Deliverable

5

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

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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 5

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 five- month period have included:

- **Practices activities**: Initial modelling of the DSS and initial design of an online survey for CSA practices

- **Process activities:** Introduction of CCA in 1 (CCA workshop 1) more community in KZN (Swayimane), individual prioritization and planning (CCA workshop 3) in the EC (3 villages), training and implementation (Workshops 4 and 5) in KZN (3 villages), the EC (3 villages) and Limpopo (3 villages). CoP engagement has consisted of presentations at the KZN CA forum (KZNDARD) and a national CA Forum (GrainSA/ Maize Trust). Capacity building; continuation of MSC's (Khethiwe Mthethwa) and MA (Mazwi Dlamini); 2 Conference presentations; 1 article; 1 cross visit (PACSA small livestock farming visit) and 1 learning event (ARC "Agricloud" app for smallholder farmers- introduction).
- **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; Limpopo, expansion of baseline information and impact assessment of CA after 4-5 years of implementation

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

Date	Activity	Description	Team
2018/05/04,05	CCA workshop 3	Ezibomvini and Eqeleni (KZN)	Phumzile, Khethiwe, Sylvester
2018/05/04,05	Water issues exploration workshop 1	Lepelle, Sedawa (Limpopo),	Sylvester, Erna
2018/06/06, 07	CCA workshop 4	Ezibomvini, Eqeleni, Thabamhlophe(KZN)	Phumzile, Khethiwe, Temakholo,
2018/06/26,27	Water issues exploration workshop 2	Lepelle, Sedawa (Limpopo)	Sylvester, Erna, Chris, Neville Meyer
2018/07/03-04	CCA workshop 1	Swayimane (KZN)	Temakholo, Khethiwe, Mazwi,
2018/07/07-14	Initial online survey	Draft concept	Erna, Matthew Evans
2018/07/26	Livestock cross visit	PACSA small livestock projects in Umgungundlovu DM	Mazwi, Temakholo, Khethiwe
2018/07-09	Initial modelling of DSS	MoU with WITS academic for initial outline and concept of model	Erna, Catherine van den Hoof
2018/05-08	Participatory video	Training of field staff; PV in KZN (Ezibomvini, Stulwane, Swayimane), EC (Alice, Middeldrift) and Limpopo (Lepelle, Sedawa)	Mazwi, Sylvester, Erna, Khethiwe, Phumzile. Neville Meyer
2018/07/30-08/03	CCA workshop 3 and 4	EC (Alice, Middeldrift), 3 villages, incl baseline interviews, construction of tunnel, dripkits, towers gardens, demos and training	Sylvester, Mazwi, Khethiwe, Temakholo, Erna, Chris and Lawrence

2018/08/07,08	Water issues workshop 2	KZN (Ezibomvini and Eqeleni)	Erna, Chris, Phumzile, Temakholo, Khethiwe
2018/08/13-15	LaRSSA conference	Presentation on CA innovation system	Erna
2018/08/20-22	Water issues workshop 3	Limpopo (Lepelle, Sedawa)	Erna, Chris, Sylvester Neville Meyer
2018/09/06	ARC_Agricloud workshop	Introducing app for smallholders - climate forecasting to assist planting, spraying and pest control	Erna, Temakholo, Phumzile, Samke,
2018/09/16	GrainSA CA forum	Presentation of CA progress; Swayimane, Bergville and overall	Erna, Phumzile, Khethiwe
2018/09/25-27	8th Biennial LandCare Conference	Presentation on CA progress	Temakholo, Khethiwe

Capacity building and publications:

- Research presentations and chapters:
    - Mazwi Dlamini – M Phil (PLAAS UWC-yr 2); Completed research tools and started on field work
    - Khethiwe Mthethwa: M Agric – University of KwaZulu Natal; January 2018. *The contribution of Climate Smart Agriculture (CSA) practices in adapting to climate change: The case of smallholder farmers in KwaZulu Natal.* Completed proposal and desktop review and started on research tools
- Publications:
    - SA Grain Newsletter; CA SFIP, 1 smallholder case study (Swayimane)
- Cross visits:
    - PACSA – small livestock production interventions in the Umgungundlovu DM
- Attendance:
    - No-Till Club Annual Conference- 4-6 September 2018
    - KZN CA Forum
    - Introduction of Agricloud app (www.rain4africa.org) for smallholder farmers – ARC – 6 September
- Conference papers:
    - Land Rehabilitation Society of South Africa: Annual Conference 13-15 August 2018. Presentation of a paper "*Learning CA the Innovation Systems Way" – E Kruger*
    - 8th Biennial LandCare Conference; 25-27 September "*CA Innovation Systems; progress and successes" – T Mathebula*

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 (May-September 2018)

Province	Site/Area; villages	Demonstration sites	CoPs	Collaborative strategies
KZN	Tabamhlophe	- CCA workshop 1 - CCA workshop 2 -**CCA workshop 3**	-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**	-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
	Swayimane	**- CCA workshop 1**	-CA open days -Umgungundlovu DM agriculture forum	-CA farmer experimentation
Limpopo	Mametja (Sedawa, Turkey)	- CCA workshop 1 - CCA workshop 2 - CCA workshop 3 - **CCA workshop 4** **-Water issues workshops 1-2**	-Agroecology network (AWARD/MDF) -Maruleng DM	- 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 and 4**	Imvotho Bubomi Learning Network (IBLN) - ERLC, Fort Cox, Farmers, Agric Extension services, NGOs	-Individual and collaborative experimentation with basket of options -Tunnel, dripkits, trench beds (Quantitative measurements)

*Note: Activities in bold under Demonstration Sites, were conducted during tis 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. The climate change adaptation process was expanded into one more village, in Southern KZN during this period.

Swayimane is a densely populate rural community close to New Hanover and Pietermaritzburg. A number of smallholders there are active in market gardening and selling of vegetables and field crops (such as amadume, sweet potatoes and maize) to the burgeoning urban population around them. Four new learning groups were started in the area during 207-2018, focussing initially on the introduction of Conservation Agriculture into their cropping systems. An exploration of climate change impacts and potential adaptive measures into their farming system and experimentation with climate smart agriculture practices both in their cropping and gardening activities was made.

2.1.1 CCA workshop 1 summary – Gobizembe (Swayimane)

Written by Temakholo Mathebula and Erna Kruger

Group understanding of Climate Change

The 20 participants in this workshop acknowledged that the weather patterns in their area have been changing, with overall higher temperatures and water scarcity in the community, becoming slowly more and more severe. This is linked to a change in the rainfall patterns, which has affected their planting dates and harvests. They appreciate the opportunity to experiment with ideas that can assist in building their resilience and mentioned that already they can see how the Conservation Agriculture they have tried this year can help. They mentioned that they were not aware how severe the situation is in other areas (as presented by Mahlathini). For some of the farmers climate change was seen a myth, but the discussion made them more aware of the issues as a real problem.

Right: The Gobizembe learning group discussing climate change, impacts and adaptive measures

They felt that the winter season has become colder and the summer season, hotter. They added that this year the rate of rainfall has increased and as a result they had snails in their vegetable gardens for the first time. There were no serious issues with soil erosion in majority of their gardens because they continued to open basins instead of ploughing which has become common practice amongst the group members and has assisted them in retaining water.

One of the participants raised the prevalent problem of water scarcity in the community, adding that if the community does not take care of the environment this will be worse. According to another farmer, if climate change goes unnoticed and misunderstood in local communities there will be no life on earth. They suggested that issues related to climate change and its effects on the environment should be taught in schools because the younger generations should be taught about the theories, reality of climate change and what can be done to combat it. They further asserted that people are the cause of climate change, therefore, communities must also be involved in driving change including faith- based organisations in KwaSwayimane. The analysis of changing in their farming system from past though to future is summarised in the table below

Table 3: Gobizembe analysis of farming system; Past, present and future

Past	Present	Future
No fertilizers used	Farmers continue to use compost produced using dead leaves	Increased use of fertilizers
Mixed cropping	Mono cropping	No water to water their crops and to give to livestock.
Use of organic fertilisers- chicken and cattle dung	Decrease in yields due to abandonment of traditional methods of planting	Integration of crops and livestock system
Traditional varieties	Shift to westernized planting methods	Deterioration of health status and energy levels
Keeping of livestock	Tram lines (beans and potatoes)	Loss in yields
There were no termites	Farmers use basins, contours and swales methods to plant sweet potatoes	Increase food insecurity
	The farmers use swales to be able to clearly see when it is time to harvest	Nutrition deficiency
	We eat genetically modified food	One home one garden
	More vulnerable to sickness.	Training of younger generation how to farm
	Crops are more vulnerable to termites	

The analysis of impact of climate change on the lives and livelihoods of the participants is presented in the table below

Table 4: Analysis of potential adaptive measures to counteract CC Impacts; Swayimane

Problem	Impact	Solutions or adaptations
Death of livestock	Poverty and Hunger	Vaccinate livestock
Increased rainfall	Increase presence of insects and pests in vegetable gardens	Spraying of pesticides and ash in the garden, use natural pest control such as wood ash, crushed garlic and water mix to kill pest and insects.
Drought	Vegetable plants dry up	Change planting season, use cattle dung as compost, keep soil covered and don't till the soil, cover crops with net
Scarcity of water	Vegetable plants dry up and shrinking of food supply	Man-made dams, recycle and reuse water, water plants once a day, creating basins to plant, rain water harvesting, provision of JoJo tanks
Fewer homes with vegetable gardens in communities	Less food supply	Every home must have a vegetable garden
Soil erosion	Reduced ability of the soil to store water and nutrients.	Create basins and farrows &ridges for planting. Don't till the soil.
Yield loss	Increase food insecurity	Implement CA practices: mulching and no-till.
Poverty	Hunger and nutrition deficiency in the community. Increase in crime and theft	Growing crops and vegetables for household consumption
Crime	Yield loss	Fencing of vegetable gardens. Encourage youth to get involved in farming activities and/or find jobs

The household visits on the 2nd day revealed a number of practices undertaken by the farmer participants that can already be considered local adaptive measures. The household farm fields of Ritta Ngobese, Khombisile Mcancana and Thandazile Mathonsi were visits to observe their fields, record current farming practices and climate change effects on farming.

They opted break up their community garden and farm in smaller cluster of 5 people together in their homesteads. They have a garden/field of around 400m^2, fenced and supplied with water through a Jo-Jo tank. They plant vegetables in winter and field crops in summer.

They use S&W conservation techniques including raised beds, planting basins, furrows and ridges, some mulching, mixed cropping and crop rotation. This last season they have used CA for their field crops.

The farmers started their season by planting potatoes. After harvesting they cover the soil with maize stalks to retain soil moisture. They also planted cover crops and intercropped using cow peas and amadumbe. Thereafter, they planted amadumbe, then the maize and bean intercrop. Currently they have planted cabbages, brinjal, mustard spinach, onions, spinach, beetroot, carrots and green pepper (see Pictures below). They have issues with pests infecting cabbage and spinach leaves that often turn purple.

Right; a mixed raised bed of chilies and onions and far right their garden, showing raised beds, basins, and sandbags to conserve soil and water

Above left: Mam Ngobese's field prepared for field cropping with furrows and ridges ready for planting potatoes and amadumbe. Above right; Thandazile Mathonsi, uses basins in her garden for planting. She uses a mixture of fertilizer and manure for planting, but her soils are obviously lacking in organic matter and are dry and infertile.

After the field visits, the exercise in suggesting and prioritising adaptive measures was conducted.

Right: Tema facilitating the impacts and adaptive measures mind mapping exercise

Here practices were introduced (using the practices power point presentation), that farmers could try out immediately or in the near future to solve some the current issues discussed and discuss the current adaptation measures they are practicing to solve these challenges. The practices are categorized in five different groups; water management, soil management, crop management, livestock, and natural resources.

Water management
- Rain Water Harvesting
- Windbreaks
- Grey water use

Soil management
- Less use of tractors (No-till)
- Plant on contours
- Plant grass to stop erosion (crop/soil cover)
- Stone lines
- Increase soil fertility
- Increase water holding

Crop management
- Natural pest & disease control (ash& garlic)
- Trench beds
- Mulching
- CA (No-till)
- Tunnels
- Inter cropping & crop rotation
- Seed type/ seed saving

From this list the following practices were prioritized by the group for implementation:

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

Criteria used to select practices are summarised below:

a) **Water usage**: 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) **Increase in crop quality**: Increases crop health and yields
e) **Seasonality**: Whether each practice is suitable for all seasons, subject to the effects of unpredictable changes in climate conditions
f) **Labour**: This relates to the labour intensity and time required to construct structures and sustain practice(s).
These criteria were then used to rate the different practices as shown in the table below.
Scale:

1-low/easy/cheap
2-medium/average
3-difficult/high/expensive

Table 5: Prioritization matrix for Gobizembe participants

	Water usage	Increase soil fertility	Cost	Crop quality	Seasonality	Labour	TOTAL
Tunnels	2	3	3	3	3	3	17
Drip kits	1	3	2	3	3	2	14
Trenches	1	3	1	3	3	3	14
Tower gardens	1	3	2	3	2	2	13
Mix cropping	2	3	2	3	1	2	13
Cover crops	2	3	3	3	1	2	14
CA (no-till)	1	3	1	3	3	3	14

This exercise helps to prioritise the practices that individual farmer participants will experiment with in the coming season and paves the way for the 3rd CCA workshop where the individual experimentation schedule is set out and training and mentoring is provided in the techniques and practices.

2.1.2 Farmer Experimentation in Conservation Agriculture

The implementation of the CA awareness raising and experimentation is managed through the Maize Trust Smallholder Farmer Innovation Programme. Outcomes, learnings and linkages with weather variability and adaptation are also reported here as these aspects are pertinent to the assessment of impact of the practices and the development of the decision support process.

Individual members of the learning groups are part of a Farmers' Association in the area. Thirty-four (34) participants conducted CA trials; consisting of 400m^2 plots intercropped with maize and beans and maize and cowpeas respectively. Cover crops are relay planted into the plots towards the end of the season. Farmer level experimentation was expanded to include planting with a 2-row tractor drawn planter for the larger fields and the experimentation layout and planting procedures were adopted to also suit this process.

Below are a few small case studies of the trials during this growing season.

The Nxusa family from Gobizembe (three sisters working together) planted an eight-plot maize-bean and maize-cowpea intercrop in one of their fields using PAN6479 (maize) and Gadra (drybeans). Crop growth was good, specifically the maize-cowpea intercrop, which showed vigorous dark green growth and canopy cover early in the season. The maize and bean intercrop plots had a lot more weeds with some yellowing of both the maize and beans evident. Lack of weeding in these plots may have exacerbated the problem.

Mrs Mkhize from Mayizekane 1, did not have faith that anything would grow from the trials planted; for her this felt like a joke where people are playing around in the field and not really working. Mrs

Left: maize-cowpea intercrop looking dense green. Right: Maize-bean intercrop looking a bit pale

Mkhize is the lead farmer for this learning group and saw to most of the planting here. She was very surprised when she saw good growth of both maize and legumes, which is when she decided to plant her control in the same manner with a little variation. Her concerns regarding the trials is firstly the close spacing; she feels this is too close and doesn't allow for proper crop growth. Secondly, she feels weeding is difficult in this system and she opted to do single instead of double rows in her trial but plating a maize and bean intercrop.

Above: Mrs Mkhize's plantings; Left, the maize and bean intercrop, middle the maize and cowpea intercrop and Right; her control plot, which she also decided to intercrop

Dumazile Nxusa, was one of 15 farmers who relay planted the cover crops in between her maize and the germination was around 85%. All the cover crops germinated and grew well. These included Sunn- hemp, Saia oats, fodder rye and fodder radish. The area planted is 1460 m^2.

Right: Views of Mrs Nxusa's cover crops in Swayimane

Observations during the growing season and group discussion and learning sessions help the farmers to understand and analyse the elements of the new practices in their farming system.

Yields were extremely variable and quite low. This is not unusual for entrant participants. The range of maize yields for these participants was between 0,5-7,2t/ha. The effects of CA on the soil and cropping system are not yet visible or obvious after the first season. These yields are more indicative of the basic conditions and management practices for each farmer.

Table 6: Crops yields in CA trials in Swayimane; 2017-2018

Crop yields in CA trials; Swayimane 2017-2018				
	Ave maize yield (t/ha	Yield range for maize	Ave bean yields (t/ha)	Ave cowpea yields (t/ha)
Gobizembe	1,6	0,5-7,2t/ha	0,2	0,2
Mayizekane 1	1,2		1	0,2
Mayizekane 2	1		0,4	0,7
Mayizekane 3	0,9		0,7	0,7

A review session with farmers was held to discuss progress with the CA trials and analyse observations made by the farmers. These discussions are summarised in the table below

Table 7: Summarised points from the discussion of introduction of Conservation Agriculture in Swayimane

	MAIN POINTS HIGHLIGHTED BY FARMERS		FEEDBACK FROM MDF TEAM
Main Topics	**Positive**	**Disadvantages Identified**	**Main Points**
CA Trials: Intercropping	➢ Saves space, can grow more food in a smaller area ➢ Allows symbiotic relationship between maize and beans (beans fix nitrogen) ➢ Reduces soil erosion	➢ Intercropping does not work well with beans. Gadra beans in particular are vulnerable to wet conditions and rot easily. ➢ Cowpeas climb on maize and stunt its growth resulting in thin and yellow stalks ➢ Recommended spacing too close	➢ Intercropping is an important component of CA. It helps reduce the use of herbicides by increasing plant canopy and reducing the growth of weeds. ➢ Intercropping also spreads the risk of disease outbreak and helps improve soil fertility when soil beneficial plants such as legumes are included in the combination. ➢ Zig-zag spacing is used to ensure that there is enough room for plant leaves to grow out and minimizes open spaces in between plants without overcrowding.
Environmental factors - Soils - Rainfall - Pest and diseases	Soils (general characteristics) ➢ Deep, well drained ➢ Good aggregation Rainfall ➢ Good summer rainfall area Pest and Disease ➢ Trial maize was much less affected by talk borer ➢ No serious disease outbreaks except on beans	➢ Shallow and rocky in some areas- Gobizembe ➢ Yellow and purple leaf colour of maize on both trial and control plots suggests issues with soil fertility, possible N and P deficiency ➢ Evidence of erosion, especially on slopes ➢ Excessive rainfall in current season resulted in fungal disease and spoiling of produce ➢ Pest identified were CMR Beetles, aphids (on cowpea), stalk borer	➢ Years of ploughing, disking and ripping the soil cannot be reversed in one season. Just like it takes time to deplete soils of nutrients, it will also take time to rebuild the soil's nutrient base. ➢ Gadra bean is early maturing and generally produces high yields. It must not be exposed to extensive wet conditions at maturing stage. Spacing can be increased to improve aeration. ➢ Cowpeas are not popular but are highly effective in N fixation, even more so than beans. ➢ It is possible to intercrop maize and cowpea without suffocating either crop. Thin stalks and uneven growth may be more linked to soil fertility than intercropping with cowpeas. ➢ Intercropping with legumes, leaving crop residues and proper fertiliser application may improve nutrient status over time.
Time of planting	Staggered Planting (usually done in three stages)	➢ In Gobizembe, planting took place in December. Although still within season,	➢ Timing has a direct impact on final yield.

	MAIN POINTS HIGHLIGHTED BY FARMERS		FEEDBACK FROM MDF TEAM
Main Topics	**Positive**	**Disadvantages Identified**	**Main Points**
	1st Planting- August 2nd Planting- November 3rd Planting- January ➢ Spreads the risk of crop failure ➢ Extends growing season ➢ In Estezi planting took place in January, and trials grew faster than normal variety.	it was not the best time to plant in. Ideal time is Mid November.	➢ Procuring inputs can be tricky at times as they are not always available at the required time or in the right quantities. In the upcoming season, the team will try to finalise the order well ahead of time.
Application of herbicide	➢ Herbicide worked but to a limited extent	➢ Weeds were above knee height in some areas, and spraying had to be done twice in order for the weeds to die back	➢ Weeds must be sprayed at early growth stages and herbicide must be applied to green, actively growing weeds. ➢ Herbicide will not be effective on weeds that have reached flowering stage i.e. stronger concentrations/different herbicide will have to be applied.
Maize Cultivars	PAN 6479 well adapted to the area, SC701-most widely used variety	PAN 53 did not do so well in Gobizembe, however need to look at soil properties	➢ There were mixed reactions about plant varieties. ➢ Some farmers from Mayizekanye prefer planting only SC701 as they grow maize for market. ➢ Gobizembe farmers happy to plant PAN 53/6479 ➢ Way forward: groups compile a list of who wants to plant which variety, will need to take into consideration the price as well.

For the most part, concerns about climate change did not enter directly into these discussions and the focus is more on better soil and water management and increased diversity. All three however are important aspects in increasing efficiency and resilience of the cropping systems

2.1.3 CoP in Swayimane

For the Swayimane groups good relationships have been built with the DARD extension officers as well as representatives from the Umswhathi LM and Umgungundlovu DM. In addition, role players from UKZN and local NGOs have been involved. Through these relationships requests were made for expansion of the CA programme into others areas in the LM. An introductory meeting was held in the Appelbosch area- (between Wartburg and Tongaat). In addition, this process has fostered cooperation with the UKZN, who is running a research process on Climate Smart Agriculture through the Water Research Commission – CA is one of the technologies they are demonstrating in their sites in KZN (Swayimanye) and the Free State.

3 NEW EMPHASIS: WATER ISSUES

3.1 Introduction

More and more, it is becoming clear that it is not possible to discuss the issues of farming in a changing climate without also tackling the issues of access to water and water availability. The assumption of this research process has been to work with people to maximise the efficient use of available water. It has however been emphasised by the participants that the reduction of available water and the greater pressure on existing water sources has already reduced their productive capacity substantially in some cases.

Participants in four of the eight learning groups presently involved have taken it upon themselves to engage with the water issues as a group. They have stressed that they now want to try and solve the water issues for themselves and can no longer wait for the Government and Municipality to provide this service for them. They have lost faith that these structures have their interest at heart.

As this is a significant step in social agency and in self determination of community people and active learning group participants, a decision was taken to develop a process of support for these activities. These learning groups have set up water committees, which they have gained permission and support for from their traditional authorities have come up with plans for their water provision schemes and have collected some funds for implementation. They have asked for assistance in the design and implementation of their plans and also in securing funders to support their activities.

Lobbying and advocacy for rural people and their desperate situation around water is also central to this theme and here Participatory Video (PV) is being used as a tool. The PV process is described in the next section of this report.

A methodology/process has been designed to assist these groups in the exploration and implementation of their agricultural water provision plans.

- Workshop 1: Exploration of all water sources available to the community, a timeline of water provision and issues in the community, and exploration of options/scenarios for intervention.

This workshop was run in four villages; 2 in KZN (Ezibomvini and Eqeleni0 and 2 in Limpopo (Lepelle and Sedawa)

- Workshop 2: Screening of community video, report back on engineering suggestions, prioritisation of scenarios (plans) and follow-up actions. This workshop was run in the two Limpopo villages.

3.2 Water issues Workshop 1

3.2.1 KZN (Ezibomvini) (22 participants)

*Wirtten by Samukhelisiwe Mkhiz*e and Temakholo Mathebula

Ezibomvini Water issues discussion

1 Introduction

On the 31st July 2018 the MDF team (including Nonkanyiso, Phumzile, Samukelisiwe, Sandile and Zanani) visited Ezibomvini village in Bergville to have an initial exploratory meeting around the issues related to water availability and accessibility in the community and explore possible solutions and opportunities for collaborative action.

The meeting started with a brief recap of the previous meeting where participants discussed how the changing climate over the past few years has increased the incidence of floods and its effects on the shortage of available food due droughts. The participants also mentioned that, there is increasingly less rainfall during spring season and places that usually have water have run out of water. Most of the community members fetch water from muddy and dirty springs that are very far from most of their homesteads. But, participants insisted that these springs are reliable water sources, at least they offer reliable water supply unlike community taps installed by the government that have no water supply for months at a time. One example is the “24/7 spring” that supplies water throughout the year.

There are no community committees working to help community members to raise and solve some of these issues. Individuals have gone to the counsellor to report these issues and request assistance. But participants claim that party politics are the main cause of skewed access to water. One of the community members Mam’ Mazibuko asserted that the councillor has favourites; he only helps those individuals from a particular political party. Participants were encouraged to form a committee that will represent them either at the municipality or amongst other relevant stakeholders in solving these issues. It was important to also emphasis the issue of keeping political issues and memberships outside of this committee in order to empower and represent all members of the committee members equally.

1.2 Timeline of past and present issues

In 1994 after voting the municipality installed a water pipe system connected to a spring neighbouring households in an effort to make water more accessible for household use. Efforts were undermined by vandalism and theft of water pipes by youth and herdsmen who have been suspected of cutting the pipes for their cattle to drink from.

One of the participants (Phumelele Hlongwane) added that, there are several springs available in the community for community members to use. She recalls fetching water from the 24/7 spring since 1998.

In 2000, the former community councillor Mr Mlotshwa also installed pipes connected to one of the springs. For a short time, it seemed that life had changed after the pipes were installed. The elderly were able to fetch water comfortably with 5 litre containers. But this did not last long, the pipe was found damaged and left leaking. Community members had a meeting about this conflict and arguments rose amongst the members. The issue remained unresolved till today.
Currently the community does not have access to clean water. A meeting was requested with the councillor Mr Musa Hadebe. The meeting did not take place. Instead, he sent a driver to deliver water to the community at R300 for 2500 litres. To simply put it, no money means no water.
Some community members have small water catchment systems, harvesting rainwater using JoJo tanks and drip irrigation systems. But, harvested water does not last very long and runs out during the lengthy dry period.

From the discussion participants proposed two possible solutions: a) Use of machines to check if there is water down (water table) in their surroundings to drill boreholes and b) Use of TLB to install a big pipe from the spring close to one of the homesteads so that they can put small pipes to their homesteads.

2. Description of all water sources
On the 7th August 2018 a more in- depth workshop was held around the water issue.

> The participants had agreed to form a committee (after the 1st meeting in July), to help them address some of the issues affecting water provision and assistance with water issues in the village. The primary idea behind this is that organizing themselves around this issue will give community members a better chance of negotiating and bargaining with other stakeholders as well as a way forward in developing a community of practice amongst the relevant stakeholders. The realisation is that communities have been establishing their own strategies to deal with the issue of lack of water access, but there is still a dearth in technical support (viable innovations) and commitment at community level. The suggestion to elect a committee will also help address political issues surrounding water access as there are a lot of politics involved in the distribution of water. Participants have begun speaking to community members about this idea and gaining support for this initiative.

The session began with each participant introducing themselves and giving a brief description of their water sources and N explanation of the location of these sources (see Table 6 and Pictures below).

