat: =IF(OR(AEZ ="tropic warm semi-arid", AEZ ="sub-tropic warm semi-arid", soil texture ="sand"),1,0)
- nutrient: =IF(OR(AEZ ="sub-tropic cool sub-humid", slope >15%=1,'DSS_input '!J4="sand"),1,0)
- disease: =IF(OR(AEZ ="sub-tropic cool sub-humid"),1,0)

a. Livestock resistance and efficiency
- water: =IF(OR(AEZ ="tropic warm semi-arid", AEZ ="sub-tropic warm semi-arid"),1,0)
- heat: =IF(OR(AEZ ="tropic warm semi-arid", AEZ ="sub-tropic warm semi-arid"),1,0)
- nutrient: =0
- disease: =IF(OR(AEZ="sub-tropic cool sub-humid"),1,0)

- B. Resources to manage based on physical properties and farming systems (=1)

In case the resource needs to be managed based on the farming system as well, as described in Table 3, it is assigned the value 1, but solely if the value 1 was already assigned to the resource in the previous table under bullet A. Otherwise it is assigned the value 0. The rules as implemented in Excel are as follows:

b. water (quantity)
- harvesting:=IF(AND(harvesting_old=1,OR(gardens=1,field=1,livestock,chickens=1,tree and natural=1)),1,0)
- retention: =IF(AND(harvesting_old=1,OR(gardens=1,field=1,livestock,chickens=1,tree and natural=1)),1,0)
- use efficiency: =IF(AND(harvesting_old=1,OR(gardens=1,field=1,livestock,chickens=1,tree and natural=1)),1,0)

c. soil (fertility)
- conservation:=IF(AND(harvesting_old=1,OR(gardens=1,field=1,livestock,chickens=1,tree and natural=1)),1,0)
- improvement:=IF(AND(harvesting_old=1,OR(gardens=1,field=1,livestock,chickens=1, tree and natural=1)),1,0)

b. crop/tree resistance and efficiency
- water: =IF(AND(water_old=1,OR(gardens =1, field =1, tree and natural =1)),1,0)
- heat: =IF(AND(heat_old=1,OR(gardens =1, field =1, tree and natural =1)),1,0)
- nutrient: =IF(AND(nutrient_old=1,OR(gardens =1, field =1, tree and natural =1)),1,0)
- disease: =IF(AND(disease_old=1,OR(gardens =1, field =1, tree and natural =1)),1)

b. disease: =IF(AND(water=1,OR(gardens =1, field =1, tree and natural =1)),1,0)
Livestock resistance and efficiency
- water: =IF(AND(water_old, livestock,chickens =1),1,0)
- heat: =IF(AND(heat_old, livestock,chickens =1),1,0)
- nutrient: =IF(AND(nutrient_old, livestock,chickens =1),1,0)

- disease: =IF(AND(disease_old, livestock,chickens =1),1,0)

4.5.4 **"Tab pract. vs res." sheet**

This sheet contains Table 4 of section 3.3.2, where the criteria for selecting practices based on the resources to manage and related strategies have been assigned value 1. The practices that have not been assigned value 1 are not suited to manage the specific resource.

4.5.5 **"Tab pract. vs constrains" sheet**

This sheet contains Table 5 of section 3.3.3, where the criteria for constraining the selected practices based on farmer's typology, physical environment and farming system have been assigned the value 1. The practices that have not been assigned value 1 are not constrained by the specific physical environment, the farming practices and/or the typology.

4.5.6 **"Tab score facilitator" sheet**

This sheet contains Table 6 of section 3.3.4.1, where scores, between 0 and 3, are assigned by a facilitator to each resource and per practice based on the estimated beneficial impact of the practice on the specific resource; i.e. water, soil, crop, livestock and natural. The last column of this table contains the sum of the scores per practices; the highest the score, the most beneficial the practice is on the different resources according to the facilitator.

4.5.7 **"Tab score farmers" sheet**

This sheet contains a table with the scores, 1 up to 3, assigned per practice by the farmers to 5 different themes, as described in section 3.3.4.2; i.e. labour intensity, investment, skills, farm productivity and water saving. Concerning intensity, investment and skills, the values go from 1 for high intensity to 3 for low intensity, and concerning productivity and water saving, the values go from 1 for low impact to 3 for high impact. The last column contains the sum of the scores per practice; the highest the score, the closest the practice fits the farmer's aspiration.

4.5.8 **"Example for HH1" sheet**

This sheet highlights the practices that have been selected by the DSS to manage the resources for the farming HH number 1, as suggested by the physical environment and the farming system, and not constrained by the environment, the farming system and the typology. This has been computed in 4 consecutive steps, represented by 4 consecutive tables within this sheet:

- A. Suggested practices based on physical environment and farming system (=1)

A practice is selected and gets value 1 if it can be used to manage a resource that needs to be managed based on the physical environment. By consequence this step combines sheet 'Resources to manage' and sheet 'Tab pract. vs res.'

- B. Suggested practices that are not constrained by physical environment and/or typology (=1)

Per physical environment and typology variable, the practice is assigned a value, 0 or 1, according to fact if it is constrained (=1) or not (=0) by this variable. If the sum of all values, 0 or 1, per practice is larger than 0, then the practice is assigned a value 1 (not constrained). By consequence, this step combines sheet 'DSS_input and sheet 'Tab pract. vs constrains'.

- C. Suggested practices that are not possible due to farming system (=0)

A practice is assigned a value, 0 or 1, according to fact ifit is constrained (=0) or not (=1) by this variable.

- D. Suggested practices that are not constrained by physical environment, typology and/or farming system (=1) / farming system

This table is a combination of the table under bullet point B and C. If the practice is not constrained by physical environment and typology (practice in table B with value 1) and not constrained by the farming system (practice in table C with value 1), then the practice in table D is assigned value 1, otherwise it is assigned value 0.

The rankings based on the score provided by facilitator and the ranking based on the score provided by the farmer are still in progress, since this will be tackled in the feedback step of the whole DSS process.

4.6 Case study for 26 households in South Africa

4.6.1 Description and analysis of DSS input for 26 households

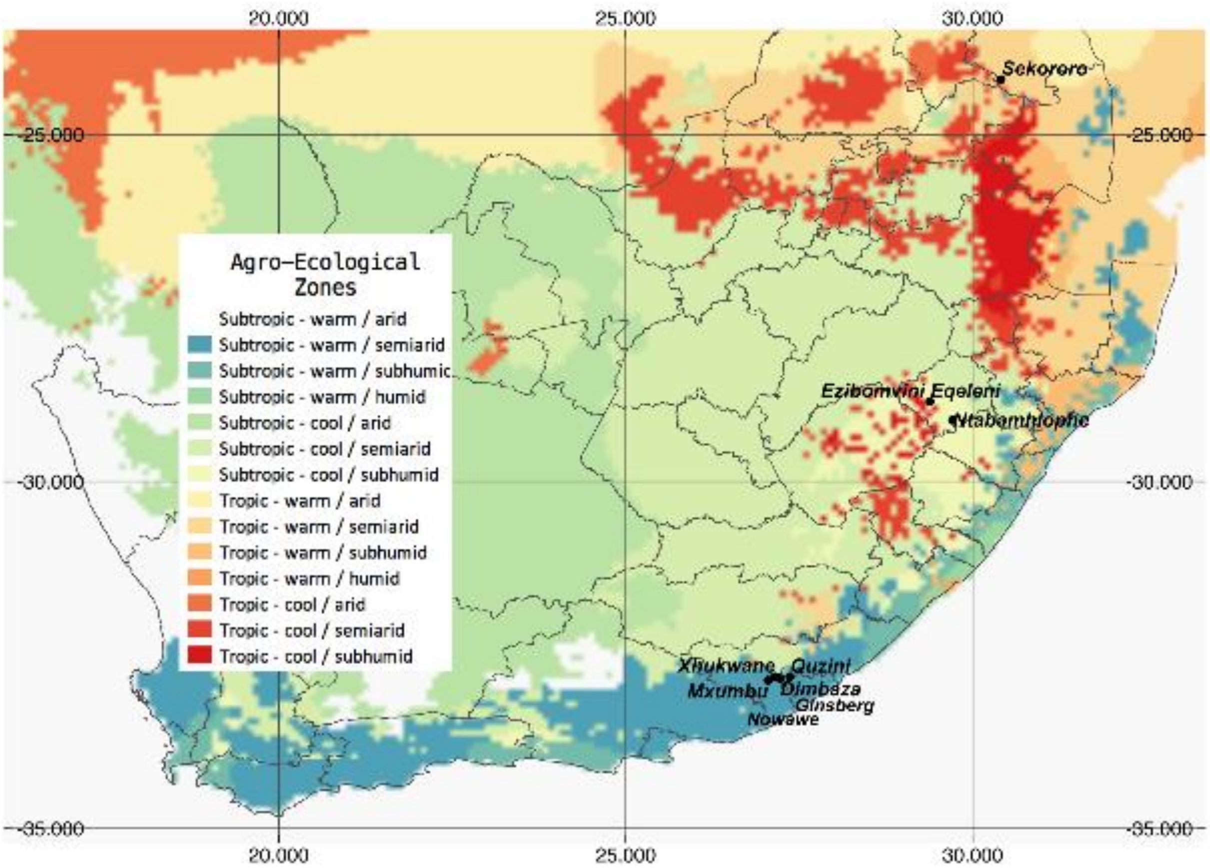


Figure 5: Location of the villages where the household surveys has been performed.

Field surveys were performed by Mahlatini Development Foundation in 26 Households (HH) located in 10 villages spread over three provinces in South Africa; (1) 6 HH are located Limpopo, in the village Sekororo, close to Tzaneen, (2) 6 HH are located in KZN, with 2 HH in Ntabamhlophe, close to Escourt, 1 in Eqeleni and 3 in Ezibomvini, both close to Bergville, and (3) 14 in Eastern Cape, with 7 HH in Mxumbu and 1 in Nowawe, both close to Alice, 2 in Dimbaza, 1 in Xhukwane, 1 in Ginsberg and 2 in Quzini, all close to King Williams Town. Those villages are provided in the map of Figure 5.

For each of the 26 HH, the physical environment data were extracted from the different available datasets, as described in section 3.2.1. The physical environment for the 26HH is provided in Table B.1 of Appendix B. According to the AEZ dataset (Sebastian, 2014; HarvestChoice, 2011), the villages around Alice and King Williams Town (Eastern Cape) are located in a sub-tropic semi-arid warm zone, the villages around Bergville and Escourt (KZN) are located in a sub-tropic sub-humid cool zone, and the villages around Tzaneen (Limpopo) are located in a tropic semi-arid warm zone (Figure 5). The slopes of the terrain are larger than 5% in 11 out of the 26HH and are located in Eastern Cape in the villages of Mxumbu, Dimbaza, Nowawe and Xhukwane.

Based on the AfSoilGrids 250m soil database (Hengl et *al.*, 2017) and the soil texture triangle, as represented in section 3.1.2.1, the soil texture at all 26 farms is classified as loamy. However according to the soil samples taken by Mahlatini Development Foundation, the soils in Sekororo (Limpopo) are sandy, those in Eqeleni, Ezibomvini (KZN) and Mxumbu (Eastern Cape) are clayey. Therefore, this has been adapted as input for the DSS. The soil organic carbon content (OC) has been extracted from the same AfSoilGrids 250m soil database. According to this database, all soils contain between 0.5% and 2% OC, except 4 HH located in Eastern Cape, in the villages of Dimbaza (2), Nowawe (1) and Xhukwane (1), where the OC is larger than 2%. According to Mahlatini Development Foundation, these values for the HH in Eastern Cape are probably too high. Since no sampling data were available for the HH in Eastern Cape, the OC values provided by the AfSoilGrids 250m soil database have been used as input for the DSS, and have not been adapted.

Based on the field surveys in the different villages, information on farming system and socio-economic background has been collected. These data for the 26 HH are provided in Table B.2 of Appendix B.

A correlation analysis has been performed between the different input datasets. This analysis shows that each province is characterised by a different AEZ, and that the soil texture and OC are significantly different between provinces, but to a lesser extent than the climate. The same is valid concerning the topography; terrain slopes also differ significantly between provinces. In addition to this, this table shows some more interesting correlations; size of the farm and farming system also relate to the provinces. None of the households in Limpopo have livestock or chickens and all of them have farms with a size less than 1ha. Most of the farming households that have fields are not into orchards, trees or use of natural resources.

4.6.2 DSS intermediate and final outputs description and analysis

(a) Typology

Based on the rules defined in Table 2 of section 3.2.3, 8 HH are classified as typology A, 8 as typology B and 10 as typology C. Table 7 provides the typology as suggested by the DSS for the 26 households. This Table has been extracted from the DSS Excel sheet "Typology". In this table, the typology of the HH is highlighted in grey and has been assigned a value 1.

no. of participant	Name & Surname	Village	Typology A	Typology B	Typology C
1	Chenne Mailula	Sekororo	0	1	0
2	Lydia Sechube	Sekororo	1	0	0
3	Xhukwane	Sekororo	0	1	0
4	Masine Morerwa	Sekororo	0	0	1
5	Mdimi Shai	Sekororo	0	1	0
6	Flora Maimela	Sekororo	1	0	0
7	Winnie Dlamini	Ntabamhlophe	0	1	0
8	Zanele Ngobese	Ntabamhlophe	0	0	1
9	Ntombakhe Zikode	Eqeleni	1	0	0
10	Nombono Dladla	Ezibomvini	1	0	0
11	Zodwa Zikode	Ezibomvini	1	0	0
12	Phumelele Hlongwane	Ezibomvini	0	1	0
13	Pheza Makisi	Mxumbu	0	0	1
14	Bongiwe Mxonywa	Mxumbu	1	0	0
15	Xolisa Dwane	Mxumbu	0	0	1
16	Mncadi Mabandla	Mxumbu	0	0	1
17	Mandisa Mama	Mxumbu	0	0	1
18	Siyabulela Gungqceni	Mxumbu	0	1	0
19	Thangolomuzi Hogana	Mxumbu	0	0	1
20	Aviwe Biko	Dimbaza	1	0	0
21	Jack Mphangeli	Nowawe	1	0	0
22	Jende Monwabisi	Xhukwane	0	1	0
23	Tshembela Nadathini	Dimbaza	0	0	1
24	Parichi Edmore	Ginsberg	0	1	0
25	Msisiwe Phindiwe	Quzini	0	0	1
26	Nomasomi Mjacu	Quzini	0	0	1

Table 7: Typology of 26 households as assigned by the DSS.

The statistical analysis of the input dataset, as described in previous section 4.1, and the typology of each farming HH, as provided in Table 7, shows that the typology is significantly related to the gender of the HH-head, the total HH income, the access or not to tap water, the access or not to formal markets and the size of the farm. 75% of the typology A HH have a female household head, have no access to tap water and have an income lower than R2000. Concerning typology B, only the gender relates significantly; all HH heads are males. Concerning typology C, 63% of the HH tend to have an income higher than R5000, 90% have access to tap-water, 90% have access to formal markets and 70% have a farm larger than 2ha. The other input variables were not significant at p=0.05.

(b) Resources to manage

Based on the rules defined in Table 3 of section of 3.3.1, the DSS suggests the resources to manage by the 26 farming households. These resources and the potential strategies are provided in Table 8 for the 26 farming households. This Table is based on the output provided in the DSS Excel sheet "Resources to manage". In this table, the resources to manage by the HH are highlighted in grey and have been assigned a value 1.

