Deliverable

8

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.8: Interim Report: Quantitative and qualitative indicators and knowledge mediation products

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ABBREVIATIONS

AEZ Agroecological Zones

ATI	Agricultural training Institute
CA	Conservation Agriculture
CCA	Climate change adaptation
CRA	Climate Resilient Agriculture
CSA	Climate Smart Agriculture
CSAG	Climate Systems Action Group
DAE	Department of Environmental Affairs
DSS	Decision Support System
ETo	Reference evapotranspiration
Etc	Actual evapotranspiration
MDF	Mahlathini Development Foundation
QCTO	Quality Council for Trade and Occupations
RIEng	Rural Integrated Engineering
S&WC	Soil and water conservation
UJ	University of Johannesburg
UKZN	University of KwaZulu Natal
VIA	Virtual Irrigation Academy
WP	Water producivity

Interim Report: Quantitative and qualitative indicators and knowledge mediation products

1 OVERVIEW OF PROJECT AND DELIVERABLE

1.1 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, manuals, handouts and other resources necessary for learning and implementation.	31 January 2019
FINANCIAL YEAR 2019/2020			
7	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. Analysis of contemporary approaches to collaborative knowledge creation within the agricultural sector. Develop appropriate knowledge mediation processes for each CoP. Develop CoP decision support systems	1 May 2019
8	Report: Appropriate quantitative measurement procedures for verification of the visual indicators.	Set up farmer and researcher level experimentation. Link proxies and benchmarks to quantitative research to verify and formalise. Explore potential incentive schemes and financing mechanisms Conduct survey of present knowledge mediation processes in community and smallholder settings	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

1.2 Overview of Deliverable 8

This report includes aspects of both deliverable 7 and 8 and focuses on the development of knowledge mediation products; a facilitation manual, associated farmer level learning materials and visual aids and a web-based survey form for the decision support system. In addition, progress with the exploration of qualitative and quantitative indicators is provided. Farmer level experimentation with practices is ongoing and progress is reported on.

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 incentive- based support schemes for smallholder farmers.

Activities in this three-month period have included:

- **Practices activities**: Inclusion of learning processes, experimentation and learning materials towards compiling practice summaries for small dam construction and livestock fodder production and supplementation and design of a web-based survey/platform for the decision support system.
- **Process activities**: Continuation of farmer level experimentation in the EC (3 villages), Bergville (2 villages) and Ntabamhlophe in KZN and in Limpopo (2 villages). CoP engagement has consisted of hosting of the Maize Trust board in Bergville to present the work on CCCA and CA for smallholders in the area, a presentation at the Virtual Irrigation Academy symposium in Pretoria, participation in a QCTO preparation workshop for development of a national agroecology curriculum at University of Johannesburg and preparation of presentations for the development of a National Risk and Vulnerability Framework for the Department of Environmental Affairs and the Howard College Symposium at Ukulinga (UKZN) on partnerships for climate resilience
- **Monitoring and evaluation:** Further testing of the resilience snapshot methodology in Limpopo.

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

Date	Activity	Description	Team
2019/05/07,09 and 07/02	Small dams construction, soil and water conservation	Experimentation with small dam construction parameters and use of bentonite as a sealant in Limpopo	Erna, Chris, Mazwi, Betty
2019/05-07 (Dates provided in Section 3.6 below)	Gardening practices	Review and workshops in in 3 viallges on agroecological practices including trench beds, mixed cropping, natural pest and disease control and seed saving	Betty, Erna
2019/06/09; 07/17	Fodder supplementation	Learning process and experimentation design for fodder production and supplementation in three villages in Bergville	Erna, Brigid Letty, Phumzile, Mazie, Nonkanyiso, Temakholo, Samukelisiwe

2019/06/12	VIA presentation	Presentation of chameleon sensor results and community level learning process	Samukelisiwe, Erna
2019/06/12; 06/26; 07/16	Chameleon sensor installation at Swayimane and Madzikane (Midlands and SKZN)	A workshop was held with the learning group to outline the process of installation, the experimentation process and use of chameleon sensors	Temakholo, Nontokhozo, Lulama, Mazwi
2019/06/15, 24, 07/09	Gardening experimentation process; Bergville	Monitoring and small learning group workshops around the tunnels, tower gardens, irrigation scheduling, trench beds and mixed cropping. Updates on water issues progress	Phumzile, Samukelisiwe,
2019/07/10	Web-based survey for DSS	Development of a web-based platform and survey for individual application of the DSS	Erna, Matthew Evans
2019/06-07	Water content and soil health	Collection and analysis of data	Erna, Lulama, Nonkanyiso

Capacity building and publications:

- Research presentations and chapters:
    - Mazwi Dlamini – M Phil (PLAAS UWC-yr 2); Continuation with fieldwork
    - Samukelisiwe Mkhize- PhD (Human Sciences): She has withdrawn from her internship at MDF and her PhD registration for personal reasons
- Publications:
    - Water Wheel: Submission of a series of 3 articles: CCA community process, The impact of CRA on rural livelihoods and the smallholder farmer CRA decision support system
- Cross visits:
- Stakeholder engagement: -
    - Maize Trust Board member visit to Bergville for CA implementation with smallholders
    - QCTO engagement workshop for design of a national curriculum in Agroecology (UJ)
    - Submission of inputs for development of a National Risk and Vulnerability Framework (CSAG and DEA)
    - Discussion of linkages with the Umngeni Resilience Project (Prof Mabaudi UKZN)
- Conference papers and presentations: -