Above left: The map of water sources drawn by the workshop participants and Above right: discussion of the sources

Table 8: Description of all water sources, as used by each participant in the workshop

Participant	Type of water source(s)	Description and location of water source	Number of households	Issues	Suggestions and comments
Mabhengu Dlamini , Zodwa Zikode, Phumelele Hlongwane, Cabangani Hlongwane Manyola Zimba, Baba Mazibuko	-Water Pipe (1) -Spring One (24/7 spring)	-Damaged and dripping water pipe -24/7 water supply -available across all seasons -Spring is quite far from homesteads -Water used for all household needs	-Previously installed water system provided water for 11 households	- Water pipes are cut by community members (2007) and has not been maintained since -Spring not fenced -Water is muddy and dirty and shared with livestock	-To install a tank system that would connect a pipe to the spring to households. -Dig deep trenches when inserting pipes underground
Madlala Zikode	-Water tap Collects water from a tap in her relatives homestead, the tap gets water from a spring	`-Located in relatives homestead -Water tap connected -Water used for all household needs	-Two households	-None mentioned	-No new suggestions
Nonhlanhla Zikode	-Water pipe Same water pipe as Mabhengu Dlamini				
Madondo KaDubazane	-Spring Two	-Spring is too far from homestead -24/7 Water supply -Muddy and dirty water -Water used for all household needs	?	-Shares water with livestock -Has to wake up early to get cleaner water	-To install a tank system that would connect a pipe to the spring to households
Macele Dlamini	-Water pipe - Spring three	-Damaged and dripping water pipe		-Has a broken tap that no longer works in her homestead -The tap needs maintenance -Has a tank that needs to be repaired	-The participant asserts that there is underground water, they just need to install a system

3. Spring Visits

The team and participants agreed on seeing the two springs and other water sources such as the leaking pipe. These springs do not have any pipes supplying water to households and there are no issues related to ownership of this spring. According to the map which is drawn by participants which shows water sources in the community there are 5 springs and 2 tanks. The pictures below are illustrations of the water sources and characteristics of each source.

Right: Spring one – More than 10 households use this spring for all household needs

Participants prefer to collect water in the morning before cattle invade the water source. Water is perennially available but due to increasing demand for water from both human and livestock, water levels have decreased.

Right: Spring two- 11 households get water form this spring, for household use as well as watering vegetable gardens

Right: An example of a leaking pipe from the piped systems that are no longer working.

Far right; Spring Three is used by more than 10 households for household activities and irrigating of gardens.

Due to the lack of access and availability of water MaCele along with her community members decided to dig this 'spring' to address this issue in 2015.

Upon further exploration, higher up the hillsides, the storage tanks for the piped scheme set up by the Dept of Agriculture was found. The source for this tank has however dried up almost completely. So, although there is some water dripping from pipes lower down this source cannot be rehabilitated.

Right: Cement tank built by the department of Agriculture, prior to the Municipality taking over the responsibility for water provision

4 Recap and Feedback Session (Way Forward)

Chris began the session with explaining how the springs can be protected including fencing, installation of a pipe and tank system. The labour for the installation of the system will involve digging deep trenches, inserting pipes then filling the trenches with gravel to catch water coming through the pipes. Two solutions were mapped out for Ezbomvini community:

Option 1: Installing a V box and pipes that will come to each household. Having pipes coming to each person's household will be difficult to do. The V box and pipes have been installed before (for different springs) but it was vandalized by jealous people out of spite, how can that be prevented this time? Pipes can be buried deep (knee height) underground to prevent them being vandalized by people. Even with taps, people removed them to go and make rings. Farmers must be willing to bury the pipe underground which is quite a lot of work. Other options may be too technical to explore.

Option 2: (more feasible) to make a furrow below the spring and install a slotted pipe with cement on either side to secure it, that way the spring will not be disturbed and people will get water. Gravel will be placed below and above the slotted pipe and then sand added on top to help purify the water. A JoJo tank will then be installed below the spring and will be filled up by water from the spring. The pipes will feed from the JoJo tank into each household. A JoJo tank is not the safest option, it might get vandalized if it is near the spring. It can either be secured/fenced or the JoJo can be at someone's house. Farmers must be willing to put money together to purchase a pipe and a JoJo tank which will be placed at someone's house. The springs are not bubbling, therefore if a JoJo tank is installed it will take a while for it to be filled up by the spring. Therefore, people will need to manage the water use and take turns in watering their gardens, collecting water for household use etc. In terms of money, quotations will need to be collected from suppliers and thereafter the group will calculate individual contributions. It is risky to decide on the amount contributed without first knowing the costs as chances are the estimations will be below the actual costs**.**

Other Organisations that have worked with Ezibomvini Community
Stakeholder engagement: farmers have been promised assistance many times regarding the water issue. Philakahle was the first organisation to assist and they asked each farmer to contribute R 100.00 towards purchasing pipes, and then disappeared. When the farmers followed up on it, it turned out two staff members had resigned from Philakahle and the organisation would no longer assist them. Lima had also undertaken to intervene; but only through their loan issuing programme where the farmers would have to pay it back.

The opinion supporting the solution was that the JoJo tank can be kept at one of the households (Phumelele Hlongwane's homestead). Two systems would have to be constructed one for the 10 people from Mam' Hlongwanes side and another for 2 people from Mam' Gumede but they still need to discuss these options with other community members.

5. Follow-up actions

1. Chris can assist with pipe specifications and site measurements and other support related to infrastructure but group must decide where the Jo-Jo tank will go and how many people will benefit from it before the work begins. Number of people in Maka Ndoza's spring: 10.
2. MDF will give feedback on the assessment made today and how the Jo-Jo can be installed.
3. Zodwa Zikode's group to meet and discuss the water issue and proposed project and bring feedback from the people. (Their water sources are below the community close to the river, rather and thus different to the two springs above the village on the hill side).
4. Follow up meeting to discuss about and prepare for implementation.

3.2.2 **KZN (Eqeleni) (28 participants)**

Written by Samukhelisiwe Mkhize andTtemakholo Mathebula

1. Introduction

On 1st August 2018 the first introductory meeting to explore water issues and possible solutions was held in Eqeleni

2. Timeline of past and present issues

According to participants the main water sources include 5 springs that have been providing water to households for more than 50 years. Water pipes were not installed until late councillor (Baba'Mzo) started to install the pipes and used engines to pump the water to the taps. The source is a borehole at the bottom of the community next to the Emmaus hospital. Even here the taps and pipes were supplied by the community and not the Municipality.
Mr Ndlovu who passed away had also promised to purify the water from the river and install pipes and taps for households to use. In 2002 community members bought taps and pipes to this water system. But due to Mr Ndlovu's death and subsequent confusion, nothing was done and the pipies and taps can no longer be located.
The municipality has provided a ''water vehicle'' that transports and delivers dirty water that can only be used for washing and irrigating. They also added that there is favouritism in terms of the distribution of water where community members who belong to certain political organizations have greater access than others.
The participants are not satisfied with service delivery. Currently there are maintenance problems with the pump and there has been no water in the taps for more than 5 months.. According to the participants their current councillor Mbuso Hadebe and municipality workers are not helpful.

Some participants have JoJo tanks to collect rainwater, but not everyone has a tank to do this.

From the discussion the participants agreed that installing water taps and pipes close to their homesteads would be most beneficial option. There is a borehole close to one of the springs but it's quite far from their households. Maybe the pipes could be connected to that spring then draws water into tanks close to their homesteads. Lastly, participants agreed on establishing a committee and meet with the MDF team including Erna and Chris on the 8th August; for a more in-depth exploration

Right: the water issues workshop participants in Eqeleni

3. Description and explanation of participants water sources

The participants use springs as their main water sources because tap water supply is inconsistent and unreliable. There are a total of 5 springs and 1 borehole used by participants:
Spring 1 (Zikode spring)
Spring 2 (Sbasha Spring)

Spring 3 (Mabaso Spring)
Spring 4 (Khumalo Spring)
Spring 5 (Hlongwane Spring)

Right: Water source map drawn by community members

The following information was recorded during the discussion:

Table 9: Eqeleni; details of water sources per participant

Participant	Type of water source(s)	Description of water source, location and use	Number of households	Participants suggestions and comments
Busisiwe Mvelase	-Community tap -**Spring One** -JoJo tank	-When there isn't water in the community taps she gets water from the spring -JoJo tank stores water during spring. -Low water levels and supply in the spring during winter season	- 15 to 20 households	-No comments
Tholwephi Mabaso, Gogo Hlatshwayo, A Gambu, Phumi Hlongwane, Phumi Khoza, T Dladla, Mphisani Mhlongo, Fisani Hlongwane, Fikile Hlongwane, Nududuzo Zikode	-Community tap -**Spring One** (Zikode Spring)	-When there's no water in the tap she collects water from the spring -The water from spring also used by livestock -Water from the spring is muddy and dirty -Spring is far from the homesteads	-Same as above	-Bab'Madondo assisted them with getting JoJo tanks
Thembalethu Ngubane , Thulile Zikode, Mam Dlamini,	-Community tap -**Spring Two (Sibasha Spring)**	-When there is no water get the water from the -Spring is far, about 1km away -Shares spring with livestock >Spring is too far from homestead (approximately 1km distance) -Too many households are using the spring…high demand but less water supply	-More than 20 households	-No comments
Nomalanga Khumalo, Konzaphi Hlongwane, Nomalanga Khumalo, Thulile Zikode, Nthombi Zikode	-Community tap -A dip tank at Kamabizela School -**Spring Three**	-Shares spring with livestock -Water tap is located at the rank which is too far from her homestead	-More than 10 households	-No comments

Gogo Khumalo	-Community water taps -**Spring Four**	-Taps close to homestead but unreliable -Spring Water used for all household needs	-More than 10 households	-No comments
Zakahle Hlongwane , Lunilge Ngubane	-**Spring Five** (Hlongwane Spring)	-Muddy and dirty water -Far from homestead	->More than 10 households	-No comments

There are also 4 boreholes in the community with handpumps attached where people can collect water. These boreholes are generally quite far from peoples' homesteads and some participants find turning the handpumps very difficult

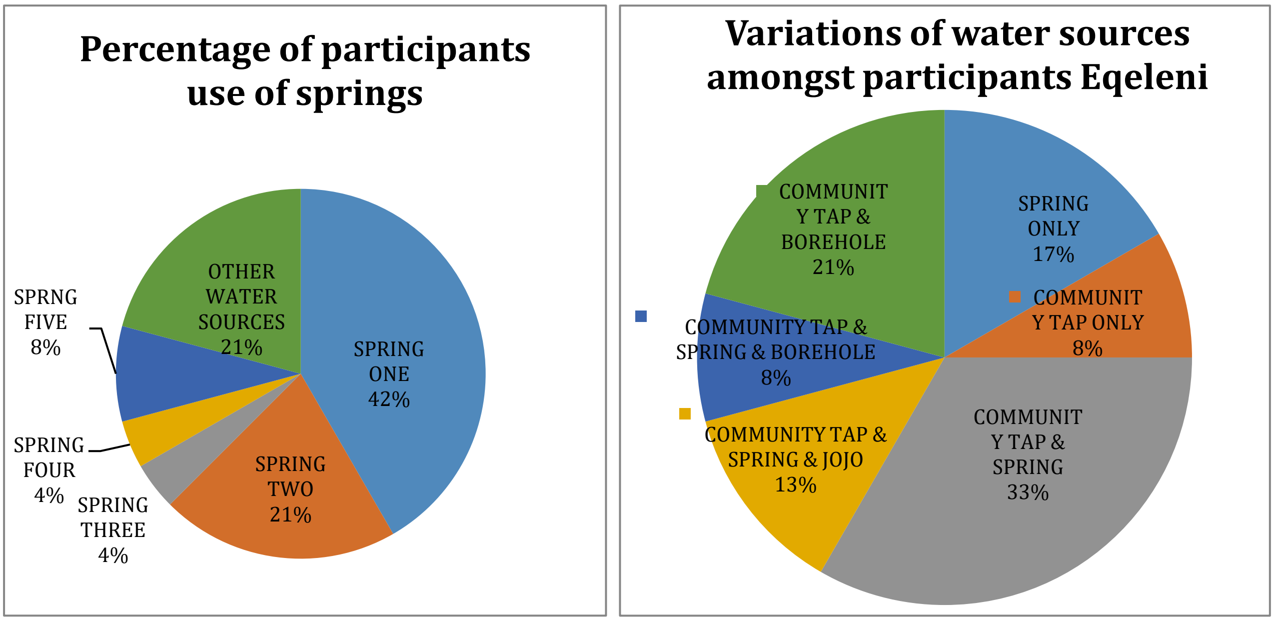


Figure 1: Left; the graph indicates the percentage of participants using each of the 5 springs mentioned. And Right: The graph indicates the percentage of participants who have access to the different water provision options in the villages (springs, community taps and boreholes)

3. Spring Visits

Spring one (Zikode spring) and two (Sbasha spring) were visited and one of the boreholes was also passed along the way. These springs are sited well below the homesteads.

Right: Mr Madondo showing the team one of the boreholes used by participants

Below left and right: Spring one (Zikode spring), used by around 15-20 households

Right: Spring two (Sbahsa spring), used by at least 10 households in the community

4. Recap and Feedback Session (Way Forward)

There are two main issues; the one being that water will need to be pumped up from the springs if it is reticulated, and the other that water will still need to be accessed by livestock

Pumping:

While in the field Chris suggested that a water pump ‘‘money maker pump” can be installed in one of the springs (Spring Two). It’s designed and manufactured by an NGO in Kenya funded in the US. It costs about R3000 to R3500.

Livestock

Participants could dig and install a water trough to allow livestock to access water as well while providing reliable water supply to community members. Another option is a mobile solar pump.

Option 1:

Protect one of the springs and pump water to a header tank (13 m head) and reticulate from there with pipes to the homeateads. This would need a pump and also a solution at the springs for cattle to drink

Option 2:

Drill a borehole, with a pump and header tank with pipes to homesteads. People liked this idea as they find boreholes in the are to be more reliable than the springs.

During the discussion Mr Madondo reminded the participants that there is no sponsor supporting this project, therefore, participants would have to make some contributions to support the project. This initiative will require old and young women to work together to solve these water issues. But one of the participants asserted that it's time that the young women and wives assist with the present water issues in the community; they have to make the financial contributions to make this project a success.

5. Follow up actions

1. Community members need to add the locations of present boreholes on the map and make suggestions as to where they think a borehole can be sited
2. MDF will provide feedback on costing of the spring protection and cattle watering trough.
3. Further exploration of the other 3 springs will still need to be done.

3.2.3 **Limpopo (Sedawa) (27 participants)**

1. Agenda

For local initiatives, municipal water supply and local sources e.g. rivers, and spring explore the following:

1. Define the sources, what they are, where, how they are manged, who has access
1. 2.What is working (enablers)
2. Challenges/barriers the communities are facing with the systems
3. Who are the role players, what are their responsibilities (gov, civil society and local structures)
4. Community led action, ideas and the way forward.
5. What do you think PV can do to assist with awareness raising and lobbying

After the focus group discussion, divide the group into three smaller groups to focus on water (summary of main points from the discussion), map (the plan) and time line. Then presentations, which will be documented/filmed with the key statements 3/4 people.

2. Participatory Video

The participatory video concept was introduced to the group. This is a story for them to tell and control and also to show whomever they choose- their learning group, other groups from the locality, their larger community, their structures such as traditional authorities, Municipality Department of Water Affairs and the general public.

They have the right to decide what is in the video and what is not and what should be covered. The idea is to learn about their struggles and their successes and then other people can learn from them. They will give consent and we will not share this footage with anyone prior to such consent being given.

Participants were given a chance to handle the video cameras and footage was shot be the facilitation team to summarise the content and learning in the focus group discussion. After editing the video will be first shown to the learning group and further edited by them before decisions are made about whom else to involve.

Participants mentioned they would like this video to go to the municipality, the DWA, the Dept of Rural Development and the Office of the Premier (the latter because the municipality is failing them. The municipality is part of the problem). They would also like MDF and AWARD to show these videos to other organisations who can potentially assist them – whoever has enough empathy to donate.

"We must help each other and remember that dealing with government can take a long time"

"We have a platform through the Municipality and District councillors, but we would appreciate if you could help set up the meeting – we will do the talking there"

Right: Betty Maimela assisting a group member with handling the video camera. And far-right; Neville sitting with betty and Bigboy (from AWARD) learning to do video editing after the workshop

3. Water sources

Wells in wetlands: Seasonal – only have water in good rainy seasons

Rivers: Now also seasonal for the small stream in the area- springs in these river beds have now mostly dried up and rivers themselves have not had water for some time – except the Olifants' river- but people are not allowed to take water from there

Springs – mostly in dry river beds – dried up some time ago , there are still small amounts in some springs but only for drinking water.

Boreholes- only for those individuals who can pay

Small dams- very few places- and these are very seasonal

Jo-Jo tanks and RWH structures – limited no of households have these and the water does not last throughout winter

Municipal Supply- in Sedawa is from boreholes linked to reservoirs and Jo-Jo tanks. The municipality pumps only twice a week to fill these (Wednesdays and Saturdays) and individuals are restricted to taking one container at a time as the 10 000l pumped on a day is not enough for everyone. People now have to collect water at the reservoirs as the pipes leading to standpipes are no longer operational

4. Comments on water situation

ALTERNATIVE SOURCES (Percentage of households with access)	
Jo-Jo tanks at household level	12 %
Buying 210l drums of water	80%
Springs (Nov-June)	8%
Wells (Nov-Dec)	36%
Municipal water (ave 1x / week)	56%

- Presently there is very little water from any of the sources and 80% of households are paying for water for household use only.
- Only those people with boreholes have reliable water access
- The springs and wells are generally quite small and only supply a few people. Animals are also drinking there
- Individuals with boreholes are selling water – if 210l drums delivered, that costs R35-R45/ drum. If people collect in 20l buckets they pay R1/bucket. This started in 2016. Before that it was easier to get water. The individuals with boreholes are now taking advantage of the water shortage.
- The springs in the river beds are no longer reliable they are systematically drying up.
- That leaves us with the only alternative of going up the mountain to the more reliable springs high up in the kloof and to connect long pipes to bring water here.
- The learning groups has collected R8 000 so far to buy this pipe.
- In 2016 there was still enough water, but people were not very active in gardening. The gardening was triggered by MDF and AWARD’s interventions, but has now come with a major drought. That is why we have decided to try and come up with our own solutions for water supply.
- Because there is now so little water the systems need to be managed. So, for example the amount of water taken from wells and springs and who is allowed to take water has caused some conflict in the community.
- Thus far there is no structure or organisation that manages water, people just do it by themselves
- The municipal supply has always been unreliable, that has not changed. It is just that there is now a lot more pressure on that water and a greater need for access
- The storage tanks are not large enough for everyone, even if they are pumping and people need now to collect the water at the tanks -the hours provided for by the municipality are not enough.
- Not everyone in the village has access to municipal pipes. Some individuals have made illegal connections into these pipes and these have been removed by other people as the water becomes less.
- None of the local sources are enough to even provide drinking and household water for the community

5. Enablers

- Good rain
- Looking after wells and springs- having shade around these have helped with supply but more maintenance is required
- Less sand mining will keep the sand dams and springs in the river beds working
- Subsurface flow is still keeping the system running – although less so than before
- The Municipal boreholes were well sited as they are all strong
- The wetlands and springs up the mountains are still intact and they keep the flow of water going – as well as boreholes. Community members must be warned not to remove the sedges and plants in these wetlands

6. Relationships in the community – the way forward

- The responsibility now falls on the beneficiaries of this project – the learning group members to make sure everything works. That is why we have started a water committee
- We have come together to have one voice for the municipality and other outsiders
- Getting water from the mountains is just one way the community is trying to sort out the water problems
- If there is no diesel in the municipal pumps the community is prepared to buy diesel themselves.
- The underground RWH tanks are very useful. This year the few with these tanks have managed to keep their crops going until early June. So if all participants can have access to these, linked with the supply form the mountains there will be enough water to carry us through.

7. The plan

The idea is to bring a very long pipe from the mountains to supply around 30-40 households in the community with water for both household use and gardening.

Figure 2: The picture alongside outlines the proposed extent of the supply

8. Water Walk

On the Thursday, 5 community members (Mr Mapekere, Mr Malepe, Alex, Sam, Christina)and 5 team members (Erna, Sylvester, Betty, Chris and Neville) braved the walk up the mountain. It was a 6km hike up the mountain moving up by 900m in elevation. The source is in fact over the neck of the kloof down another 120m on the other side.

The whole water course on the way up is now dry and there are a few very long pipes already in this stream bed- now all dried up.

Just above the village we came across a garden being irrigated using sprinklers and flood irrigation. The water source here was a pipe for this individual in a different stream – which he said has now dried up and which he has replaced with a borehole and a tank. He is obviously a well-resourced individual in the community.



Above: The irrigated garden nestled above the village, owned by one person with his "own" water source
Left: The beginning of the walk – The star in the pic shows the neck over which the members climbed to find the source.



Clockwise from top left: Members of the village team who made it to the top of the neck. The small waterfall on the other side and finally the water source they would like to use

3.2.4 Limpopo (Lepelle)

1.Introduction

MDF had undertaken at a previous meeting in April 2018, to bring an engineer who could give advice to the group regarding their plan for maintenance of the furrow and extending the reach of the water system to new households. Chris Stimie was introduced.

The learning group reported back that they took their water committee idea and suggestion for a membership organisation to manage the water furrow supply system to the traditional Authority. A number of agreements were made there:

1. Those using water for farming should be on the forefront of managing the water provision from the furrow
2. Each member of this water management group is to donate 1 bag of cement initially to be considered a member
3. Those who do not join can have their pipes removed from the furrow. The idea is that people need to be prepared to contribute to management and maintenance to be able to have access to the furrow.
4. There is room for expansion to more people and those people will also have to make a contribution
5. Committee members include Josias, Salfina Sebasha, Daphne Ngobeni, Shakes Searane, Anna Lithebele, Norah Sibashe, Clara Lithebele, and George Sebatjane. The composition was chosen to have representation from the TA, the Ward Councillor (George) and the learning group.

The people elected from the Traditional Authority and the water committee are now working together as one group. This is a major step forward for this community, who have been at an impasse regarding beneficiation through this furrow for a long time.

2. Water sources

> **"We rely on this furrow to make a living. It is life itself to us"**

The present furrow was started in the 1920's when there were still households higher up the mountain by a few families. In 1986 and 1996 there were floods that broke the furrow and then due to leakages caused by this which were difficult to fix, water became scarce and people started to put pipes into the furrow.

The furrow originally could supply water to everyone in the village where gravity feed was possible – all the way along. Now the furrow only goes as far as the school – due to maintenance and management issues. The source is still as strong as it was.

The furrow has brought us together. Everyone is given access to use the furrow directly, even the newcomers. They collect water and do their laundry there.

The pipes were put in higher up along the furrow (for individuals) as conflicts arose due to everyone wanting to irrigate form the furrow at the same time and people not wanting to wait for each other. The furrow runs along two blocks in the community – one towards and past the chief's house and one further down closer to the Lepelle river. After a meeting, some time ago the cement "dam" was constructed so that people could put their pipes in there. As the space ran out individuals would just come and put their pipe in the bank or remove others' pipes. This has caused a lot of leakages and reduced the water in the furrow further. So now the furrow ends close to the school as there is no longer enough water to flow all the way along.

Right:The sub-group working on the timeline for water sources, provision and issues in the community of Lepelle

There are presently around 40 pipes linked into the furrows and overall around 50 households that benefit. (The community consists of around 208 households). The plan is to extend the use of the furrow to another 50-60 households.

These pipes are open ended and run continually once placed into the furrow. Those underneath are more reliable than the pipes placed on top of them. So, some pipes end up not having water in them. We have learnt that it is quite wasteful of water to do that and now we have taps and ways to close off the pipes when we are not using them. We have also made better furrows and basins for irrigation in our yard in- stead of letting the water just run everywhere.

Right and below; George Sebatjane has made improved furrows and basins around his mango trees to improve his irrigation efficiency from the furrow and also to save water.

Far- right: He has also constructed small terraces in his mango nursery to ensure even irrigation, less erosion and better growth for the small mango trees.

Maintenance is very important. When is rains rocks fall into the furrow and damage it. Also, crabs make holes in the banks which then have many leaks. Cows also become a problem when it is dry elsewhere and the start to graze on the green grass around the banks of the furrow.

In around 1999 the Municipality (Tubatse) put in a system – it is a borehole with water pumped into a tank and reticulate to stand pipes It does not cover the whole village and is very unreliable. Section 1, which is below the main road has some access to municipal water. Section 2 of Lepelle – above the main road has no municipal access. They have been sharing a spring/ stream with another community Leboeng. This community recently placed a weir across the stream which effectively has dried up the water lower down and Lepelle (section 2) is now in a very difficult position.

3. The plan/idea

We have always wanted to do something about the furrow and as water is becoming more scarce we are now taking on this responsibility. The cement to fix the furrow is just the first step. We will need help with how to design and build the furrow in a way that does not break so easily and how to fit in all the pipes that people want to put in without destroying the furrow. Each individual will also need around 600m of piping (100m each of 40-32-20-15) – so this will cost around R3 000/household. We also will insist that people put taps on their pipe- not so much to regulate how much water they use, but to ensure that they are not wasting water.

Above and Right:the sub-group working on the plan / design of the water provision process through the furrow

Presently there are those individuals who look after the furrow voluntarily, they are tired of fixing the furrow for other people. With the water committee this process will be made more formal.

It is possible also to bring pipes directly from the source for those who are presently above the gravity fed system of the furrow. There is already one individual who has done this. The idea of having main pipes from which participants take their pipes was also discussed, instead of each individual having to put their own pipe into the furrow.

5. The water walk

6 Community members, including two team members (Chris Stimie and Sylvester) undertook the water walk to the source of the furrow on the Friday (22 June). The engineer will make recommendations regarding requirements for fixing the furrow and how to lay out the cement dam/basin for putting in pipes.

Below are a few images of the furrow and pipes

Above left: A plethora of pipes coming from the mina furrow- each household has their own and Above right: Irrigating making use of the furrow. This option is only open to a smaller number of households

Above left: Walking up to the source of the furrow in Lepelle. This region was once inhabited by members of the village. Above left The furrow higher up, closer to the source. Some individuals have opted to put their pipes into the furrow higher up, and still other have taken their pipes all the way to the source.

Above: One of the sites where pipes are placed in the furrow.

3.3 Water issues workshop 2

These workshops were held in Limpopo with the Lepelle and Sedawa learning groups. In Lepelle the inability of the community to focus on anything other than their water provision issues, initially galvanised our team into considering this as part of the overall methodology and process. The Sedawa learning group has been very active in experimenting with the CSA practices and their implementation has suffered under the extreme water scarcity in their area. This section reports on the process and outcomes of these workshops.