		B. Resources to manage based on physical properties and farming systems (=1)												
		Physical properties + farming system												
		Resources and management strategies												
		water (quantity)			soil (fertility)		p/tree resistance and efficie				estock resistance and efficie			
no. of participant	Name & Surname	harvesting	retention	use efficiency	conservation	improvement	water	Heat	nutrient	disease	water	heat	nutrient	disease
1	Chenne Mailula	1	1	1	1	1	1	1	1	0	0	0	0	0
2	Lydia Sechube	1	1	1	1	1	1	1	1	0	0	0	0	0
3	Dimakatso Thobejane	1	1	1	1	1	1	1	1	0	0	0	0	0
4	Masine Morerwa	1	1	1	1	1	1	1	1	0	0	0	0	0
5	Mdimi Shai	1	1	1	1	1	1	1	1	0	0	0	0	0
6	Flora Maimela	1	1	1	1	1	1	1	1	0	0	0	0	0
7	Winnie Dlamini	0	0	0	0	0	0	0	1	1	0	0	0	1
8	Zanele Ngobese	0	0	0	0	0	0	0	1	1	0	0	0	1
9	Ntombakhe Zikode	0	0	0	0	1	0	0	1	1	0	0	0	1
10	Nombono Dladla	0	0	0	0	1	0	0	1	1	0	0	0	1
11	Zodwa Zikode	0	0	0	0	1	0	0	1	1	0	0	0	1
12	Phumelele Hlongwane	0	0	0	0	1	0	0	1	1	0	0	0	1
13	Pheza Makisi	1	1	1	1	1	1	1	1	0	0	0	0	0
14	Bongiwe Mxonywa	1	1	1	1	1	1	1	1	0	1	1	0	0
15	Xolisa Dwane	1	1	1	1	1	1	1	1	0	1	1	0	0
16	Mncadi Mabandla	1	1	1	1	1	1	1	1	0	1	1	0	0
17	Mandisa Mama	1	1	1	1	1	1	1	1	0	1	1	0	0
18	Siyabulela Gungqceni	1	1	1	1	1	1	1	1	0	1	1	0	0
19	Thangolomuzi Hogana	1	1	1	1	1	1	1	1	0	1	1	0	0
20	Aviwe Biko	1	1	1	1	0	1	1	1	0	1	1	0	0
21	Jack Mphangeli	1	1	1	1	0	1	1	1	0	1	1	0	0
22	Jende Monwabisi	1	1	1	1	0	1	1	1	0	1	1	0	0
23	Tshembela Nadathini	1	1	1	1	0	1	1	1	0	1	1	0	0
24	Parichi Edmore	1	1	1	0	1	1	1	0	0	1	1	0	0
25	Msisiwe Phindiwe	1	1	1	0	1	1	1	0	0	1	1	0	0
26	Nomasomi Mjacu	1	1	1	0	1	1	1	0	0	1	1	0	0

Table 8: Resources to manage on the 26 farms according to the DSS, based on the physical environment and the farming system.

This Table 8 shows significant differences in resources to manage between villages and between the management strategies. This is also supported by the statistical analysis performed on the input dataset, as described in section 4.1, and the suggested resources to manage by each farming HH, as provided in Table 8. This analysis shows that water needs to be managed in all villages except those located in KZN where the climate is more humid (tropic sub-humid cool). Concerning the soil, conservation practices, these are mainly suggested on the poorly structured soils, the sandier soils located in the Limpopo province. The soil fertility is suggested to be improved on all farms except those with slightly higher organic matter; i.e. 2 HH is KZN and 4 HH in Eastern Cape. Concerning resistance and efficiency of crop and livestock, water and heat are suggested to be tackled at all farms, except those located in the cooler and more humid KZN. In this province however, diseases are suggested to be managed since more humid climate favours disease development. There is no need to manage resistance and efficiency of livestock and chicken in the 6 farms in Limpopo since this farming system is not represented here. A more efficient uptake of nutrients by crop is suggested everywhere, except on 3 farms in Eastern Cape, where nutrient leaching or run off are minimised. Currently the management of livestock nutrient efficiency has not yet been defined in the DSS.

(c) Suggested practices based on the resources to manage

Based on the rules defined in Table 5 of section 3.3.2 and on the physical environment as well as the farming system, the DSS suggests practices that could be used by the 26 farming households to manage the resources. These suggested practices, highlighted in light and dark grey, are provided in Table 9 for the 26 farming households. This Table is based on the output provided in the DSS Excel sheet “Output for HHx”

(d) Suggested practices constrained by farmer typology, farming system and or physical environment

Based on the rules defined in Table 4 of section 3.3.3, the physical environment, farming system, and typology constrain the number of suggested practices. The practices suggested in previous section that are not constrained are highlighted in dark grey in Table 9 for the 26 farming households. This Table is based on the output provided in the DSS Excel sheet “Output for HHx”

The analysis of Table 9 shows that some practices are suggested for all 26HH, based on the resources to manage (light and dark grey); i.e.:

- Shade cloth tunnels
- Mulching
- Improved organic matter
- Targeted application of small quantities of fertilizer, lime etc
- Liquid manures
- Woody hedgerows for browse, mulch, green manure, soil conservation
- Conservation Agriculture
- Planting legumes, manure, green manures
- Mixed cropping
- Planting herbs and multifunctional plants
- Agroforestry
- Trench beds/ eco-circles
- Integrated weed management
- Breeding improved varieties
- Seed production / saving / storing
- Crop rotation

- Tower garden
- Keyhole beds

But only four of these are finally selected since not constrained by the physical environment, farming system or farmers typology; i.e

- Improved organic matter
- Integrated weed management
- Breeding improved varieties
- Seed production / saving / storing

Crop rotation is solely constrained in 1 out of the 26 cases due to the fact that the farming HH had no garden or field.

In opposite to this, some practices seemed to be unsuitable in all 26 cases:

- Drip irrigation
- Bucket drip kits
- Furrows and ridges/ furrow irrigation
- Shade cloth tunnels
- Small dams
- Contours; ploughing and planting
- Stone bunds
- Terraces
- Trench beds/ eco-circles

no. of participant	Name & Surname	Village	Drip irrigation	Bucket drip kits	Furrows and ridges/ furrow irrigation	Greywater management	Shade cloth tunnels	Mulching	Improved organic matter (manure and crop	Diversion ditches	Grass water ways	Infiltration pits / banana circles	Zai pits	Rain water harvesting storage	Tied ridges	Half moon basins	Small dams	Contours; ploughing and planting	Gabions	Stone bunds	Check dams	Cut off drains / swales	Terraces	Stone packs	Strip cropping	Pitting	Woodlots for soil reclamation	Targeted application of small quantities of f	Liquid manures	Woody hedgerows for browse, mulch, gree	Conservation Agriculture	Planting legumes, manure, green manures	Mixed cropping	Planting herbs and multifunctional plants	Agroforestry (trees + agriculture)	Trench beds/ ecocircles	push-pull technology	Natural pest and disease control	Integrated weed management	Breeding improved varieties (early maturing	Seed production / saving / storing	Crop rotation	Stall feeding and haymaking	Creep feeding and supplementation	Rotational grazing	Debushing and oversowing	Rangeland reinforcement	Bioturbation	Tower garden	Keyhole beds
1	Chenne Mailula	Sekororo																																																
2	Lydia Sechube	Sekororo																																																
3	Xhukwane	Sekororo																																																
4	Masine Morerwa	Sekororo																																																
5	Mdimi Shai	Sekororo																																																
6	Flora Maimela	Sekororo																																																
7	Winnie Dlamini	Ntabamhlophe																																																
8	Zanele Ngobese	Ntabamhlophe																																																
9	Ntombakhe Zikode	Eqeleni																																																
10	Nombono Dladla	Ezibomvini																																																
11	Zodwa Zikode	Ezibomvini																																																
12	Phumelele Hlongwane	Ezibomvini																																																
13	Pheza Makisi	Mxumbu																																																
14	Bongiwe Mxonywa	Mxumbu																																																
15	Xolisa Dwane	Mxumbu																																																
16	Mncadi Mabandla	Mxumbu																																																
17	Mandisa Mama	Mxumbu																																																
18	Siyabulela Gungqceni	Mxumbu																																																
19	Thangolomuzi Hogana	Mxumbu																																																
20	Aviwe Biko	Dimbaza																																																
21	Jack Mphangeli	Nowawe																																																
22	Jende Monwabisi	Xhukwane																																																
23	Tshembela Nadathini	Dimbaza																																																
24	Parichi Edmore	Ginsberg																																																
25	Msisiwe Phindiwe	Quzini																																																
26	Nomasomi Mjacu	Quzini																																																

Table 9: All suggested practices based on physical environment and farming system are highlighted in light and dark grey and those that are not constrained by the typology, farming system or physical environment are highlighted in dark grey.

(e) Ranking of suggested practices based on score provided by facilitator and farmer.

Based on scores provided by the facilitator and the farmer as defined in section 3.3.4, the practices highlighted in dark grey in Table 9, can be ordered by preferences. In Table 10 a ranking, based on facilitator's scores, is provided for the farming HH 'Mdimi Shai' located in Sekororo, Limpopo. According to the facilitator, improving organic matter and pitting are the most appropriate practices suggested by the DSS for this HH, which is only farming trees and natural resources, regarding the impact on the resources to manage.

Practices	Field cropping	gardening vegetable	Livestock	nat. resources Tree and other
Improved organic matter (manure and crop residues)	0	0	0	11
Pitting	0	0	0	11
Rain water harvesting storage	0	0	0	9
Bioturbation	0	0	0	9
Integrated weed management	0	0	0	7
Breeding improved varieties (early maturing, drought tolerant, improved nutrients),	0	0	0	7
Seed production / saving / storing	0	0	0	6

Table 10: Ranking of suggested practices, based on the scores provided by a facilitator, for farming HH Mdimi Shai located in Sekororo, Limpopo.

4.7 Conclusion, further work and limitations of the DSS

In this report, the conceptual framework of the DSS, including inputs, processes and output has been introduced. The implementation of the conceptual DSS into Excel has been described, and the DDS has been run for 26 farming households, based on input data from state-of-the art studies and on the results of the field survey. The 26HH are located in 3 different provinces in South Africa; i.e. Limpopo, KZN and Eastern Cape. The soil texture input data taken from the AfSoilGrids 250m soil database seemed to be too generic and not appropriate to the scale of the farming systems and has therefore been adapted with the information provided from the soil samples taken by Mahlathini Development Foundation.

At a first glance the practices suggested by the DSS are shown to be sensitive to the physical environment, the farming system and the farmers socio-economic background. The DSS has however not yet gone through an in-depth evaluation. Therefore, in a next step, it is suggested to perform sensitivity analyses and to validate the output of the DSS against observations. The practices suggested by the DSS need now also to be discussed with farmers and facilitators. Based on their feedback, tables with ranking of practices will be built. In addition, the DSS will go through a reiteration process and might need in depth adaptations. This might for example be the case of the different rules provided in Tables 3-5 on resources to manage and the suggested practices. For example, in south Africa, water is very scarce and therefore it might be more appropriate to suggest to manage water resources under all conditions and not only in semi-arid climate, or on sandy soils, or on undulating up to very steep slopes.

The list of management practices needs to be extended, as well as the descriptions in Appendix A. In addition, some practices might need to be split-up in sub-categories; eg. into "constructed" and "dug" since both differ in requirements.

Finally, the next step is to access the data concerning future climate, and in particular the geographical spread of the AEZ according to future projects, and run the DSS using this dataset, and evaluate the impact on the suggested practices.

4.8 Appendix A: Benefits and requirements for management practices

- *Drip irrigation*: reduces water use; 30-50% less than conventional watering methods such as sprinklers. Smaller amounts of water are applied locally over a longer amount of time provide ideal growing conditions and reduces leaching. Appropriate for most agro-ecological zones and most soil types- although very sandy soils and heavy clays need additional management support
- *Bucket drip kits*: In bucket kit drip irrigation, water flows into the drip lines from a bucket reservoir placed 0.5–1 m above the ground to provide the required water pressure. It is fitted for gardens less than 0.1ha. It requires medium cost, skills and labour, with easy maintenance. Appropriate for most agro-ecological zones and most soil types- although very sandy soils and heavy clays need additional management support
- *Furrows and ridges:* A bed design techniques appropriate for gardens and fields (0,1-2ha), designed on contour to manage flow of water – which is a form of furrow irrigation. Assists in efficient use of water and soil conservation. Crops are planted on the tops or sides of the ridges - requires additional management such as mulching and improved organic matter to be effective- especially in more arid, hot climates with sandier soils, as well as heavy clay soils. It requires temperatures above 5°C, precipitation rate above 150mm/year and slopes less than 5%.
- *Furrow irrigation*: reduces water use and protects soil from erosion. It includes lower initial investment of equipment and lower pumping costs as it relies on gravity assisted water flow in the furrows. Disadvantages include greater labour costs and lower application efficiency compared to sprinkler and subsurface drip irrigation. It is suitable for gardens and fields up to 2ha. It requires temperatures above 5°C, precipitation rate above 150mm/year and slopes of less than 5%. It is not appropriate in very sandy soils or very well drained soils as the soil dries out too fast.
- *Greywater irrigation*: reduces the use of freshwater and the amount of wastewater. Greywater contains nutrients, such as nitrogen and phosphorus, that can be beneficial to plant growth, which would otherwise be wasted. It is fitted for small areas, but not on slopes.
- *Shade cloth tunnel*: reduces heat and by consequence evapotranspiration, as well as pest incidence. It is fitted for gardens less than 0.1ha. It requires medium cost, skills and low maintenance. It helps reduce stress in plants due to weather variability, increases efficiency of water use and assists in soil conservation. As the assumption is that irrigation is available it is suited to most agro-ecological zones, with different heat and rainfall options as well as most soil types.
- *Mulching*: Reduces water use as it protects the soil from evaporation. Provides valuable nutrients as the mulch breaks down and thereby improve the soil's texture and protects soil from erosion. Encourages worms, which aerate the soil and provide fertiliser in the form of

worm castings. Reduces the number of weeds by inhibiting the germination of weed seeds. It is fitted for gardens less than 0.1ha. It requires low cost and skills but is labour intensive. Temperatures need to be higher than 5°C and precipitation rate above 150mm/year. Mulching can be problematic on steep slopes as it washes and blows away. Only local resources are required to implement this practice.

- *Manure and crop residues*: improve soil structure, increase organic matter content in the soil, reduce evaporation, reduces soil borne diseases, keep soil cooler and help fix CO_2 in the soil. They enhance the water holding capacity of sandy soils, while it improves the drainage of clayey soils.
- *Diversion ditches*: are constructed along the contour lines and across slopes for the purpose of intercepting surface runoff and diverting it to suitable outlets or for rain water harvesting. It is fitted for gardens and fields up to 1ha. It requires low cost, skills and maintenance but is labour intensive. Temperatures need to be higher than 5°C and precipitation rate above 150mm/year. The slopes cannot be steeper than 10% and the soil should be relatively stable. Only local resources are required.
- *Grass water ways*: carry large flows, making it suited to safely carry runoff from large upstream watersheds and divert it to suitable outlets or for rain water harvesting. Once vegetation is established, maintenance is low. However, working around the waterway with farm equipment can be difficult. It is only implemented in the context of field cropping and not at the smaller scale of gardening.
- *Infiltration pits* (with e.g. banana): this practice includes placing organic matter in the pits. It collects runoff which is stored in the infiltration pit and improves water retention by allowing water to infiltrate slowly. This technique is appropriate for small-scale tree planting in any area which has a moisture deficit. Besides harvesting water for the trees, it simultaneously conserves soil. They are relatively easy to construct and well suited for hand construction. Once the trees are planted, it is not possible to operate and cultivate with machines between the tree lines. It is fitted for gardens less than 0.1ha. It requires low cost and skills but is labour intensive. Temperatures need to be higher than 5°C and precipitation rate above 150mm/year. The slopes need to be less than 30% but there is no soil type restriction. Only local resources are required.
- *Zai pits (planting pits)*: improve infiltration of the captured runoff. The holes are deepened each winter. Improvements in the traditional pits by the addition of fertilizer and organic matter (compost) have resulted in dramatic improvements in yield. The pits are easy to manage. It is designed to be implemented in field cropping where slopes are <10%.
- *Rain water harvesting storage*: Different storage options are possible. Underground tanks collect runoff water. It requires high cost and skills, intensive labour but medium maintenance. Temperatures need to be higher than 5°C and precipitation rate above 450mm/year. The slopes need to be less than 30% but there is no soil type restriction.
- *Tied ridges*: collects rainfall from an unplanted sloping basin and catching it with a furrow and ridge. Tied ridges assist in soil conservation and water infiltration. Planting takes place on either side of the furrow where the water has infiltrated. It requires low cost but intensive labour. Temperatures need to be higher than 5°C. The slopes need to be less than 7% and the soil should be relatively stable. Suitable for areas between 0,1-1ha.
- *Half-moon basins*: small semi-circular earth bunds for catching water flowing down a slope. These are usually constructed for planting of trees in a natural landscape. No suitable for gardens as the basins need to be quite large to intercept runoff coming downslope. Suitable for areas with rainfall >450m per year. Soils need to be stable and not too sandy