2 COMMUNITIES OF PRACTICE AND DEMONSTRATION SITES

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

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

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

Province	Site/Area; villages	Demonstration sites	CoPs	Collaborative strategies
KZN	Ntabamhlophe	- CCA workshop 1-5 - Monitoring and PIA **- Monitoring and review of CA experimentation**	-Farmers w NGO support (Lima RDF)	- Tunnels and drip kits - Individual experimentation with basket of options
	Ezibomvini/ , Eqeleni	- CCA workshop 1-4 - Water issues workshops 1,2 -Water issues follow-up -CCA workshop 5 **-Water issues continuation** **-Monitoring and review of CA experimentation** **- Fodder and supplementation learning process**	-CA open days, cross visits (LandCare, DARD, ARC, GrainSA), LM Agric forums, ….	- Tunnels (Quantitative measurements - CA farmer experimentation (Quantitative measurements) – case studies -Individual experimentation with basket of options; monitoring review and re-planning - Livestock integration learning group and experimentation focus
	Swayimane	- CCA workshop 1-4 - Monitoring, review and re planning - **Monitoring of garden, tunnel and CA experimentation**	-CA open days -Umgungundlovu DM agriculture forum	- CA farmer experimentation - gardening level experimentation; tunnel, trench beds drip kits etc.
	Madzikane	-CCA workshop 1-4 **- -Set up of gardening and tunnel experimentation**	-CA open days - Madzikane stakeholder forum	-CA farmer experimentation - gardening level experimentation; tunnel, trench beds drip kits etc

Limpopo	Mametja (Sedawa, Turkey)	- CCA workshop 1-5 -Water issues workshops 1-2, follow-up - Poultry production learning and mentoring -CA learning and mentoring - Monitoring, review and re-planning -**S&WC and small dams learning and experimentation** **-Monitoring of CA experimentation**	-Agroecology network (AWARD/MDF) -Maruleng DM	-Review of CSA implementation and re-planning for next season Tunnels (Quantitative measurements - CA farmer experimentation (Quantitative measurements) – case studies - Individual experimentation with basket of options -water committee, plan for agric water provision
	Lepelle	Water issues workshops 1-2	-	-water committee, plan for agric water provision
	Tzaneen (Sekororo-Lourene)	- CCA workshop 1-2 - Assessment of farmer experimentation	Farmers learning group	-Tunnels and drip kits
EC	Alice/Middledrift area	- CCA workshop 1-5- Monitoring, review and re-planning - **Set up tunnel experimentation process**	Imvotho Bubomi Learning Network (IBLN) - ERLC, Fort Cox, Farmers, Agric Extension services, NGOs	- Monitoring and review of implementation of CSA practices and experimentation - Training and mentoring _CA, furrow irrigation, …. -Planning for further implementation and experimentation and quantitative measurements

Below summary reports for progress in each area is presented.

2.1 Swayimane_SKZN

Written by Temakholo Mathebula and Nontokozo Mdletshe

2.1.1 Gobizembe shade cloth tunnel construction

The learning group in the area took some time to focus on the gardening processes; being involved in field cropping until the end of the cropping season (March -April). The group decided to host the experimentation process for tunnels at Mrs Mcinyana's household, based on the availability of fencing and water and Mrs Mcinyana's agreement to look after the crops in the tunnel. She is also situated close to other groups members. Initially the trench beds were dug in a different homestead- but the presence of large rocks underground negated this site as an option.
The three trench beds were prepared prior to erecting the tunnel materials were delivered a day or two before the construction to allow group members to sew the netting onto the frames (6th April 2019).
Trench beds preparations
Inside the tunnel the three beds were prepared in slightly different ways to allow for comparison;

- One deep trench bed
- One shallow trench bed and
- One raised bed (the 'normal' practice in the area

Mrs Mncinyana was advised to also follow the same process for the beds outside the tunnel as her control so that we can compare results from inside and out of the tunnel.


Figure 1: Left; Preparing the deep and shallow trench beds for the tunnel. And right;the deep trench on the right, shallow trench in the middle and raised bed on the left of the picture.

Tunnel construction

The metal conduit poles were bent to make the arches for the tunnel using a jig and the netting was sewed onto the two end arches to make the back and the front of the tunnel. It was then possible to put up the arches, and pull and secure the rest of the netting for the tunnel. The group worked together and the tunnel was easily constructed in one day.


Figure 2: Tunnel construction. Top left; the net while being opened, Top Right; the jig on top of the net, Below Left; the poles being bent using the jig and Below Right; sewing of the net onto the poles.

After sewing, the slots in the ground were opened using a steel column which was hammered into the ground to a depth of around 40cm, for the arches to be well anchored into the soil.

Figure 3: Tunnel construction. Left; the placement of the arches and Right; pulling the netting over the arches to create the shade cloth structure.

Planting.

A mixture of vegetables and herb seedlings were bought for planting in the tunnel (9th April 2019); kale, lettuce, red cabbage, Chinese cabbage, broccoli, beetroot, turnips, leeks, parsley, rocket, thyme, marigolds, coriander and celery. These were distributed between the three bed types to ensure that the same crops were planted in all three beds to be able to compare the results.

Right: Planting of vegetable and herb seedlings in the new tunnel

Conclusion

It was very difficult choosing one participant to experiment with the shade cloth tunnel as all the learning group members were very enthusiastic about this idea, as they had already seen that tunnels protect crops from climate variability and also from livestock invasions in their gardens.