3.3.1 Agenda; water issues workshop 2

INTRODUCTION

- Recap process; water issues workshop water walk, progress and issues in the meantime
- Video making process

VIDEO SCREEENING

- Screen video
- Discussions:
    - Does this movie present your situation and conversations well?
    - Any additions of changes?
    - How can this movie help us? Who can we show it to? Purpose? Process

REPORT BACK- WATER WALK

- Chris's reports and suggestions presented
- Discussions, scenarios, options, alternatives
- Rate scenarios
- Follow-up actions

3.3.2 SEDAWA Water issues Workshop 2

Introduction

Some of the learning group members went to speak to people in Botshableo who have done this before (protected a spring in the mountain and reticulated with pipes in the village). In that case only 8 of all the initial 'volunteers" went ahead with the process. But technically it seems feasible. If he can do it, so can we.

The strikes and road blockages in the area as because of water issues. It appears to be the only way to get the Municipality to hear us the municipal borehole pumps are broken; there are maintenance issues. The municipal water trucks that deliver water do not come to this village- so there is presently no water at all. The Maruleng Municipality is quite small and only have 2-3 water trucks, which are not enough to service all the areas. There are rumours of them combining with Palaborwa.

No one has been informed of the impending bulk water supply system, although they have seen the pipes being laid along the main road and some of the big new reservoirs built on the hills. There is no direct communication form the municipality. We can only hear news via the radio/ newspapers. The meetings that do happen are about votes, they are not real things. There is friction as they make promises that they do not fulfil.

Different scenarios were discussed

1. Divert water from the Olifant's river and bring it through Botshabelo to Sedawa – it is a shorter route than the mountain spring
2. The alternative spring at the foot of the hills in Sedawa (we passed the infrastructure and irrigated gardens on the way up). The group felt that they could communicate with him, but there is a practice in the area, that if someone discovers a spring and uses it first, it even gets their name, so it becomes a bit of a challenge. There were conflicts before that eventually had to be sorted out by the tribal authority. It might get to that here, or it might be better
3. We still need to take the walk around the mountain to see how far it is (Maphikiri). We do not yet want to let go of this option. We would need to run the pipe around the back of the mountain through Botshabelo and then bring it here.
4. Boreholes, maybe three sperate ones to be able to take pipes from there to the various participants, who are in three separate areas. The fear here is that some boreholes are running dry and sometimes people drill and do not get water.

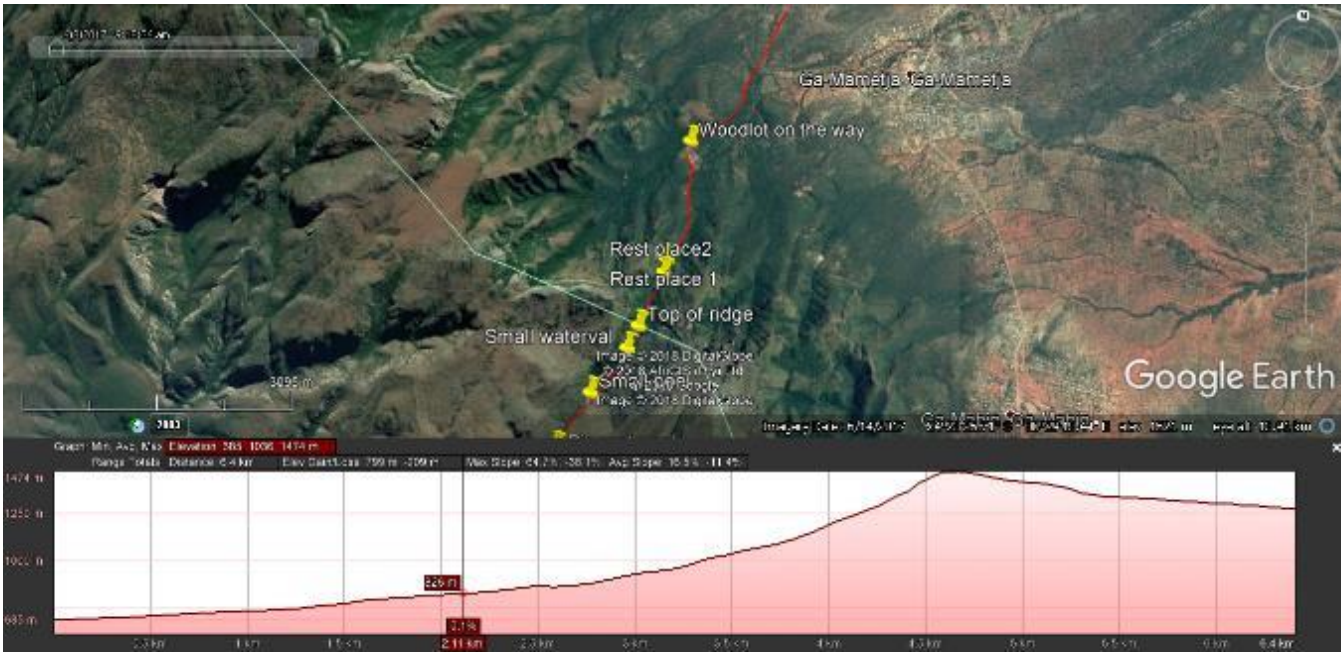
Comments on the screening of the movie

1. The movie is perfect as it is
2. It's a nice way of keeping a record of what we did
3. It was a very long walk, hopefully it will bear some fruit
4. Thirsty from seeing that water- this video is giving us encouragement and hope
5. We've seen the water- now let's go get it
6. We are seeing how steep the slope is, the pipe will have to go around
7. The way it looks, the source seems small, but I know from the past that it is a very good source
8. This video can be used to show prospective donors
9. Just the effort we took should impress the funders

10. We can go as far as the premier and the president's office. We need to start at the top and work down as the local officials are corrupt and do not care about us.
11. It is a tool we can use with the municipality to negotiate what we need.
12. Government officials at different levels can be contacted including DWA
13. We can find a way for you guys (MDF and AWARD) to enter- to help us with this as we know a few of these people personally
14. The Motsepe Foundation is a potential funder
15. We can show the tribal office what we are doing here
16. Nicholas Sechaba does TV programmes to get more attention
17. We could also go to MamGobosa at the Daily Sun newspaper
18. Nothing comes easy – this shows our first steps towards making things happen

Water walk report back

Report on the visit to Sedawa on 21 June 2018 (2018/07/21)



Background

The village was visited on 21 June 2018 to look at possible sources of water for vegetable production for about 30 participants of the project. The local villagers wanted to show us a water source at the adjacent mountain and we walked with them the up the valley over the water shed to the other side of the mountain. We started walking at about 07:30 and returned at about 18:00. The distance that we walked was 6.4 km one way and the elevation about 790m. The villagers suggested that a pipe be installed from the river on the other side of the ridge around the mountain. This may be possible although the terrain is likely to be very difficult. The estimated distance would be more than 12km and to install a gravity pipe with a constant gradient would be very problematic. The height difference of about 600m is also very challenging as the excess pressure would need to be nullified with the use of several reservoirs along the pipeline.

Recommendation

The 12km pipeline around the mountain will be technically very difficult but the cost would be prohibitive. A rough costing indicates that the costs for this option could be in excess of R3m. This option is therefore not recommended. The option of taking the route that we walked is also not recommended for the same reasons with the added complication that the water would need to be pumped.
The amount of water is also not much and the flow rate at the time of visit was estimated to be between 5 and 10 m^3/h.
It is therefore recommended that a much more cost effective and practical option be considered. In my opinion a borehole would be a far better solution to develop a water source. It would need to be managed in such a way that it is sustainable and equitable. These problems could be overcome with clear definition of roles and responsibilities based on sound management and maintenance.

SUMMARY AND DISCUSSIONS

Summary: the spring as it is now, supplies around 10 000l/hr, which is not very strong. The distance the pipe would need to go is 12 km (around the mountain) and the spring is 800m higher than the village. This provides too much pressure for a pipe and “breaker” tanks and pressure release valves would need to be built along the way. The overall estimated cost is around R3 000 000. SUGGESTION: Communal borehole that belongs to the group.

Water Group
22 people have contributed R 9000 towards the proposed water system. There are around another 50 people who are waiting to see what happens.

Min water required:600l/hh/day
Gardens: 250 000l/week (fill up whole yard with trench beds, 50 hh)
Fields: 420 000l/week (Ave 3,6ha, 8 hh)(THUS AROUND 700 000l/week)

SPRING: 10 000l/hr ~200 000l/day = 700 000- 1 400 00l/week ***(COST:R1,5-3million)***

BOREHOLE: 2 500l/hr ~ 175 000l/week (will need 3-4 boreholes) (***COST R150 000-R300 000)***
* this was based on Christina’s borehole =, which is strong and fills her 24 000l tank in 10 hours

COMMENTS

1. I agree with the borehole option. It could make sense to drill them in Mabins A and then bring the water to Sedawa
2. R3 million sounds scary, but maybe we can break down these costs and start step by step
3. It the source is not so strong, maybe we can build a wall and collect water to get more
4. There are boreholes that aren’t yielding that much water. Up there we are sure there is water, so let’s explore
5. We can use different classes of pipe, even class 6
6. Going for a borehole is going one step backwards – let’s go forward rather
7. We’ve set our sights on that water, so let’s keep going
8. There are a lot of people with boreholes that are not giving good yields. Do we have goo ways of detecting whether boreholes will be strong or not?

COMMUNITY HOMEWORK – end September

Go and visit people with boreholes to find out

- When it was drilled
- Who did the drilling
- How deep it is
- Yield – l/hr
- Does it change in winter and summer; is it getting weaker
- How did you decide to put it there?

And find some places to provisionally site 3 boreholes based on this information and on where we think there most likely is water (ie close to the riverbed) (get GPS coordinates for those spots – Betty can help with that)

MEETING 1: We need to meet to discuss the options more (23 August)

OPTIONS	Next steps	What we still need to know or do
Boreholes		
Shorter term, more manageable, but there may not be enough water	How will they be distributed? Group people into areas? Pick water sources and number of people TEST WATER	Siting? Quality of water? Operational costs, who will pay for maintenance.? Who will open and close the taps/ pumps? Fixing pipes and pumps (We are starting to earn income from our gardens and can contribute)
Mountain spring		
Longer term. There is a danger of burning of pipes There is not clarity in the longer term how much water there is	Are there cheaper ways? TEST WATER Organise a meeting for the man from Botshabelo to explain his process, costs, issues etc. Get Chris to do quantities	Steel pipes may be needed, but this could be very expensive Need to walk along where the pipe will be. And talk to the man from Botshabelo again. There is the concern that 205 needs to be left for the environment.

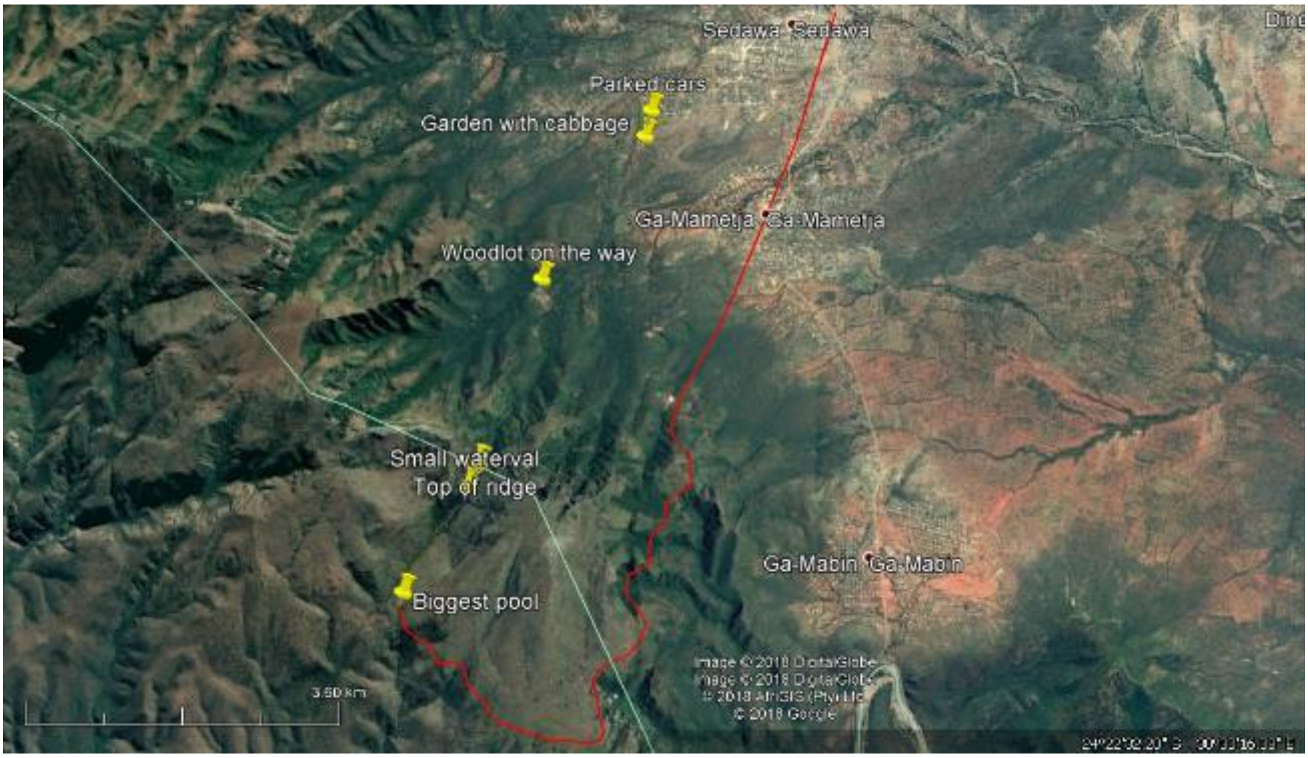
Dipua Thobejane is the Muaruleng Mayor – he can be approached
Also Rebecca Malepe is the councillor and she can be informed. To see if they will provide support
Lebo from DWA can also be contacted

COMMENT: Cryton: the municipality needs to be informed as it is under their jurisdiction – so that there are no legal repercussions. And you will need to specify that it is water for agriculture, not household use

MAHLATHINI/AWARD HOMEWORK- end-September

- Are there good drilling companies in the area, and which are they?
- Is there an underground water survey for the area?
- Costs of an exploration/survey (or water divining)
- MDF is in the process of writing a funding proposal, which will be able to assist with the funding (not R3million though). We will know by end November whether that is possible
- Derrick/ William from the municipal support unit in AWARD – can show the video

SEDAWA-MORE DETAILED COSTING OF THE PIPE FROM THE MOUNTAIN (2018/09/02)



The above Google Earth map shows the path of the possible pipeline from the biggest pool to the middle of the village of Sedawa. The length of the path is 12km as indicated. The total height difference is 680 m from the pool to the centre of the village.

This means that 6 5000litre plastic tanks on stands will have to be constructed to prevent the pressure of building up. A class 12 HDPE pipe will have to be used. This pipe will be vulnerable to vandalism and veld fires and should be buried or protected.

The cost estimates are as follows:

The first 7km has a fairly flat slope and to be able to get at least 3000 litre per h a 50mm pipe will have to be used. Cost R250 000

The last 5km can be a smaller pipe as the slope is much steeper – 32mm HDPE Class 12: Cost R100 000

Installation for 12km at R150/m: Cost R1.8m This will very likely be much more than this estimate.

The 6 tanks are R5 000 each and their stands are about R10 000 each: Cost R 90 000

Erection of these tanks: cost R180 000

Contingencies:R180 000

Total estimated cost: R2.5m

3.3.3 Lepelle Water Issues Workshop 2

Introduction

The water committee attended a traditional council meeting. The agreement is still a 50kg bag of cement per household. A committee members has been tasked with making a list of people interested in access to water from the furrow, plus those who are willing to make a contribution. Another meeting with the council planned after this feedback meeting from MDF

The water committee was accepted by the TA and it now has 9 members. (4 more members added by the TA)

A questions was asked whether MDF can assist with trying to raise funding: in answer MDF is in the process of writing a proposal to the Govt of Flanders which will leverage some funding (not a very large amount, but enough to assist with the present plan) and also can write a proposal to a private funder (details provided by Neville) who assist with community water projects.

The group reiterated that they also need assistance with planning and advice to do the repairs. There was a question as to whether MDF and the engineer walked the whole length from start- end. Apparently the furrow ended much further along – below the second school and not at the first school as presently indicated in the report back.

Comments on the screening of the movie

- We like it, but there was a lot of mention of drinking water (Did you only get the tip about this needing to be agricultural water after you made the movie?)
- Also want to include the mango trees
- We can use it to attract funders for the water stuff
- The water committee and tribal authority should also have a copy
- If we use it for funder we need to do a lot of cuts to show how we use it for farming and not “sharing the water with the baboons”.
- There is support for purifying this same water from government. The dept of Health (Matilda Ledwaba) have done trainings on purification of water as part of a typhoid fever awareness raising programme
- There is municipal water supply – 5 boreholes with pipes and taps. It is however not enough and often the pumps break and then there is no water for long period
- We can share this movie with outside stakeholders- but it must be prettier first and we want to see the updated version first
- We need some more shots of the impact of the shortage of water- some shots from the “drier” side of the village would be good
- We should show some of the farming activities - may need some more footage of this as there is some of George’s homestead and orchards only. We need to include all household activities including making bricks, building, washing etc
- Want to include a bit more around the municipal supply

ACTION: Three volunteers to join Betty and Neville after the workshop to take more footage: George, Patricia, Joyce

Water Walk report Back

Furrow Inspection Report and Recommendations (2018/08/05)

The village was visited on 22 June and the furrow was inspected by CM Stimie, guided by some villagers, from the village up to its source at the Tshwenyane River.

Description

The furrow is about 1km in length from the inlet from the river to where the furrow is still visible. In the 1980's the furrow extended another 0.7km to be able to serve the whole village. It also had a spill into the Olifants River at its end.
The furrow is being maintained by the villagers and from the way they speak about it and how the look after it, is it evident that this furrow is very important to them. They estimate that it was built in the 1920's. There are number of leaks which cause the flow in the furrow to decrease over a distance.
Recently villagers started to install individual pipes in the wall of the furrow to take the water directly to where they want it. At one place 13 of these pipes are placed next to each other. It is estimated that there are 30 to 40 of these pipes installed taking water from the furrow. This resulted in major wastage at the end of these pipes as these are left open when not in use. People at the end of the furrow only get water by arrangement as the furrow is normally dry for the last 200m or so. There is some conflict in the village around the distribution of water from the furrow.

Recommendations

Repair of Leaks

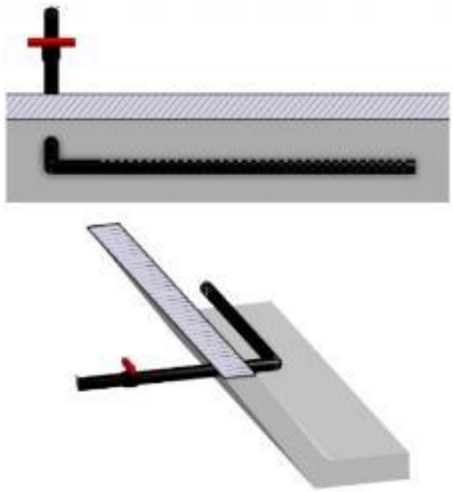
The major leaks in the canal should be repaired to enhance the effectiveness of the furrow. Villagers have been maintaining the furrow for years with soil and sometimes with ferro-cement and developed a working skill for these maintenance activities. These repairs are usually of a more temporary nature, mainly because of the lack of funds. The equitable distribution of water is however a major challenge.

The over extraction of water needs to be regulated with a technical solution and a management system in order to curb wastage as far as possible and to provide water for production to as many as possible. Bentonite could be used to repair smaller leaks. This method will have to be demonstrated on site. The cost of bentonite is R150 per bag of 40kg. Five bags to start with will be sufficient to test the system. There are places where more severe leaks occur. These leaks have to be repaired by lining the whole width of the furrow for a few metres or at least replacing the leaking earth wall with ferro-cement. The repair of these areas could be done by the villagers but if the engineer is on site direction will be given for these repairs. It is very important to dig down at these places to prevent water finding escape routes underneath the construction.

Water Management

Standard outlets could be constructed in the furrow with consent of all villagers. This will make it possible to manage the water in an equitable way.

The following concept is proposed. It is basically a slotted plastic pipe which takes water out of the furrow, through the wall while being regulated by a plastic valve. The total material cost for this system is less than R250 when it is bought at the best prices in bigger centres. See sketch alongside.



Description of the proposed concept:

It must be noted at the outset that this concept should first be tested on site before implemented on a large scale. When people have used it and is happy with its operation they should be willing to agree to use it as an equitable management system to match the technical system. The technical system description is as follows: It is proposed that only controlled offtake s are installed in the furrow. These will very likely look like the sketch above. These offtakes will take the same amount of water out of the furrow and it will be controlled by a valve at the beginning of the pipe and at the end. These pipes would be able to deliver around 1500 litre/h and if the flow rate in the furrow is 15 000 litres/ h only 8-10 of these pipes should be opened at the same time. The flow rate of the furrow during the time of the visit was estimated to be between 10 000 and 20 000 litres/h.

The offtake position(s) will need to be concrete lined in a form of a rectangular canal to enable proper functioning of the off take pipes and ease of maintenance. A length of 10m is proposed for this purpose. The thickness of the lined furrow (wall and floor) should be 100mm. About 10 bags of cement will be needed, as well as 600 litres of sand and 600 litres of crushed stone for a 10m length. (That is 30 x buckets of 20 litres each). Depending on the cost of sand and stone the material cost for this 10m lining will be at least R10 000.

One off take can be shared by 5 to 6 participants. Each participant would have their own pipe and will connect it to the off take system when it is their turn. In this way the participants will get a turn once a week to get water from the furrow. If this is accepted it means that 5 off takes will be able to serve 30 participants, and 7 will be able to serve 42 participants. This needs to be discussed with the villagers.

Estimation of costs

Item	description	Costs
Bentonite (powder clay)	4x40kg bags @R150	R600
Fix 2 large leaks in furrow	2 x Cement (4 bags, 240ℓ sand, 240 ℓ stones)	R8 000
Offtake basin; 100mm depth of floor	Cement (10 bags, 600 ℓ sand, 600 ℓ stones)	R10 000
Individual slotted pipes with valves (40mm/50mm)	2 x Valves , fittings, 1m slotted pipe, R250per participant x 40	R10 000

Summary and discussions

The furrow provides around 15 000l/hr. A 40mm valve in the furrow provides for around 1 500l/hr, which is around 30 000l in a 24hr period. If a 50mm pipe is used this pulls out 9 500l/hr (225 000l/24hrs). As the overall flow of the furrow is only around 15 000l/hr 40mm pipes are recommended. In this way 10 pipes can be placed in the furrow at a time.

~40 people with pipes
~5 people using furrow directly
~30 new people who want to put in pipes

Suggestions (cheaper version)

1. Make 8-10 permanent valves or off take points with taps at the offtake basin and at the household (around R200/participant). As there are presently around 40 beneficiaries, it would mean each person would have access to water for a 24hr period every 5-7 days
2. This would then require arranging for storage options at the households
3. Fix the offtake basin and cement in these valves as the first step (~R10 000 ' 10 bags cement, 600l of sand)
4. Then fix the main leaks in the furrow (R 8 000(cement, stone, sand) and R600 (bentonite)
5. First start with the existing beneficiaries and then think of expanding, when it becomes clear how much water there is (once the leaks have been reduced)

COMMENTS

- Yes, to money rather than cement
- The more pipes there are the less flow there will be in the furrow. Then it cannot go far – so the decision is around more pipes or longer furrow, but both are not possible. It also means that those further away will need to have longer pipes and it will be more expensive for them
- New people accept the idea of pipes and the greater expense.
- Once things start moving there will be a lot more people wanting water and that could be an issue.
- The committee's first suggestion was to use cement paving blocks in the furrow - why did MDF not quote on that for the whole furrow?
- Our reason for taking the whole stream form the source is because of all the leaks. If we fix the whole furrow then we can leave some of the water in the stream for the reserve
- The problem with not fixing the whole furrow is that leaks will develop again; crabs will make holes in the banks etc

- We were hoping for the "expensive" version, but as it seems that this furrow can never serve everybody in the community, the cheaper option may be better as a group activity, as then we ca not be expected to provide water for everyone (without them contributing)
- We understand that this is a starting point, but most of the contributions have and are coming from those who presently do not have access to the furrow – so that makes it complicated.
- It is good to tackle the issues of leaking pipes as a start. And we should involve the traditional authority. Individuals with leaking pipes need to fix those
- We must get a better sense of who the new people are and how many
- And we want to remove those not contributing.
- Generally, the idea of the permanent valves at the offtake basin is a good idea. But I think each valve should have a t piece with 5 pipes linked in so that the pipes are there permanently and people do not need to go and link their pipes to the valve every time
- We should start with the two big leaks first
- Regarding people who don't contribute to maintenance. We cannot forget this is a community thing, so we need to work on ways that the committee can enforce – its not as easy as removing pipes fo those who did not contribute.
- The committee has to earned the power as yet. The Traditional authority says it's a communal thing. It still ahs to be requested that it is managed by the water committee and only those who pay have access to the pipes
- Neville; if the committee is trusted by the community, you get the mandate form them rather than the TA
- MDF contribution: Engineer's time for 3-4 days and we can match the community contribution
- Contribution in money rather than cement makes sense
- Still worry that section 2 above the road is not included. MDF; It is not – this is a separate area with a different water source, different issues and will need to be tackled separately.
- Presently those who do not have water through the furrow still have hope to be included. It DOES mean that they will have to buy pipes, but they feel that they have permission to sue the water as it stands now

PRIORITIZED ACTION PLAN

1. Those with pipes should contribute to maintenance (not just new people)
2. Pipes should have taps, so not run all the time to save water
3. We need to get more water to be able to provide access to new people
4. Fix leakages in existing pipes
5. Fix the main leaks in the furrow.

COMMUNITY HOMEWORK

- Go to the TA to do a report back – 1st weekend of September. _the plan is now based on recommendations and also talk about how and when to make contributions
- Contribution equivalent to cement is ~R100

Make a list of potential participants and what they promise to contribute. We are hoping collect around R4 000

MDF HOMEWORK

- Get Chris to draw up specific options for the leaks
- Lepelle will let us know when they are ready to do something practical. Chris can come back for a few days to assist
- Mango training and fruit tree deliveries Sept-Oct. (Community need to be informed in advance so that they can organise the cash for the trees (r25/tree)

4 CSA PRACTICES / DECISION SUPPORT SYSTEM

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.