- *Small dams*: can be dug in soils that can hold water – they tend to lose water and only stay full for a short period – but provide a lot of water to the soil profile in the area. Usually they are dug in places where small springs can fill them up on a continuous basis. It requires low cost and skills but requires intensive labour. Temperatures need to be higher than 5°C. It is suitable for gardens up to 1ha. The soil should be relatively stable and slopes between 5-15%
- *Contours ploughing and planting*: creates a water break which reduces erosion by ploughing and/or planting across a slope following its elevation contour lines. The water break also allows more time for the water to settle into the soil. This method is suggested when slopes are between 5-15%. Suitable for areas between0,1-2ha.
- *Gabions*: is a cage, cylinder, or box filled with rocks, concrete, or sometimes sand and soil used for erosion control. Gabions are expensive, labour intensive and require skill, so not really implementable on small scale. They are used for erosion control ins natural landscapes where high levels of water erosion occur.
- *Stone bunds*: are used along contour lines to slow down, filter and spread out runoff water, thus increasing infiltration and reducing soil erosion. It requires stones of different sizes. It is of low cost and skills but requires intensive labour. Temperatures need to be higher than 5°C and precipitation rate above 150mm/year. It is suitable for fields and gardens of all sizes. The soil can be of any type, but stones are required, which is often not the case in sandy soils. The slopes need to be between 5-15%.
- *Check dams*: are small, sometimes temporary dams constructed across a drainage ditch, or waterway to counteract erosion by reducing water flow velocity and allowing sedimentation of silt. It requires low cost and skills but requires intensive labour. Temperatures need to be higher than 5°C and precipitation rate above 150mm/year. It suitable for fields and garden of all sizes. The soil can be of any type. This method is suggested when slopes are > 2.5% but < 25%.
- *Swale/ cut off drain*: is an earth bank constructed along the contour with a furrow on the up-slope side. The top of the earth bank is levelled off to allow planting. The swale intercepts runoff, spreads it out and helps it infiltrate deep into the ground. It requires low cost and skills but requires intensive labour. Temperatures need to be higher than 5°C and precipitation rates above 150mm/year but less than 1200mm/year. It suitable for fields and garden of all sizes. The soil can be of any type but not too clayey or sandy. This method is suggested when slopes are > 5% but < 25%.
- *Terrace*: is a level strip of soil built along the contour of a slope and supported by an earth or stone bund, or rows of old tyres. A series of terraces creates a step-like effect which slows down runoff, increases the infiltration of water into the soil, and helps control soil erosion. It requires low cost but requires intensive labour. Temperatures need to be higher than 5°C and precipitation rate above 350mm/year. It suitable for fields and garden of all sizes. The soil can be of any type. This method is suggested when slopes are > 10% but < 40%.
- *Stone packs*: are built on contour across erosion ditches and gulleys, to slow down water flow, improve infiltration of water and promote sedimentation. They are suitable for fields and gardens of all sizes and but used primarily in a natural landscape as an erosion control measure
- *Strip cropping*: This is a technique used in field cropping (any size field) where strips of natural vegetation (on contour) are left in between the areas of planting to prevent erosion and improve water infiltration. The width of the strips and planting areas depend on the slope. Generally

slopes of 5-30% are acceptable. The technique is possible in all soil types, with a rainfall of >450mmm per year.

- *Pitting:* it is used to rehabilitate denuded areas, where hard pans have developed and is primarily a method for rehabilitation of natural landscapes- not used in gardening or field cropping situations.
- *Mixed woodlots:* are established to reduce erosion and increase soil fertility in landscapes where erosion is occurring. Trees provide soil cover and stabilise the soil. Depending on tree species, it can improve water retention. It is not implemented in a gardening or field cropping context. It needs a minimum of around 350mm rainfall and it is not appropriate to very sandy soils.
- *Trees:* Planted for fodder, honey production, timber, shade, fruit, medicinal purposes, erosion control and soil fertility. It is implemented in a gardening or field cropping context. It needs a minimum of around 350mm rainfall and is appropriate to all soil types- given the assumption of irrigation for establishment.
- *Windbreaks:* Bushes and trees are planted in banks across the line of the major destructive winds in the area (either cold or hot)to protected planted crops in gardens, fields and orchards. It needs a minimum of around 350mm rainfall and is appropriate to all soil types- given the assumption of irrigation for establishment.
- *Targeted application of fertilizer and lime*: fertilizers are added according to soil fertility recommendations, targeted next to growing plants rather than spreading or banding. Lime can be added to reduce soil acidification and maintain low acid saturation. It requires medium cost and intensive labour. Temperatures need to be higher than 5°C and precipitation rate should be above 450mm/year. It suitable for fields of all sizes. It is not well suited to sandy soils. This method is suggested when slopes are < 10%.
- *Liquid manure*: fermented manure or green waste diluted in water to fertilise gardens. It provides water, nutrients and some protection against pests and diseases. It requires low cost and labour. It is only suited for small areas such as gardens.
- *Woody hedgerows*: can be used for browse, mulch, green manure, soil conservation, etc. It requires a minimum of 350mm rainfall. It is not suited for very sandy soils, and small areas such as gardens.
- *Conservation agriculture*: comprises (1) minimal soil disturbance- no ploughing, (2) soil cover – through stover, mulches and cropping cycles, and (3) diversification; intercropping, relay cropping, cover crops (legume- brassicas and grain mixtures). It also provides fodder for cattle. It requires medium cost and intensive labour. Temperatures need to be higher than 5°C and precipitation rate above 350mm/year. It suitable for fields and gardens of all sizes. The soil can be of any type, but is difficult to implement on soils with low soil organic carbon content. This method is suggested when slopes are < 15%.
- *Planting legumes (e.g. during fallow*): crop rotation, intercropping relay cropping and fallow cropping with legumes (either annuals or perennials) assist in building and maintaining soil fertility and soil health. Crops can be worked into the soil as green manure, slashed and left as soil cover, or harvested for fodder and food depending on the situation. Since legumes fix their own nitrogen from the atmosphere, green manuring can maintain or improve soil fertility without direct costs for fertilizer. It improves soil structure, supresses weeds, control pest and lets the soil rest. It requires medium cost and it is easy do. It suitable for fields and garden of all

sizes. The soil can be of any type but is difficult to implement on soils with very low soil organic carbon content. The precipitation rate needs to be above 350mm/year

- *Mixed cropping/intercropping*: promotes soil organic matter build up, improves soil fertility and balanced use and provision of nutrients, soil structure and soil health, reduces prevalence and types of weeds, and helps to manage the pests and disease incidence and severity. It requires low cost and it is easy do. It is suitable for fields and garden of all sizes. The soil can be of any type but is difficult to implement on soils with very low soil organic carbon content. The precipitation rate needs to be above 350mm/year.
- *Crop diversification:* In all contexts; gardens, fields and livestock (including alternative fodder crops) and orchards, increase the variety of crops planted to ensure a range of options for nutrient uptake, drought and heat tolerance, early and late maturing and continuity in food production. Focus to be on open pollinated and heirloom varieties to ensure seed saving options. Varieties are chosen to suit local agroecology, weather and soil conditions and thus suitable for all areas
- *Planting herbs/ multifunctional plants*: Mixed cropping with herbs and multifunctional plants for culinary and medicinal purposes and also to control pests and diseases in the garden/ field. It requires medium cost and it is easy do. It suitable for fields and garden of all sizes. The soil can be of any type but is difficult to implement on soils with low soil organic carbon content. The precipitation rate needs to be above 350mm/year.
- *Agroforestry*: Trees, mostly fodder species, are mixed into the farming system either as fallows, monocrops or between annual crops (usually as strip cropping in rows). It requires medium cost and intensive labour and knowledge. Temperatures need to be higher than 5°C and precipitation rate above 350mm/year. It is suitable for fields and garden of all sizes. The soil can be of any type but is difficult to implement on soils with very low soil organic carbon content. This method is suggested when slopes are < 15%. It maximises benefits per unit area. It can improve soil fertility and water holding capacity. The trees can provide fodder, fruit, timber and shade for animals. It can help to reduce erosion by water and wind.
- *Trench beds/ eco-circles*: is a way to increase soil fertility and water holding capacity. It reduces heat, and improves the management of soil borne diseases. It is an intensive way of providing good soil for vegetables production on a small scale. It involves digging a hole and filling it with organic matter, so that your bed can be fertile for a long time. It requires low cost but intensive labour. Temperatures need to be higher than 5°C. It is suitable for smaller garden. The soil can be of any type. This method is suggested when slopes are between 5-15%. Irrigation is assumed.
- *Push- pull technique*: is a strategy for controlling agricultural pests by using repellent "push" plants and trap "pull" plants. It requires knowledge and the correct varieties of plants to provide the trap and the lure. The soil can be of any type but is difficult to implement on soils with low soil organic carbon content. The precipitation rate needs to be above 350mm/year. It is suitable for field cropping of any size and as such is best suited for slopes between 5-15%
- *Natural pest and disease control*: by mixed cropping, multi-functional plants, good soil fertility management, pest replant plants, predator attractant plants, and brews. It requires low cost but medium intensive labour and is knowledge intensive. It suitable for small gardens and fields up to 1ha. The soil can be of any type.
- *Integrated weed management*: includes a number of different practices- such as soil health (structure, fertility), landscape management (e.g. close spacing of crops to shade out weeds), cultivation, mechanical and chemical control measures. It requires low cost but medium intensive

labour and is knowledge intensive. The soil can be of any type. It is suitable for gardens and fields of any size. The precipitation rate needs to be above 350mm/year

- *Breeding improved varieties:* using varieties that are better suited to drought, heat, short growing seasons, more efficient uptake of nutrients, etc. It is suitable for gardens and fields of any size, in climates that can sustain plant growth. Actual breeding of plant varieties is not generally within the ambit of smallholder farmers. They can however experiment with and adapt varieties to their situations
- *Seed saving/production/storage*: of open pollinated or heirloom varieties (not hybrids), that are locally adapted to climate, pests and diseases. They are genetically diverse. It requires low cost but is labour and knowledge intensive.
- *Crop rotation*: helps to break disease cycles and improve soil health, fertility and structure. It can alleviate the negative factors of monoculture cropping systems. It helps with water and nutrient use efficiency as different crops use water and nutrients in different ways. Overall financial risks are more widely distributed over more diverse production of crops. It requires low cost but is labour and knowledge intensive. It is suitable for gardens and field cropping of any size.
- *Stall feeding and hay making*: Improving livestock productivity in the area will require strategies that support forage production and conservation to enhance year-round fodder availability. Problems in haymaking vary according to the crop, climate and prevailing weather at harvest: under sub-humid and humid temperate conditions, the main problems are related to slowness of drying, so, to avoid loss by spoilage, the aim is to dry the crop or grass as quickly as conditions will allow. Typology A is unlikely to have access to livestock, or areas to make hay.
- *Supplementation and protein licks*: is a livestock management practice used to provide animals with those nutrients that the pastures lack. It requires medium cost but is labour and knowledge intensive.
- *Rotational grazing and resting of veld*: To retain the productivity of grasslands it is necessary to rest a portion of the grazing area for a full growing season. This allows the grass plants to store nutrients in their root systems and make the grasses more nutritious. It is important to work with livestock owners to work together to develop a rotational resting system. It requires medium cost but is labour and knowledge intensive.
- *De-bushing and over-sowing:* Bush encroachment is a major problem for livestock. This practice can help to increase food availability for cattle, by reducing erosion, increasing soil fertility and having a general beneficial effect on livestock health - due to reduced load of parasites etc. Woody vegetation can be removed mechanically or chemically. The cleared areas can be over-sowed with pasture grass. It requires medium cost but is labour and knowledge intensive.
- *Rangeland reinforcement*: entails the sowing of improved grass and legume species into native pasture to improve rangeland productivity.
- *Bioturbation*: is defined as the reworking of soils and sediments by animals or plants. These include burrowing, ingestion and defecation of sediment grains. Bioturbating activities have a profound effect on the environment and are thought to be a primary driver of biodiversity. In agriculture this can be achieved primarily through the use of tree species and working with earthworms. In this context it can also be hoof trampling in veld situations that allow nutrient and water infiltration and cycling.

- *Poultry production options*: Broilers, layer and traditional poultry management options for small-scale implementation including production and processing of local feed, housing, health and system integration; Mostly for farmers in typologies A and B, appropriate to all areas
- *Tower gardens*: are built up from the ground by using four poles and wrapping a tube of 80% shade cloth around these poles. The bed is filled in with a pre-prepared mixture of soil, manure, and ash. Small holes are made in the side of the bag and seedlings are planted vertically into holes. The top of the bed can be used for planting other crops. It requires low cost and skills. It suitable for small gardens and is designed for use of greywater.
- *Keyhole beds*: are intensive built-up beds with a central compost basket/column for watering and greywater application. It requires low cost and skills. It suitable for small gardens and is designed for use of greywater.

4.9 References

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5 QUANTITATIVE MEASUREMENTS FOR MONITORING IMPACT

Initial site selection for the 2018 period is shown below (as reported in Deliverable 3)

Province	Site 1	Site 2
KZN	Bergville: Eibomvini, Thamela (Mahlathini, GrainSA)	Estcourt: Thabamhlophe (Lima, Mahlathini)
Limpopo	Hoedspruit: Sedawa, Turkey (Mahlathini, AWARD)	Tzaneen: Sekororo (Lima, Mahlathini)
EC	Fort Cox: Imvutho Buboni Learning Network (Amanzi for Food, Mahlathini)	

The table below outlines the sites selected for both dry land farming and vegetable gardening farmer level experimentation in KZN and Limpopo. Conservation Agriculture (CA) plots in KZN were planted in the last week of November while the ones in Limpopo were planted in early to mid- December 2017. The results for the experimentation process in Limpopo were report on the in Deliverable 5

Table 14: Participants in quantitative measurements for trials; KZN and Limpopo

Province	Category	Name of participants	Name of village	Date of planting
Limpopo	Field cropping	Koko Maphori	Sedawa	05/12/2017
		Moruti Sekgobela	Mametja	06/12/2017
		Mariam Malepe	Botshabelo	07/12/2017
	Gardening	Christinah Tobetjane	Sedawa	April-Aug 2018
		Norah Malepe	Mametja	April-Aug 2018
		Mariam Malepe	Botshabelo	April -Aug 2018
KwaZulu-Natal	Field cropping	Ntombake Zikode	Eqeleni	20-24 Nov 2017
		Phumelele Hlongwane	Ezimbomzini	20-24 Nov 2017

		Phumzile Zimba	Mhlwazini	20-24 Nov 2017
	Gardening	Smephi Hlatswayo	Eqeleni	June-Sept 2018
		Phumelele Hlongwane	Ezibomvini	June-Sept 2018

Table 15: Measurements taken for the gardening trials

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

Table 16: Measurements taken for the field cropping trials

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

5.1 Measurements report Bergville (KZN)

5.1.1 Visual/ Qualitative Assessments

Written by Nonkanyiso Zondi and Erna Kruger

This methodology has been tried each year in the Bergville area, as a potential peer review system for assessing soil quality. Below is the scoring sheet that has been designed for this assessment. This assessment has been altered slightly in terms of indicators used when compared to similar processes employed[1][2], to accommodate for tests that are seen to be very similar in the original forms. An example is surface ponding and infiltration, which in our version has been changed to infiltration only.