Even at the onset of this process participants had the following comments about tunnels;

- They protect the crops from too much sun and heat
- The save water, by reducing evaporation and also through reduced run-off from the trench beds and bed layout process

They understood the experimentation process and undertook to plant the three beds outside the tunnel and also to keep records of irrigation times and amounts inside and outside the tunnel

2.1.2 **Installation of sensors**

Installation of water mark sensors in Gobizembe

Two sensors were installed at Mrs Mcanyana's household; one in the tunnel in a deep trench and one outside the tunnel also in a deep trench. The two sensors were buried at 20cm, 40cm and 60cm after having been soaked in water for over an hour before being put in. The ladies were taken through how the sensor works and why it is important to record data frequently. The robot system makes it very easy for the old ladies to work with this tool helping them to decide whether or not they need to water their crops. Prior the installation of these sensors Mrs Mcanyana was irrigating as and when she deemed necessary. She was advised and left with a sheet where she will be recording when and how much she has watered.

She was also taken through the careful storage of the equipment and the cost of having these installed. She was shown how to carefully insert and pull out the reader cable as it is quite fragile with minimal damage translating to the costly replacement of the equipment. Upon installation, the cables were tied to a wooden dropper, covered with plastic and a covered with a cold drink two litre bottle. Mrs Mcanyana will be doing uploads every Monday of the week using her daughter's phone.

All beds inside and outside the tunnel have a grass mulch on them, this is not only

for moisture retention but also to protect the soil form the frost, although to the confusion of the farmers, this winter is not as cold as they normally have their winters. The crops, however, were

Figure 4: From left to right; sensor cables installed at different depths, soil replaced and pushed in, sensor cable covered with bottle

looking very healthy and well-watered and were growing well with no pests spotted as yet on either the inside or the outside.

Conclusion

Below is a summary of the chameleon sensor readings taken to date. It indicates that Mrs Mcinyana has been watering her beds attentively and has been paying attention to the Chameleon readings.

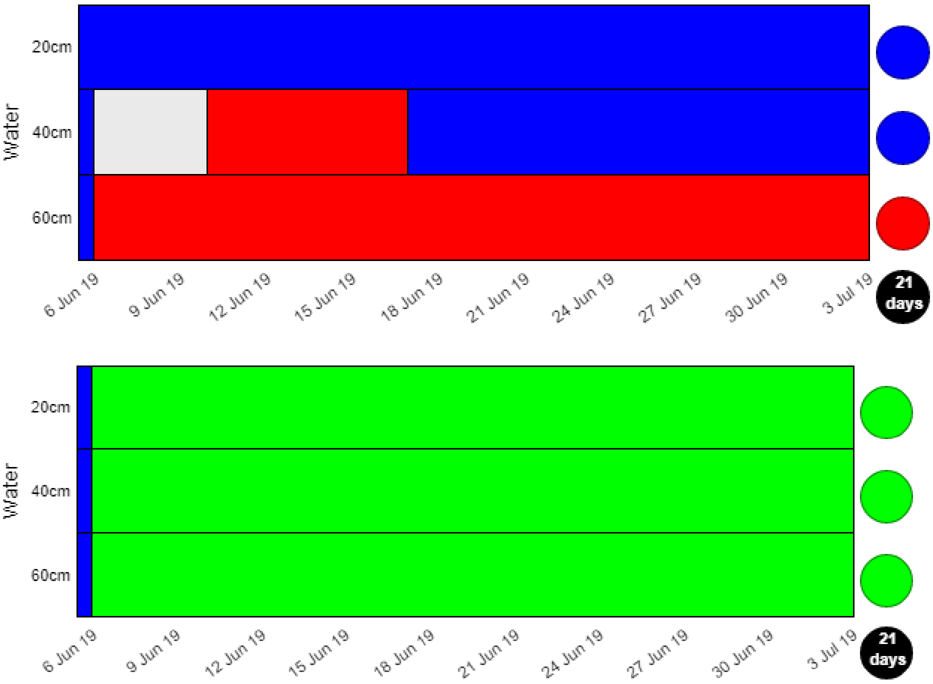

Figure 5: Chameleon readings inside the tunnel (Above) and outside the tunnel (Below) at Gobizembe (Swayimane) for June 2019

2.2 Ntabamhlophe; CA report

Written by Samukelisiwe Mkhize

Ntabamhlophe participants have completed their first year of conservation agriculture experimentation. They intercropped maize and beans on 100m^2 plots as their first trail. All the participants planted late between the 15th and 18th of December 2018. This season was very dry until early January and was characterised by heavy rainfall towards the end of season (March and April). late and heavy rains. This affected the maize yield with some of the participants' maize rotting.

However, most of the participants shared that the maize cobs were generally of good quality with a few exceptions were the maize was affected by stalk borer and rot. Their usual planting season begins mid-October to latest early November. Low maize yields were mostly due to livestock invasion in the fields. This is an issue in the community, where cattle are released back into the village prior to people being able to harvest their maize and is a trend in the whole region. As grazing for cattle is diminished through a combination of climate variability and lack of grazing management, the traditional authorities allow the cattle back into the villages earlier; jeopardising harvests for those villagers who have produced crops.

Cinelele Sibiya

Gogo Sibiya has naturally assumed the role of local facilitator by visiting the trial plots of other farmers in the learning group to monitor crop growth.

As this was their first CA trail, they were not sure whether the practice would germinate. grow and produce any yield. She shared this because she has shallow sandy soil with hard rock that does not favour good crop growth.