4.1 Objectives of DSS

The objective of this decision support system is to assist the smallholder farmers in South Africa in selecting appropriate options for management practices to sustain and increase farm productivity given current biophysical environmental conditions; i.e. climate, soil and topography, as well as farming practices and socio-economic conditions at the household farm level. The DSS considers individual circumstances, needs and aspirations. The aim of the DSS is for individual farmers or farming collectives to be capacitated to strengthen their farming practices not only under current conditions but also in the light of climate change impacts.

The proposed architecture allows different agricultural actors; i.e. farmers, experts and facilitators, to participate in the decision flow. It is based on a participatory approach, with those actors, for the identification of site-specific CSA interventions. The DSS has been built to be accessible to most farmers. The data required as input for the DSS is either specialist technical information, which is freely available, or information provided by the farmers themselves.

4.2 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 approaches. The practices have been identified by both farmers (traditional or local practices) 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.

4.3 Conceptual framework

The input data, the flow of processes and the outputs of the DSS are represented in Figure 3. 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 his/her 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, for his/her ranking. 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 farmers.

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.

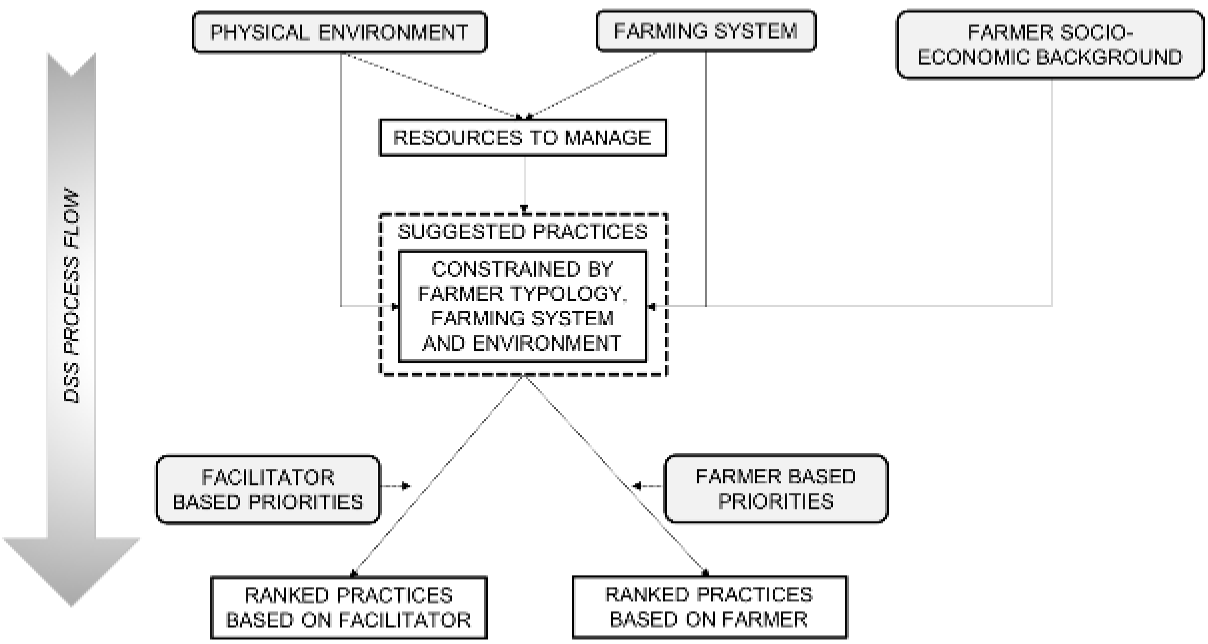


Figure 3*:* Schematic of the Decision Support System (DSS), with model inputs highlighted in grey.

4.4 DSS inputs

4.4.1 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 detail in the following sections.

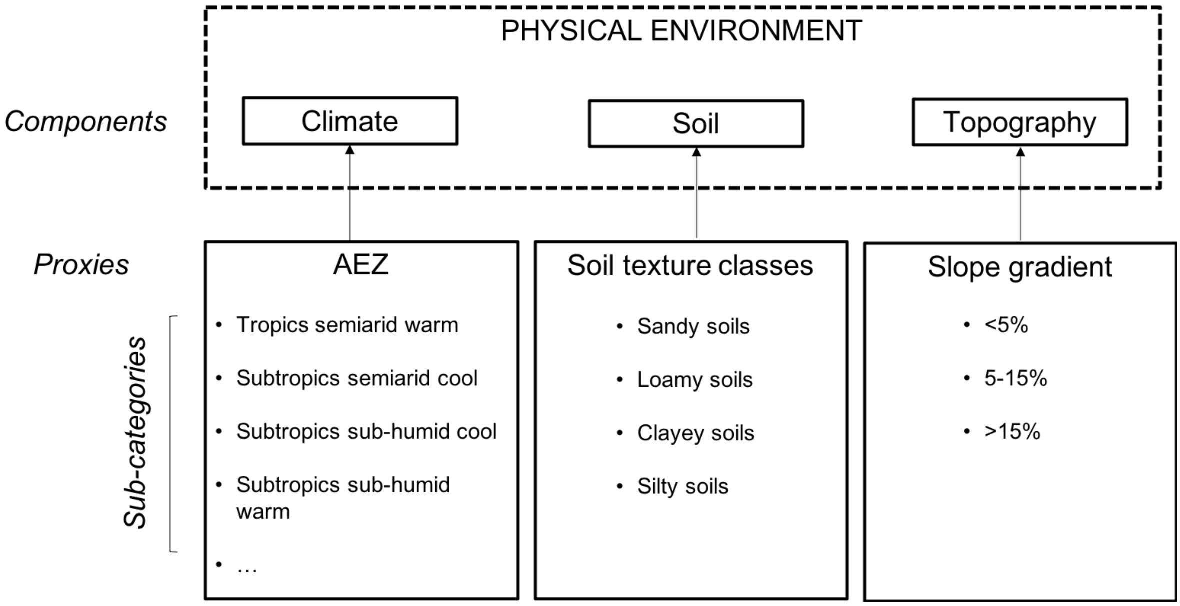


Figure 4: Components, proxies and sub-categories of the physical environment.

(a) Climate

Precipitation and temperature, through evapotranspiration, largely defines 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 the precipitation pattern, also has an impact on soil health and fertility through soil erosion, weathering, leaching, crust formation etc. Climate also affects weed growth, which can strongly reduce harvests. Many crops will fail almost completely when no weeding is done and labour requirements 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. The temperature variation is not common in the hot semi-arid regions. Therefore, in this context, the Agro-Ecological Zones (AEZs) typology seems to be an appropriate proxy for climate.

Currently in the DSS, the climate is defined based on the Agro-Ecological Zones for Africa South of the Sahara (Sebastian, 2014; Harvest Choice, 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 10.

Table 10: Agro-Ecological Zones encountered in South Africa (grey) and location of study sites within these zones

	Subtropics		Tropics	
	warm	cool	warm	cool
Arid				
Semiarid		Fort Cox, Bergville	Hoedspruit,	
Subhumid		Bergville, Estcourt		
Humid				

The different terms in Table 10 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 the 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 semiarid – warm, subtropics semiarid – cool and subtropics subhumid – cool. Those are also represented in Table 10.

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.

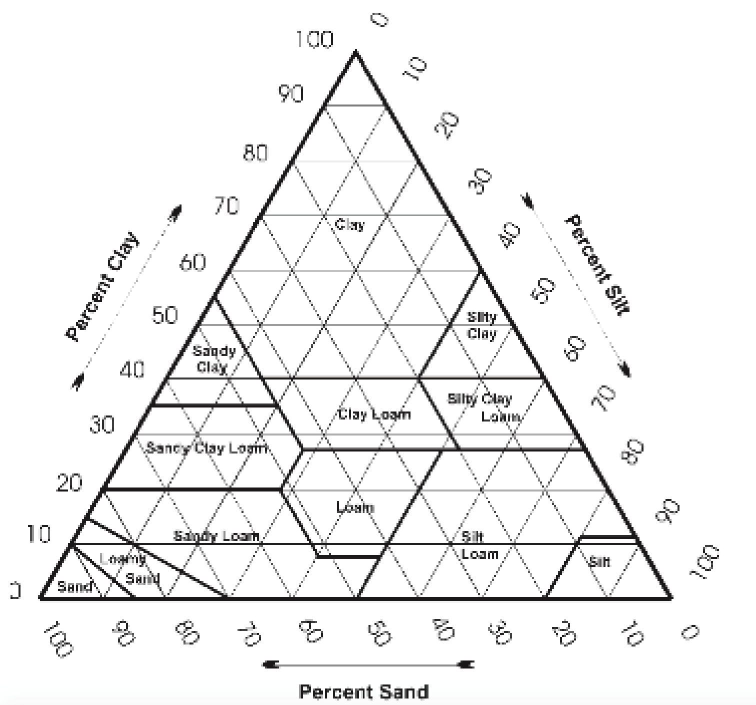


Figure 5: Soil texture triangle.

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 one 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.

4.4.2 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 follows: crops, livestock and other natural resources. Crops have been divided into 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.

4.4.3 Farmer socio-economic background

Extensive socio-economic and demographic background information from the different farming households (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 stresses, 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 differentiated by the HH head gender, dependency ratio, level of education, employment status, income, access to services and formal markets, farming purpose and farm size. The different options of outcome for those 9 socio-economic and demographic characteristics are provided in Table 11, as well as to which typology they belong. An outcome can belong to different typologies; 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 the 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 11.

Table 11: Socio-economic characteristics and range of values used to define the three typologies

Socio-economic charcateristics	Typology A	 B	 C
Gender	female	male/female	male
Dependency ratio	<0.33	0.33-0.66	>0.66
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	0,1- 1ha	>1ha

The farming HH considered in this example is characterised by a male head (typology B or C), with a dependency ratio less than 0.33 (typology A), who went to school up to grade 9 (typology A or B), is employed with a total income of R1500 (typology A or B), has access to electricity but has no tap-water (typology B), has no access to formal markets (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 five out of the nine socio-economic characteristics could be assigned to typology A, seven to typology B and one to typology C. This means that there is a similar probability that the farming HH belongs to typology A and B. Based in the fact that in case two typologies are equally frequent, the farming HH will be assigned with the typology with the lowest level; by consequence, this farming HH will be assigned typology A.

4.4.4 Resources and management strategies

The management strategies have been grouped by resources to manage. Four types of resources have been identified: water, and in particular quantity (1), soil, in particular fertility (2), crops (3) and livestock (4), as represented in Figure 6.

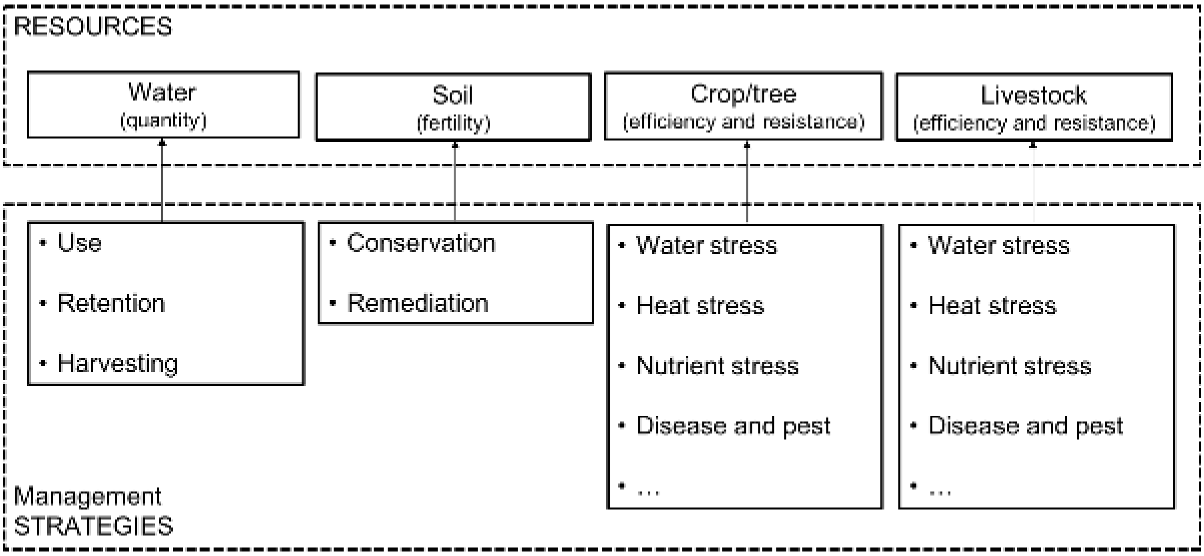


Figure 6: Resources and related management strategies.

4.4.5 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 4.4.3, 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 is not exhaustive and can be extended with other 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.
- *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 suitable for gardens less than 0.1ha. It requires medium cost, skills and labour, with easy maintenance.
- *Furrow irrigation*: includes lower initial investment of equipment and lower pumping costs per ha-mm of water pumped. 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 1ha on all soil types, but requires temperatures above 5°C, precipitation rate above 150mm/year and slopes less than 5%.
- *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.

- *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.
- *Mulching*: Reduces water use as it protects the soil from evaporation. Provides valuable nutrients as the mulch breaks down and thereby improves the soil's texture. 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. There is no restriction concerning slopes or soil type. Only local resources are required.
- *Manure and crop residues*: improve soil structure, increase organic matter content in the soil, reduce evaporation, 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 to intercept surface runoff and divert 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. There is no restriction concerning slopes but 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. Suitable for larger areas 0,1-1ha to >1ha, slope of 5-15% and precipitation rate above 450mm/year.
- *Infiltration pits* (with e.g. banana): collect runoff which is stored in the infiltration pit. 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. Suitable for larger areas 0,1-1ha to >1ha, slope of 5-15% and precipitation rate above 150mm/year.
- *Rain water harvesting storage*: 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. 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 and precipitation rate above 400mm/year. The slopes need to be less than 7% and the soil should be relatively stable.

- *Half-moon basins*: small semi-circular earth bunds for catching water flowing down a slope. No restriction ins size, slope or precipitation – although the designs are different under different conditions.
- *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 and precipitation rate above 400mm/year. It suitable for fields and garden up to 1ha. The soil should be relatively stable.
- ……

These practices have been taken as examples from the present database, which is being updated and refined to accommodate this DDS process.

4.5 DSS processes and intermediate steps

4.5.1 Defining resources to manage based on physical environment and farming systems

As introduced in section 4.4.4, 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 also has 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 zones with slopes greater than 15%, whereas slightly to moderately eroded soils are found in the sub-humid zone under the same slope classes.

The information provided in this section as well as in section 4.4.4 has been compiled and used to build Table 12. This table allows for the identification of the resources to manage and the related strategies provided the farming system and the environmental conditions are known. For example, a farming HH in Hoedspruit (tropic semi-arid warm climate according to Table 1), whose main farming systems are crop field and gardening on sandy soils with less than 0.5% organic carbon (OC) in the soil 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 increasing the resistance to drought and the water use efficiency of crops and vegetables, to conserve and improve soil fertility, to increase the heat resistance of crops/vegetables and the efficiency of nutrient uptake by the crops/vegetables.

Table 12:Criteria for defining the resources to manage and related strategies, based on the physical environment and farming system (grey boxes) (*:solely for semiarid zone)

			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 cool													
		Subtropics sub-humid cool													
		Subtropics sub-humid warm													
	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													

Each farming HH falls within a sub-category of the physical environmental components (see Figure 4); i.e. AEZ, soil textures, OC and slope. If one of these sub-categories vs. resources and management strategies box in Table 12 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 suggests to do so. In case of field cropping, vegetable gardening and others such as trees, the resources to manage are restricted to water quantity, soil 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 needs soil conservation if it is located in a semi-arid region.

4.5.2 **Suggesting management practices based on resources to manage**

Based on the information provided in section 4.5.1 Table 13 has been built. This table 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 allows the selection of practices that could be used to manage the resources, through specific strategies, that were identified in section 4.5.1

Table 13: Criteria for selecting practices based on the resources to manage and related strategies (grey boxes)

	Resources and management strategies												
	Water (quantity)			soil (fertility)		crop resistance and efficiency				ivestock resistance and efficienc			
Practices	Harvesting	retention	use efficiency	conservation	improvement	Water	Heat	nutrient	disease	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													
Zai pits													
Rain water harvesting storage													
Tied ridges													
Half moon basins													
Small dams													
Contours; ploughing and planting													
Gabions													
Stone bunds													
Check dams													
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 options (multipurpose, fast growing trees and fodder species)													
Bed design; trench beds, ecocircles													

Understand soil health aspects using visual indicators													
crop diversification													
push-pull technology													
Natural pest and disease control													
Integrated weed management													
Breeding improved varieties (early maturing, drought tolerant, improved nutrients).													
OPV and heirloom varieties													
Seed saving													
Crop rotation													
Windbreaks													
Trees and bushes lining fish ponds for optimal pond conditions and fish "browsing"													
Trees suitable for honey production													
Production of protein-rich tree fodder on farm/rangelands for cut-and-carry fodder production													
Woodlots for timber, fodder, soil protection, soil reclamation													
Woodly legumious crops planted and left to grow during fallow phase to improve fallow													
Trees planted for shading crops or animals													
Small scale broiler production													
Small scale egg production													
Small scale milk production													
Small scale intensive cattle farming													
Small scale goat production													
Stall feeding													
Creep feeding													
Cultivation of alternative fodder crops													
Haymaking													
manure harvesting													
Resting camps for a full growing season													
Even utilisation													
Fire													
Protein licks													
Debushing and oversowing													
Rangeland reinforcement													
Bioturbation													

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

Table 14: Criteria for confining the selected practices based on farmer typology, physical environment and farming system (grey boxes)

	Proxies for physical environment														Farming system				Typology		
	AEZ				Soil texture				Soil OC			Slope									
Practices	Tropics semiarid warm	Subtropics semiarid cool	Subtropics sub-humid cool	Subtropics sub-humid warm	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																					
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 options (multipurpose, fast growing trees and fodder species)																					
Bed design; trench beds, ecocircles																					

Understand soil health aspects using visual indicators																					
Crop diversification																					
push-pull technology																					
Natural pest and disease control																					
Integrated weed management																					
Breeding improved varieties (early maturing, drought tolerant, improved nutrients),																					
OPV and heirloom varieties																					
Seed saving																					
Crop rotation																					
Windbreaks																					
Trees and bushes lining fish ponds for optimal pond conditions and fish "browsing"																					
Trees suitable for honey production																					
Production of protein-rich tree fodder on farm/rangelands for cut-and-carry fodder production																					
Woodlots for timber, fodder, soil protection, soil reclamation																					
Woodly legumious crops planted and left to grow during fallow phase to improve fallow																					
Trees planted for shading crops or animals																					
Small scale broiler production																					
Small scale egg production																					
Small scale milk production																					
Small scale intensive cattle farming																					
Small scale goat production																					
Stall feeding																					
Creep feeding																					
Cultivation of alternative fodder crops																					
Haymaking																					
manure harvesting																					
Resting camps for a full growing season																					
Even utilisation																					
Fire																					
Protein licks																					
Debushing and oversowing																					
Rangeland reinforcement																					
Bioturbation																					

Practices that have been suggested in section 4.5.2 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 4.4.3, 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 14.

This table 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 is not suitable for one of these categories or sub-categories characterising the farming HH, the practice is rejected from the list of suggested practices.

4.5.4 **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 thinks 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 15.

The relevant practices that were selected in section 3.3.3 based on the physical environment, the farming 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's knowledge/experience, to improve or to sustain the different resources. A separate ranking can be made for the contribution to the natural resources only.

Table 15: 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

	Resources					
Practices	water	soil	crop	livestock	natural	total
Drip irrigation	3	1	2	0	1	7
Bucket drip kits	3	1	2	0	1	7
Furrows and ridges/ furrow irrigation	3	2	2	1	1	9
Greywater management	3	1	2	1	1	8
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 cicles	3	2	3	1	1	10
Zai pits	3	2	3	1	1	10
rain water harvesting	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
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	2	1	3	1	1	8
Liquid manures	1	1	3	1	1	7
Woody hedgerows for browse, mulch, green manure, soil	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 options (multipurpose, fast growing trees and fodder species)	2	2	3	3	1	11
Bed design; trench beds, ecocircles	2	2	3	1	1	9
Understand soil health aspects using visual indicators	1	3	2	1	1	8
crop diversification	1	2	3	1	1	8
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
OPV and heirloom varieties	1	1	2	1	1	6
Seed saving	1	1	2	1	1	6
Crop rotation	1	2	3	2	1	9
Windbreaks	1	2	2	1	2	8
Trees and bushes lining fish ponds for optimal pond conditions and fish "browsing"	3	1	2	2	1	9
Trees suitable for honey production	1	1	2	1	2	7
Production of protein-rich tree fodder on farm/rangelands for cut-and-carry fodder production	1	2	2	3	2	10
Woodlots for timber, fodder, soil protection, soil reclamation	1	2	2	2	1	8
Woodly legumious crops planted and left to grow during fallow phase to improve fallow	1	2	3	3	2	11

Trees planted for shading crops or animals	1	1	1	3	1	7
Small scale broiler production	1	1	1	3	1	7
Small scale egg production	1	1	1	3	1	7
Small scale milk production	1	1	1	3	1	7
Small scale intensive cattle farming	1	1	1	3	1	7
Small scale goat production	1	1	1	3	1	7
Stall feeding	1	1	1	3	1	7
Creep feeding	1	1	1	3	1	7
Cultivation of alternative fodder crops	1	1	2	3	2	9
Haymaking	1	1	1	3	1	7
manure harvesting	1	2	3	2	1	9
Resting camps for a full growing season	1	1	1	3	3	9
Even utilisation	1	1	1	3	3	9
Fire	1	1	1	3	3	9
Protein licks	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

(b) Ranking based on farmer input

The relevant practices that were elected 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.

The criteria used here are those that have to date most frequently been used by farmers at field level.

4.6 Limitations of the DSS and further work

Here the conceptual framework of the DSS has been introduced. The DSS has however not yet been evaluated. Therefore, in a next step, it is suggested to perform sensitivity analyses, to validate the output of the DSS against observations and to get feedback from the farmers, experts and facilitators. Based on the outcomes, the DSS will likely need some adaptation. This might for example be the case of the resources to manage based on the physical environment under section 3.3.1, and in particular concerning the water quantity. 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.

In addition, the list of practices needs to be fully populated with all required information to allow for decision making. Currently the required information has only been provided for the listed practices up to small dams.

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5 CCA WORKSHOP 3 AND 4: INDIVIDUAL PRIORITIZATION AND FARMER EXPERIMENTATION

As a continuation of the CCA process this has been conducted in all three sites (EC, KZN and Limpopo). It is based on the group level prioritisation undertaken in the CCA workshop 2 process and builds in a further level of individual choice and experimentation. Training and mentoring are provided for practices new to the community participants. This is summarised in table 2 of this report.

5.1 Eastern Cape (Alice, Middledrift, King Williams Town)

Written by Khethiwe Mthethwa and Erna Kruger

Introduction

The research team spent a week in the EC, to continue work started with the Fort Cox College and the Imvotho Buboni learning network.

5.1.1 CoP: Climate smart agriculture meeting: Fort Cox college of Agriculture and forestry Institute

The meeting was attended by lecturers from Fort Cox (animal science, crop production, business studies, engineering and the academic head of the college), along with the WRC team. The purpose of the meeting was to see whether more active collaboration in CSA could be established in some way with the college, to strengthen their interaction with the Amanzi for Food networking process they are already involved in. One of the main concerns that was highlighted by Fort Cox staff members was that their curriculum does not include CSA, as it focusses on commercial farming. In their view the two sets of ideas are not directly compatible. So, although they have an active interest in CSA, they did not see it as central to their present brief and curriculum. They felt also that curriculum reviews processes are possible, but cumbersome and time consuming. In addition, there are few or no opportunities for students to work directly with farmers provided through the College. The Extension project presently run by the college is a short- term interaction of a few weeks. There is however interest form both lecturers and students to be involved in information dissemination processes, as well as workshops and networking events.

5.1.2 CCA Workshop 3 agenda and process

Participants (24) of the workshop included members of the Imvotho Buboni network and lecturers and students from Fort Cox Agricultural College. The agenda for the workshop consisted broadly of a review of Workshop 2 (including prioritization of practices), discussion around climate change predictions and weather forecasts and planning for the demonstrations and individual experimentation process.

The agenda is outlined below.

Agenda	**Facilitation**
1.1. Review of Climate Change discussion: Summery Present pictures from a [previous workshop	Mazwi
1.2. SCION weather projections	Erna
2.1. Impact maps; Adaptive measures	Tema
3.1. Prioritisation of practices	Lawrence
3.1. Matrix	Erna
3.2. Research: Demonstration Sites	Sylvester, Mazwi
3.3. Presentation of Practices *Conservation Agriculture (Handouts) *Tunnels *Furrows *Mixed cropping and trench beds	 Mazwi Sylvester Chris Erna
3.4 Discussion of logistics for demo suites	Erna
3.5 Farmer experimentation	Erna
3.6 Individual choices	Lawrence
3.7 Scheduling (Finding out the locations)	Team
3.8. Scouting visit (4pm) to UmXhumbu (CA and furrow irrigation	Lawrence, Mazwi and Chris

Along with broad changes in climatic conditions, such as increased temperatures and rainfall variability, the previous workshop highlighted that farmers are already taking measures towards adapting to climate change. Farmers listed the practices that they can put into place to cope to the changes with climate. Some of the practices mentioned were mulching, tunnels and trench beds.

(a) SCION Weather projections

Here an overview was provided of the Seasonal Climate Watch projections that are provided through the SA Weather Services. Some of the quarterly temperature and rainfall maps were reviewed (Aug-Sept-Oct 2018) and participants briefly discussed how useful they thought this information could be to them.

Most felt that they could not rely on information like this to make decisions around planting times, although it does help to some extent with giving and indication of what the season would be like. The maps corroborated their feeling that planting times are later, as the summer rainfalls have been starting later and later. It can now even be as late as the 1st week of December. They do not know when to plant, but just do it and hope for the best.

Lives stock farmers suggested that they need to come up with practices that can be used, such as making hay and silage in summer, for making food available in winter, as winter grazing is becoming more and more of a problem.

Farmers liked the idea of being able to have some local indicators, such as rain gauges to help them make decisions, but did not feel confident about relying on information such as the seasonal climate watch forecasts.

(b) Adaptive measures

The following table shows the impacts and adaptive measures that were discussed in the previous workshop and were brought forward on the day of the workshop.