Table 17: VSA Indicator sheet

Visual indicator of Soil Quality	Visual Score (VS)	Weight	Comments
Soil Structure (aggregates)	0 = Poor conditions 1 = Moderate conditions 2 = Good conditions	× 3	Shatter test and assessment of clods for distribution of aggregated 0=many large clods, few smaller ones, 1=equal proportions of large and finer aggregates, 2= larger proportion of friable soil and fine aggregated
Soil porosity		× 3	0=hard compact clods, 1= breakable clods, 2= easily breakable with organic matter and some roots
Soil colour and organic matter		× 2	Here the organic matter is what counts. 0=none,1=little, 2=Some to lots
Number and colour of soil mottles		× 1	0= many mottles, 1=some mottles, 2= no mottles
Earthworm counts		× 2	As per manual
Soil cover (residue cover)		× 2	As per manual
Soil depth (presence of a tillage pan), depth of rod into soil		× 2	0=0-10cm, 1=10-15cm, 2=>15cm
Run-off		× 2	As per manual
Infiltration (surface ponding)		x 2	0= evidence of ponding (yellowing plants, standing water after rain), 1= some ponding (water takes a while to infiltrate) 2=no ponding
TOTAL		**37**	

VSAs were conducted for 13 of the longer- term participants this season. Soil from the CA trial plots were compared with the control plots. As is the case with a number of other indicators, the value of comparing trials and controls has been minimised due to the fact that all these participants started using CA in their control plots as well. There are however still marked differences in crop diversification between the trial and control plots, as all participants plant only maize in their controls.
Below is a summary table for the soil-based indicators of the VSAs for the 13 participants.

[1] Sheperd G. 2010. Visual Soil Assessment Field Guide: Part 1: Maize. FAO, Rome
[2] Sheperd G, Bailey J, Johnson P. 2012. Visual Soil Assessment. SMI and Vaderstad. New Zealand.

Table 18: Visual Soil Assessments for 4th and 5th year CA participants in Bergville:2017-2018

May-18																										
Visual soil Indicators	Stulwane												Eqeleni										Ezibomvini			
NAME OF PARTICIPANT	K Dladla(T)	K Dladla(C)	D Hlongwane(T)	D Hlongwane(C)	T Dlamini (T)	T Dlamini (C)	M Dladla(T)	M Dladla(C)	C Buthelezi(T)	C Buthelezi(C)	P Sthebe(T)	P Sthebe(C)	ThZikode (T)	ThZikode (C)	T Zikode (T)	T Zikode (C)	T Mabaso (T)	T Mabaso (C)	N Zikode (T)	N Zikode (C)	S Hlatshwayo (T)	S Hlatshwayo (C)	C Hlongwane (T)	C Hlongwane (C)	P Hlongwane (T)	P Hlongwane (C)
SOIL TEXTURE	6	6	6	6	6	6	6	3	6	6	3	6	3	6	3	6	3	3	3	3	3	3	6	6	6	3
SOIL STRUCTURE(AGGR)	6	6	6	6	6	3	6	3	6	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
SOIL POROSITY	6	3	3	3	6	3	6	0	3	3	3	3	6	6	3	3	3	6	3	3	3	0	3	3	6	3
SOIL COLOUR	2	2	2	2	2	2	4	4	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	4	2
NO. OF SOIL MOTTLES AND COLOUR	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	1	0	0	0	1	2	1	1	1	0
EARTHWORM COUNTS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SOIL COVER (RESIDUE)	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
SOIL DEPTH(CM)	4	4	4	4	4	4	2	4	4	4	4	4	4	4	4	4	4	2	2	2	2	4	2	2	2	2
RUN-OFF	4	4	0	2	2	4	0	0	2	2	2	2	2	2	2	4	2	2	2	0	2	2	0	2	2	2
INFILTRATION	4	4	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
TOTALS	**33**	**30**	**24**	**26**	**31**	**25**	**28**	**18**	**27**	**23**	**20**	**23**	**23**	**26**	**20**	**25**	**20**	**20**	**17**	**15**	**18**	**18**	**19**	**21**	**27**	**17**

The VSA scores for 6 of the 13 participants are higher for their CA trial plots (T) when compared with their control plots (C), the scores for 2 participants are the same and the scores for 5 of the participants are lower. As this is the fourth year that these scores have been used and the results are still very inconclusive in terms of a methodology to assess improvement under CA, the tests are to be discontinued in the future as a CA assessment methodology. While VSAs provide a good set of visual indicators for testing soil quality, some of the indicators are not directly related to short term management benefits and changes in the soil. A selection of these indicators, notably soil structure, run-off and soil cover are however to be continued, as they do provide visible differences in the shorter term (4-5years).

Some interesting points however can be made from the table above:

Even after 5 years of implementation there are no earthworms counted in the soil across all the villages.

The only indicator that shows either a positive change for the CA trial plots, or where soils remain similar for that indicator across the trial and control plots is Soil Structure (aggregates).

For the 2018-2019 a revised VSA has been conducted taking the learnings from the previous seasons into account.

Some of the indicators have been removed as their visual assessment by team members in the field was either too subjective or could not be done in a way that real differences between fields and participants could be assessed. These include: soil colour, soil porosity, soil mottles and run-off. Soil cover is still being assessed, but through a different monitoring process.

It also included some new techniques, mostly ones from a visual scoring index for soil compaction developed by Prof. Dr Thomas Weyer from Westphalia University in Germany[3] . These are soil surface texture, root growth, soil colour, bulk density and Coarse pore content.

The implementation team was re-trained in this new methodology in the field on 22-23 October 2018. Then a piloting exercise for this new methodology was conducted in one village (Stulwane) in Bergville late in November

Right; Sylvester Selala demonstrates the use of a quadrant to more reliably assess percentage soil cover.

An updated VSA manual (see Attachment 2) with the revised indicator sheet shown below has been produced.

Table 19: New redesigned VSA Indicator sheet for 2018

Visual indicator of Soil Quality	**Visual Score (VS)**	**Weight**	**Comments**
Soil Structure (clods, aggregates)	0 = Poor conditions; 1 = Moderate conditions; 2 = Good conditions	× 4	Shatter test
Soil porosity (macro pores, clods)		× 5	Coarse pore content
Soil colour (dark, average, light and uniformity (mottles)		× 3	Incl mottles and organic matter
Soil surface (crusting, siltation, runoff)		x 3	Assessment of soil surface texture
Earthworm counts		× 2	
Soil cover (0-15%;15-30%; >30%)		× 3	Revised scale, using quadrant
Soil depth (penetration resistance to rod into soil)		× 2	
Bulk density		× 2	Using knife tip penetration in a small pit.
Root growth and development		× 2	New scale
Ranking Score (sum of VS rankings) Max =52			

(a) Piloting of the new VSA methodology.

This exercise was conducted by members of the implementation in conjunction with Palesa Motaung, An M. Agric student form the University of Pretoria, being supported in her fieldwork through this research process.

The assessments were done for 5 participants in Stulwane, who have been participating in the CA programme for 4-5 years:

1. Thulani Dlamini
2. Khulekani Dladla
3. Makhethi Dladla
4. Cuphile Buthelezi

[3] Ministry of Climate Protection, Environment, Agriculture and Consumer Protection. May 2016. **Preventing Soil Compaction.** Preserving and restoring soil fertility. Including the classification key for detection and evaluation of Harmful Soil Compaction in the Field. Authors T Weyer and SR.S. Boeddinghaus, Westphalia University, Dusseldorf, Germany.

5. Mtholeni Buthelezi

Below are a few photographs indicative of the VS assessment and sampling process

Above Left-Right: Doing the bulk density test using a knife blade. A clod of earth showing good aggregation, organic matter and fine root system. A soil sausage showing the high clay content of the soil.

Above left to right: Examples of the shatter test for soil structure – showing good soil structure; with porous loos soil with irregular aggregates of a dark colour indicate of higher organic matter – an intermediate or moderate soil structure – With a larger proportion of clods that break up into unaggregated soil, but also larger clods staying intact and Poor Soil structure with a large clod showing very little root penetration and few macro pores.

The small table below summarises the new VSA methodology results for the five participants. This approach appears to be a lot more promising and will be further explored during this growing season. An important consideration, not taken into account previously is that the soils have to be moist when these tests are conducted. Dry soils and especially those in higher clay soils will show "signs" of compaction under dry conditions, regardless of the condition of the soil.

Table 20: VSA scores using the new methodology for 5 participants in Stulwane, November 2018.

	VSA Score		
Name and Surname	**CA Maize**	**CA Maize + Beans**	**Veld**
Mthuleni Dlamini	40	24,5	41
Khulekani Ddladla	34,5	31,5	27
Makhethi Dladla	25	33	34
Cuphile Buthelezi	28	30	37
Thulani Dlamini	31	26,5	39

The veld samples are considered to be high benchmarks to compare the cropping plots against. Sampled plots (from the CA trial plots) were two maize only plots and two maize and beans plots for each participant. From the table above the following observations can be made:

The score ranges are:

Visual Soil Quality Assessment	Ranking score
Poor	0-20
Moderate	21-35
Good	36-52

- For the veld samples, even though they are meant to be high benchmarks only 3 of the 5 samples can be considered good under the VS assessment. This means that soil conditions generally in the Bergville area tend towards compaction, lack of soil aggregation and low to medium organic matter, even in undisturbed soils.
- The farmer who has been the most successful in changing his soils for the better through his CA implementation is Kulekani Dladla, where the results for both his CA Maize only and CA maize and bean intercropped plots are higher than the veld benchmark, although the overall rating is still considered as moderate. In real terms this is a significant outcome- being able to improve soils' health and structure above that of the surrounding veld.
- For three of the five farmers their VS assessment is higher for their CA maize plots than their CA Maize and Bean intercropped plots.
- Soil characteristics that gave similar scores across the different farmers and plots are soil surface texture and soil depth. This points towards the general compaction of soils in the area and slow build -up of organic matter, even in the CA plots.
- Soil characteristics that differed between farmers and their different trial plots include soil structure (aggregates), soil porosity and bulk density. This indicates that these soil characteristics are being affected positively through the CA cropping practices.
- There were zero earthworm counts throughout the whole system, including the veld plots.

The re-oriented VSA process is much more able to provide a qualitative assessment of individual's fields and the effect of their cropping practices on their soil characteristics.

5.2 Quantitative assessments/ measurements

Written by Sylvester Selala

Most of the information was meant to go into an AquaCrop model, a crop growth model developed by FAO to assess the effect of environment and the management on crop production as well as addressing food security. The model uses climatic variables (rainfall, air temperature, relative humidity, solar radiation, wind speed and direction) and environmental variables (soil characteristic which includes, soil structure, Bulk density, soil texture, as well as crop data).

The model is more suitable for simulating crop growth in mono-cropped fields, even though under conservation agriculture (CA), multiple cropping is highly promoted. We have chosen to focus on the primary crop (maize) and did not include the secondary crop (dry bean, cowpea and cover crops)
One-year data records are usually not enough to run a model, but data collection was conducted to build on.

5.2.1 Approaches and methodology

A number of different measurements have been proposed to go alongside visual indicators, both as benchmarks and potentially to serve as proxies for some of the indicators being observed.
The intention is to create a process/methodology primarily of visual assessments, benchmarked with some scientific measurements as a means to assess impact of climate smart agriculture practices in a participatory manner with farmers. Below, an outline of each methods is provided with some comments on the implementation of that methods, followed by this season's results and some analysis.

(a) Rainfall

In the light of climate change, studies have shown the importance of the need for routine dissemination of climatic information which serves as a guide to improving the local agricultural decision making. Establishment of community agrotechnological participatory extension strategies is needed to ensure sustainability of routine dissemination of climatic information. The first step towards building a routine dissemination of climatic data, is capacity building on how to collect and use climatic information at community level. Rainfall is one of the climatic factors (easy to measure) which hugely affect agricultural production, especially in rainfed field cropping systems. Through the WRC and farmers innovation development programme we have introduced farmers to collecting rainfall data from standard rain gauges installed in their homesteads.
Rain gauges have been installed across 5 villages (Ezibomvini, Eqeleni, Thamela, Stulwane and Ndunwana). Some of the rainfall data is collected using a tipping bucket method from the Davis weather station installed at Ezimbomvini village. Data sheets are provided to the farmers to record the rainfall data on. Rainfall readings are taken in the mornings

Challenges

- Time of taking rainfall readings (rainfall readings are taken at different times each day and sometime are taken after mid- day when some evaporation has taken place)
- Systematic errors
- Random errors

(b) Biomass samples

Above ground biomass samples were collected towards the end of May 2018 just before farmers harvested. The samples were set to be collected in three sites (Ezibomvini, Eqeleni and Thamela) where experiments have been setup. In Thamela, the farmers harvested early and let the livestock into the field before biomass samples were collected. Five plants (maize) samples are collected randomly from each of the 10 m^2 plot in Ezibomvini (Phumelele Hlongwane's field) and Eqeleni (Ntombakhe Zikode's field). Samples were taken to the lab for drying.

At the lab, the maize was de-cobbed and grain and the cob were weighed separately. The maize stover of each plant was cut into small pieces (to allow it to dry faster) using a knife and put into a brown paper bag. The brown paper bags were then put in an oven (100 °C) for 24 hours. After 24 hours samples were weighed, and the mass was recorded.

Right and Far right; weighing of cob and maize grain

(c) Bulk density

The soil bulk density (BD), also known as dry bulk density, is the weight of dry soil (Msolids) divided by the total soil volume (Vsoil). The total soil volume is the combined volume of solids and pores which may contain air (V_{air}) or water (V_{water}), or both. To account for variability, usually several samples' measurements are taken at the same location over time at different depths (e.g. 10, 30 and 50 cm). For this report we collected three samples in each plot (of size 10m^2) at one depth of 10 cm only. This was premised on the assumption that the changes or increases in organic matter due to implementation of Conservation Agriculture would occur primarily in the top 5 cm of the soil). The idea was to compare BD of Conversation Agriculture (CA) with conventional tillage and within CA to compare BD for different management practices. The samples were collected between the 13th and 14th of June 2018, after harvesting was completed. The samples were collected using 7.2 cm diameter rings with a height or depth of 5 cm.

The soil sample collection procedure was as follows,

- The ring was pushed (buried) into the ground using a piece of wood and a hammer (the piece of wood was used to protect the ring)
- A spade was used to dig the ring out of the soil
- Excess soil sticking out of the ring was cut using a knife to ensure the soil fit perfectly into the ring (making sure the volume is the same for all samples).

- The soil samples (in the ring) were wrapped with aluminium foil and transported to the lab for analysis
- At the lab samples were unwrapped, placed in aluminium dishes, weighed and assigned codes and put in an oven (at 100°C) for 48 hours to dry
- After 24 hours, samples were weighed, and the masses were recorded
- Then the fresh mass and the dry mass were used to calculate the bulk density

The equation used to calculate the total soil volume is as shown below.

$$Volume_{(soil)} = \pi r^2 \times d \quad (1)$$

Where, π is Pi and r is radius for the ring and d is depth of the ring and the volume was calculated in cm^3 while the mass of the sample was measured in grams (g)

Average dry mass for all samples collected in the same plot was used in calculation the bulk density and the same volume (based on the dimensions of the ring) was used. Equation 2 was used to calculate the BD

$$Bulk\ density\ (BD) = \frac{Mass\ of\ soil\ (g)}{Volume\ of\ soil\ (cm^3)} \quad (g/cm^3) \quad (2)$$

Above Left to right: Process for taking bulk density samples

(d) Gravimetric water measurements (procedure)

Soil samples for analysis of gravimetric water content (in gram per gram) were collected at different stages of crop development (planting, end of establishment, vegetative growth, tasselling, and physiological maturity). These stages of crop development are shown in Figure 3 below. Three samples per plot at each depth were collected at four depths (30, 60, 90 and 120 cm).