She was happy with the 'good lines formed and satisfied with maize cobs sizes'. She thinks the MAP (33) fertilizer and lime used had a great impact on the 41.607 kg yield (~4,7t/ha) she harvested this season and wants to continue on with the programme next season.

Right: Mrs Sibiya showing the quality of maize cobs she harvested

Robert Gabuza

Maize = 53.258 kg (~6,08t/ha)

Beans = 5 litres (~0,7t/ha)

Right: Robert Gabuza's wife with the samples from his harvest..

Sibongile Zuma

Sibongile's plot was invaded by cattle and her yields of both maize and beans were greatly reduced:
Beans = 1.850 kg (~0,054t/ha)
Maize = 18.520 kg (~2,1t/ha)
Right: Sibongile showing a portion of her bean yield

Two other participants whose yields were monitored; Vusi Nkabinde (~0,7t/ha of beans), Thembi Xaba (~1,4t/ha beans and 2,3t/ha maize) shared that their yields were low due to cattle invasions. They also felt that their cobs were a bit small and under-developed and believed that this was due to the late planting. They all felt that it would be important for them to continue their experimentation with CA, as their harvests were nevertheless better than before and they appreciate the idea that benefits from improving soil health and organic matter would take a few seasons to be seen.

Way forward

Being introduced to an existing group was beneficial because the participants were already working together and identify themselves as part of the collective. There is potential to reach other farmers in the communities who are grain crop farmers including those producing soya beans. The partnership with LIMA RDF has been effective in introducing CCA into the thinking of the learning groups there, but more effort needs to be put in engaging our partners throughout the experimentation phase.

2.3 Eqeleni and Ezibomvini- Bergville-KZN

Written by Phumzile Ngcobo

2.3.1 Gardening and fodder experimentation update

Tower gardens

Three demonstration workshops were held in the Bergville area at Ezibomvini, Thamela and Emabunzini related to tower gardens. These demonstrations were held at Mam Phumelele Hlongwane, Mam Constance Hlongwane and Mam Valindaba Khumalo's homesteads respectively.

The tower gardens were introduced primarily to assist farmers to increase their production, using the little greywater they have available in their homesteads. Materials used included 50 kg,80 kg or 1000kg bags, kraal manure, wood ash dry grass and greens, all of these being accessible to the farmers.

Planting materials used included leafy plants including mustard spinach and kale, some herbs- parsley, marigold and thyme and below ground harvestable plants in spring onion and regular onions and cabbage. They selected the regular crop choices that they are used to like cabbage and spinach but also included onions for pest control and rotation purposes to include above and below soil harvestable crops to balance nutrient uptake in the soil and disrupt plant disease cycles.

Figure 6: Above left to right: Examples of tower gardens planted in Bergville

At Ezibomvini the following farmers have included tower gardens into their gardening practices:

- Phumelele Hlongwane
- Balungile Mkhwanazi
- Nombono Dladla
- Zodwa Zikode
- Nonhlanhla Zikode

According to the farmers tower gardens save them water because they do not have to go to the local spring or river because they can use water that has been used for other household purposes. Weeding is also one of the positives identified from the use of this practice. The tower gardens are also easy to work with and maintain, so once constructed labour requirements are minimal.

Fodder production and supplementation

In Ezibomvini and Stulwane farmers have been preparing for the fodder supplementation experiments undertaken in early June. They have cut grass for baling and will now start to make bales, as the 2nd baler has been delivered; meaning there is one baler for each of the respective areas. The idea was the farmer centres in these two villages would procure and supply the premix and the LS33. This has worked well for the protein blocks as well. For the LS33, there was none available from their closest town for a period and thus they have only now bought this liquid supplement.
In addition, farmers have approached the experimentation process a little haphazardly – feeding all their cows every now and again, rather than having a more controlled experimentation process. The idea was thus re-introduced. There is also the issue that the few bales that they will be able to make (usually not more than 10 per participant), are not likely to last long, and thus their attempts at

introducing the supplements directly. This will of course be rather difficult with the liquid version (LS33), but has in fact been working quite well with the pre-mix 450.

In Ezibomvini, two farmers have already started with the supplementary feeding process:

1. Ntombenhle Hlongwane

She has 12 cows and has cut grass and made bales for supplementary feeding. She has not been very systematic about this but has placed a bale of grass in the kraal from time to time. She mentioned that her cows are still in a good condition because of that and fall in category 4 of the condition scoring sheet. For the experimentation process she has now undertaken to feed two cows with calves using bales with premix 450 or LS33 and will then use her other 10 cows as her control sample.

2. Phumelele Hlongwane

She has two young bulls and have been giving them 2kg premix 450 per day. She will then undertake to mix this supplement with the bales of grass, which are ready, when there is no longer grazing available. Another participant, Thulile Zikode will continue to feed the premix 450 by itself, as she has left cutting grass to late and there is presently very little grass available.

Right: Phumelele Hlongwane measuring out the 2kg of pre-mix for her cattle

3. Phumlani Dladla

He has undertaken to do bales with grass, as well as bean and cowpea straw, and to add the LS33 supplement to these bales.

For Stulwane the following 4 farmers have outlined their supplementation experiments as follows:

1. Mtholeni Buthelezi

He has done collecting grass for bales, at the moment he is already started feeding his livestock with protein block, and will use LS33 as a supplement to grazing. For the trial he will feed his pregnant and lactating cows and observe the rest of his small herd as a control.

2. Dlezakhe Hlongwane

He will do grass bales with premix 450. The trial will be the cows with calves as well as those that are thin and the control will be the rest of his herd.