Impacts	Adaptive measures
• Drought caused by high temperatures • No produce • More poverty • Unemployment • High rate of sickness • Decrease in profit • Increase in food prices • Social impact: More crime, lack of employment which leads to theft and loss of livestock.	• Rain water harvesting (will lead to More yields, more profit, Decrease in food prices) • Conserve water sources • Raise beds and trench beds • Intercropping • Mulching and tunnels. • Planting indigenous plants (use natural herbs as vaccinations to cure livestock. • Mixed cropping-natural pests control (At the school there is a programme of nutrition where students are encouraged to practice it at home by mixed cropping and planning different crops). **New options** • Awareness raising • Changing planting dates

(c) Prioritising of Practices

In prioritization of practices, this exercise focussed on which practices people are already using and which not, given that most of the learning network members are already conversant with the CSA practices. This was done to then be able to introduce the exercise of individual choices and farmer level experimentation. The table below summarises this exercise.

Table 16: CSA practices prioritized by individual participants

Practices	Short description of Practices	Already Used	Interested
Swales	These are ditches that goes on contours, the soils are dig up in the ditch. It is labour intensive and designed for large scales.	0	2
Grey water harvesting	Re using of dirty water which were used for washing dishes or bathing.	4	2
Small dams	Basically, it is a small dam, with designed furrows channelling water into the dam. Very common for rain water harvesting.	4	0
Fertility/ infiltration pits	Dig a hole	0	2
Contours		0	0
Terraces	Very steep slopes. Most of the land in the EC is flat, the practice is not common and cannot be practise.	0	0
Furrows and ridges	Very shallow on flat grounds with steep slopes.	6	3
Raised beds	According to farmers it harvests more water. It is suitable for areas that get flooded when there is rain.	8	0
Trench beds is for compost	Involves digging of a deep whole field with compost.	0	0
Tower gardens	For elderly people, and disable people, you can grow a lot in a small space. They started doing it at the begging of the year	6	1
Shade Tunnels	These are structures made of shade clothes used to protect the plants from high wind, rain, frost, and snow. The practice is practiced on Campus- Fort Cox college.	1	Everyone
In fields basins	Creating basins within the field, to collect water. Concentrating water into the field. I collect more rains and reduces runoff.	0	2

Mulching	It is very common practice which involves using of dead plant material and grass to cover the soil as a result of protecting it from erosion and retaining soil moisture.	12	12
Mixed cropping, intercropping and close spacing	Putting different plants close together in one field or one plot.	8	Everyone
Crop rotation	Rotating different crops, in different seasons in one field i.e. The farmers are already rotating cabbage, spinach, beetroot and onions.	12	Everyone
Underground storage		0	0
Rain water harvesting	Include infiltration, diverging water also help to increase organic content of the soil.	Everybody	Everyone
Bucket Drip	Simple and a small-scale drip irrigation system.	0	6
Liquid manure		5	2
Herbs	Grown for health purposes and act as pest control in the garden. Farmers also use it also for soil fertilisation.	3	3
Conservation Agriculture	Practice described below	0	12

(d) More detailed introduction to certain practices

Available learning materials, power-point presentations and learning videos were used to introduce a number of topics, including Conservation Agriculture (CA), tunnels and drip irrigation, furrow irrigation and mixed cropping. A discussion followed mostly centred around CA and definitions of minimum tillage and zero tillage.

What is the difference between minimum tillage and zero tillage?

*Minimum till entails little disturbance of the soil- one makes basins or lines where you will directly deposit your seeds and zero tillage is when you do not till the soil at all. Normally with zero tillage implements are used.

*0% Disturbance -Zero tillage. 0-5% Disturbance - minimum tillage. 0-15% Disturbance – Conservation tillage

Farmers asked why CA is promoted in a way that encourages the use of chemicals and fertiliser, which does not keep the soil as sustainable as promoted. The response was that in some cases smallholders prefer to us these chemicals, and MDF is no prescriptive in that regard. Also, it is tricky to start CA on very depleted and infertile soils and often weeding becomes a major challenge for farmers.

Thus an approach of using chemicals in the beginning, but sparingly, has been advocated, with a gradual conversion to a low external input system.

Furthermore, Lawrence said each farmer needs to make their own decisions in their context. As an ecological farmer you can choose not to use herbicides at all. Farmers were very convinced that they are trying by all means to reduce dependency on fertiliser.

A further question regarding the tunnels and drip irrigation, was where drip irrigation is only suitable for small areas.

How big is the piece of land to do drip irrigation and crop rotation?

It does not matter how big the space is, it all relies on the kind of soil. The spacing depends on the type of soil then the type of plants. Drip irrigation is tested out on the soil.

(e) Farmer Experimentation

Farmer experimentation was introduced explaining that t*he best way to learn is to do it and compare it with whatever you are doing.* Thus, the control becomes the "normal way" and that is compared with the new idea. It is important to try new ideas out on a small scale to reduce risk. Decisions about how to observe and measure the differences are made at the onset of the experiment and these observations and measurements are recorded throughout the season, so that an informed decision can be made about the potential benefits and challenges of the new idea. An example was made of implementation of a tunnel (shade-house structure): Here both the trail and the control will have trench beds, mulching and drip irrigation and be planted at the same time to the same crop, so that the only variable becomes the tunnel itself.

(f) Individual choices

Below is that table filled out by the participants in choosing the practices they would want to experiment with for this coming season.

Table 17: Individual farmer led experimentation choices; EC, Aug 2018

Name and Surname	Tunnel	Bucket Drip	Tower Garden	Trench bed	Furrow and ridges	Grey water	Small Pans	Herbs	terraces	Fertility pit	Swales or contour
Aviwe Biko	✓	✓				✓			✓	✓	✓
Monwabisi Jende	✓	✓			✓	✓	✓	✓			
Xolisa Dwane	✓	✓	✓		✓		✓	✓			
Thango Hogana			✓	✓							
Phindisiwe Msesiwe	✓	✓									
Siyabulela Hafe							✓	✓			

(g) Scheduling of practical demonstrations

The following table shows the practices that were going to be demonstrated in the upcoming days.

Gardening	Field cropping
Tunnels (shade-house), with drip irrigation - construction Trench beds, mulching Tower garden	Conservation Agriculture including: - Mixed cropping, including cowpeas - Winter cover crops - Planters; MBLI, HARAKA Contours; using a line-level Swales; how to construct Furrows and ridges; how to construct on contour Short furrow irrigation

This group of farmers come from three different villages; uMxumbu, Berlin, and Qunwini. The demonstrations were planned to allow those most interested to attend the trainings, as the sites are far apart and not all participants can travel between them.

	Practice	Venue	Time	Contact Person	Contact Details
Demo 1 (day 1)	**Field cropping**	UMxumbu location	9:30	Xolisa Dwane	0790580774
Demo 2 (day 2)	**Tunnel and bucket Drip**	Berlin. Izingisi Education Centre- No 6 Carl Pape street	8:30	Eddie Parichi	0782971373 /0436852040 Izingisi Educational Project
Demo 3 (day 3	**Tower Garden**	Qunwini	09:00	Phindiwe Msesiwe	0835926707

Demonstration 1: Field cropping

The demonstration took place in Middledrift in UMxumbu. The learning group is made up of young 11 farmers from a community co-operative called UMxumbu Agricultural Youth co-op. The demonstration took place on the 01st of August. Two group members were available and the undertook to share their knowledge with group members.

For CA plot preparation and layout was demonstrated and the use of the two types of planters shown with the different seed types; maize, beans, cowpeas, saia oats, fodder rye and fodder radish. Planting was not done- as the participants felt they would rather plant when there was a better chance of success (November).

Right: Mazwi explaining layout; basins and rows in CA planting to the participants

Similarly, the construction of furrows, for short furrow irrigation was demonstrated at a household level. Participants would extend this practice to their larger fields when preparing for summer planting.

Right; Chris demonstrating the construction and layout of short furrows

Demonstration 2: Tunnel and bucket Drip

The training took place in Berlin at Izingisi Education Centre. There were 11 participantswho attended the training. The practices that were demonstrated was the tunnel, bucket drip and a chameleon water sensors.

Normally a tunnel is built over three trench beds (1mx5m0 that have already been constructed. In this case there was one existing trench bed which was used. The tunnel construction process includes bending the pipes for the arches, sewing of the nets, fitting and tightening of the nets onto the arches, layout of the tunnel using a template, drilling of the holes for placement of the arches and then the actual construction.



Right: Clockwise from top left: Placement of arches, sewing of net onto arches and the final tunnel

A chameleon is a sensor that measures soil moisture and temperature at different depths in the soil; 20 cm, 40cm and 60 cm.
This is a tool that can help farmers to make decisions about when to irrigate and how much water to apply. The amount of water available in the soil is indicated by colours where the sensor turns from blue to green or red, where for example, blue shows that the soil has enough water and no further irrigation is required.

Chameleons were installed in the trench bed inside and outside the tunnel as well as in a "normal" bed in the garden, so that the irrigation requirements of these three beds can be compared throughout the season.
A student from Fort Cox, Siya, who is an intern at the centre undertook to do the monitoring and upload the readings from the chameleon on a weekly basis.

Right; Sylvester and Mazwi assisting Siya with how the chameleon reader works

Buckek drip kits were also installed. Th bucket contains a gravel and sand filter to allow for the use of greywater in the system. It should be flushed once a week with clean water.

Right; the gravel and sand placement in the bucket to filter greywater

Demonstrations 3: Tower Garden and bucket drip

The MDF team split into two; one group remained in Berlin to finalise the tunnel and chameleons installation and the other sub-group went to Quzini to do the tower garden demonstration in Mama Phindiwe Msisiwe's Garden.

Materials needed were a 3m shade net, 4 poles, spades, Soil: manure: ash mixture -6:3:2, a wheel barrow, seedlings, tape measure, bucket, water and a knife. The soil mixture was prepared by the farmer the day before. The following explains the tower garden making process step by step.

Step 1: identifying space and measuring

The tower garden was installed on a very flat surface. A 90mm diameter was used to measure the length between the poles. One pole was initially installed. And holes were dug for other three poles to be placed later on.

Step 2: Measuring and sewing of the net

The net size that is required to make a tower garden is 3m long. Once the net is properly measured it is then sewed on the ends. Sewing was done on the ends of the net to achieve a round skirt like shape.

Step 3: Placing of the poles and shaping of nets

The net was initially placed on the pole that was already positioned. The net was stretched enough to place the other three poles. The poles were positioned in a way that they would fit on the holes that had been dug. A square shape was achieved.

Step 4: Filling up the tower garden with soil

Excessive shade net was pulled through the poles to create a good foundation for the soil. A mixture of 6 wheel barrows of soil, 3 wheel burrows for the manure and 2 wheel burrows ash was mixed together and then a30cm layer was poured into the net.

Step 5: Stones

A ‘pillar of gravel is placed at the centre of the growing media to provideproper drainage of water at irrigation and also flitration for greywater. An old bucket was cut at it bottom to make a cylindical shape. This cylinder was placed in the centre of the tower and filled with gavel, then the bag was backfilled with the soil medium to the level of the bucket, which is then carefully pulled up to be abel to be filled again. The process is repeated until the tower is complete

Step 6: Watering and planting of the tower

The tower was watered until it was very wet. A tape measure was used to make a proper spacing between rows and plants. A knife was used to make holes in the net. Seedlings of spinach were directly deposited into the growing media through the holes. The tower godern can also be planted on top. Later on the farmer will plant more crops on the surface and add mulch.

5.2 KwaZulu Natal (Ezibomvini and Thabamhlophe)

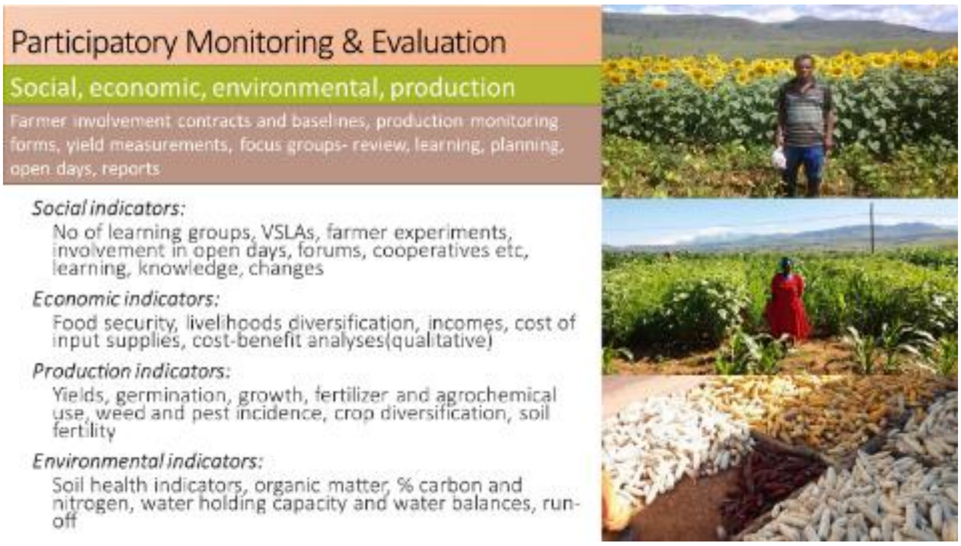
The CSA experimentation process around gardening, which includes farmer led experimentation in topics covered such as trench beds, eco-circles, mulching, mixed cropping and natural pest and disease control as well as the group-based demonstrations and experimentation around tunnels and drip-kits for both Thabamhlophe and Ezibomvini, is to be reported for the next deliverable.

Here a selection of results obtained in Conservation Agriculture farmer led experimentation, implemented primarily under the Maize Trust funded Smallholder Farmer Innovation Programme (SFIP) are to be reported. In this process, we are primarily interested in the outcomes of experimentation, linked to impact indicators related to livelihoods, productivity and the environment (soil and water conservation, soil health).

5.2.1 Indicators used an Innovation Systems model

A large number and range of indicators have been used within this programme, to be able to assess the value the ease of use and the potential for gauging impact using these indicators.

The slide alongside gives an indication of some of these indicators and monitoring tools used to gather this information



A summary of progress with social, economic and production indicators is provided in the table below.

Table 18:Innovation Systems indicators for the CA-SFIP in Bergville

Social agency		Value chain		Productivity	
No of female farmers	83%	Saving for inputs	28%	Intercropping – maize and beans	92%
Learning groups (No)	36	Reduced labour in CA plots	78%	Intercropping maize and legumes (cowpeas, lab-lab, velvet bean	17%
VSLAs - % of participants involved	79%	Reduced weeding in CA plots	39%	Crop rotation	20%
Months of food provisioning through small CA plots 10-12 7-9 4-6 1-3	 15% 38% 39% 8%	**Use of planters** Hand hoes Hand planters Animal drawn planters Tractor drawn planters	 26% 69% 5% 0,5%	Cover crops; summer mix – sunflower, millet, sunn hemp, sorghum	26%
Sale of crops locally (maize, beans, cowpeas, sunflowers)	10%	Local financing of infrastructure Threshers Mills	 1 1	Cover crops; winter mix relay cropping – Saia oats, fodder sorghum, fodder radish	31%
Innovation platforms; including external stakeholders	5	Farmer centres	1	Fodder; provisioning of livestock through cut and carry	5%
				Seed saving	11%

In this way the programme is able to track and analyse the impact of these CA trials on the whole livelihood system of these smallholder farmers. Trends in the last few years have been:

1. Smallholder farmers have been increasing their household food provisioning through these trials substantially. At the beginning of the programme all participants were in the category of being able to provision for 1-3 months of the year only. Now around 53% of participants are providing enough food to last for 7-12 months of the year. **This indicates that around 90% of participants have improved their food provisioning and thus their food security status through using CA**
2. More and more smallholder farmers are joining the VSLAs (Village savings and loan associations). At the start of the programme none of the participants belonged to formal local savings associations. **Now around 79% of participants are active in savings and of these 28% are saving for inputs.** In itself, this development has made a significant impact on the sustainability of local farming systems, but in particular because they use these inputs to do CA.
3. Now **10% of participants are producing enough to be able to sell locally as well as provide food** for their families. None of the participants were selling produce at the start of the programme.
4. The programme started with **5 learning groups in 2013; there are now 36 learning groups**. Every year, new participants are brought on board and the horizontal scaling approach of clusters of learning groups in a locality is working well. In five years, the number of farmer- led experiments has increased from 28 to 440.
5. Affordability and reduction in labour are important considerations in uptake of CA. **Around 78% of participants feel that their labour requirements have been reduced for land preparation and planting and around 39% feel their labour for weeding has reduced**. Note that the system promoted provides for herbicide use pre-planting only and that during the season hand weeding

is required. If participants follow the close spacing and inter-cropping regimes promoted, then weeding is reduced considerably

6. A number of the indicators look at the implementation of the diversified cropping principle in CA. We thus track the number of participants using **intercropping (92%), crop rotation (20%), planting cover crops (31%), fodder provisioning for livestock (5%) and saving seed (11%).** This indicates a strong uptake of the diversification principle, given that prior to this programme 95% of participants were producing maize only in their field plots.

5.2.2 Trends for longer term smallholder participants in the CA SFIP

A specific survey was conducted this season (2017/18), with smallholder participants who have now cropped for 4 and 5 seasons respectively to ascertain their uptake and adaptation of the CA systems introduced as well as aspects of sustainability, including – increased cropping area, use of CA principles in all their fields (thus including the control plots), increased yields, increased food security and increased incomes/savings.

A total of 15 case studies with 5 participants in each of three villages (Eqeleni, Ezibomvini and Stulwane) in the Bergville area (shown below), were conducted between March- May 2018. (This is a sub- sample of the total number of participants (27) who started CA in 2013 and 2014).

Eqeleni	Ezibomvini	Stulwane
Smephi Hlatshwayo	Phumelele Hlongwane	Khulekani Dladla
Ntombakhe Zikode	Phumelele Gumede	Dlezakhe Hlongwane
Thulile Zikode	Cabangani Hlongwane	Thulani Dlamini
Tombi Zikode	Alfred Gumede	Makhethi Dladla
Tholwephi Mabaso	Velephi Zimba	Phasazile Sthebe

Below is a summary for the 15 participants interviewed. The values in the graph represent the number of participants for that indicator

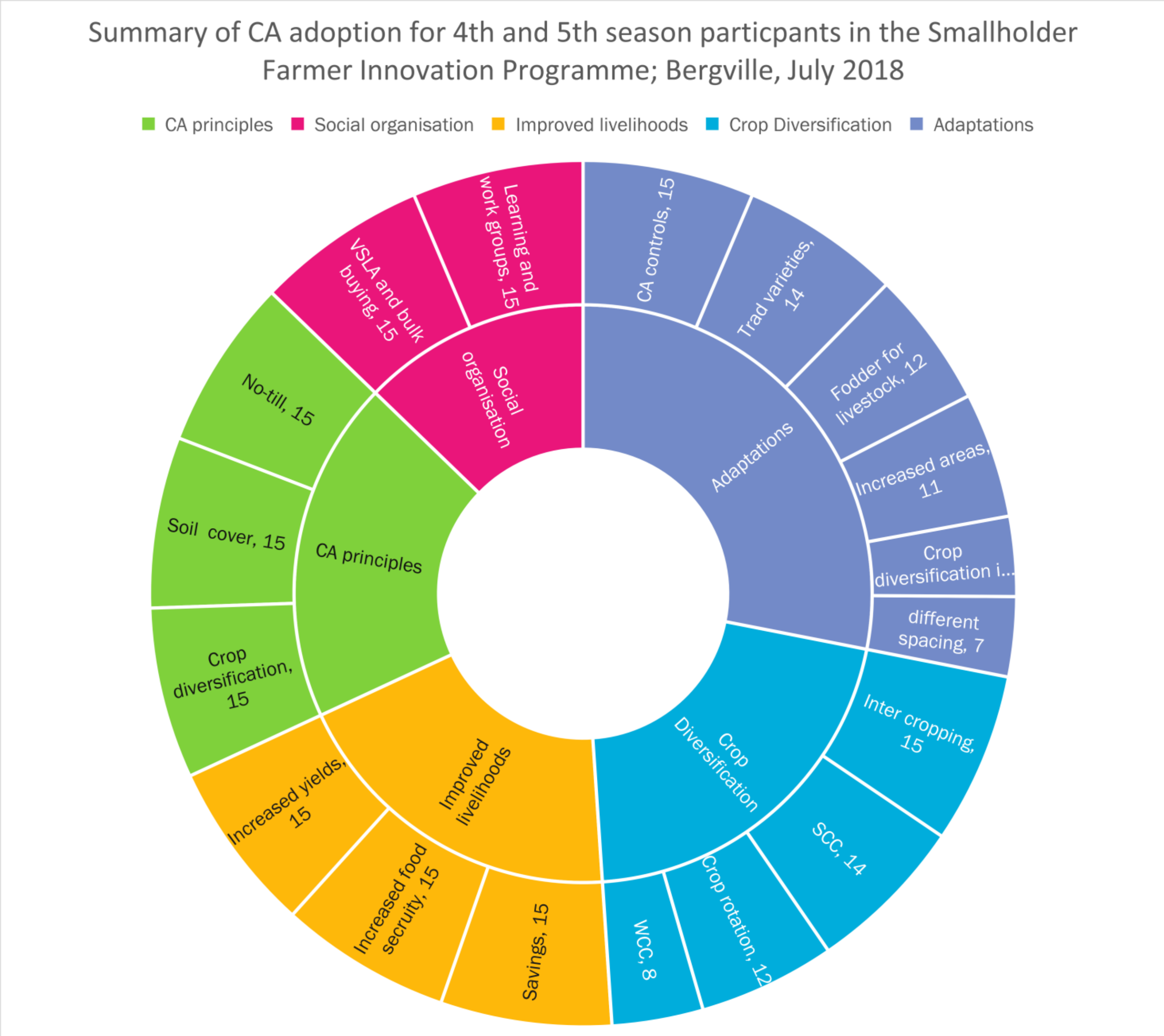


Figure 7: Summary of CA adoption for 4th and 5th season participants in the SFIP, Bergville, July 2018.

Summary of results:

All these participants are implementing all three principles of CA, are involved in intercropping and have included CA into their overall farming practices. They will now use CA as their farming approach going into the future. All participants agree that this approach has saved them money and increased food security considerably and all are involved in local VSLAs (Village savings and loan associations). All participants also use traditional seed varieties alongside the more modern OPVs, hybrids and GM varieties promoted.

There are some individual variations and adaptations in terms of crop rotation systems, spacing, use of cover crops and use of fodder for livestock. Around 73% of these respondents have already increased their area of cropping and feel that with the introduction of the animal drawn and tractor drawn implements, they will be able to expand even further.

This summary provides a very clear indication that after around 5 years of experimentation with CA, the farmers are now willing and able to implement CA without any further external mentoring. Support in the form of farmer centres that can assist in the provision of access to implements and inputs as well as the small subsidies for continued experimentation is however still important.

Present challenges are primarily around storage systems and capacity as all are producing more maize than they can easily harvest and store. Stray livestock provide a challenge for many participants and some still have some challenges around weeding and pest incidence (such as cutworms and Bagrada beetles). In addition, we have as yet been unable to come up with a satisfactory process of inclusion of winter cover crops (WCC's) in this CA farming system. Relay cropping and broadcasting of WCC's have been largely unsuccessful in this system.

A few other comments of interest are:

1. A proportion of participants have included the broadcasting of kraal manure into their cropping system, along with the micro-dosing of fertilizer and believe this works well. This is a practice that warrants further attention and experimentation
2. Around 36% of these participants have also been involved in the Grain SA Farmer Development Programme's Job Funds project. They have now all withdrawn given that the inputs provided through this programme have become unaffordable. Most of these participants have also kept the seed they obtained through that process for more than one season as their cropping areas are in fact smaller than 1ha.

Below is a summary of comments made by the interviewees.

The Conservation Agriculture system

"I am very happy with my current method of farming (CA) and I try by all means to recruit people into CA as it breaks the strong boundaries of poverty and food insecurity" (Ntombakhe Zikode)

"We really appreciate having Mahlathini as a stepping stone towards poverty alleviation in our village. The learning groups and farmer's day have played a huge role in enhancing our knowledge and learning. It has taught me to experiment with the skills that I have picked up. Phumzile and her team encourage us to keep our plots looking good. When they do monitoring rounds, we are able to ask more questions and share new ideas and in turn acquire more skills." (Khulekani Dladla)

"The workshops that were given in the introductory phase of the programme led me to believe that this system can be a very useful tool to solve our production problem of obtaining poor yields and also at the same time contribute to better food security in my homestead. Soils that we worked were tired after numerous years of tillage and had very little potential and the CA principles presented helped to form a more complete picture of the factors influencing good productivity of the soil which includes the combined use of practices such as intercropping, crop rotation and cover cropping and how these can assist in terms of building up the nutrients in the soil and also increase moisture retention capacity of the soils when practicing CA. I have now seen a drastic improvement in my fields with increased yields and soils are always workable as they are moist (cover)". (Thulani Dlamini)

- CA helps to save money and improves yields
- CA reduces water erosion and run-off in the fields
- CA reduces wind damage to crops as maize is not blown over, as it is under conventional tillage
- CA increases soil fertility and soil health
- CA increase soil moisture and makes the soil soft and more workable

Crop rotation

"Crop rotation helps most when it comes to disease control and balancing the way nutrients are taken from the soil as well as putting them back into the soil. This includes planting maize for one season then changing in the following season and planting cover crops, which are ideal for soil health". (Khulekani Dladla)

Below is a summary of some of the observations related to crop rotation:

- Maize-beans-beans-maize. This rotation has been introduced as maize grows a lot better after the bean rotations than without
- Maize-SCC-maize; this rotation provides the best growth of maize when compared to other intercropped and rotated plots.
- Rotations after planting Lab-Lab beans grow very well

Intercropping

Below is a summary of some of the observations made related to intercropping:

- Intercropping assists with weeding and keeping the soil soft and moist
- Intercropping also assists in boosting the fertility of the soil and helps with good growth in follow-on crops. It improves the yield of maize
- Intercropping helps with weeding
- Cowpeas provide for excellent soil cover due to its vigorous growth and thus also helps with weeding, containing soil moisture and soil fertility. Participants are no longer used to eating cowpeas and for this reason it is not preferred.
- There can be problems with bean yields in intercropped plots due to shading and excessive moisture where the pods rot prior to harvest.
- It also assists in providing different food sources over a longer period of time
- In maize and cowpea intercrops, the maize grows and yields better than in the maize and bean intercropped plots.
- Cowpeas provide more nutrients for follow-on crops.
- The yields of the mono cropped maize in the CA control plots varies a lot from year to year, while the maize yields in the trail plots where intercropping and cover crops have been used increase every year.