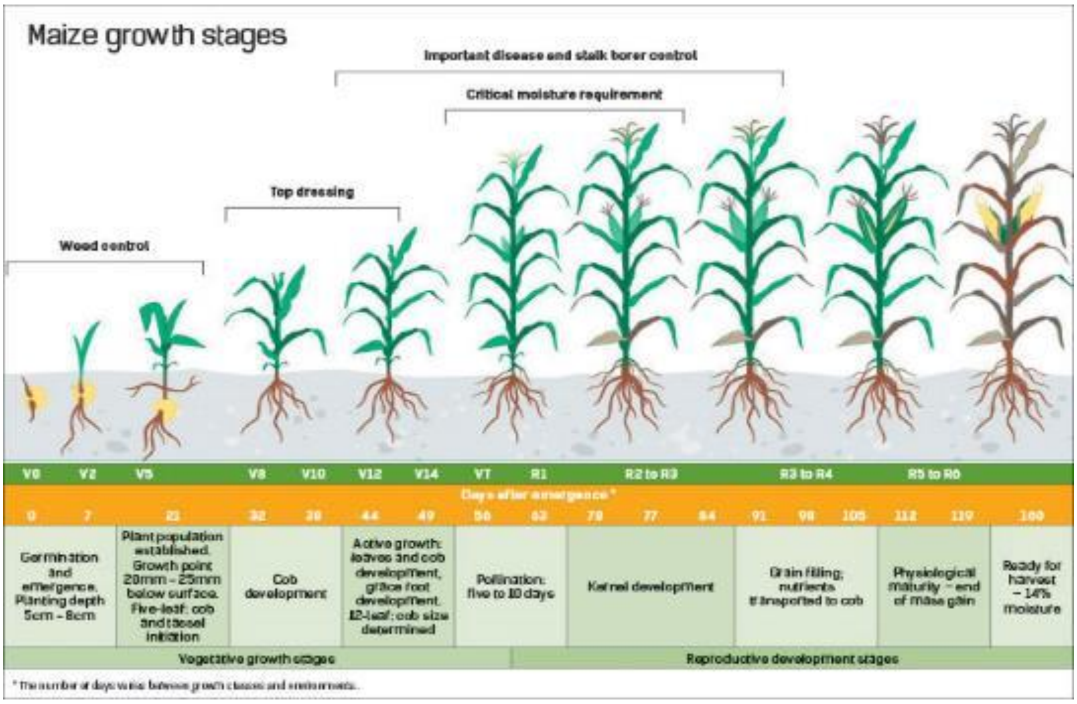


Figure 12: Stage of crop development used as a guide for collection of samples for analysis of gravimetric water content

Closed and open bucket soil augers were used to collect the soil samples. Samples were collected into zipper plastic bag to minimise or prevent loss of moisture from the soil sample. Samples were then put in a cooler box and stored in a cool dry place before were sent to the lab for analysis. Larger samples were mixed and subsampled in the lab (ensuring that all samples were almost the same size). The soil samples were weighed for fresh or wet mass and put in an oven (at 100 °C) for 48 hours. After 48 hours the samples were weighed again and the dry mass was recorded.
In calculating gravimetric water content, equation 3 below was used:

$$Gravimetric\ Water\ Content\ (GWC) = \frac{Mass\ of\ wet\ soil\ (g) - Mass\ of\ dry\ soil\ (g)}{Mass\ of\ dry\ soil\ (g)}$$

Above Left to right: Process for analysis of gravimetric soil water smaples

(e) Infiltration measurements

Three different methods of measuring infiltration rates were tested to try and find an easy method which can be used by farmers. This was also meant to investigate the pattern in the measurements made using each of the methods.

Method 1: This method uses a single ring infiltrometer with a known volume of water (1 litre). A thin layer of plastic is laid inside the infiltrometer before pouring water and then removed once the water has been poured in to ensure an even distribution of the water inside the ring. Once removed the stop watch was started to time the infiltration rate. This procedure is repeated 4 times, the first reading is discarded, and an average of the following three readings is used to calculate the infiltration rate (mm/hr).

Tools required:

- 1 litre container or bottle
- A stopwatch
- A single ring infiltrometer (20 cm diameter)
- Recording sheet

Right and Far right: measuring infiltration using a single ring infiltrometer

Method 2: This method uses a double ring infiltrometer (inner and outer) in measuring the infiltration rate. Calibrations of 1 cm apart are made in the outer ring where readings are taken (time is recorded after every 1 cm drop in the water level inside the outer ring). The inner ring is also filled with water to promote more vertical movement of water from the outer ring into the soil.

Tools required:

- Double ring infiltrometer (inner ring 20 cm diameter and outer ring 60 cm diameter)
- Water
- A spirit level is used to ensure that the infiltrometer is level
- Hammer (to drive the infiltrometers into the ground)
- A stopwatch

The time intervals for every 1 cm drop in the water level is recorded and the difference between the intervals is calculated. This process is repeated until the difference in time intervals is almost constant. The infiltration rate is then calculated using the depth (worked out from the dimensions of an infiltrometer) and the average time interval.

$$Infiltration\ Rate\ (mm\ per\ hour) = \frac{Depth\ (mm)}{Time\ (hours)}$$

Above Left to Right: Measuring infiltration rate using double ring infiltrometer

Method 3: Making a small pit with a spade of size 25 cm^2 to allow water to sit (the pit serves as an infiltrometer). Like method one, a known volume of water (1 litter) is poured in the pit and the time it takes to infiltrate that water is recorded. This process is repeated until the time it takes to infiltrate the water is almost constant.

Tools required:

- A spade (to make the pit)
- Tape measure (to measure dimensions of the pit)
- Stopwatch

The infiltration rate is calculated in the same way as described in method two.

Above: Infiltration measurement using the third method

(f) Runoff measurements

Five 1m^2 runoff plots were installed in 5 plots of size 10 m^2 planted with different crops to investigate the effect crop management on runoff generation for three sites in Bergville (Ezibomvini, Eqeleni and Thamela). The runoff plots are connected to 25-litre collection buckets through a pipe. These buckets/ basins are covered with lids, so that rain does not fall directly into these containers. In the current design, the lids tend to be removed by the farmers and not replaced, leading to a potential over-estimation of run-off.

During a rainfall event, water infiltrates the soil and excess water flows into the collection bucket as runoff. The runoff plots are driven into the ground to ensure excess water only exits the runoff plot through the hole connected to the pipe into the collection bucket. A spirt level was used to keep the runoff plots levelled and the slope is considered (runoff plots were not installed on slopes higher that 7 %) when installing the runoff plots. Excess water generated from the runoff plots flows in to collection basin which is part of or attached to the runoff plots. A data sheet is provided to the farmer to collect runoff data, a day after a rainfall event.

Above: Runoff measurements and at village level

(g) Water productivity

The main variables used in calculating water productivity (WP) are yields and volume of water used to produce that particular yield. There are standard methods used in working out the yield (e.g. putting the harvested grain or biomass on a scale and weighing it, weighing a sample of cobs for maize and estimating yield using the plant population). The challenge is in determining the volume of water used to produce the yield. There are a couple of methods (simple and more complicated) used in determining the volume of water used. We explored three of these methods in this report. Normally, for maize only the grain yield is considered when calculating WP, for this repot we used both grain yield and dry biomass.

Method 1: This method uses climatic information (solar radiation, air temperature, relative humidity, wind speed and etc) to calculate reference evapotranspiration (ET_0). From the Davis weather station ET_0 is calculated of hourly time steps (the weather station automatically calculated the ET_0). Due to a faulty solar radiation measuring component of the weather station, the Davis weather station did not generate ET_0 value. We then obtained solar radiation surrogate data from a South African Environmental Observation Network (SAEON) weather station in Didima in the Drakensburg. The ET_0 was calculated manually through a series of formulas shown below.

After obtaining the ET_0 values, they are then multiplied by the crop coefficient to find the actual evapotranspiration (Etc), which is the volume of water used to produce the yield.

Method 2: This method uses the water balance equation to derive the ET_0 and this is calculated for growing season.

$$P = R \pm \Delta SWC + D + ET_0$$

Where p=precipitation, R=runoff, ΔSWC= change in soil water content, D= deep percolation and ET_0 =reference evapotranspiration.
Here the gravimetric soil water results were used.

Method 3: This is a simple method which required only one variable (rainfall) which famers find easy to measure. The main assumption hear is that, all water (in the form of rainfall or irrigation) contributes to plant growth and to producing yield. Therefore, precipitation becomes the volume of water used to produce a yield in a dryland cropping situation and rainfall plus water applied is used in irrigated situation

5.3 Results and discussion

Written by Erna Kruger

5.3.1 Results (bulk density)

*Note; This section was reported in deliverable 5 and are included here for completion sake

Soil tillage has been a popular agricultural practise throughout the world due to the initial improvement of crop productivity, control of weeds and ease with which crops can be planted. However, it has been recognised in many regions that this improved productivity is temporary and overall, soil organic matter (SOM) content decreases under conventional tillage (CT).

This decrease in SOM results in a decline of soil quality as SOM plays a major role in the soil's structural and pore characteristics by influencing aggregate stability.

Bulk density samples were taken for three participants, towards the end of the cropping season (early May 2018). Samples were taken this late in the season as many authors report greater porosity, lower ρb and reduced soil strength under CT than under (no-till) NT due to the creation of macro-pores during ploughing. These provide for a lower ρb reading early in the season, as during the course of the season the soil settles again and the readings increase (Basset, 2010)[4].

Below is a summary of the results of the bulk density calculations for different cropping practices within the CA system of the three participants. They were chosen for having differing period of cropping under CA and for inclusion of a number of practices within their CA system; namely intercropping and planting of summer cover crops (SCC).

Table 21: Bulk density results for three CA participants

Village	Period under CA	Name and Surname	Control CT	Control CA	M	M+B	M+CP	SCC	Average
Ezibomvini	4	Phumelele Hlongwane	1,30	1,36	1,38	1,33	1,38	1,28	**1,34**
Eqeleni	5	Ntombakhe Zikode		1,35		1,49	1,37	1,32	**1,38**
Thamela	1	Mkhuliseni Zwane			1,14	1,08	1,09	1,07	**1,10**
Average bulk density									**1,27**

These results indicate an increase in ρb over period of involvement in CA. There is little to no difference between the CA practices, although in all three cases the planting of SCC has reduced the ρb fractionally.

An explanation for this trend is that ploughing increases the presence of macro-pores in the short term but, less structural stability under CT can lead to lower porosity, higher bulk densities and greater soil strength with time, as tillage-induced pores readily collapse. Although initial conversion from CT to CA usually results in higher bulk densities it is unlikely that plant growth will suffer markedly as a consequence of insufficient moisture and poor aeration status. Improved aggregation and pore connectivity under CA allows the soil to maintain an adequate supply of moisture and air (Cavalieri et al., 2009)[5].

The average ρb of 1,3g/cm^3 is to be used for the water productivity calculations

5.3.2 Results (rainfall data)

Rain gauges were installed across 5 villages in the Bergville area. The rain gauges installed previously (2016-2017) in Okhombe and Emangweni were moved to other villages, as the participants there were not meticulous about taking the rainfall records. For the most part, rainfall records this season were not very well kept and only a generalised analysis of rainfall has been possible.

Below is a small table that summarises the information. The cumulative average rainfall for the area as recorded by the farmers was 563 mm between December2017-May 2018.

[4] Basset, T.S. 2010. A comparison of the effects of tillage on Soil physical properties and microbial Activity at different levels of nitrogen Fertilizer at Gourton farm, Loskop, Kwazulu-Natal. MSC thesis. Dept of Soil Science, UKZN.

[5] Cavalieri K.M.V., da Silva A.P., Tormena C.A., Leão T.P., Dexter A.R. and Håkansson I., 2009. Long-term effects of no-tillage on soil physical properties in a Rhodic Ferrasol in Paraná, Brazil. Soil and Tillage Research, 103 (158-164).

Averages for Ezibomvini, Eqeleni, Stulwane, Thamela and Ndunwana	Dec	Jan	Feb	March	April	May
Monthly rainfall (mm)	185	72,25	169,2	114,7	17	5
Mean (mm) per rainfall event	7,9	5,8	8,2	7,6	2,1	0,4
Max (mm) per rainfall event	60	30	30	20	1	3,5

An analysis of the rainfall patterns for January-February 2018 were done for Ndunwana as an example of the rainfall distribution in these months.

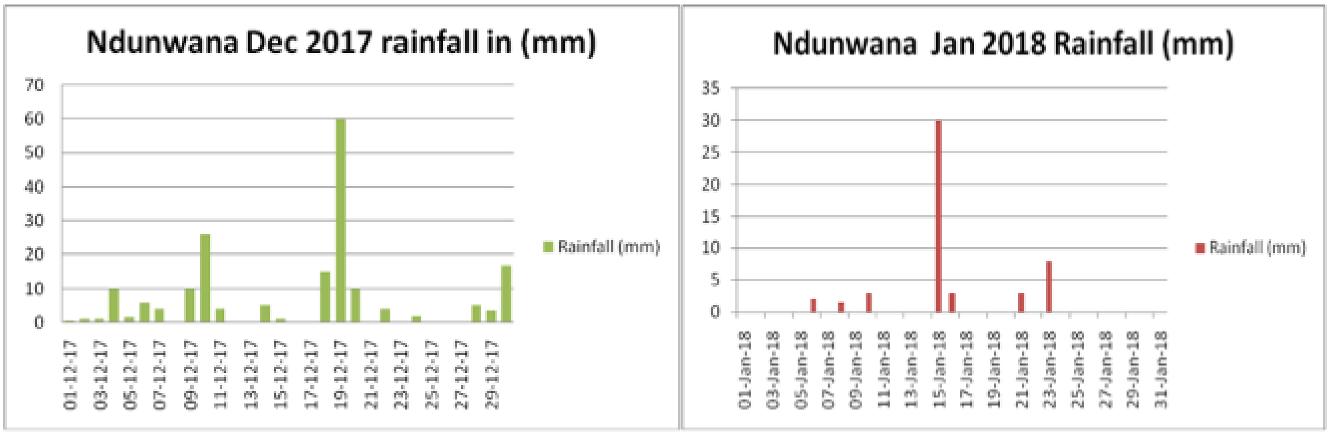


Figure 13: rainfall data for Ndunwana for December 2017-January 2018

A few observations can be made from the two small graphs above:

- The number of rainfall events in December was 13 and in January 7
- In each month one large rainfall event occurred; 60mm in December and 30mm in January
- The average rainfall per event for December was 6mm and for January was 2,2mm

This indicates a high variability in rainfall with extreme events punctuated by small amounts of rain which were unevenly distributed. This dry spell in the period of maturation of beans and maize have had a detrimental effect on yields – more specifically for the beans.
For the coming season a process of much more close monitoring of data recording by the implementation team and a research intern to be employed, will be undertaken.

5.3.3 **Results (runoff)**

For most households the taking of runoff measurements was given to teenagers living in the homestead as their responsibility. The reasoning was that these teenagers, being in high school are the more literate members of the household and are also the most available on an ongoing basis as they do not travel. We also thought it would be an interesting exercise for them.
However, these assumptions did not hold as the teenagers tended to lose focus and forget about checking the runoff plots, especially after long periods without rain. They also did not check the plots meticulously after each rainfall event, so that even where runoff data was recorded it stretched across a few events – Data for this season are thus rather sparse.

A decision was made for the coming season to include both interns and postgraduate students into this process to ensure better recording of events. In addition, the runoff plots are now installed in the

households of Local Facilitators in the three sites, who work regularly with the implementation team, to ensure regular recordings are taken.
Below is a small table indicating runoff results for one participant; Phumelele Hlongwane

Table 22: Run-off results for Phumelele Hlongwane for her conventional control plot and her CA trail plot

Control plot -Conventional tillage				Trial plot -Conservation Agriculture		
Rainfall event (mm)	Runoff (mm)	ratio	% rainfall converted into runoff	Runoff (mm)	ratio	% rainfall converted into runoff
14	4	3,5:1	28.6	2.5	5,6:1	17.9
22	2.5	8,8:1	11.4	1.5	14,7:1	6.8
9	1.25	7,2:1	13.9	1	9:1	11.1
20	3.25	6,2:1	16.3	2	10:1	10.0
13	5	2,6:1	38.5	2.25	5,8:1	17.3
21	2.5	8,4:1	11.9	1.5	14:1	7.1
AVERAGE	**3,1**		**20,1%**	**1,1**		**11,7%**

5.3.4 **Results (Infiltration)**

*Note: Some of these results were presented in deliverable 5, but have been included her for completion sake.

Infiltration rates of water into the soil are expected to increase for the CA trial plots over time. The assumption is that the pore continuity and pore size distribution are improved due to greater structural stability and biological activity and thus saturated hydraulic conductivity and the plant available water are greater under CA than conventional tillage.
The infiltration tests were done to assess the impact of CA on water infiltration in the soil.
Results from infiltrometer tests (single ring) from 2016-2017 season for 16 participants were extremely varied and appeared unreliable. They are not reported on. For the 2017-2018 season, a double ring infiltrometer was acquired and readings were taken for 13 participants. Again, there were problems with accuracy of results, due mainly to the following factors:

- Extremely high clay content of these soils (40-50% clay)
- Hardness of soil- making knocking of the infiltrometer rings into the soil almost impossible
- Inexperience on the part of the implementation team - taking these measurements when the soil was dry and hard towards the end of the growing season (Feb- April 2018). This meant taking a lot more time to get the rea where the measurements were being taken wetted properly and
- Extreme difficulty in collecting and carting enough water to the measurement sites.