3. Thulani Dlamini

He will do grass with lab lab, grass with cow peas and LS33. The trial will be the cows with calves as well as those that are thin and the control will be the rest of his herd.

4. Mkhathini Dladla

He will do bales with LS 33 and premix 450, he will feed the thin ones and those with calves.

2.3.2 Water productivity for Tunnel experimentation

Although three participants have undertaken the tunnel experimentation process in Bergville, record keeping related to their irrigation and harvests, needed for calculation of water productivity, was not meticulous enough for analysis for two of the participants; Nombono Dladla and Ntombakhe ZIkode.

Both these ladies are illiterate and the careful process co-designed with them for keeping records was unfortunately adhered to rather haphazardly. For the third participants, Phumelele Hlongwane WP has been calculated for a 2nd season.

The two methods used; scientific method – using all variable including ETc, runoff and leaching along with rainfall and what we have called the farmers' method – using only water provide (rainfall and irrigation) related to yields, were used. These processes were considered in detail in Deliverables 5 and 6.

Case study: Phumelele Hlongwane

Phumelele Hlongwane has a 2500l jojo tank for roof rain water harvesting. She also walks for approximately 30mins to and from a spring, collecting water to irrigate. The expansion of her garden has made her realise the necessity of having reliable and accessible water for irrigation because the garden uses more water than she needs for household use. Three chameleon sensors were installed in three different beds in her garden (outside tunnel trench bed, inside tunnel trench bed and raised bed) to help her to monitor the changes in soil water content in order to assist her to make an informed decision to irrigate or not. The chameleons with bucket drip irrigation were introduced to help her to save water.

The procedure for the bucket drip kits is to water once a day every day. Working with the chameleons showed Phumelele that a more efficient irrigation process was is to employ deep watering, less often; around every 4th-6th day depending on the reading.

Phumelele shared the following comments about the practice:

- Using the chameleons and drip kits saved her time and water; she can now irrigate only when it is needed
- She is changing her practice from irrigating every day to deep watering every 4-6 days depending on the conditions.
- The chameleon colours are good and simple indicators
- But she doesn't know when it's time to charge the reader and sometimes doesn't know how to deal with technical issues with the chameleons and uploading the information

In the first round of experimentation she planted spinach. She followed this with a mixed crop of Chinese cabbage, onions, spinach and beetroot. Her latest round of cropping consisted of Chinese cabbage and green peppers. She has noticed a marked difference in growth and plant health inside the tunnel in the trench beds, when compared to trench beds outside the tunnel. During the process of these experiments, she has discontinued her normal practice of raised beds, having seen the advantages of using trench beds. She has also noticed that soil moisture is retained for a longer period of time inside the tunnel.

The Chinese cabbage and green peppers are weighed in the quantities they are sold in. She sells green peppers in plates of five and Chinese cabbage in bunches. Inside the tunnel, the average yield for the Chinese cabbage is 0.83 kg/ head sold for R10 and for green peppers 0.38 kg/plate sold for R10. For the season she harvested at total of 104.8 kgs of green peppers and 32.4 kgs of Chinese cabbage.

Figure 7: Weighing Chinese cabbage and green peppers during yield determinations for this experiment.

Outside tunnel she harvested 11.5 kgs of Chinese cabbage and 138.9 kgs of green peppers. She records her harvest and amount of water irrigated which are used to measure water use efficiency. The facilitation team visits her homestead garden to upload readings and monitor the data she records has been collecting on the water use and chameleon readings.

A visualisation of the chameleon readings for Phumelele's tunnel is shown in the figure below. From this figure it can be seen that she has managed to keep her soil reasonably well wetted, up to the end of her cropping cycle at the end of May 2019. She has added enough water in her latest cropping cycle to wet the soil profile down to around 40cm in depth; which is adequate for vegetable production and has worked out an irrigation practice for herself using as little water as possible to gain the greatest growth advantage – given her major limitations in access to water.

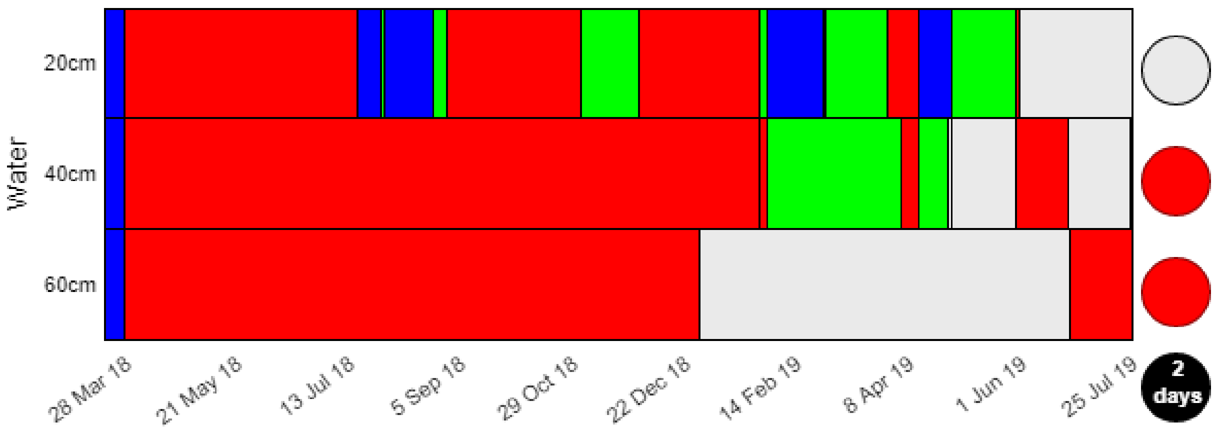

Figure 8: Chameleon sensor readings for Phumelele Hlongwane's trench bed inside her tunnel (July 2019)

During the second round of experimentation she obtained the following results.