Cover crops

Below is a summary of observations related to cover crops:

- Planting of millet improves soil quality (making it soft and easy to work with) and soil health. It assists the follow-on crop substantially in terms of growth and yield
- Millet is eaten by birds and thus harvesting the grain has been impossible for most participants.
- Sunflowers grow well and most participants have harvested the seed to feed to their chickens. Some participants prepare a feed of crushed maize and sunflower for their poultry and have found this to greatly increase their survival rate.
- SCC's are cut and dried as a fodder for livestock – both goats and cattle.
- Cover crops increase the fertility of the soil; especially cowpeas and millet.
- Lab-Lab beans also have medicinal properties in assisting to regulate blood pressure. This is preferred over the modern medications as it is more natural. It also provides for much increased soil fertility and improved soil health.
- Cover crops help keeping the soil moist and in a good condition during the off season
- Cover crops help in providing fodder for livestock in winter when they do not have enough food.

Crop varieties

"I like the modern cultivars, such as PAN6479 as they have the capacity to produce more as compared to the traditional maize which I use in my control plot. The traditional maize is good when it comes to disease resistance and adaptation to weather changes; however, it does not have the best yield" (Smephi Hlatshwayo)

"The Gadra beans are more susceptible to pests and diseases as well as poor adaptation to weather changes, which makes it better to plant this bean late in the planting season. Usuthu (a traditional cultivar of climbing bean) is much more disease resistant and can adapt to weather changes, which is why I have both these cultivars in my trial and control plots" (Smephi Hlatshwayo).

Traditional varieties are used as it is possible to keep seed for following seasons and this is seen as important. Participants also prefer the taste of the traditional maize. Below is a small table put together from comments made by Khulekani Dladla on comparing different seed types.

Hybrid seed Pro's	Hybrid seed cons
Yields big cobs with multiple lines	Sometimes it is too sensitive to chemicals
Produces quality maize	
GM seeds Pro	**GM seeds cons**
Persistent and not too sensitive to weather and chemicals	Has many bad weather hazards
Easy to work with because they don't require labour when it comes to weeding (chemically friendly)	Has many bad health hazards
Traditional seeds Pro	**Traditional seeds cons**
Resistant to many diseases	Yield is too small (the traditional seed cob has fewer lines of seeds/pips).
It is filling	

Plot layout and spacing

Overall the standard design of the experimental plots has been adapted by the whole group in Eqeleni under the direction of the local facilitator in the area. They have altered plant spacing from the recommended 50 cmx50 cm for maize to 70 cmx70 cm. They share that this solves the problem of ease of weeding as with the close spacing the feeling was that the growing bean plants intercropped with the maize cannot escape damage from human traffic and implements used. Apart from this, increased competition between growing plants was observed and for this reason spacing altered. Their 1000 m^2 trials (50 m*20 m) 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, sunn-hemp and millet respectively.

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

In the other two villages the decisions have been based a lot more on individual observations. For the control plots, which are the 'rest' of the field crop plantings for each individual, most of the participants have now included elements of the CA system, including no till and micro dosing fertilizer. For the most part however, they have continued with a maize monocropping system in their control plots.

Below are some descriptive photographs.

(a) Eqeleni

Eqeleni village is one of the pioneer villages of CA in the Bergville. The group currently comprises of a total 21 participants 6 of which are new entrants into the programme having joined in the current 2017/2018 growing season. This group has really taken on the CA principles and made these their own by modifying certain aspects of the model but also sticking to basic concepts of CA. There are 2 VSLAs in the village

Right: Tholwephi Mabaso stands in front of her mono-cropped maize trial plot.

Below: Close-up mono cropped maize from Smephi Hlatshwayo's trial.

Right: control maize (CA) – Her trial maize performs better than her continually mono-cropped control

Left: 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.

Thulile Zikode. Below: A view of her late bean planting with her maize and bean intercropped plot behind her. Right: Her SCC plot with millet, sunflower and sunn-hemp mix

(b) Ezibomvini

This village started the CA process in the 2015-2015 season. There are presently 26 participants, of whom 6 are new entrants into the programme. Ezibomvini hosts a farmer centre and 2 VSLA groups.

Right: Alfred Gumede standing next to a plot of Lab-lab beans planted in the 2015-2016 season. Towards the back of the picture are the millet stalks from a SCC plot. Right below: A view of one of his CA mono cropped maize plots.

Above- Velephi Zimba standing in her SCC plot (sunn-hemp, millet and sunflower)

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.

(c) Stulwane

This village started their CA process in 2013. There are presently 19 participants. A new group has been started in another part of this village this past season, with 12 members

Left above: A view of Khulekani Dladla's field showing maize and bean and maize and cowpea intercropped plot. Left below – he stands in front of a plot of sunflowers and Right – he indicates yields form different types of beans planted in his fields.

Right: Thulani Dlamini stands in a single crop bean plot, ready for harvest and in front of a plot of single cropped sunflower that he planted in the 2016-2017 season.

Above left: A view of Makhethi Dladla's field with a mono-cropped bean plot in view and towards the back of that is maize and SCC intercropped plot. Above right: Makhethi stands in a maize and bean intercropped plot.

5.2.3 Environmental and productivity indicators

In addition, more quantitative indicators have been measured; including yields and soil and water conservation indicators such as soil fertility, soil health (soil aggregates, organic matter, microbial respiration percentage organic carbon and nitrogen, bulk density, gravimetric water content, run-off and infiltration). Some of these results are to be reported in the next deliverable cycle.

Below a snapshot of indicators reported for the CA SFIP are provided, to give an indication of the learning and trends coming out of that work.

(a) Yields

Yields for the CA farmer-led trials are recorded for each participant on a yearly basis. They are compared also with the participants' control plots.

CA is understood to steadily improve soil fertility and soil health. This aspect of CA; improvement of yield over time, is clearly visible in the yield summaries presented in the table below, where average yields for maize, between 2013-2017 have increased from 3,74t/ha to 5,7 t/ha, despite the challenging weather conditions. This trend has not been matched in the control plots where average yields for Bergville are still in the region of 3,44t/ha for maize. Bean yields have been a lot more variable, being more susceptible to the varying weather conditions and have hovered around 1t/ha throughout.

Table 19: Crop yields in CA farmer-led trials in Bergville; 2013-2017

	Bergville				
Season	2013	2014	2015	2016	2017
No of villages	3	9	11	17	18
No of trial participants	28	83	73	212	259
Area planted (trials) - ha	2,8	7,2	5,9	13,5	17,4
Average yield maize (t/ha)	**3,74**	**3,63**	**4,12**	**5,03**	**5,7**
Min and max yield maize (t/ha)	2-4,3	1-6,7	0,6-7,4	0,3-11,7	0,5-12,2
Average trial quantity of maize (kg)	233	576	654	487	206
Rand replacement value (maizemeal) for trial plots	R1 600	R4 500	R5 500	R4 900	R2350
Average yield beans (t/ha), trial plots	1,24	0,26	0,79	1,05	1,22

One of the aspects of farmer-led experimentation is the great variability in production between the different farmers involved in the experimentation. Although the maximum yields obtained by some of the farmers have increased dramatically, being around 12,2 t/ha for maize in this last season, the lower end (minimum) yields have remained low at around 0,5t/ha. This is due both to the fact that new participants come on board every year (around 37% of participants in 2017) and that some participants fail to achieve the improved yields in their CA plots. Crop management and soil condition, especially acidity are important factors in yield reduction.

(b) Soil health status

Soil health status is tested for a selection of the longer-term participants in the CA farmer-led trials to ascertain levels of and changes in; microbial activity, percentage soil organic carbon, percentage organic nitrogen, upstream availability of nutrients to follow-on crops and aggregate stability.

Below an analysis has been done to ascertain soil health changes dependant on length of CA practice. Results from Ezibomvini (three 4th year participants) are compared to Mhlwazini (two 2nd year participants). These results are qualitative and give an indication of trends only.

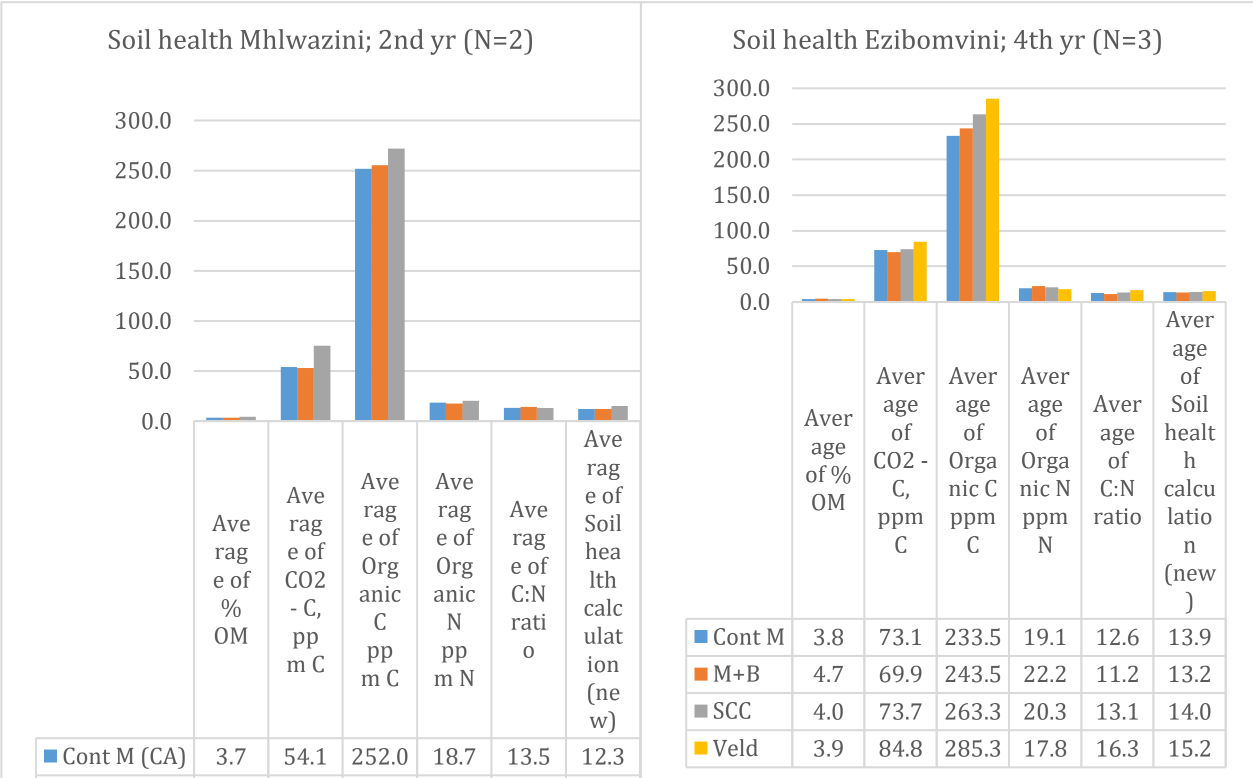


Figure 8: Comparison of soil health test results for 2nd and 4th year CA participants

From the above figures the following comments can be made:

- After 4 years the % OM accumulation for the CA plots (M+B and SCC) is higher than the veld benchmark. This indicates good accumulation of organic matter in the intercropped and summer cover crop plots of the CA trials over time. The maize only plots do not accumulate organic matter to the same extent. For the 2nd year participants the % OM is lower than the veld benchmark and there is as yet no distinction between the maize only and maize and bean plots.
- There is an increase in the average organic C from the maize(M) only plots, to the maize and bean intercrops (M+B) to the summer cover crops (SCC), indicating an accumulation of Organic C for the M+B plots from the 2nd year onwards. Use of SCC over a period of time provides for the highest increase in Organic C.
- The largest accumulation of Organic N is for the 4th year M+B plots, when compared to M and SCC plots. This indicates a cumulative effect of increased Organic N when intercropping is used and the effect becomes more visible over time.
- This links to the lower C:N ratio for M+B plots for 4th year participants.
- C:N ratios for the CA plots (M, M+B and SCC) for the 4th year participants are lower than the veld benchmarks. This is not the case for the 2nd year participants. This indicates the lowering of C:N ratios over time for the CA practices.

In summary, the use of CA practices and especially including intercropping and summer cover crops in the cropping system increases % soil organic matter and the accumulation of organic C and Organic N

over time. C:N ratios decrease. These trends become clearer after a period of 4-5 years of implementation of CA.
The savings in R for inorganic N that needs to be applied is also cumulative. For Mhlwazini (2nd year) this value is R374,50/ha and for Ezibomvini (4th year) the value is R437,13. These values are equivalent to 12% and 14% of total fertilizer costs respectively.

This season an additional measurement has been included, that of soil bulk density (ρb). This measurement is needed for the calculation of water productivity. Bulk density is directly related to soil porosity and indicates the degree of soil compaction (Assouline, 2006[1]). Consequently, ρbis considered a good measure of soil quality as it affects other soil physical parameters such as water holding capacity and ease at which roots can penetrate the soil.

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)[2].

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 20: Bulk density results for three CA participants

Village	Period undue	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**

[11] Assouline S., 2006. Modelling the relationship between soil bulk density and the water retention curve. Vadose Zone Journal, 5 (554-563).

[2] 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.

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

(c) Run-off and infiltration

Run-off plots have been installed for 1 participant in 2016-2017 and four participants in the last season in Bergville. It has been extremely difficult for participants to practice the required amount of meticulous measurements required for this process and they very often did not record the run-off after every rainfall event; especially at times when small amounts of rain fell for a number of days in a row. This has meant that most of the data recorded has not be useable.

The two small analyses below however provide a good indication of the positive impact of CA on run-off.
Runoff data was collected in 2016-2017 for Phumelele Hlongwane who has been active in CA trails since 2014. The results are shown in the table below. Only those rainfall events between November 2016-April 2017 where rainfall and runoff could be directly compared have been used

Table 21: Run-off data from Phumelele Hlongwane; 2016-2017

Control plot			Trail plot	
Rainfall (mm)	Runoff (mm)	% rainfall converted into runoff	Runoff (mm)	% rainfall converted into runoff
14	4	28,5	2,5	17,9
22	2,5	11,5	1,5	6,8
9	1,25	13,9	1	11,1
20	3,25	16,2	2	10,0
13	5	38.,5	2,25	17,3
21	2,5	11,9	1,5	7,1

There was more runoff in conventional tillage plot compared to the CA plots. The percentage of rainfall converted into runoff, ranges between 11,4% and 38,5% under conventional tillage, while it ranges between 6,8% and 17,9 %under CA. These results agree with the study conducted in the Bergville are

[3] 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).

by Mchunu et al. (2012), which shows that CA (even under <10% crop residue cover) has the potential to significantly reduce soil and soil organic carbon losses by water under small-scale agriculture.

For the 2017-2018 planting season run-off plots were placed in 5 different plots within Phumelele Hlongwane's CA trial. In this case only monthly averages for both run-off and rainfall could be used

Date	**Rainfall (mm)**	**Run-off plots litres**				
		Maize + Beans	**Maize only**	**Maize + Cowpea**	**Summer cover crops**	**Control**
Feb-18	169	35,61	18,53	37,05	35	57,59
Mar-18	114,7	7,5	1,52	8,9	7,7	23,32
		Percentage rain converted to runoff				
Feb-18	169	21%	11%	22%	21%	34%
Mar-18	114,7	7%	1%	8%	7%	20%

The results are very similar to the previous year with run-off in the CA plots being lower than the control plot of conventionally tilled maize and the average percentage runoff is again between around 7-17% for the CA plots and between 20-34% for the control plot.
What is however unexpected is that the runoff in the mono-cropped maize plot was lower for both months than those with the intercrops and summer cover crops. It would appear from this result that the reduction in run-off has a lot more to do with the fact that the soil was not disturbed during planting than with the actual crop planted. This does make sense, although the assumption was that the canopy cover provided in the mixed cropping plots would have an impact on the amount of run-off.

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 were not reported on. For the 2017-2018 a double ring infiltrometer was acquired and readings were taken for 13 participants. 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.
The results are presented below.

Table 22: 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.

Phumelele Hlongwane is one of the best CA farmers in the Bergville area. She has used all cropping practices including intercropping, rotation and summer and winter cover crops and has consistently achieved very high yields (ave 10-12t/ha). Here soils however, are not good structurally and the implementation of CA for the last 4 years has not changed the water infiltration rate of her soil. Soils are also variable across her field with some parts being shallow and rocky and other less clayey with deeper soil. Generally, her infiltration rates are slow.

Figure 9: From Left to Right: A spade of her soil graded to show large clods but little structural integrity; An example of root size and depth of one of her maize plant - showing quite shallow rooting and the double ring infiltrometer set up for readings. The walls of the rings are quite battered due to extreme difficulty of getting the rings into the soil

In summary, although the soil health indicators have improved in the last 4-5 years of implementation for the CA farmer-led trial participants, indicators for structural improvement in the soil are slow to show changes. It was hoped that some of these structural characteristics such as bulk density, soil aggregates, infiltration and run-off could be used as proxy indicators for soil improvement under CA. Given the results to date however, it is starting to appear as though these indicators would not work for that purpose.

5.3 Limpopo (Sedawa, Lorraine (Sekororo), Turkey)

For the Limpopo CoPs or learning groups, no workshops around CCA have been run between May-September. Garden monitoring has however been conducted for 29 participants across the three villages participating in this process, to get a qualitative impression of implementation of CSA practices and their impact.

For the period of July-September 2018, 29 garden monitoring forms have been filled in by the intern, Betty Maimela, with assistance from the Local Facilitator for Sedawa, Christinah Thobejane. Monitoring has been conducted for the following villages: Sedawa, Mabins A, Botshabelo, Turkey and Lorraine (Sekororo). Lorraine is a village where MDF worked in partnership with Lima-RDF to introduce tunnels (4 participants) and farmer experimentation. This collaboration was started in the 2017-2018 project period, but has not continued, due to staff and project changes within Lima. We conducted the monitoring to check progress for these participants in the last year and to provide some closure for this activity.

The two graphs below indicate the implementation for the participants monitored during this period.

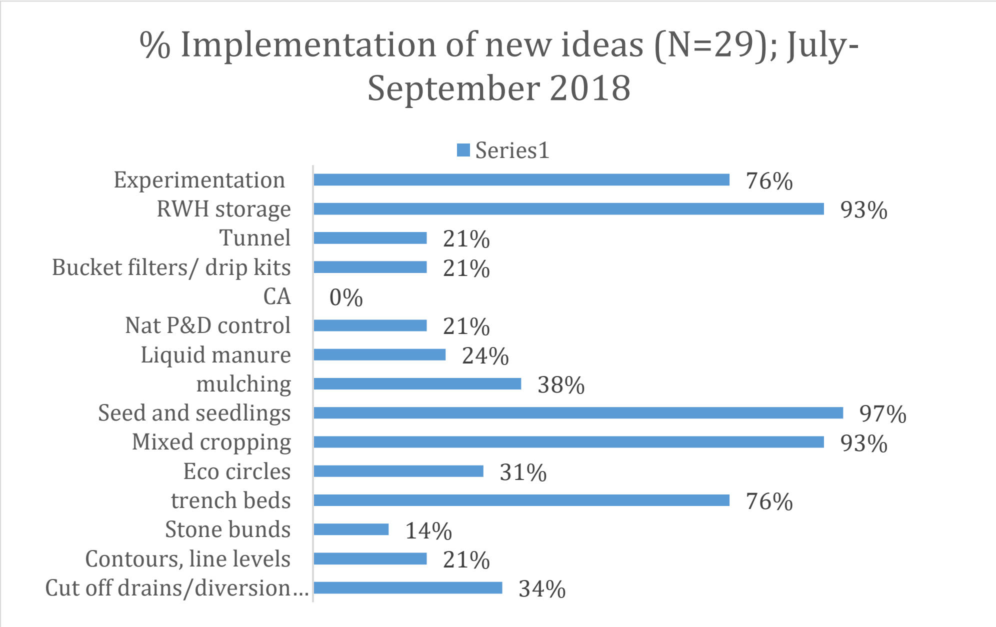


Figure 10: Percentage implementation of new interventions and new innovations for a selection of participants from 3 villages; July-September 2018

From Figure 10 above, the implementation of new interventions (CSA practices) is high for vegetable production practices; including for example keeping seed, growing seedlings from seed, mixed cropping, trench beds and RWH storage. It is clear that these participants are active in gardening and focussing on activities that can maximise their production. Practices related to soil and water conservation show much less enthusiastic uptake.

Farmer experimentation shows a high level of uptake (76%). The small table below shows the experiments undertaken by these participants. In all cases participants have experimented with different bed designs that could maximise production and efficient use of scarce water resources. Trench beds are by far the most popular option. Here participants have made an average of 3 trench beds each for the 29 participants where monitoring was conducted. A few participants now have as many as 10 trench beds, indicating their level of commitment to this practice.

Farmer Experimentation	No of participants (N=29)
trench beds	21
tower gardens	4

banana basins	3
Eco-circles	5

Implementation of natural pest and disease control has lagged behind a bit. Participants use ash, aloes and liquid manure, but not the brews suggested in the learning sessions. They do however practice mixed cropping. Most participants stated here that they have not had pest problems ad have thus not needed to try out the options introduced. In addition, they prefer to use what they have at hand, rather than having to buy or acquire the ingredients for the recipes (e.g. soap, paraffin, chillies and garlic).

Use of greywater is also not as common as would be expected. Participants still believe that they cannot use greywater on crops and have not taken on the use of tower gardens and bucket filters for themselves. The participants who use greywater (55% - see Figure 11 below), use ash to clean the water and prefer to use this water on perennial plants and fruit trees. It is becoming apparent that innovations that require 'outside' resources, such as shade cloth, buckets, gravel etc are not being implemented by the participants.

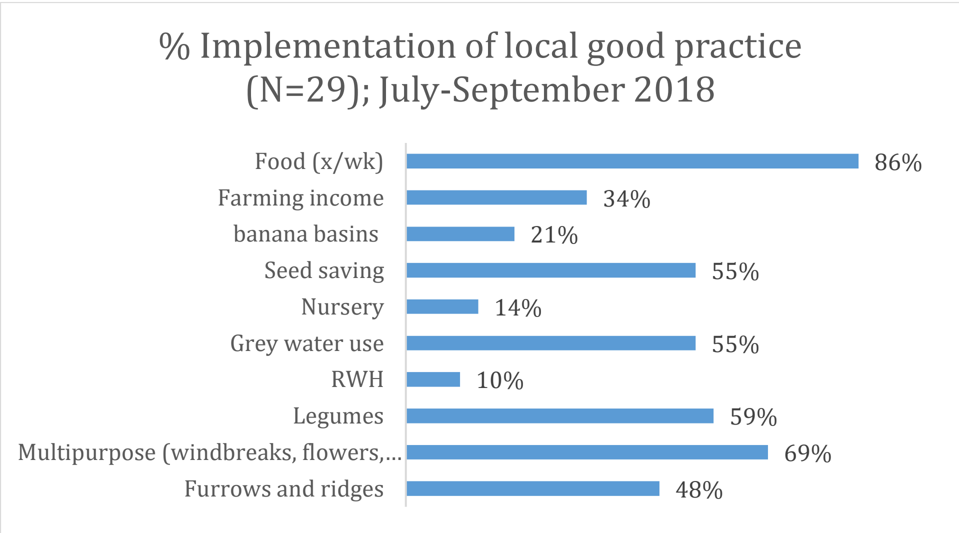


Figure 11: Percentage implementation of local good practices for a selection of participants from 3 villages; July-September 2018

From Figure 11 it is clear that the primary intention of vegetable production is for household food supply. Participants grow a wide range of crops and vegetables including: sweet potatoes, carrots, beetroot, cabbage, tomatoes, green peppers, green beans and onions. In addition, 52% of participants are now harvesting, eating and selling "new" vegetable varieties introduced through the experimentation process, including kale, mustard spinach, lettuce and spring onions. On average 2,3 different types of vegetable are eaten 1,4 times/week. This indicator gives an impression of food security, which includes an indication of diversity of food produced as well as continuity of food production. For the latter, participants are still struggling a bit with continuity, producing crops in batches and not all the time. This indictor would ideally be around 3 vegetable types eaten 3x/week.

In terms of farming incomes, 40% of these participants are selling surplus from their gardens, making on average R237,50/month. They sell locally and crops sold include tomatoes, onions, spinach and mustard spinach. For the few participants in this sample who are part of an organic marketing scheme to restaurants and shops in Hoedspruit (in partnership with the Hoedspruit Hub), the incomes from herbs and vegetables have averaged R600/month. This indicates the potential of increased incomes given a committed and reliable market outside the community.

The percentage of participants saving seed is around 55%. This is significantly higher than the percentage of participants who saved seed in the corresponding period last year, which was around 25%, for the 38 participants for whom monitoring was done in July-August 2017. This could potentially be due to the renewed focus and interest in seed saving as a result of the seed saving workshops and trainings that have been conducted in these villages.

Below are a few case studies for selected participants.

Case study: Matibela Moradiya (Sedawa)

Matibela is an active participant who has tried out most of the new interventions and innovations introduced in the learning sessions. She has experimented with trench beds, eco-circles, mixed cropping, seeds and seedlings, mulching and liquid manure. She also has a tunnel and drip kits. Like many other participants she is really struggling with water supply and is purchasing water in 210l drums for irrigating her garden. This has meant that she has focussed almost exclusively on her tunnel. She manages to eat 1-2x/week from her tunnel and also sells small quantities of surplus vegetables and herbs.

Clockwise from top Left: Matibela's tunnel; with spinach and peas visible; her yard which is now almost entirely devoid of other crops due to drought; a bed of carrots in her tunnel; and the drip kit irrigating a bed of spring onions and parsley in the tunnel.

The most significant innovation for Matibela, is that she has tried to extend her tunnel.

Right: Matibela's tunnel extension.

Case study: Eco-circles

Eco-circles are small double dug beds containing manure and organic matter (grass and weeds) and also is provided with a 2litre bottle sunk into the bed itself to provide slow below ground irrigation. The bed is designed as a circle with a width that will allow full irrigation of the bed from the bottle. So, it is a process of intensification of production, linked to efficient use of water. This bed type is really used as a learning tool and participants are encouraged to experiment with the design and layout to suit their needs.

Below are 3 examples of eco-circles as implemented by project participants

Above left: Josephina Malepe's eco-circle (Sedawa)- she has used cut grass as mulch. Above right; Makgalangakhe Mohale's (Turkey 2) eco-circle. She has made a sunken bed here and integrated it with another bed and a furrow and ridge. She has used leaves as mulch.

Right and far right: Phelecia Shaai's (Turkey 1) eco-circle. She has also used an adaption of sunken beds and has included the eco-circle in her overall garden design. On the far right are her trench beds (not planted yet)

Sekororo (Lorraine) case study

Sekororo (Lorraine), the joint implementation site with Lima -RDF, has four participants experimenting with tunnels and a number of other gardening practices. Of the four participants, three have borehole water in their yards. Below are some pictures for two of the participants.