Thus, the results were discarded and the team reverted back to using a single ring infiltrometer.
The comparison of control and trial plots is somewhat artificial, given that a number of participants have been practising CA on their control plots as well. We are thus comparing fertility, crop type and spacing regimes rather than tilling and no-till in these cases. In the control plots the farmers use their own versions of soil fertility improvement (potentially different fertilizers, in different amounts) and their own choice of crop seed (often traditional or home kept maize seed, rather than the hybrids planted in the CA trials). They also tend to use different spacing (mostly wider between row spacing than for the trial plots).
The results are presented below.

Table 23: Summary of water infiltration results for 13 participants in Bergville; 2017-2018

Village	Name and Surname	Yrs under CA	infiltration rate (mm/hr) control	infiltration rate (mm/hr) trial
Stulwane	Khulekani Dladla	5	587,4	531,4
	Dlezakhe Hlongwane	5	226,2	423,8
	Thulani Dlamini	5	422,7	450,0
	Makhethi Dladla	5	226,6	587,4
	Pasazile Sithebe	5	544,4	478,3
	Cuphile Buthelezi	5	429,2	637,7
Ezibomvini	Phumelele Hlongwane	4	455,5	282,5
	Cabangile Hlongwane	3	183,0	133,9
Eqeleni	Tholwephi Mabaso	5	218,8	250,8
	Tombi Zikode	5	618,1	177,1
	Smephi Hlatshwayo	5	434,8	218,8

In summary, infiltration results were higher and thus faster for the CA plots for only 5 of the 13 participants. Generally, soils are hard, with high clay content and a lot of compaction and soil crusting is still visible, in both the control and CA plots. The intention has been to use these infiltration results as one of the proxies for determination of improvement of soil structure through implementation of CA. However, structural improvements in the soil cannot be gauged using water infiltration as a proxy as there are too many other variables and parameters to also consider.

(a) Results for Phumelele Hlongwane

Right: the infiltrometer ring being used in one of Phumelele's trial plots

The infiltration measurements were collected on 2 consecutive days following the same method. A single ring (core ring) was used and it was levelled using a spirit level and placed in the middle of each plot at a point most representative of the whole plot. A 1 l bottle was used to add water into the infiltrometer. With a known volume of water added at a given time, the following equation was used to calculate the infiltration rate;

$$\text{Volume of water} = \text{area of the infiltrometer} \times \text{depth} \quad (1)$$

Making the depth a subject of the formula

$$\text{Therefore Depth} = \frac{\text{Volume (of water)}}{\text{area (of the infiltrometer)}} \quad (2)$$

Then the calculated depth was 31.85 mm and the only variable was time taken to infiltrate 31.85 mm of water.

The table below summarizes the infiltration rates for a selection of experimental plots – those where maize yields could be compared.

Table 24:Water infiltration for a selection of Phumelele Hlongwane's trial and control plots

<table>
<tr><th>Plots</th><th>Trial plots
Infiltration rate (mm/hr)</th><th>Conventional tillage plot infiltration rate (mm/hr)</th></tr>
<tr><td>Plot 1 (M)</td><td>96.84</td><td rowspan="10">Conventional control 49.8</td></tr>
<tr><td>Plot 2 (M)</td><td>187.23</td></tr>
<tr><td>Plot 3 (M+B)</td><td>82.25</td></tr>
<tr><td>Plot 4 (lab lab)</td><td>166.94</td></tr>
<tr><td>Plot 5 (M)</td><td>195</td></tr>
<tr><td>Plot 10(M+B)</td><td>183.51</td></tr>
<tr><td>Plot 7 (M)</td><td>85.35</td></tr>
<tr><td>Plot 8 (M+C)</td><td>82.28</td></tr>
<tr><td>Plot 9 (M +B)</td><td>122.85</td></tr>
<tr><td>Plot 6 (SCC)</td><td>182.94</td></tr>
<tr><td>CA control</td><td>247.3</td><td></td></tr>
</table>

From the table above, it can be seen that the CA trial plots have a substantially higher infiltration rate than the conventional control plot. Within the CA trial plots the following comments can be made:

- The CA control plot planted to maize had the highest infiltration rate,
- CA trial plots planted to summer cover crops (SCC) had higher infiltration rates than the intercropped or single crop plots – especially if one takes both seasons into account. This indicates the beneficial effect of cover crops on water infiltration in the soil
- The maize and legume intercropped plots had high infiltration rates and also had the least variability in infiltration rates- pointing towards the consistent and beneficial soil building properties of intercropping over single cropping.

For the 2017-2018 season Phumelele's infiltration data is summarized below

Village	Name and Surname	Yrs under CA	infiltration rate (mm/hr) CA control	infiltration rate (mm/hr) CA trial
Ezibomvini	Phumelele Hlongwane	4	455,5	282,5

The outcome is similar to the previous season where he CA control plot infiltration is much higher than the rest of her trial. It is likely that this has a lot more to do with the soil structure profile of her soils, than the CA cropping practices she employs.

(b) Challenges and Solutions

One of the biggest challenges in doing the infiltrometer readings was accessing enough water. Each site would take on average around 100 lit of water. The households had no access to water and thus this had to be found and brought to site, usually from a nearby stream or spring -which was extremely time consuming.

The double ring infiltrometer was construted locally in Pietermatizburg and was not of a high enough quality to withstand the strain of being hammered into extremely hard soils.
For the coming seaons the following remedial activities are to be undertken:

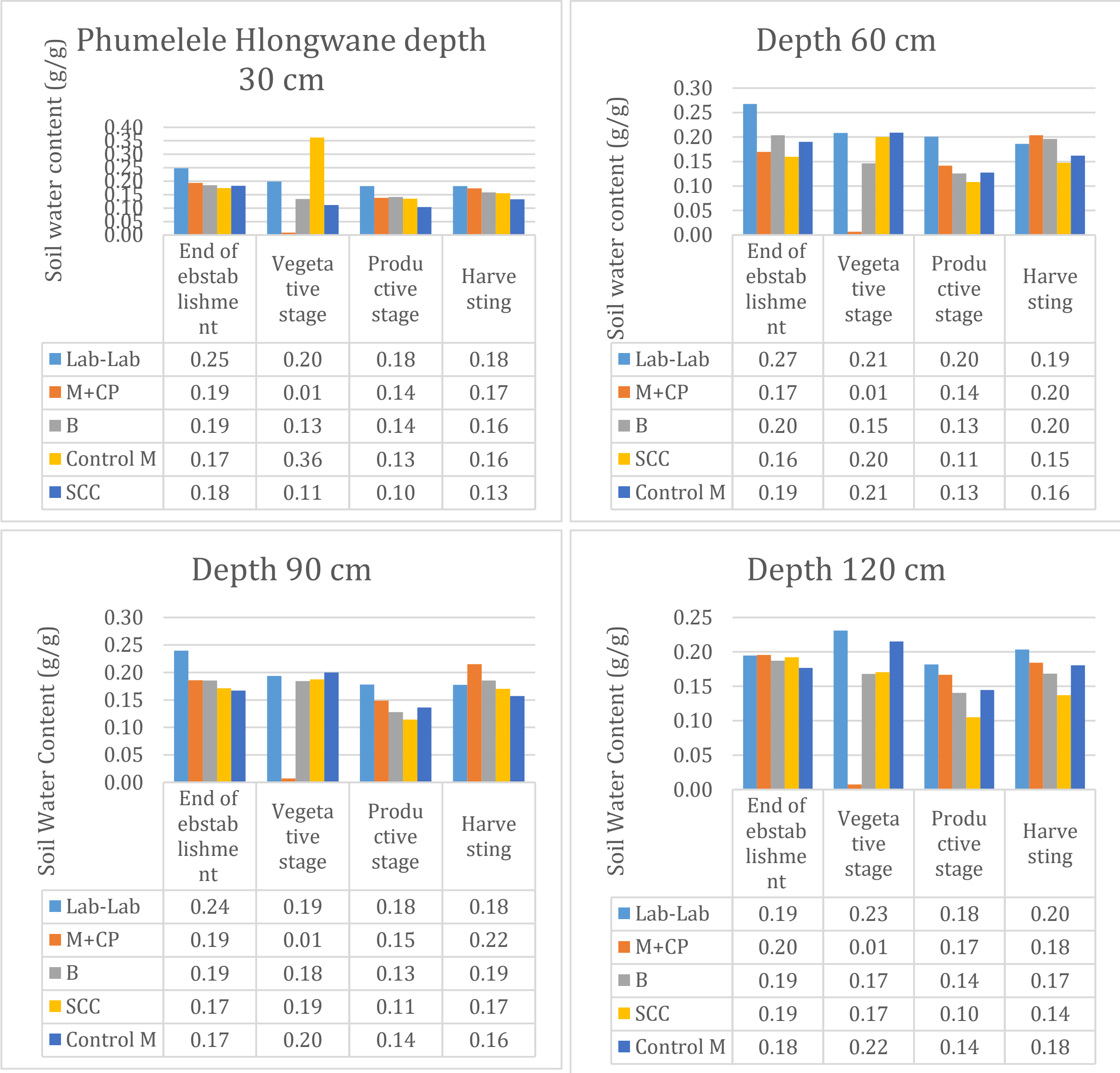
- Compare only CA plots with conventional control plots and discard the comparsion of different CA cropping prctices
- Ensure that infiltrometer readsing are taken in a rainy perdio when soils are reasonably wet
- Include infiltrometer tests for other areas and regions – e.g. Southern KwaZulu Natal, Midlands, Limpopo (although for the latter continued lack of rain is likley to be an issue)

It is likely that the project will discontinue these efforts in the future and rely more heavily on gravimetric water soil sampling and analysis.

5.3.5 **Gravimetric soil water content results and discussion**

Gravimetric soil water content gives us an indication of available water in the soil at different stages of crop growth and also gives us an indication of water use by the crops at these different stages.
It does not indicate whether the water in the soil is enough to support the growth of the particular crop, but provides for a qualitative assessment of how much water a crop is using for growth at different stages of growth.
The assessments were done at four stages; namely establishment, vegetative growth, productive growth and harvesting at four different soil depths; 30cm,60cm, 90cm and 120cm.

The 4 small tables below indicate the gravimetric soil water content for different crops within Phumelele Hlongwane's CA trail plots for 2017-2018



Phumelele Hlongwane depth 30 cm

	End of ebstablishment	Vegetative stage	Productive stage	Harvesting
Lab-Lab	0.25	0.20	0.18	0.18
M+CP	0.19	0.01	0.14	0.17
B	0.19	0.13	0.14	0.16
Control M	0.17	0.36	0.13	0.16
SCC	0.18	0.11	0.10	0.13

Depth 60 cm

	End of ebstablishment	Vegetative stage	Productive stage	Harvesting
Lab-Lab	0.27	0.21	0.20	0.19
M+CP	0.17	0.01	0.14	0.20
B	0.20	0.15	0.13	0.20
SCC	0.16	0.20	0.11	0.15
Control M	0.19	0.21	0.13	0.16

Depth 90 cm

	End of ebstablishment	Vegetative stage	Productive stage	Harvesting
Lab-Lab	0.24	0.19	0.18	0.18
M+CP	0.19	0.01	0.15	0.22
B	0.19	0.18	0.13	0.19
SCC	0.17	0.19	0.11	0.17
Control M	0.17	0.20	0.14	0.16

Depth 120 cm

	End of ebstablishment	Vegetative stage	Productive stage	Harvesting
Lab-Lab	0.19	0.23	0.18	0.20
M+CP	0.20	0.01	0.17	0.18
B	0.19	0.17	0.14	0.17
SCC	0.19	0.17	0.10	0.14
Control M	0.18	0.22	0.14	0.18

Figure 14: Gravimetric soil water content at four different depths for a selection of Phumelele Hlongwane's CA trial plots (M=maize, SCC-= summer cover crop mix, B=beans, CP=cowpea and Lab-lab= Dolichos beans

From the figure above the following observations can be made:

- The soil water content at all four depths is similar throughout the growing season indicating a deep well drained soil and also pointing to the presence of enough soil water to support the growth of the crops planted.
- Lab-Lab beans use the most water during their vegetative growth stage at depths from 30-90cm in the soil and access soil water down to 120cm in depth for their productive growth. It indicates their ability to resist drought by accessing water deep in the soil for seed production towards the end of the season. In addition, the water use from the vegetative and productive stages of growth (for all four soil depths) is the least of all the crops (which could indicate less water use, but also saving water through reduced evaporation and canopy cover.

- Maize has a high demand for water in the productive stage at all four depths measured.
- Beans use water evenly through their vegetative and productive stage and access water for the productive stage primarily from the deeper soil depths of 90-120cm.
- The SCC use the most water of all the crops during the establishment phase at around 30cm of soil depth. Once these crops reach the vegetative and productive stage, they draw their water from deeper in the soil; 60-120cm depths.
- The Maize and cowpea combination use a large amount of water from all four soil depths 30-120cm in the vegetative stage of growth. This points towards considerable competition between the maize and cowpea during this growth stage. This result is corroborated by the water productivity results indicating lower productivity for maize when intercropped with cowpeas.

This exercise provides a reasonably good benchmark for crops suitable for saving water in the soil profile over the full period of crop growth, which crops use water where in the soil profile and consequently good intercropping combinations. From the results, Lab-Lab beans show a remarkable ability to save soil water during the vegetative and productive phases of the maize crop – meaning that this crop is very suitable for intercropping; much more so than cowpeas from a water use perspective, as the latter compete with maize during the vegetative growth phase.
Care needs to be taken with planting SCC mixes as these require a lot of water in the 30-60cm soil depth range for establishment.

5.3.6 Results (Water Productivity in Conservation Agriculture fields)

Data collection in this season provided a few challenges:

- Inexperience with working with weather stations meant the ET_0 values were not automatically recorded as could have been the case, but had to be manually calculated using surrogate data
- Rainfall was not measured very accurately by the households with rain gauges- some participants were a lot more meticulous than others.

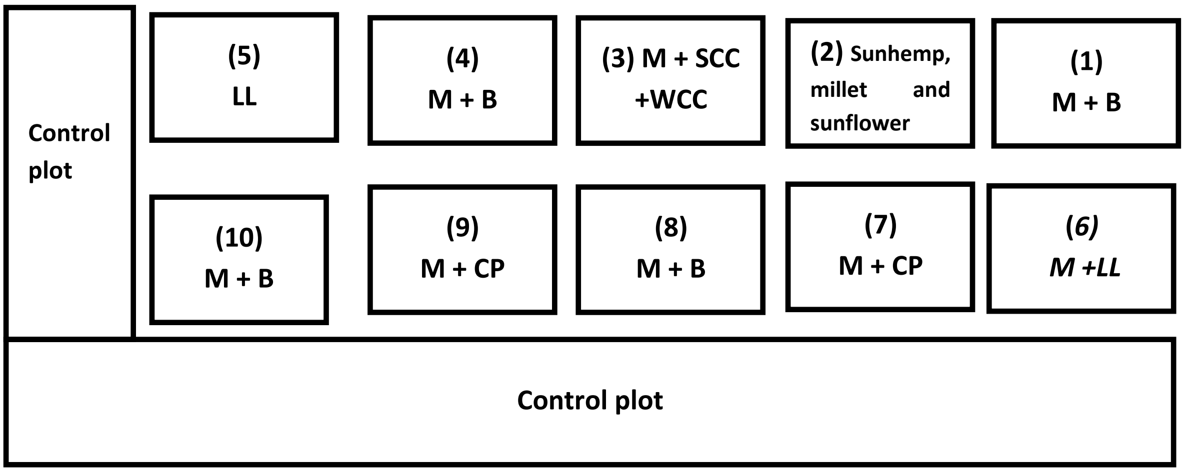
As a result, the data collected in this season was not adequate to run a model to allow us to compare simulated and observed values of evapotranspiration (ET) and water productivity (WP). The results presented in this section were observed values and were computed manually following the equations presented in the methodology section.
Our assumption for this farmer level experiment, or the hypothesis, is that water productivity of an intercropping system will be better than that of a monocropping system under CA.
Enough data was collected for two of the three sites and participants; Phumelele Hlongwane from Ezibomvini (PH) and Ntombakhe Zikode from Eqeleni (NZ).