Table 3: Water productivity results for Phumelele Hlongwane; Feb-May 2019.

Water Productivity: Phumelele Hlongwane							
Bgvl Feb-May 2019		**Scientific method (ET)**			**Farmers' method (Water applied)**		
Plot	**Crop**	**Yield per plot (5x1m) (kg)**	**Water use (m^3)**	**WP (kg/m^3)**	**Yield per plot (5x1m) (kg)**	**Water use (m^3)**	**WP (kg/m^3)**
Tunnel	Chinese cabbage	60,5	0,5	**122,0**	60,5	0,6	**100,9**
Trench (outside)	Chinese cabbage	34,7	0,5	**72,1**	34,7	0,6	**57,9**
Tunnel	Green Pepper	3,7	0,5	**7,2**	3,7	0,5	**7,2**
Trench (outside)	Green Pepper	2,9	0,5	**5,8**	2,9	0,5	**5,6**

Note: A crop coefficient of 1,0 was used for both Chinese cabbage and green pepper and was gleaned form literature[1]

For this production cycle, the scientific and farmers' methods for calculating WP have produced very similar results in terms of the water use. This means that Phumelele has managed to intuitively adjust her irrigation schedule to suite the climatic conditions of the season almost perfectly.

The yield advantage for both Chinese cabbage and green peppers produced inside the tunnel, when compared to outside is clearly visible. The average percentage increase in WP for Chinese cabbage grown inside the tunnel is 42% and for green Peppers is 26,5%

[1] FAO, 1998. Crop Evapotranspiration guidelines for computing crop water requirements. In FAO Irrigation and Drainage Paper No 56. Chapter 6:Simple Crop Coefficients. FAO, Rome,

When this is compared to the WP results for her previous cropping cycle of Spinach, as shown in the table below, the average percentage increase in WP for the spinach grown was around 56%.

Table 4: Water productivity results for Phumelele Hlongwane; June-September 2018

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

Further, the water use for the 2018 winter season was much higher than the 2019 summer season, which points to the fact that Phumelele has adjusted the amount of water she provides during this experimentation process and has reduced her overall water use significantly, without jeopardising her yields or water productivity.

2.3.3 **Water issues- Ezibomvini**

Very little progress has been made. During May 2019, when participants were meant to start collecting their contributions towards the spring protection and reticulation of water to their households, due to elections and a brief spurt of activity from the Local Municipality- hopes were raised that the Government would in fact finally assist with water provision. Most participants are still waiting to see if anything will happen there and have thus lost focus on contributing towards their own initiative. The experimentation process with spring protection can only happen if they agree to work together and contribute towards this process with their labour and a small financial contribution.

2.3.4 **Conservation Agriculture monitoring in Bergville**

For the CA experimentation the bulk of field work and monitoring are conducted under the auspices of the Maize Trust Smallholder Farmer Innovation project. Here, we report some of the relevant monitoring information for this time period; including the rainfall and runoff results, water holding capacity, gravimetric soil water content, and soil health data .yield data for the season is still being compiled.

RAINFALL

This season rain gauges were installed in six villages within the Bergville study site. The monthly average rainfall data for these gauges are summarised in the table below and are compared to the local weather station data (Davis weather station in Ezibomvini)

Table 5: Rainfall data for 6 villages in the Bergville site; September 2018-May 2019

Rainfall (mm/month) 2018-2019 summer rainfall season; Bergville villages									
	Village							**Weather station (Ezibomvini)**	
Month	**Stulwane**	**Ndunwana**	**Ezibomvini**	**Eqeleni**	**Emhlwazini**	**Thamela**	**Average**	**Rain (mm/ month)**	**ET0 (mm/ day)**
Sep-18	5	71	15				30,3	5,8	154,36
Oct-18	19,5	28	6				17,8	24,6	117,47
Nov-18		106	68,1	180	74,8	47,7	95,3	50,4	148,16
Dec-18	64	22	61	64	76,5	52	56,6	80	152,34
Jan-19	57	321	27,5	258,5	290,4	97	175,2	70,6	142,01
Feb-19	135	253	218,7	254	171,8	356	231,4	139,8	108
Mar-19	177,5	73	214	205,5	63,2	66	133,2	212,4	100
Apr-19	136,5	63	89	67		53	81,7	149,9	100
May-19	0	0	0	0	0	0	0,0	11	84,92
TOTALS	**594,5**	**937**	**699,3**	**1029**	**676,7**	**671,7**	**768,0**	**744,5**	**1107,26**

Note: values in dark grey were estimated from online weather data for the period – as the weather station was faulty during this period

The seasonal average for the rain gauges and weather station compare quite well at 768mm and 744mm respectively. This can be considered a reasonably high rainfall for this area, but given the extremely late onset of rain and the high evapotranspiration values for this season, crop growth was severely hampered.

The average rainfall recorded for the 2017-2018 season for December- May was averaged at 563mm. For this season in the same time period the average rainfall was 678mm. The reference ETo for 2017-2018 was however substantially lower at 702,8 mm than this year, which was calculated at 1107,3 mm for the season. This indicates the major difference between the two seasons and why the crops fared so badly this year, even with higher rainfall than last year.