*Above: Lydia Setshebu's tunnel. She has four *4.5m trench beds (3 in her tunnel and one outside) where she planted spinach, beetroot, kale and tomatoes.*

Left: Tree leavers and vegetation collected for use as mulch and Right; Lydia's traditional furrows and ridges, where she has planted mustard spinach and kale.

Lydia works as a home- based carer in her community. She produces vegetables for household use and sells surplus. She also practices mulching and uses liquid manure to control pests and diseases in her garden. She sells one bundle of spinach for R10.00 and she can sell close to eight bundles a day, making an income of R80.00/day.

Tshwene Maebelo is the local facilitator in the community. He doesn't have borehole water, but uses grey water and buys water both for household use and gardening. Mr Tshwene has established a poultry house in his yard, early last year and produces broilers for sale to the community. In addition, he is trying out a number of different gardening practices, including a tunnel, tower garden and eco-circle. He uses mulching, mixed cropping and liquid manure, both for fertility and as a pest and disease control measure.

Clockwise from top Left: Mr Maebelo's poultry house, a tower garden, and eco-circle and his tunnel with three trench beds and drip kits.

6 QUANTITATIVE MEASUREMENTS FOR MONITORING IMPACT

For the individual experimentation cycle of November 2017- April 2018, a number of quantitative measurements were undertaken. The table below provides a summary.

Table 23: Participants in quantitative measurements for trials; KZN, Limpopo and EC: September 2018

Province	Category	Name of participants	Name of village	Measurements undertaken
Limpopo, KZN	Field cropping and gardening	Christina Tobejane Phumelele Hlongwane	Sedawa Ezibomvini	Weather station; rainfall, air temperature, solar radiation, wind speed, wind direction, relative humidity) Rain gauges; 4 in Limpopo, 6 in KZN
Limpopo	Field cropping (CA)	Koko Maphori	Sedawa	Run-off plots, bulk density, gravimetric soil samples,
		Lerato Lewele	Mametja	
		Seemole Malepe	Botshabelo	
	Gardening (Tunnels, drip kits – trench beds, mixed cropping, mulching)	Christina Tobejane	Sedawa	Chameleon sensors
		Norah Malepe	Mametja	
		Mariam Malepe	Botshabelo	
KwaZulu-Natal	Field cropping (CA)	Ntombake Zikode	Eqeleni	Run-off plots, bulk density, gravimetric soil samples,
		Phumelele Hlongwane	Ezimbomzini	
		Phumzile Zimba	Mhlwazini	
	Gardening (Tunnels, drip kits – trench beds, mixed cropping, mulching)	Ntombakhe Zikode	Eqeleni	Chameleon sensors
		Phumelele Hlongwane, Zodwa Zikode, Nombono Dladla	Ezibomvini	
EC	Gardening Tunnels, drip kits – trench beds, mixed cropping, mulching)	Eddie Padichi	Berlin (Izingisi Education Centre)	Chameleon sensors

6.1 Limpopo measurements for individual experimentation

*Written by Sylvester Selala (*Note: Mr Selala is intending to register for a PhD in Bioresources, but wanted to do this first round of implementation to gauge the overall potential of this topic)

6.1.1 Outline of the process

Most smallholder farmers are aware that current farming practices are no longer producing expected yields. In the light of extreme temperatures and low and erratic rainfall (associated with climate change), farmers are desperate to try anything which looks like it might have potential to improve their productivity. It is part of national policy priority to promote sustainable farming practices in smallholder farming communities, and such practices include climate smart agriculture practices (CSA). Learning around new practices occurs through workshops, mentoring and farmer experimentation. How farmers prioritize implementation of new technologies has always been a question, especially if they are introduced to several technologies at the same time. Some of the criteria found in literature that famers use in prioritizing farming practices include, ease of implementation and perceived benefits. We have learnt through our engagement with the farmers that introduced practices and their experimentation have to give immediate positive effects (in the first season of implementation) for them to be interested to continue with those practices. While this makes sense, it also complicates the introduction of practices (such as Conservation Agriculture for example) that could take longer to show positive results

Even though smallholder farmers are interested in practices which will give them good yields, they generally do not have a good understanding of their yields in relation to actual yield potential or the size of the areas they have planted.

The purpose of introducing quantitative measurements in this setup is; firstly to develop benchmarks around a range of indicators (including yield, soil fertility and soil health _microbial activity, organic matter, carbon), run-off, infiltration, bulk density, water holding capacity and water productivity), and secondly to works with farmers to develop set of visual indicators for prioritizing CSA practices. The latter would allow farmers to make decisions about adjustments they can make to the practices to best suit their situation or condition.

Some of the questions asked by farmers could be answered through these more intensive measurement processes. These questions include for example;

- How many trench beds are required to make a profit on vegetable sales,
- Which crops/ varieties will give higher yields,
- What is the return on investment if buying the tunnels (shade house structures);
- How to reduce stress and wilting in crops;
- And the amount of water needed to run a garden throughout the season.

We as the researchers also included some indicators we thought would be useful for comparing scientific derived indicators with locally derived indicators. This would assist in assessing the impact of these practices in the particular localities they have been introduced in.

6.1.2 **Methodology**

Farmers were introduced to a wide range of CSA practices, but they have chosen to carry on with certain practices and never tried others. They have praised the practices they have carried on with as producing good crops of good quality, saving water and working better than the traditional practices. In trying to understand how farmers arrived at the decision of prioritizing certain practices over others we setup experiment to test their theories around the practices. Deep trench beds, conservation agriculture and tunnels are the most favored practices.

For each of them we looked at, water productivity, evaluated whether the practices improve soil fertility or soil health and evaluated how farmers have received working with measurements (use of rain gauges, weather stations, runoff plots and chameleon sensors).

For water productivity (WP), the experiments were aimed at comparing water productivity of different systems (e.g. comparing water productivity of conservation agriculture to that of conventional tillage). With regards to gardening, the experiments were aimed at comparing the WP of trench beds that are inside a tunnel, trench beds outside tunnel and the traditional way farmers use to grow vegetables.

Three sites were selected and were situated in Botshabelo, Sedawa and Mametja. The idea is to use these three sites as parent sites and establish mini experiments with other farmers in the learning groups.

6.1.3 **Background on water productivity**

With extreme temperatures reaching and average of 37^{o}C in the summer season and average seasonal rainfall of less than 200 mm (now concentrated in a few months) growing anything without supplementary irrigation is almost impossible in the area. Possible sources of water for irrigation include, municipal water (water from boreholes), streams, wells (natural springs) and rooftop rainwater harvesting and more recently, yard or surface rainwater harvesting. Although some of these sources are drying out, the most feasible option for farmers as far as water is concerned is managing the limited water they have as best they can. In realizing that options for increasing water supply (e.g. building dams, underground rainwater harvesting tanks and drilling boreholes) are limited we opted to focus initially on management of available water, especially in the homesteads.
In field cropping systems, the focus has been on dryland cropping, given that sources of water such as streams are situated far from the fields and cost of conveying water into the fields are very high. Those with fields in proximity to a stream do not have water licenses or permits to abstract water from the streams (river).

We set up and experiments to evaluate water productivity of both gardening and field cropping systems. In field cropping systems we measured the following parameters; rainfall, runoff and weather station information (air temperature, solar radiation, wind speed, wind direction, relative humidity).
Farmers are unfamiliar with some of the techniques used to gather information (e.g. rainfall data, runoff and soil fertility). We introduced farmers to some to these techniques and explained what the data can be used for and how taking measurement could contribute to the decisions making process regarding what to plant and when and how much. Most importantly the techniques were introduced for purposes of ensuring that farmers explore them and see if they can be of use to them. Building capacity around scientific data collecting and how it fits into farming was central to this process.

We worked with the farmers in settingup the instruments for measuring parameters. Local facilitators were tasked with collecting rainfall, runoff and chameleon sensor data. Four standard rain gauges were installed in 2 villages, Botshabelo, Mametja and 2 in Sedawa.

Right and far right: Installation of rain gauges and explaining the process for reading and recording rainfall events.

Record keeping of rainfall was done reasonably well by all four participants selected and are presented in the table below.

Table 24: Rainfall records from 4 standard rain gauges in Sedawa, Mametja and Botshableo

	Sedawa		Mametja	Botshabelo
	Christina Tobejane	***Koko Maphori***	***Lerato Lewele***	***Mariam Malephe***
Date	rainfall (mm)	rainfall (mm)	rainfall (mm)	rainfall (mm)
21/12/2017	5	10	8	7
24/12/2017	1	4	3	4
30/12/2017	22	32	30	28
25/01/2018	1.5	3.5	3.8	5
28/01/2018	1.6	2.1	2	3
30/01/2018	1	1.5	1.8	1.4
24/02/2018	2	2.6	2.8	2.4
16/03/2018	28	51	30.2	10.2
21/03/2018	9	20.8	10.2	20.5
24/03/2018	20	32	28	9
01/04/2018	9	8	15	30
02/04/208	1.4	2	2	1.8
Total	**101.5**	**169.5**	**136.8**	**122.3**
Ave for each rainfall event	8.5	14.1	11.4	10.2

It is interesting to note the variability in records between the 4 rain gauges from the table above. Readings from the two rain gauges in Sedawa are expected to be quite similar; which they are not. This points towards some inaccuracies in record keeping on one of the participants. The slightly higher rainfall values for Mametja and Botshabelo are not significant and do not indicate an overall difference in rainfall in these villages. It is clear that the amount of rainfall in this area has been extremely low for this season.

Although the intention has been to compare these results with the rainfall data from the weather station, ongoing calibration and charging problems with the weather station meant that data was only available from April onwards.

Rainfall records from the weather station (Based at Christina Tobejane's homestead for early April of 8,9 mm between 01-03 April 2018, compare well with those taken from the rain gauge - 10,4 mm.

In determining the water productivity, parameters (temperature, relative humanity, solar radiation, wind speed, wind direction to calculated ET_0) are required and these parameters are gathered from automatic weather stations. This information can be used to benchmark simpler methods used in the field, that farmers can be involved in.
Scientist have made a point that, not all water applied in an agricultural fields or plots whether through rainfall or in the form of irrigation is used by the crop. To simplify this process two assumptions have been made.
To calculate the ET_0 equation 2 is used. The weather station calculates the reference evaporation ET_0 using the Penman Monteith equation shown below

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad (1)$$

Where,
ET_0 reference evapotranspiration (mm/day),
R_n net radiation at the crop surface (MJ m^{-2} day^{-1}),
G soil heat flux density (MJ m^{-2} day^{-1}),
T air temperature at 2 m height (°C),
u_2 wind speed at 2 m height (m s^{-1}),
e_s saturation vapour pressure (kPa),
D slope vapour pressure curve (kPa °C^{-1}),
g psychrometric constant (kPa °C^{-1}),

Water productivity in rainfed field cropping systems

Water productivity (WP) is a measure of the output of a given system in relation to the water it consumes. It is expressed by the equation bellow:

$$WP = \frac{Agricutural\ benefit}{water\ use} \quad (2)$$

Agricultural benefit is the grain or crop yield.
In field cropping systems, to simplify the equation used, but include the necessary and monitored indicators, parameters for measuring water use were chosen following the water balance equation

$$P = ET + R + \Delta S$$

Where P is Precipitation, ET is evapotranspiration, R is runoff and ΔS, is change in soil water storage. In this case P represents the water use in the above equation

Water productivity in gardening systems

In trying to determine water productivity for gardening systems, only the amount of water transpired by the plant is considered. This is because run-off is considered negligible in garden level irrigation practices, as is change in soil moisture content. For the latter Chameleon sensors have been installed to assist the farmers to understand the available water in their soil and irrigate in a way that ensures good water availability.

In the gardening system, using Equation (2) above, water use then refers to the evapotranspiration only.
From ET_0 (Equation 1), the actual evapotranspiration is calculated using the equation below, where ETc is the Actual evapotranspiration (mm/day) and Kc is the crop coefficient. If one takes spinach to be the reference crop, as this was planted in the farmer experiments, it is possible to use existing crop coefficients. For spinach this is taken to be 0,95 (According to the FAO, Kc for spinach at maximum height is 0.95).
The actual evapotranspiration is then substituted into the WP equation (2)

$$ET_c = K_c \times ET_0 \quad (3)$$

Where ETc is the actual evapotranspiration, Kc is the crop coefficient and ET_0 is the reference evapotranspiration.

These "simpler" equations were used for calculation of the WP for the field cropping (CA) and gardening (tunnels, trench beds) experiments. The results are discussed in the two small sections below.

6.1.4 Conservation Agriculture vs conventional tillage

With regards to field cropping, traditionally, farmers used conventional tillage practices and planted sorghum, millet, maize, cowpea, beans, watermelons, groundnuts, jugo beans and pumpkins. Over the years they have since abandoned sorghum and millet (because of birds and low yields due to heat and drought) and focused on maize and ground cover crops. They have observed a decline in maize yields in the previous years due to lack of rainfall. We introduced conservation agriculture, which is defined in terms of its three pillars or principles which are minimum soil disturbance, permanent soil over (at least 30% cover) and mix cropping. The aim of this experiment was to see whether CA conserves soil moisture and increases water productivity compared to conventional tillage.

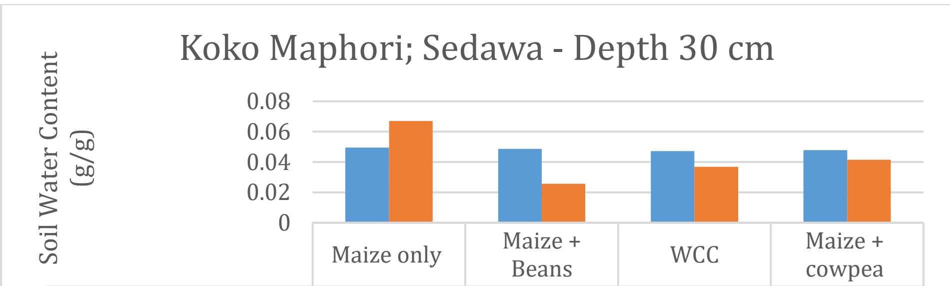
We worked with farmers for the installation of runoff plots in all three sites.

Right and far right: Installation of runoff plot with farmers in Sedawa

To work out the water productivity of these "trials' (CA vs conventional tillage), we setup instruments to measure elements of the water balance equation which are;

- Rainfall (measured in four sites using a standard rain gauge and in one site using a tipping bucket rain gauge on a Davis weather station). Data was collected by the local facilitator from Sedawa village
- Runoff data (1 m^2 runoff plots were installed in one of 4 times 10 m^2 plots in each of the three sites)
- Deep Drainage (it was set at zero, given the tricky nature of measuring it in the field)
- Change in soil moisture content (gravimetric water content measurements were taken) the samples were collected at four different depths (30 cm, 60 cm, 90 cm and 120 cm)
- Evapotranspiration (was measured from the Davis weather station)

As mentioned in the April report, there was total crop failure due to the high temperatures and extremely low rainfall, despite attempts at replanting. Runoff data was only collected on two occasion and the results indicate that, generally 25 – 35 % of the rainfall is converted into runoff. This was observed in CA plots and as well as in conventional tillage plots irrespective of the crop planted. Gravimetric soil water samples we collected on 2 events at the Sedawa and Mametja sites. These measurements were discontinued for obvious reasons that there was no crop to monitor. They were however taken at planting (Mid-December 2017) at depths of 30,60,90 and 120cm and after the establishment phase (Mid-January) at 30 and 60cm depths.



	Maize only	Maize + Beans	WCC	Maize + cowpea
Planting	0.049411188	0.048689251	0.047255719	0.047724713
End of establishement	0.067056086	0.025736359	0.036796218	0.041469097

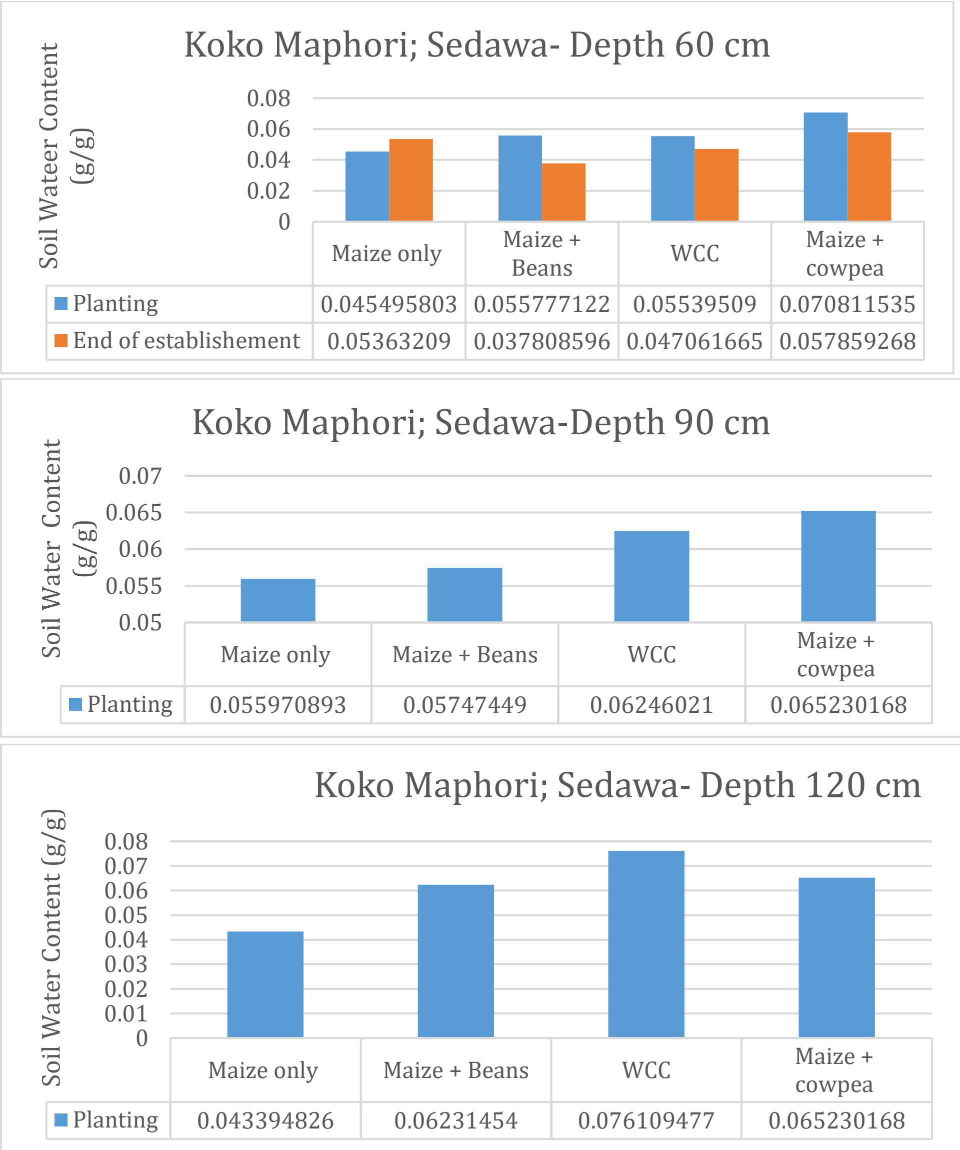


Figure 12: The gravimetric soil water content for Koko Maphori's CA plot in Sedawa at 30,60,90 and 120cm depth

The figures above indicate a rather low soil water content at all depths at planting and some minor variability between the plots in her field. They also indicate the reduction on soil water content towards the end of the establishment phase. Overall, however it was not possible to measure the impact of the crops and cropping system on soil water content, given the lack of growth of crops. The water productivity could not be calculated.

In conclusion, some CSA practices cannot work or be tested under certain conditions; there are thresholds in terms of rainfall amounts and distribution. It was clear that with less than 200 mm of rain throughout the season, CA plots would not have survived without supplementary irrigation.

6.1.5 Gardening systems

To recap, the farmer led experiment for gardening involves planting spinach;

In a trench bed inside a tunnel (shade house structure)

In a trench bed outside the tunnel

In a traditional bed (ridges and furrows) outside the tunnel

There are a number of aims for this experiment:

1. To help farmers make informed decisions about which CSA practices are best suited to their locality and conditions
2. To help farmer develop visual indicators for evaluation of CSA options
3. to assess if and to what extent CSA practices contribute to increased productivity and household income generation and
4. To assess whether traditional practices are still fully functional under varying weather conditions or in the light of climate change

Water productivity, changes in soil fertility (plant essential nutrients, N, P, K) and soil health are the main indicators used for assessing CSA practices. Visual observation from the famers have indicated that some CSA practices, different bed designs (deep trenches, tower garden, eco-circle) increase productivity compared to traditional practices (gardening on ridges). Use of other technologies, for example drip irrigation, and tunnels have also been reported to do better than the traditional system and these observations have been used as the basis for this experimentation process.

We have taken input costs into account and have also analysed the CSA practices adopted from a cost-benefit point of view.

Comparing the farmer method of calculating WP with the "simple" method outlined above

According to the farmers all the water applied in the garden goes into producing the yield. They argued that because water applied in garden or field cannot be reused for something else, they consider all that water as going to production of yield. Therefore, in determining WP we considered runoff, deep percolation and soil evaporation to be negligible and assumed that water applied becomes transpired by the crop. Therefore, from Equation 2 above, the water use becomes the water applied instead water transpired by the crop.

Farmers kept records of various indicators throughout the growing season. The following information is recorded on the data sheet:

- Amount of water applied (normally farmers use 10 l watering cans to irrigate, therefore the number watering cans applied are recorded)
- Size of irrigation bay or size of bed (in which the spinach was planted)
- Yield produced from the bed (the average weight of the spinach bundles harvested from the same bed is recorded, a kitchen scale is used to weight the spinach) and the number of bundles harvested are also recorded
- Cost of the produce (These bundles of spinach are usually sold for R 10)

Results

The WP calculations were done for the simple scientific and farmer versions of the equation; using actual evapotranspiration and water applied respectively as the water use value.

The small table below outlines the results for those few farmer- led experiments where enough data could be collected.

Table 25: Water productivity calculations for the gardening system farmer led experiments

	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

The simple scientific method of estimating water productivity provides for higher values than the water applied method that the farmers prefer. The WP results between the two methods are not directly comparable.

It can be seen that the two methods of calculating WP have provided the following information:

- For Christina; Her WP in her tunnel is obviously much higher than for her traditional planting method of furrows and ridges. Here the trench beds were mulched and she followed a strict regime of deep watering once a week. This indicates a close relationship between the water applied and that used by the plants in the tunnel
- For the furrows and ridges, using the water applied version of calculating WP shows an extremely low WP of 5kg/m^3 versus the 56,7/m^3 in the tunnel. The production in the tunnel is functionally ten times that of the furrows and ridges.
- For Christina's trench beds inside and outside the tunnel there as also a large difference in WP (water applied); 56,7 vs 11,3kg/m^3.
- For Norah's tunnel the situation is quite different. She did not do mulching and she kept to the 'traditional' watering practice of a little in the morning and a little in the evening every day. She has used a lot more water than her plants have used. This indicates that her practices greatly increase the required amount of water, without increasing the efficiency of use of this water. For these two tunnels the WP calculation (using water applied) is 56,7 kg/m^3 for Christina's tunnel and 5 kg/m^3 for Norah. This is a significant difference in yield brought about by a number of factors;
    - Mulching and deep watering inside the tunnel vs no mulching and repetitive shallow watering
    - Harvesting practises: Another aspect mentioned by farmers when analysing these results is that it is possible that Norah overharvested her spinach, with the outcome that regrowth and further harvesting was reduced.
    - Farmers also mentioned that there is generally more shade from trees, in Christina's garden, even her tunnel is provided with some shade during the day, while Norah's tunnel has no shade.
    - Different planting times: This could in fact have played a large part in the WP differences in the two tunnels as Norah planted at the end of February (when it was very hot) and Christina planted at the beginning of April (when it was much cooler)

These results clearly indicate the productive advantage of using tunnels in these hot, dry conditions and further show the added yield and water productivity advantages of mulching and deep watering as crop management practices. Attention will also need to be given to harvesting practices to ensure maximum growth of the spinach.

It is interesting to compare the farmers version of WP to that using evapotranspiration. When one looks at WP in relation to water added, it gives a much clearer picture of how much production is possible with how much water and how the different practices affect this. In this context it can thus be considered a good proxy or visual indicator for water productivity. More farmer led experiments will be conducted comparing these WP indicators.

Generally, it is expected that the WP from the same practices (e,g trench beds in tunnels) should have less variability, but the results have shown otherwise. In a farmers' experimentation setup, some extra variables are often introduced during the process and are sometimes unavoidable. For results to be comparable attention needs to be given to those variables. It is a scientifically frustrating process, but one that provides for ample learning opportunities in such an adaptive research process such as this.

A cost benefit analysis of WP

In these villages farmers pay for their water; either for transport of 210l drums to their homes ("bought from local people with borehoels0 or for pumping the water from their own boreholes. Presently municipal supply of water is too little to use for gardening and all surface sources have dried up in the last few drought years.

Farmer pay R35/201l drum of water

$$Cost\ of\ water\ (per\ liter) = \frac{R35}{210l} = 0.17\ R/l$$

Christina Thobejane planted a 5 m^2 deep trench in a tunnel to spinach and we recorded the amount of water applied and weighed each bundle of spinach she sold. She sold a total of 30 bundles of spinach at R10-00 each and made R300 from this in one season. She applied a total of 1100l of water as irrigation (100 litres per week for 11 weeks). In a deep trench bed of 3.5 m2 in size outside the tunnel she planted spinach she applied 266 l/ week of water for 11 weeks which makes a total of 2926 litres (13.9 * 210 l) at a cost of R35-00 per litre she would have paid R487.7 for water applied. She was able sell 9 bunches of spinach at R10-00 each making R90-00 for this bed in a season.

	Water	**Cost (R/m^2)**	**Yield**	**Sales (Rands/ m^2)**	**Profit (R/m^2)**
Trench inside tunnel	1100	R18,70	6 bundles/m^2	R60	R41,30
Trench outside tunnel	2926	R48,80	4,2 bundles/m^2	R42	-R6,80
Furrows and ridges	3913	R130,40	2,4 bundles/m^2	R24	-R106,40

From a water use efficiency point of view, planting in a trench bed without shading (microclimate management) requires 2.9 times the amount of water required in a deep trench under shade cloth. The quantities of spinach produced in the tunnel are much higher than those produced outside the tunnel. The cost-benefit analysis above indicates, that if water needs to be bought, it would only be profitable to plant inside the tunnel. The profit is however not very high in this context (~R620/tunnel fully planted ($15m^2$)), for a season. Obviously, if cheaper water can be accessed, this would be a lot more.