(a) Trial and Control layouts and parameters

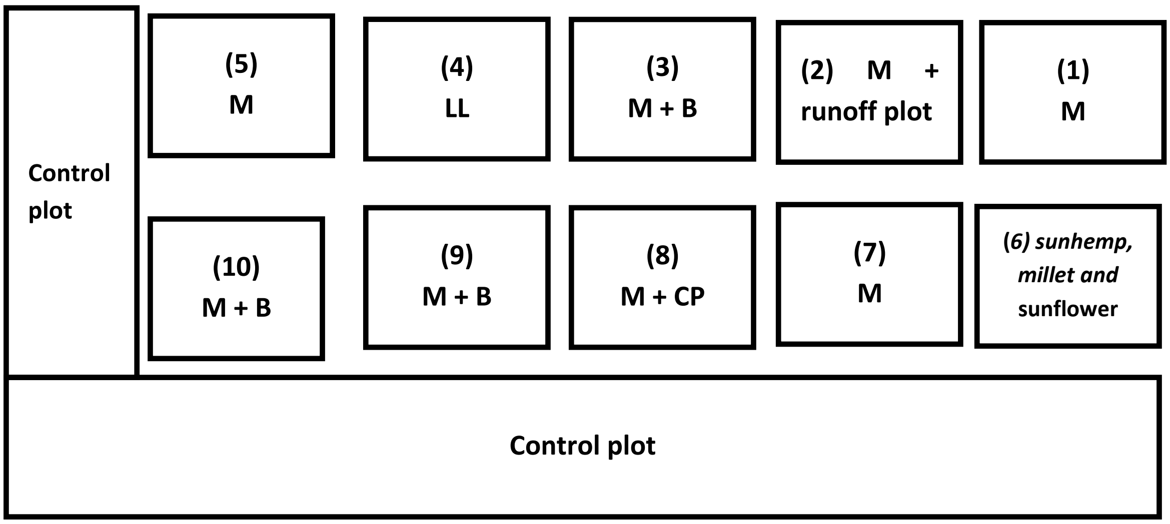
Phumelele Hlongwane (Ezibomvini- Bergville)

Experimentation

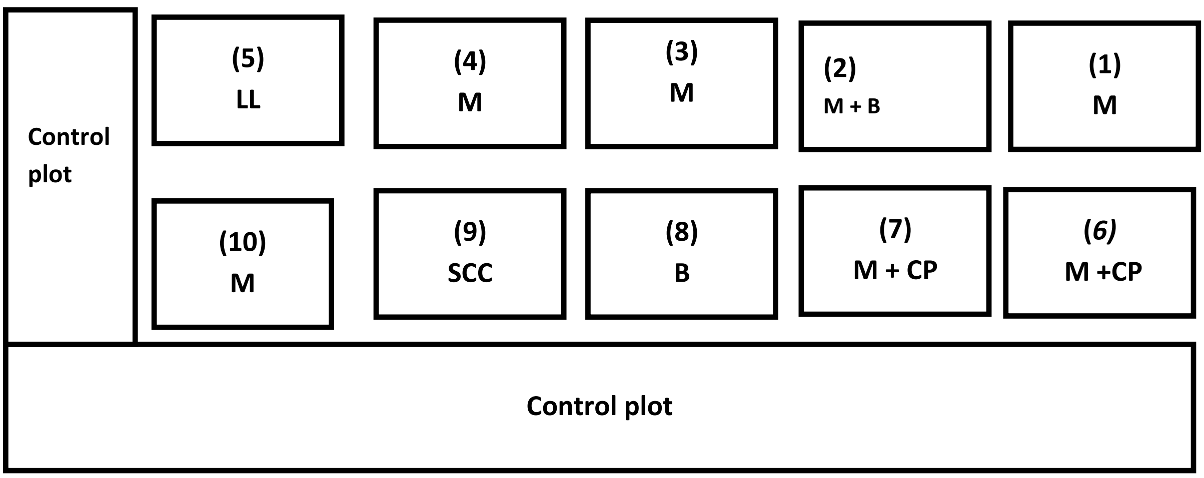
Phumelele's trials were continued in this season. The layout of her plots is shown below for the 2015/16, 2016/17 and 2017/18 planting seasons. She is practicing crop rotation as well as intercropping and planting of summer and winter cover crop mixes.



Trial layout 2015/16 **Legend**: *M – Maize; B – Beans; CP – Cowpea; LL – Lab Lab*



Trial layout 2016/17 **Legend**: *M – Maize; B – Beans; CP – Cowpea; LL – Lab lab*



Trial layout 2017/18 **Legend**: *M – Maize; B – Beans; CP – Cowpea; LL – Lab Lab*

The table below provides a summary of the rotations employed across her trial plots.

Table 25: Table outlining rotations undertaken in Phumelele's trial and control plots over the last three seasons, including and indication of installation of runoff plots.

Plot no	2015/16	2016/17	2017/18	Run off plots
1	M+B	M	M +WCC	Grey squares indicate run-off plots
2	SCC	M	M+B	Rotations have been done attempting to ensure a different crop/crop mix on each plot in each consecutive year. A further refinement of the schedule to be a 3- year rotation of; single crop – intercrop- cover crop, will be adhered to into the future
3	M+SCC+WCC	M+B	M	
4	M+B	LL	M	
5	LL	M	LL	
6	M+LL	SCC	M+CP	
7	M+CP	M	M+CP	
8	M+B	M+CP	B	
9	M+CP	M+B	SCC	
10	M+B	M+B	M	
		Control: M	Control: M	
	Control: M (CA)		Control: M+B (CA)	

Right: A view of Phumelele's maize and cowpea intercropped plot and Far Right: A view of Phumelele's Lab-Lab plot in the 2017-2018 season. She rotates these plots in her intercropping and rotation system. Behind the visitors is a plot of inter cropped maize and sunflower.

Ntombakhe Zikode (Eqeleni)

Experimentation

In Eqeleni, the 1000 m^2 farmer level trials are divided into 5 plots (20 m*10 m). The last crop rotation plot is split into two to allow for 2x (10 m* 10 m) plots, planted to sole Maize crop and summer cover crop mix of sunflower, sunnhemp and millet respectively.

M+B+WCC	**M+B+WCC**	**M+C**	**M+B**	**M SCC**

Right: Ntombakhe's trial plot, early stages of the summer cover crops in the foreground. Behind that and to the right are her inter cropped plots and on the left at the back her mono-cropped maize plots.

5.3.7 Water Productivity results and discussion; Method 1

The results for calculating the WP using method 1 (weather station data) for both Phumelele Hlongwane and Ntombakhe Zikode are shown below.

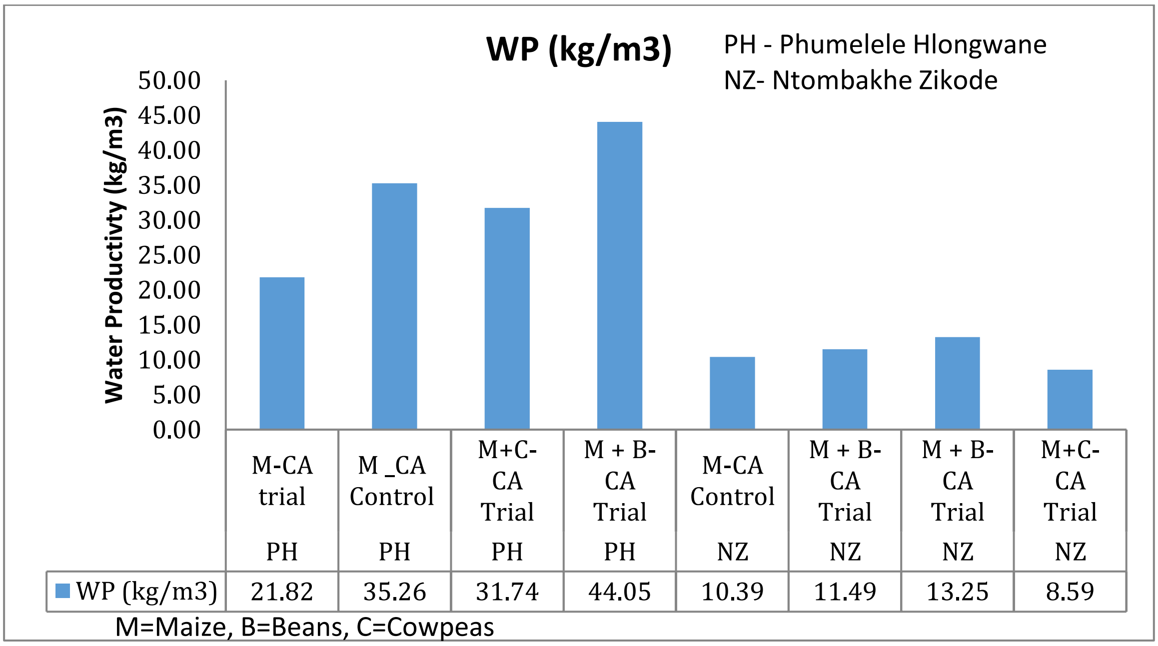


Figure 15: Water productivity results using weather station data for dryland field cropping using CA

Water productivity here has been calculated using the maize grain only.
From the above diagram the following observations can be made:

- Phumelele's water productivity for all her plots is substantially higher than Ntombakhe's. This is expected, as her soil fertility and soil health results are also substantially higher. This means that her soil has a much higher nutrient and water holding capacity, despite the fact that both participants have bene practising CA for 4-5 years. It points also to the fact that her management practices within the CA system are improving her soils more substantially than those that Ntombakhe have been using. Crop rotation by itself improves soil health and water holding capacity much more slowly than a combination of rotation and intercropping. Larger crop diversity is also important.

- For both participants the water productivity for their maize and bean intercropped plots is higher than for the maize only and the maize and cowpea plots. This trend has been noted also in the soil health test results and is interesting as it does not hold with the assumptions made by the implantation team that the maize and cowpea intercropped plots would out-perform the maize and bean intercrops.
- For both participants the water productivity of the mono-cropped maize plots is higher than that of their maize and cowpea intercropped plots. This points to a certain level of competition from the cowpeas intercropped with the maize
- For Phumelele, water productivity for her CA control mono-cropped maize is quite a bit higher than her CA trial mono-cropped maize. Her management practices for the two plots are very similar (using the same procedures, fertilizers and maize varieties), pointing to different water productivity potentials in her plots. This variability has been noted also in measurements of soil characteristics, water holding capacity and yields.

The yields across the plots within a trial can vary considerably. The expectation is that after a number of years, the mixture of intercropping and crop rotation would mean that the soil builds up across the plots and that the yields would even out as they increase. This is as yet not happening.

A more in-depth look at the actual rotations and yields for Phumelele Hlongwane, are presented in the table below.

Table 26: Maize yields per plot in Phumelele Hlongwane's rotation system:2015-2017

Phumelele Hlongwane: Comparison of maize yields per plot:2015-2017							
Plots	**2015/2016 season**		**2016/2017 Season**		**2017/2018 Season**		
	Crops Planted	**Yields (t/ha)**	**Crops planted**	**Yields (t/ha)**	**Crops planted**	**Yields (t/ha)**	**Change in yield (t/ha)**
Plot 10	Maize +Beans	8,3	Maize + Beans	8,8	Maize	11,5	2,8
Plot 9	Maize +Cowpea	8,7	Maize + Beans	8,9	SCC		
Plot 8	Maize + Beans	10,4	Maize + Cowpea	7,7	Beans		
Plot 7	Maize +Cowpea	6,9	Maize	6,5	Maize + Beans	16,3	9,8
Plot 6	Maize +Lab-lab	3,4	SCC		Maize + Cowpea	12,4	
Plot 5	Lab-Lab	NA	Maize	8,8	Lab-Lab	NA	
Plot 4	Maize+ Beans	8,7	Lab-lab		Maize	10,3	
Plot 3	M +SCC+WCC	8,7	Maize + Beans	10,1	Maize	11,0	0,9
Plot 2	SCC		Maize	10,0	Maize + Beans	14,2	4,2
Plot 1	Maize +Beans	6,9	Maize	6,2	Maize	8,9	2,7

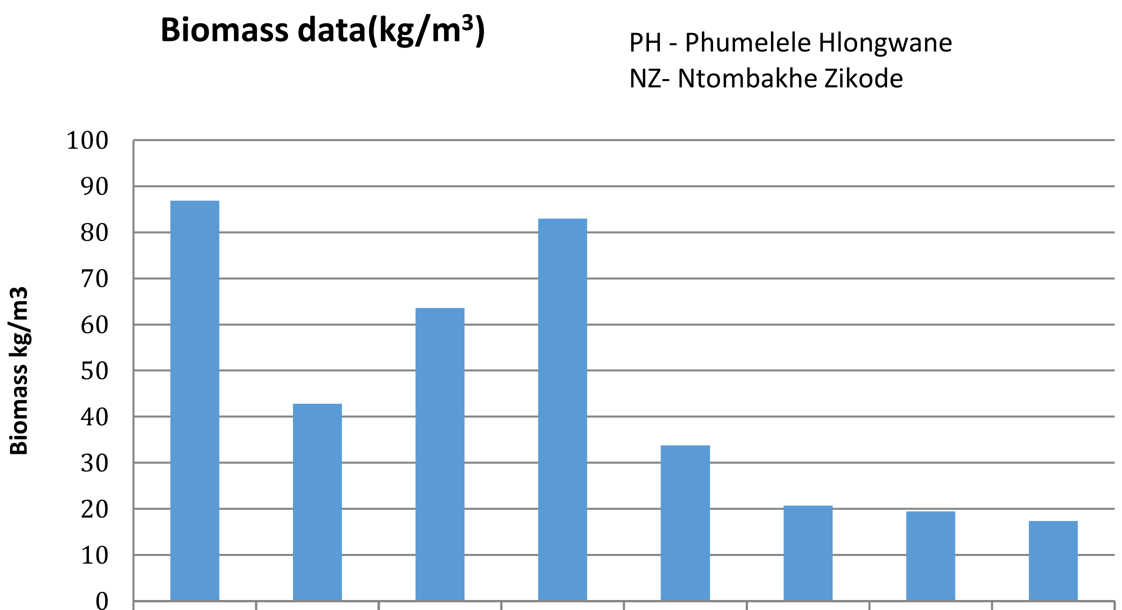
This season (2017-2018) has seen a remarkable increase in yield across all the plots where maize has been grown, with yields that seem to be almost unheard of. These calculations and yields have been checked and re-checked given this near impossible outcome and appear to be correct as far as the team can tell. The variety of maize planted was PAN6479.

Rainfall as recorded by the farmers has averaged around 563mm this season as compared to an average of around 527mm for last season. These amounts are considered similar enough to not have a major influence on yield differences noticed.

The difference in maize yield from one plot to another does not appear to be directly related to the previous rotations, although in general those that include legumes and summer cover crops in a three-year rotation prior to planting a monocrop of maize, are higher than the plots where maize has followed on maize.

(a) Biomass water productivity results

These have been calculated for maize plants only. The graph below provides the dry mass of the whole above ground plant, for those plants selected also to measure the grain yiled for the WP results shown above



	M-CA trial PH	M _CA Control PH	M+C- CA Trial PH	M + B-CA Trial PH	M-CA Control NZ	M + B-CA Trial NZ	M + B-CA Trial NZ	M+C- CA Trial NZ
Series1	87	43	64	83	34	21	19	17

Figure 16: Biomass water productivity results using weather station data for dryland field cropping using CA

From the graph above the following comments can be made:

- Phumelele's biomass results for all her plots is substantially higher than Ntombakhe's.
- Biomass results for the mono-cropped trial maize plots are higher than the maize and bean and maize and cowpea intercropped plots for both participants. This shows that even though the grain production for maize is increased in the maize and bean intercropped plots, the biomass yield of maize is reduced in the intercropping situation. This does however not include the added grain and biomass yields of the legumes themselves.
- Biomass results for the maize and bean intercropped plots are higher than the maize and cowpea intercropped plots for both participants. For the maize and cowpea intercropped plots both the grain and biomass yields for maize are reduced and do not hold with the assumption that intercropping with cowpeas can improve growth of the maize plants.
- For Phumelele, the biomass results for her maize mono-crop trial plots are substantially higher than her maize monocrop CA control plot. Here the value of the rotation and intercropping becomes more visible, given that the CA control plot is planted to maize every year but the maize CA trial plot is rotated within her trial. The latter provides for a substantial increase in biomass production and also water productivity.