This observation is supported by a number of other studies, indicating the evaporative potential in a growing season has a much greater potential effect on maize yield potential than overall rainfall and temperature, as explained in the quote below:

"Recent studies indicate that the negative effect of high summer temperatures is due less to effects on reproductive growth (e.g., heat damage between anthesis and silking, reducing pollen and grain set) and more to increased moisture stress driven by vapor pressure deficit (VPD). Rising VPD increases evapotranspiration, which has a two-fold impact on crop moisture stress: 1) photosynthesis declines

as crops that are unable to meet transpirative demand reduce their stomatal conductance and 2) soil water supply to the crop declines due to increased evaporation from the soil surface”[2]

These authors proposed the need for increased soil organic matter to effect greater water holding capacity (WHC) in the soil to mitigate these effects. *They also state that “Other strategies will be required to complement WHC increases, such as crop genetic improvement, cropping system design, and irrigation technologies, among others”.*

RUNOFF

This season 4 farmers managed run-off plots in their CA trials alongside their rain gauges to ascertain the difference in runoff between the conservation agriculture trial plots and a conventional control plot. The results are summarised below.

Data is summarised on a monthly basis, with the understanding that the run-off is generally related to amount and intensity of rainfall as well as dryness of the soil. Given that the soils in Bergville are high clay soils they also tend to be quite compacted and become extremely hard when dry. This could lead to increased run-off, but this depends on the intensity of the rainfall events.

Table 6: Run-off results for 4 participants across Bergville; 2018-2019

	Stulwane		**Ndunwana**		**Ezibomvini**		**Eqeleni**	
	Runoff Trial(ml)	**Runoff Control (ml)**	**Runoff Trial(ml)**	**Runoff Control (ml)**	**Runoff Trial(ml)**	**Runoff Control (ml)**	**Runoff Trial(ml)**	**Runoff Control (ml)**
Nov-18					2808,0	3267,0		
Dec-18	3 343	2 600	11	14	35,2	39,5	5 800	5750
Jan-19	5 900	2 250	305	348	30,8	31,0	10 000	12750
Feb-19	3 266	6 275	471	609	66,0	74,5	12710	13 250
Mar-19	2 423	1 615	69	117	24,1	27,5	9 800	9 000
Apr -19	4 836	5 875	41	29	2,7	2,3	4 000	4 000
Average Nov-Apr	**3 954**	**3 723**	**179,4**	**223,4**	**494,5**	**573,6**	**8 500**	**8950**

From the table above it can be seen that for 3 of the 4 villages the run-off in the CA trial pots were on average lower than the conventional control plots. The difference in run-off between the CA trial and conventional control plots is not as significant as it has been in previous years. This is likely due to the larger number of small rainfall events this season.

In the section below the effect of different cropping options within each of the CA trials is explored in more detail.

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[2]Williams A, Hunter M.C, Kammerer M,. Kane D.A, Jordan N.R, Mortensen D.A, Smith R.G, Snapp S, and. Davis A.S. 2016. Water Holding Capacity Mitigates Downside Risk and Volatility in US Rainfed Maize: Time to Invest in Soil Organic Matter? Published: August 25, 2016https://doi.org/10.1371/journal.pone.0160974Soil.

NELISIWE MSELE; STULWANE

Table 7: Run-off results or different cropping options within the CA trial; Stulwane 2018-2019

Stulwane; Nelisiwe Msele							
	Rainfall	**CA Plot 1 (M+CP)**	**CA Plot 3 (Maize)**	**CA Plot 6 (Beans)**	**CA Plot 9 (M+CP)**	**CA average**	**Conventional Control**
	mm	ml	ml	ml	ml		ml
Dec-18	64	3 750	1 170	4 100	4 350	3 343	2 600
Jan-19	57	11 000	9 600	2 000	1 000	5 900	2 250
Feb-19	135	4 995	2 955	2 135	2 980	3 266	6 275
Mar-19	177,5	3 950	1 050	0	2 270	2 423	1 615
Apr-19	136,5	6 333	3 910	6 100	3 000	4 836	5 875
Average seasonal runoff						**3 954**	**3 723**

For Nelisiwe Msele the expected trend of higher run-off on the CA plots early in the season, leading into lower runoff values towards the end of the season is clearly visible, as is the trend for the conventional (ploughed) control) of having less run-off early in the season and higher runoff as the season progresses. This trend has been recorded in the literature and can be explained through increased macropores in the soil after ploughing, that gradually collapse throughout the season to lead to higher compaction in the soil. Soils under CA are also generally more compacted, but aggregate stability and micropores are present that improve water infiltration and water holding capacity (Cavalieri et al., 2009, Basset ,T.S 2010)[3].

Overall the CA plots for Nelisiwe had slightly greater average run-off than her conventional control plot. She has been practicing CA for 5 years, but her soil cover has been recorded at between 1-5% over the years; meaning that it has remained very low.

If one considers the percentage rainfall that has been converted to run-off, as shown in the small table below, it can be seen that this percentage is quite low, averaging 4,6% for the CA trial plots and 4,3% for the conventional control plot. This can be related to the general stability of high % clay soils as well as the reasonably high percentage of organic matter (OM); 4,3% in the CA trial plot.

Table 8: Percentage rainfall converted to runoff for CA trial and conventional control plots in Stulwane; 2018-2019

Percentage rainfall converted to runoff

[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).
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.