6.1.6 **Working with Chameleons**

Chameleons measure soil water content, work similarly to tensiometers and provide readings using colour codes (red, green and blue) for available soil water at three depths in the soil; 20,40 and 60cm. These sensors have been installed at Christina Thobejane (Sedawa), Mariam Malephe (Botshabelo and Norah Mahlaku (Mametja), for their gardening experiments. The intention is to provide the farmers with an irrigation management tool to help them decide when and how much to irrigate. As the readings are uploaded onto the Virtual Irrigation Academy website, they also provide an analytical tool for the research team, as well as real time data on the status to the farmer level experiments.

Irrigation case study: Christina Thobejane

Christina has a small petrol water pump and used to pump water up from the Maphere River (approximately 50m downhill from her homestead) for her gardening activities. That streambed however dried up completely about a year ago. She also has a 5 000l Jo-Jo tank for roof rainwater harvesting and last year was the recipient of a 24000l underground RWH tank. In addition, she used money from her stipend as an LF to have a borehole installed in her yard and she has a pipe linked into the municipal supply system, for the unlikely moments that there is some municipal water supply. She now pumps water from her borehole into her underground RWH tank for use in the garden. She is the only person in her village who is this well organised.

Chameleon sensors were installed in three different beds (trench bed in a tunnel, furrows and ridges outside the tunnel and a trench bed outside the tunnel) to monitor the changes in soil water content. The chameleons were introduced as an irrigation scheduling tool, to her save water.

Christina has made the following comments about the chameleons:

- Applying water until the chameleon changes colour (goes blue) seems to be a good idea as this saves her some water and means that she only has to irrigate once a week (every 7 days).
- She has thus now changed her irrigation practice of watering a little every morning and afternoon, to a deep watering every 5-7 days. Even though this was discussed in the learning workshops, she was not convinced until she managed to work it out for herself.
- The chameleon in the tunnel stays blue (indicating enough water in the soil) for longer than in the other beds.
- She appreciates the ease of using the chameleons – by just checking the colour.

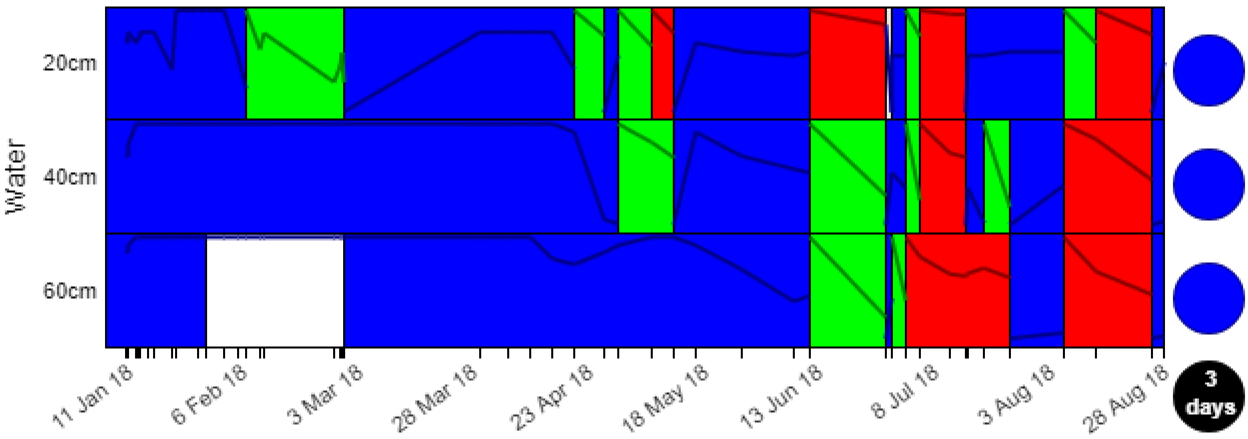
Right: A chameleon reader showing red for all three soil depths (20,40 and 60cm)

Christina managed to harvest the spinach worth R 300 using 1100 litter of water (which she considers to be little water). From our Water productivity results we observed that her water productivity was higher, at 44,5 kg/m^3, than the commercial water productivity (ave 13 kg/m$^{3)}$ in spinach fields. She praised the spinach planted in a trench bed inside the tunnel, saying it looks good even when she takes too long to irrigate. However, she has said her preferred practice is the tower garden (it gives good quality crops, saves water and saves space). She made the decisions about the tower garden based on her visual observation. This highlights the importance of identifying and developing visual indicator which farmers used to make decision regarding practices.

Christina felt that all the weighing and recording of water applied was time consuming and unnecessary, since she could visually see the difference in the plant. Another difficulty lay in the reading the data from the chameleons as this was often frustrated by small wires coming loose in the chameleon array. Uploading this data was also a bit problematic, given that it requires a sizeable amount of data, along with good cell phone reception. She was supplied with a dedicated smart phone (as hers could not manage the app properly) and dedicated data for this purpose and she also does the readings for the other nearby chameleons.

Right: Spinach growing on Christina's trench beds in the tunnel, Sylvester fixing and testing the chameleon

Below are the graphs for the chameleon sensors as uploaded onto the VIA site.

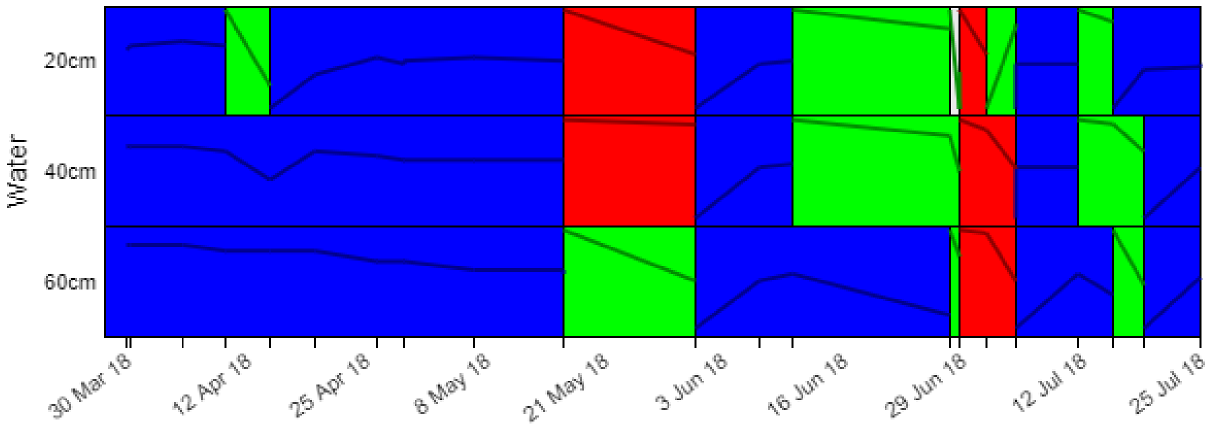


Crop and field management details

Crop Type	Spinach
First Planting Date (assume continuous cropping)	31 Oct 17
Soil moisture summary	68.0% Blue; 15.0% Green and 17.0% Red
Readings taken	67

Figure 13: Soil water content: Christina's trench bed inside the tunnel (1 September2018)

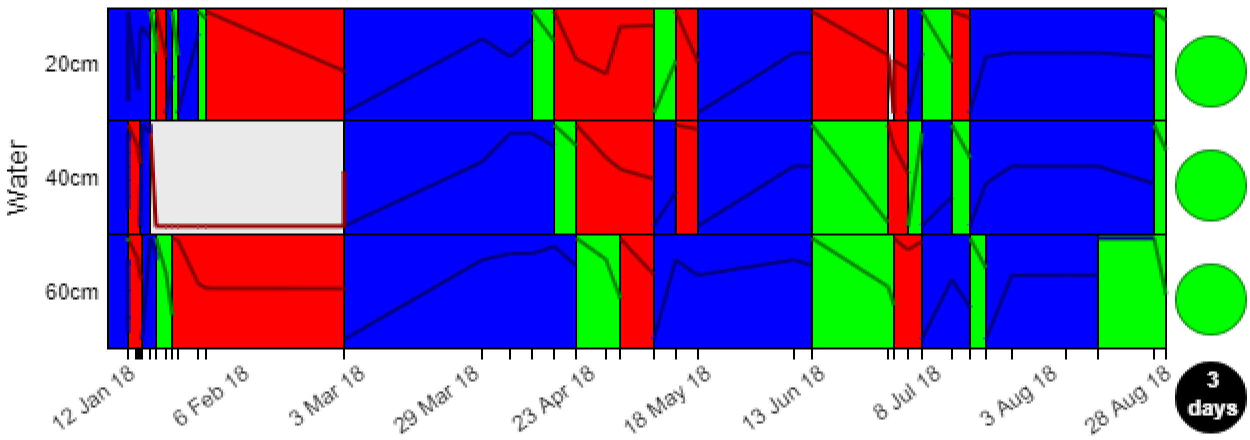
In the last 11 months (since the end of October 2017) Christina has taken readings 67 times- which is a very good average. She has managed to keep her soil moist enough for most of the time. The lines within each soil depth bar show the decrease and increase in soil water content according to the actual readings taken. The increase in green and red chameleon readings toward the ned of the winter season, indicates the overall drying of the soil and potentially an increase in irrigation requirements to ensure good soil water content in all three layers measured.



Crop and field management details	
Crop Type	Spinach
Planting Date	25 Mar 18
Soil moisture summary	67.0% Blue; 19.0% Green and 14.0% Red
Readings taken	33

Figure 14: Soil water content; Christina's furrows-and ridges (traditional beds or control)

The figure above indicates Christina's irrigation scheduling for her traditional bed outside the tunnel. Here she also managed to keep her soil reasonably evenly moist, but she used almost three times more water to do this than in the trench beds.



Crop and field management details	
Crop Type	Spinach
Planting Date	31 Oct 2017
Soil moisture summary	54.0% Blue; 15.0% Green and 31.0% Red
Readings taken	63

Figure 15: Soil water content: Christina's trench bed outside the tunnel

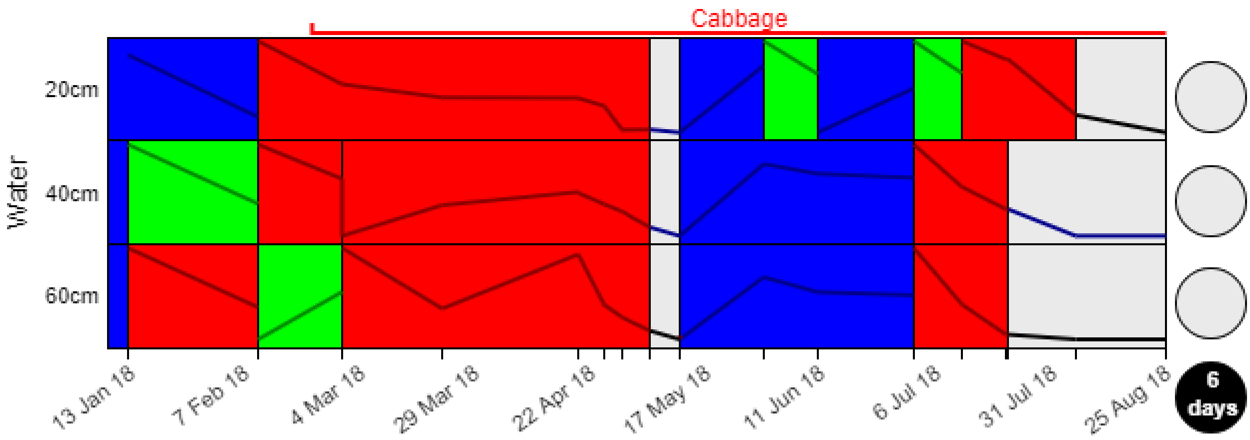
If one compares Figure 11 and Figure 12, it can be seen that the trench bed outside the tunnel dried out faster than the trench bed inside the tunnel, needing more and more frequent irrigation.

Irrigation Case study: Nora Mahlako

Even though these farmers live in the same area, their water situations are different. Nora Mahlako relies on municipal water supply for household uses as well as gardening. This water supply scheme serves a lot of people and is overloaded to make provisions for other activities (e.g. farming) on top of water for household consumption. In the time that Nora had planted the municipal water was cut for several weeks and she did not have water for irrigation. She then prioritized the spinach in the tunnel and abandoned the crops growing in the other beds. From the chameleon records below, we observed that the soil water content in trench beds and ridges and furrows outside the tunnel was very low.

Nora sees the chameleons as a complicated tool which requires a lot of technical skills from an expert. This was partly because her soil was too dry for the chameleons to detected anything most of the time. Often, we had to go and troubleshoot the problem with her, and this in some ways has made her lose confidence in the tool.

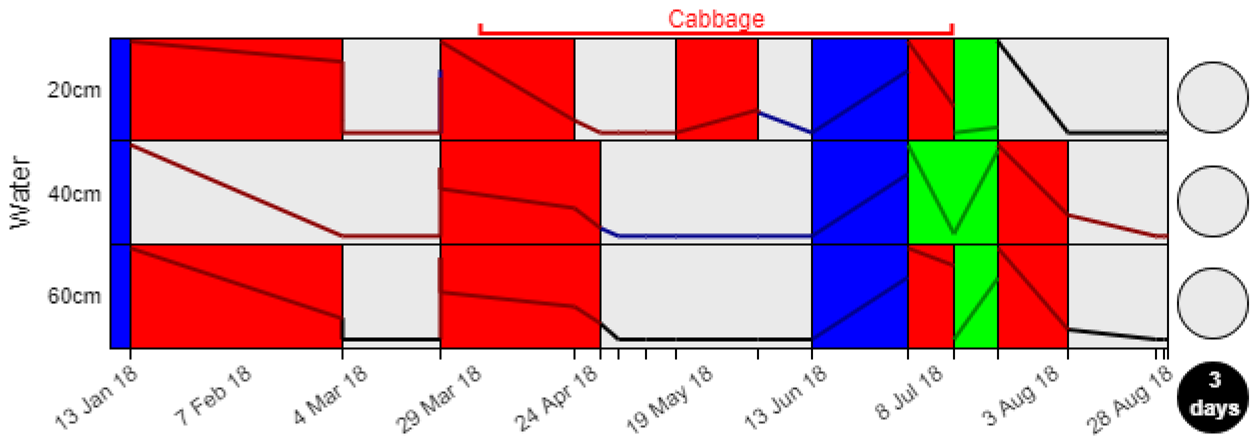
Regarding irrigation, she continued with business as usual (watering small amounts in the mornings and afternoons). We observed for the graphs obtained from the Virtual Irrigation Academy (VIA) website that chameleons did not change colour even when she was irrigating.



Crop and field management details	
Crop Type	Spinach
Planting Date	22 Feb 18
Soil moisture summary	26.0% Blue; 4.0% Green and 70.0% Red
Readings taken	20

Figure 16: Soil Water content; Norah Mahlako -trench bed inside tunnel

For Figure 16, the grey blocks in the Chameleon sensor data indicate soils so dry that readings were not even made.



Crop and field management details	
Crop Type	Spinach
Planting Date	22 Feb 18
Soil moisture summary	29.0% Blue; 0.0% Green and 71.0% Red
Readings taken	10

Figure 17: Soil Water Content; Norah Mahlako- trench bed outside the tunnel

For Figure 17, the situation with overly dry soils is even more severe than in the tunnel.

Irrigation case study: Mariam Malepe of Botshabelo village

Mariam has a Jo-Jo tank in her homestead for roof rainwater harvesting and was also a recipient of an underground RWH tanks. She used to have a pipe trailing down from the hillside (around 3-4km away) from a spring, but this dried up more than a year ago. She also has municipal water supply when that is available. At the moment they fetch water in containers from the Olifant's river, which is about 500 m along the road.

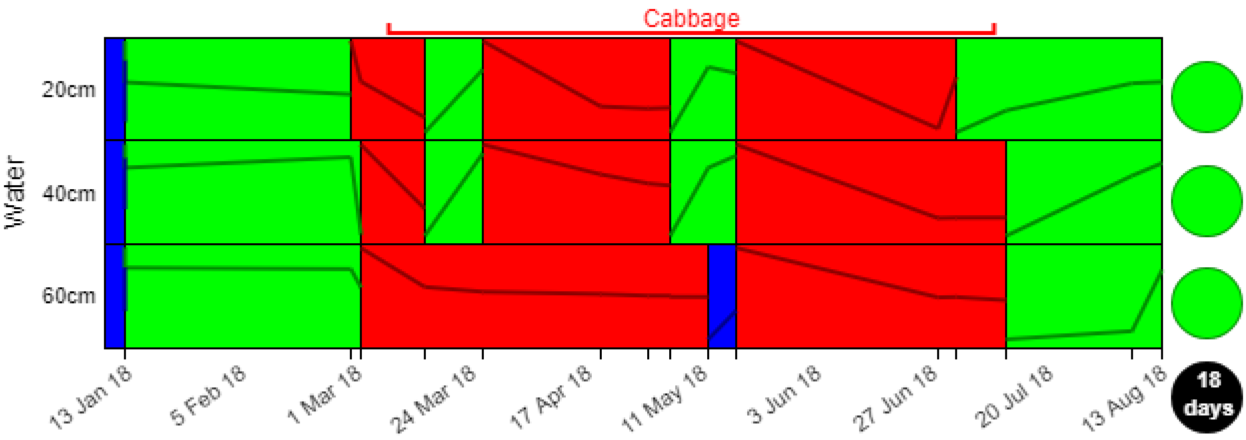
Mariam Malepe tried planting spinach in late February in her experimental beds, but due to lack of water the spinach died. She then planted beans (lazy house wife) in late March, from which she has also not managed to glean any harvests. We thus could not do the WP calculations for this participant. At the in late June she the planted spinach again in the experimental beds which is growing well and she is hoping to get some yield.

Her decision about when to irrigate is based on crops showing signs of wilting, as she feels it takes too much water to change the chameleon readings from red to green (not even blue). She prefers to give a little bit of water to all her crops. It means that she has not managed to benefit much from having the chameleons in her plots, as she would not follow the suggested irrigation practices. It can however be understood, as all the water required at the time had to be carried in buckets.

The effect of growing in the tunnel is clearly demonstrated in her garden where the growth rate for the beans in the tunnel was higher than in other beds, given though she applied roughly the same amount of water to each bed.

Mariam's situation demonstrates that even though observation, monitoring and experimentation tools might have the potential of improving the situation, conditions can be too extreme to abide by recommendations.

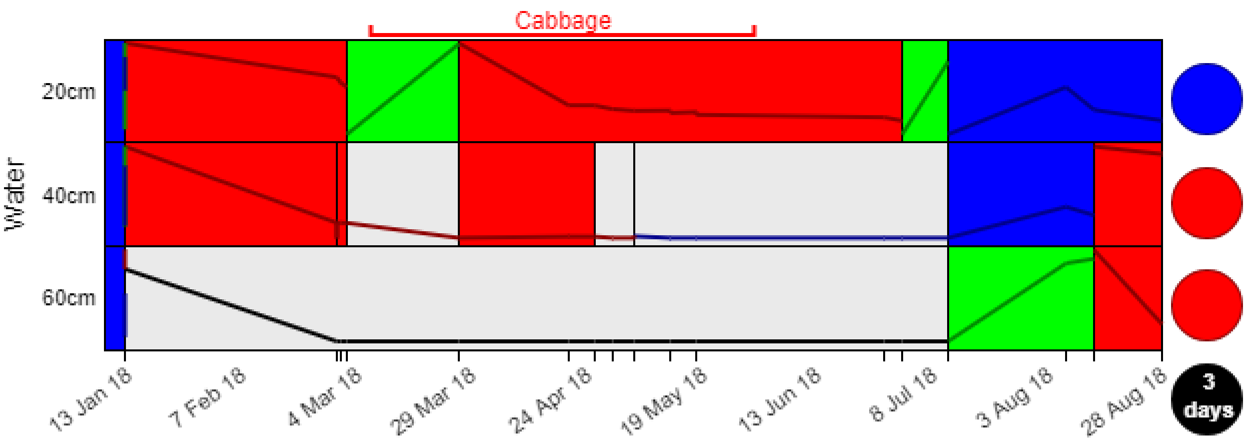
Above Left to right: Mariam's beans planted in a trench bed inside the tunnel, a mulched trench bed outside the tunnel and in furrows and ridges outside the tunnel. Photos were taken on the same day and the difference in growth is visible and obvious



Crop and field management details	
Crop Type	Beans and later spinach
Planting Date	8 Mar 18
Soil moisture summary	2.0% Blue; 50.0% Green and 48.0% Red
Readings taken	11

Figure 18: Soil water content; Mariam Malephe-trench bed inside the tunnel

From Figure 18, Mariam's decision to irrigate only until the chameleon turns green is quite obvious. One can also see that she was not as fastidious about taking readings as Christina for example, as she only took 11 readings during a 9- month period.



Crop and field management details	
Crop Type	Beans and later spinach
Planting Date	8 Mar 18
Soil moisture summary	20.0% Blue; 16.0% Green and 64.0% Red
Readings taken	11

Figure 19: Soil Water Content: Mariam Malephe- trench bed outside the tunnel

For her trench bed outside the tunnel, shown in Figure 19, her soil was mostly too dry to even take readings. Since July, when her latest batch of spinach was planted, she has tried harder to ensure a blue reading when she irrigates.

6.1.7 Soil fertility

Soil samples were taken in a few of the villages where the farmer led experimentation is taking place, to give a baseline for soil fertility status in these areas, against which later samples from the different CSA practices can be compared.
The results are shown in the table below.

Figure 20: Soil fertility analysis results for four villages in Limpopo.

			Required			
Village name	**Clay %**	**Org. C %**	**N (kg/ha)**	**P (kg/ha)**	**K (kg/ha)**	**Lime (t/ha)**
Willows	22	1.7	80	60	0	0
Sedawa	14	<0.5	80	20	0	0
Oaks	24	0.7	80	20	0	0
Botshabelo	25	<0.5	80	20	0	0

From the brief summary above it can be seen that the soils have extremely low percentages of organic carbon and are generally sandy-clay soils. This information will need to be augmented with soil health information as well (in particular soil aggregates, microbial respiration and organic Nitrogen) to improve on the potential of soil fertility and soil health to be used as indicators for impact of CSA practices.

6.1.8 Learning and conclusions

Learnings have included the following observations:

- Each farmer makes his/her own decisions which is different from those of other farmers (e.g. when to irrigate, how much water to apply and how often). This ten provides for large variability in the results from the same experiment precludes rigorous scientific analysis in some cases. Because of this also, a lot more descriptive information is required around the experiments to understand what the data means as some of the farmers change what they are doing along the way
- The monitoring for the farmer led experiments is intensive, as one cannot leave them to do the recording for extended periods of time without going back to check.
- The monitoring process has been changed over this last season from leaving the farmers to record how they will, to designing forms for them, to getting the LFs and interns to collect forms on a more regular basis and more recently to have the interns and field workers “interrogate” the forms with the farmers before submitting them; all to ensure more rigour in the data collection process.
- Just working with three farmers per site has not worked well. In future 5 farmers per site will be needed to ensure that some comparative data at least is available
- Specific time will need to be allocated on a monthly basis to ensure the data has been submitted (1 week/ month for the 25 odd farmer led experiments presently being conducted)

and then to record this data properly for timely analysis (1-2 days). It did not work well to keep all the data in rough versions and then try and analyse all of it towards the end of the season.

- The potential for having a researcher managed experimental site is being considered.
- Processes for working with farmers in learning from and analysing data from the measurements need to be more formally designed and implemented.
- There is some confusion about what a good yield represents under any particular circumstance. Farmers have an impression that their yields used to be better, but they do not have a meticulous way of working out what their yields are and only compare now with the past. So, in a way a trend of low yields becomes entrenched, as they are not even aware that it I possible to obtain higher yields. Some work with farmers in terms of working with more generic values for yields for particular crops and benchmarking these against the yields they are now receiving is required, to be able to make sense of an indicator around improved yields.
- Farmers acknowledge the importance of having a system that could allow them to make informed decisions about prioritization of practices (however, such systems should allow room for famers to make their own judgements and decisions.
- Because of this, the next round of experimentation will need to widen to include specific choices of practices by the farmers and our indictors for impact will need to be generic enough to be able to compare different sets of practices against one another in terms of improved productivity and livelihoods

7 CAPACITY BUILDING AND PUBLICATIONS

Capacity building has been undertaken on three levels:

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

7.1 Community level learning

This has been discussed at length in previous sections. In summary learning workshop have been conducted in 10 villages across three provinces (EC, KZN and Limpopo) with a total of 148 participants including a number of topics including; scientific and community level understanding of climate change and weather variability, impact of climate change on production, adaptive measures, introduction to a range of CSA practices, farmer level experimentation and practical learning for a range of CSA practices. Collaborative action around water issues and local provision of water has been discussed in depth for 4 villages.

7.2 Organisational capacity building

Within 3 NGOs (MDF, Lima RDF and AWARD) capacity of field staff to facilitate and work with climate change concepts and facilitation of CSA at community level has been enhanced through:

- Collaborative design of workshop outlines and facilitation processes
- Training sessions in CC and CSA facilitation, including appropriate CSA practices
- Mentored facilitation of CC and CSA workshops
- Field staff managed facilitation of learning events
- Setting up of CoPs and
- Attendance at stakeholder CoP processes related to this work (Agroecology network in Limpopo, Rangeland management cross visit with UCPP in Eastern Cape and regenerative agriculture symposium in the Free State.

7.3 Post graduate students

Below is a summary of the postgraduate studies and progress made for 2017-2018

- 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*

Mazwi has finalised his research tools (focus group discussion semi structured interviews) and individual questionnaires and is in the process of gathering data for these from around 20 participants in the Bergville area.

- Khethiwe Mthethwa: M Agric – University of KwaZulu Natal; January 2018. *The contribution of Climate Smart Agriculture (CSA) practices in adapting to climate change: The case of smallholder farmers in KwaZulu Natal.*

Khethiwe has finalised her proposal and research methodology and has completed her initial literature review. She is in the process of designing her first individual questionnaire related to implementation and uptake of CSA practices.

7.4 Publications and networking

- Publications:
  - SA Grain Newsletter; CA SFIP, 1 smallholder case study (Swayimane)
- Cross visits:
  - PACSA – small livestock production interventions in the Umgungundlovu DM
- Attendance:
  - No-Till Club Annual Conference- 4-6 September 2018
  - KZN CA Forum
  - Introduction of Agricloud app (www.rain4africa.org) for smallholder farmers – ARC – 6 September
- Conference papers:
  - Land Rehabilitation Society of South Africa: Annual Conference 13-15 August 2018. Presentation of a paper "*Learning CA the Innovation Systems Way" – E Kruger*
  - 8th Biennial LandCare Conference; 25-27 September "*CA Innovation Systems; progress and successes" – T Mathebula*