In summary the WP results indicate the following:

- Water productivity for mono cropped maize is substantially improved in a crop rotation system under CA (3- year rotation that includes legumes and a mix of cover crops)
- Water productivity for maize and bean intercrops (grain and biomass yield) is higher than maize produced in a mono-crop under CA
- Water productivity for maize and cowpea intercrops (grain and biomass) is lower than both maize produced in a mono-crop and maize and bean intercrops.

5.4 Water productivity for gardening systems

Both Phumelele Hlongwane of Ezibomvini village and Ntombakhe Zikode of Eqeleni village in Bergville established experiments to investigate water productivity in their household vegetable gardening systems. Their experiment consisted of:

- Trench bed under tunnel, with mulching (shading) and
- trench bed without shading with mulching and
- Normal bed (this is the control bed, planted in the “normal” way that these participants have been preparing vegetable production beds- mostly dug over, with some manure added in the planting holes.)

They both planted spinach for this experiment which ran from 2nd of July November 2018. In both cases chameleon water sensors were installed in all three beds for participants to explore their irrigation scheduling and participants also recorded amount of irrigation and harvests.
In the end, only the crops in the two trench beds (inside and outside the tunnel) were compared, as both participants abandoned their normally planted beds mid-season due to lack of growth and difficulties with access to water for irrigation.
The table below outlines WP determined using both the weather station data and the simpler version of water applied that farmers prefer.

Table 27: Water productivity for gardening practices for two participants from Bergville; July-Aug 2018

Bgvl June-Sept 2018	**Simple scientific method (ET)**			**Farmers' method (Water applied)**		
Name of famer	**water use (m^3)**	**Total weight (kg)**	**WP (kg/m^3)**	**water use (m^3)**	**Total weight (kg)**	**WP (kg/m^3)**
Phumelele Hlongwane (PH); trench bed inside tunnel	1,65	21,06	12,76	1,85	21,06	11,38
Phumelele Hlongwane; trench bed outside tunnel	0,83	5,32	6,45	1,75	5,32	3,04
Ntombakhe Zikode (NZ); trench bed inside tunnel	1,65	17,71	10,73	2,37	17,71	7,47
Ntombakhe Zikode; trench bed outside tunnel	0,50	3,35	6,76	0,53	3,35	6,33

*Note; irrigation records for NZ were not very reliable and from inspection show more water applied in her tunnel than is likely the case. Thus the difference in WP for farmers’ method for NZ do not follow the trend.

From the table, the WP results (scientific) indicate that the WP for the trench beds inside the tunnel is around double that of the WP outside the tunnel for the trench beds. For three of the four results (excluding NZ’s tunnel inside her tunnel due to unreliable records for water applied) the WP calculated using the scientific and simpler methods correlate well; indicating little effect from evaporation or deep percolation – which is to be expected for the winter season in KZN.

The effect of micro climate control (shade cloth tunnel) on crop production is much more pronounced than would have been expected for KZN.

If the results of this experiment is compared to the same process that was conducted with participants in Limpopo (See the table below for reference – from Deliverable 5), the WP in Limpopo, at least for one of the two participants is substantially higher.

Table 28: Water productivity for gardening practices for two participants from Limpopo (Sedawa); April -July 2018

	Simple scientific method (ET)			Farmers' method (Water applied)		
Name of famer	**water use (m^3)**	**Total weight (kg)**	**WP (kg/m^3)**	**water use (m^3)**	**Total weight (kg)**	**WP (kg/m^3)**
Christina Thobejane (Tunnel; trench beds, with mulch)	0,8	48,9	65	1,10	48,9	56,7
Christina Thobejane (Furrows and ridges with mulch)	0,5	24,5	46,4	3,91	24,5	5
Christina trench outside	0,8	14,7	18,4	2,93	14,7	11,3
Nora Mahlako (Tunnel; trench beds without mulch)	0,8	19,6	26	9,47	19,6	5

One of the reasons for this trend could be that the participants in Bergville were in fact over-irrigating their beds initially, an assumption corroborated by the Chameleon water sensor data presented below. The Bergville participants kept more to the suggested practice of using the drip kits and then added water by hand if they thought that their beds looked dry. They did not water according the chameleon sensor readings. It would appear that the suggested practice of one bucket (20l) per day for the dripping system in fact led to overwatering. This could also be due to the fact that these crops were grown during the winter and that water demand in this period is lower.

A rough cost-benefit analysis for the trench beds in and outside tunnels for the Bergville area is shown in the table below

	Water applied	**Cost (R/m^2)**	**Yield/ m^2**	**Sales (Rands / m^2)**	**Profit (R/m^2)**
Trench inside tunnel	1650	R0,00	2,6	R26	R26,00
Trench inside tunnel	1650	R13,12	2,6	R26	R12,80
Trench outside tunnel	830	R0,00	1,6	R16	R16,00
Trench outside tunnel	830	R6,64	1,6	R16	R9,36

This indicates the income potential for these small tunnels to be around R400 for a 3month period, growing spinach and assuming water does not need to be paid for. Note that in some cases participants are paying R300/2500l to have their Jo-Jo tanks filled up. In this case the profitability reduces dramatically to around R12,8/m^2 (assume 15m^2 of planting inside and outside the tunnel)
The participants also visually compared the growth of the spinach crop throughout the season
The photos below are indicative.

Right: Spinach growing in Phumelele's Tunnel Far Right: Spinach growing outside the tunnel

Right: Spinach harvested from trench bed insidetunnel and Far Right: spinah harvested from outside the tunnels

From observations, the quality of the spinach in the tunnel is better than that of the spinach ouside the tunnel, spinach leaves outside the tunnel are darker and shorter compared to those inside the tunnel.

Right: Spinach growing in Ntombakhe'sTunnel Far Right: Spinach growing outside the tunnel

Right: Weighing of spinach and Ntombakhe with a bundle of spainch from her tunnel

5.4.1 Chameleon Results for the cropping period inside and outside the tunnels

Below are the readings of the chameleon water sensros for Phumelele Hlongwane in the trench beds inside and outside her tunnel, as well as a normal garden bed, summarised for the last 6 months.

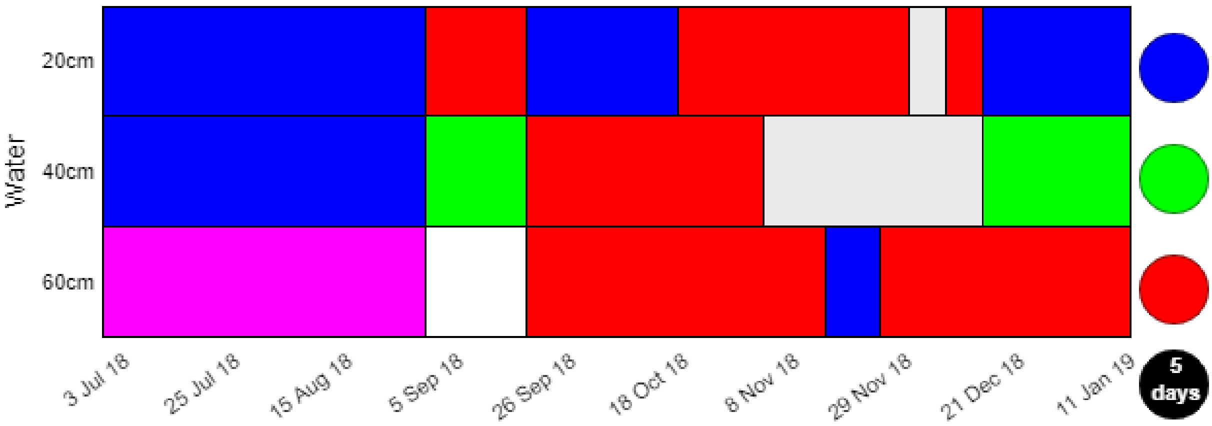


Figure 17: Chameleon readings for Phumelele Hlongwane inside her tunnel

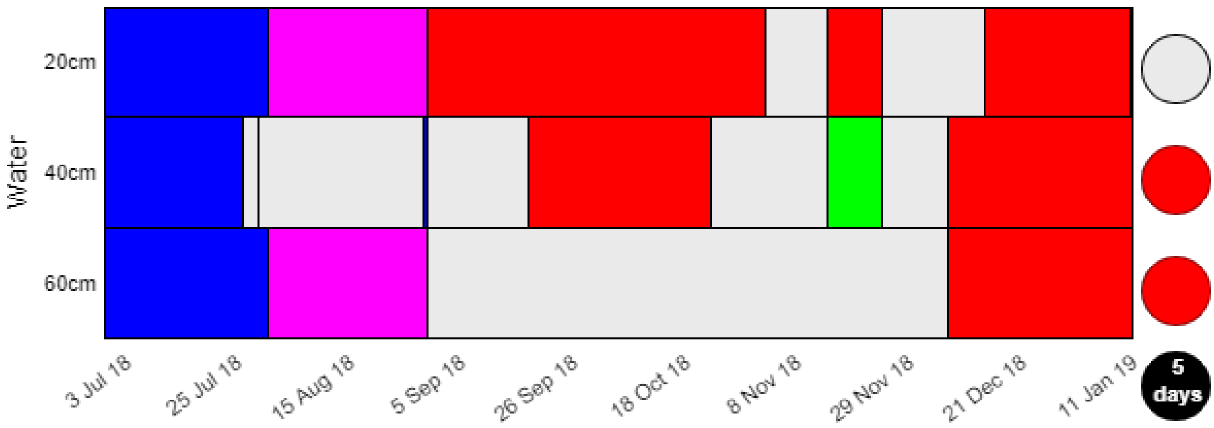


Figure 18: Chameleon readings for Phumelele Hlongwane outside her tunnel

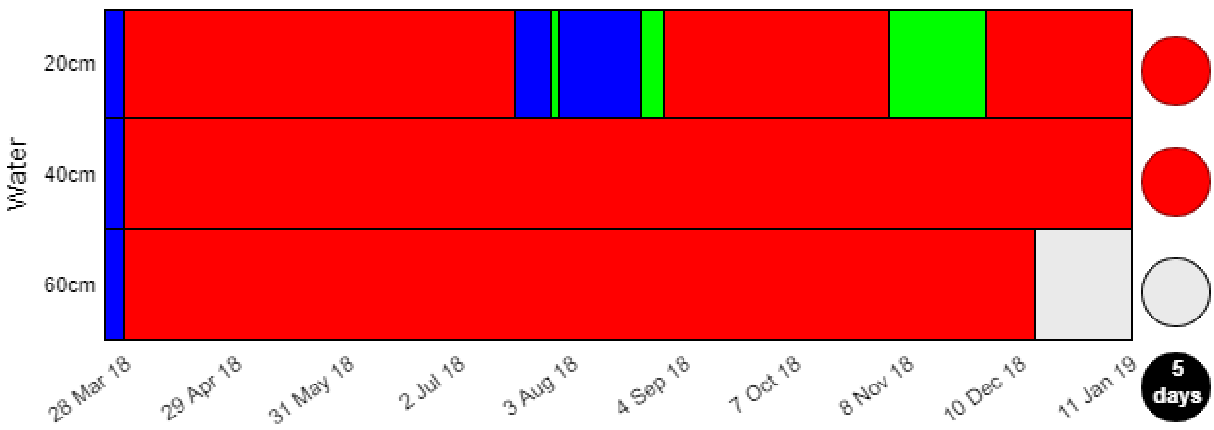


Figure 19: Chameleon readings for Phumelele Hlongwane for a normal bed in her garden

The ideal colour in terms of managing water content in the soil by adjusting the amount of water used would be green and blue. The pink showing in the two trench bed graphs indicate overwatering. From this it can be seen the Phumelele initially (July-August) overwatered her two trench beds (both inside and outside the tunnel), mainly as the drip irrigation practice is to fill the 20l buckets on a daily basis. After that she started to adjust the amount of water provided. The increased red and grey blocks here indicate underwatering. It also coincides with very little water being available for irrigation. In general tough she has now been underwatering somewhat.

Clearly adjusting irrigation using the chameleons as an indication has not been an easy task for Phumelele. The lack of water in the village of Ezibomvini is a significant challenge as access to water in this community is mainly limited to small springs. The lack of this then limits gardening in many of the homesteads in the village. The local municipality does provide water through water tank trucks where village members leave out their containers on local routes within the village for the truck to fill their containers. Bigger containers such as Jo-Jo tanks are also filled, but for this the community members have to pay R300 per 2500l. They have agreed to this, even though they suspect that they are not meant to pay these amounts officially.

In November 2018 a small workshop was held for sharing this experiment with local facilitators and interested participants from other viallges around Bergville. Mrs Hlongwane took these ladies thorugh her epxeimrentation process and showed them the production sinde and outside her tunnel as well as the chameleons nad weather station

Above Left and right: Learning group participants form neighbouring villages are taken through the tunnel and trench bed experiments by Phumelele.

Above left and Right: And are shown the instrumentation used to assess conditions and irrigation requirements. Note that the spinach at this point outside the tunnel was quite wilted.

The chameleon data obtained for two more participants; Ntombakhe Zikode and Zodwa Zikode, showed a similar trend of initially providing sufficient water and struggles to keep up with enough watering after August. More attention needs to be given for these sensors to be able to work as an irrigation management tool. Participants water and check the chameleons quite soon thereafter. Once the top layer shows a green light they feel that enough water has been added. This has lead to the lower soil layers drying out and staying dry later in the winter season and into the early summer period. This is not likely to have affected the crop growth of the spinach that much, as it is shallow rooted, but has led to regular stress and wilting, which has affected the growth and quality.

6 CAPACITY BUILDING AND PUBLICATIONS

Capacity building has been undertaken on three levels:

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

Community level and organisational capacity building have continued within this reporting period..

6.1 Post graduate students

A number of changes have occurred within the postgraduate students. Two students have withdrawn from this process:

- Sylvester Selala has withdrawn from registration of hi PhD concept and has left the employ of MDF. He will not pursue a doctorate at this time.
- Khethwie Mthethwa has found permanent employment and is not presently registered for her second year of an MSC. This is mostly due to the fact the UKZN only offers 1 year of fee remission for Masters candidates and the director of MDF was not made aware of this fact in time.

Another student has re-registered and is presently self-funded:

- Palesa Motaung has suffered in her registration process due to the ARC not paying bursaries as awarded to postgraduate students. She has now paid some of her own fees and commenced with her field work.

And a new PhD candidate has come on board as an intern at MDF

- Samukhelisiwe Mkhize has recently registered for a PhD in Social Sciences (Policy and Development Studies). The topic of her concept proposal is *An investigation into the factors limiting and promoting the adoption of CA in smallholder systems in South Africa* (See her concept proposal in Attachment 3)

Progress: Research methodology and initial field work:

- Mazwi Dlamini: MPhil - UWC_PLAAS. *Factors influencing the adoption and non-adoption of Conservation Agriculture in smallholder farming systems, and the implications of these for livelihoods and food security in Bergville, Kwazulu-Natal*

In the last five months Mazwi has commenced with his field work and has undertaken a number of focus group discussions and started on the individual interviews- which is the first round of the research process.

Publications and networking

- Publications:
  - Institute of Natural resources: Agroforestry implementation at community level.
- Presentation at conference, networks and forums:
  - 2nd African Conservation Agriculture Conference (2 ACCA 9-12 October 2018);

        - *Erna Kruger (2 papers); Doing Conservation Agriculture the Innovations Systems way and Soil health aspects of CA in smallholder farming systems in South Africa*
    - National Climate Change Committee Stakeholder Forum (11 November 2018) See Attachment 4
        - *Erna Kruger: Community Based Climate Smart Agriculture*
    - Agroecology network workshop (22 November 2018)
        - *Erna Kruger: Agroecology best practices in CCA*
        - *Betty Maimela :Taking stock- Linking Mahlathini farmers to markets*
- Awards:
    - LandCare: Best Civil Society Organisation in LandCare, 2018
    - 2 ACCA Conservation Agriculture Champion award.