	Rainfall	CA	Conv
	mm		
Dec-18	*64*	*5,2%*	*4,1%*
Jan-19	*57*	*10,4%*	*3,9%*
Feb-19	*135*	*2,4%*	*4,6%*
Mar-19	*177,5*	*1,4%*	*0,9%*
Apr-19	*136,5*	*3,5%*	*4,3%*
Average % runoff		**4,6%**	**3,6%**

PHUMELELE HLONGWANE: EZIBOMVINI

Table 9: Run-off results or different cropping options within the CA trial; Ezibomvini 2018-2019

Phumelele Hlongwane: Ezibomvini							
	Rainfall	**runoff (ml)**					
	mm	**CA Plot 2 (M+CP)**	**CA Plot 6 (M+B)**	**CA Plot 9 (Maize)**	**CA trial ave**	**CA control**	**Conven contrl**
Sep-18	15						
Oct-18	6						
Nov-18	68,1	2393,0	2016,0	4015,0	2808,0	3267,0	
Dec-18	61	35,0	37,0	33,5	35,2	39,5	
Jan-19	27,5	35,1	29,4	28,0	30,8	31,0	1007,5
Feb-19	218,7	60,0	72,5	65,5	66,0	74,5	16,5
Mar-19	214	31,7	21,2	19,5	24,1	27,5	3,0
Apr-19	89	4,0	2,0	2,0	2,7	2,3	1,8
Ave Seasonal runoff		**426,5**	**363,0**	**693,9**	**494,5**	**573,6**	**257,2**

Phumelele has converted most of her farming to CA. She is in her 5th year of implementation. This year we attempted to find a conventional control- this plot was planted to sweet potatoes and means it was cultivated. For Phumelele her % soil cover linked to stover, is around 10%, given that she has fenced her field and control her livestock's grazing in this field.

This season the average seasonal run-off in her Maize only CA plot was substantially higher than for her intercropped plots (M+B and M+CP). As Phumelele rotates the crops in her plot every season, it would appear that the differences in runoff between the plots is related a lot more to the specific soil properties in each plot, than the specific seasonal cropping option. This result may also be linked to canopy cover – this season, growth of the crops was impeded by the weather conditions and canopy cover was never reached, while in the previous season full canopy cover had been reached by the end of January.

If one considers the percentage rainfall that has been converted to run-off, as shown in the small table below, it can be seen that this percentage is very low, averaging 0,95% for the CA trial plots, 1,11% for the CA control plots and 0,36% for the conventional control plot. In Phumelele's case her %OM is 3,6% for her CA Trial plot and 2,9% for her conventional control. It is unclear why the runoff for the conventional control plot is lower than that of the CA trial. It is possible that the slope of the run-off pans were not well calibrated and that the cultivation practices for sweet potatoes provide for differentvrun0off conditions in this plot. In retrospect, using a field allocated to a different crop may not have been such a good idea. The trend for lower run-off from the CA trial plot, when compared to the CA control plot, which has been observed in the 2 previous seasons has continued into this season.

The percentage rainfall converted to runoff for Phumelele is substantially lower than that of Nelisiwe (presented above) and attests to her continued good soil management practices

Table 10: Percentage rainfall converted to runoff for CA trial and conventional control plots in Ezibomvini; 2018-2019

Percentage rainfall converted to runoff				
	mm (Weather station)	**CA trial**	**CA control**	**Conv control**
Nov-18	50,4	5,57%	6,48%	
Dec-18	80	0,04%	0,05%	
Jan-19	70,6	0,04%	0,04%	1,43%
Feb-19	139,8	0,05%	0,05%	0,01%
Mar-19	212,4	0,01%	0,01%	0,00%
Apr-19	149,9	0,00%	0,00%	0,00%
Average % runoff		**0,95%**	**1,11%**	**0,36%**

NTOMBAKHE ZIKODE: EQELENI

Table 11: Run-off results or different cropping options within the CA trial; Eqeleni 2018-2019

Ntombakhe Zikode; Eqeleni								
	Rainfall	**Runoff (l)**						
	mm	**CA plot 1**	**CA plot 2**	**CA plot 3**	**CA Ave**	**CA Control**	**Convenl Control**	**Control Ave**
Dec-18	64	5,5	5,5	6,5	**5,8**	5	6,5	**5,75**
Jan-19	258,5	10	10,5	9,5	**10,0**	13	12,5	**12,75**
Feb-19	254	14	10,5	13,5	**12,7**	14	12,5	**13,25**
Mar-19	205,5	9	9	11,5	**9,8**	8,5	9,5	**9**
Apr-19	67	4	4	4	**4,0**	3,5	4,5	**4**
Ave Seasonal runoff		**8,5**	**7,9**	**9**	**8,5**	**8,8**	**9,1**	**8,95**

Ntombakhe Zikode is in her 6th year of CA implementation. She also employs a combination of multi-cropping and crop rotation in her CA trial and has improved her soil management practices substantially over the last five years. Because of pressure form livestock in the area, her soil cover from stover is still low; averaging around 3-5%. In addition, the %OM in her trial plot no averages around 1,9%, which is an improvement, but still quite low for the area.

It can be seen form the table above that her runoff from both her CA trial plots (Ave 8,8l) are quite high and much higher than those for Ezibomvini (Ave 0,5l) and Stulwane (Ave 4,4l).This points towards the damage of her soil caused by long term monocropping and ploughing and the length of time required to re-build her soil. Ntombakhe has ploughed her fields regularly for many years, unlike Nelisiwe, who has only done this occasionally and Phumelele who has always tilled by hand.

Table 12: Percentage rainfall converted to runoff for CA trial and conventional control plots in Eqeleni; 2018-209

Percentage rainfall converted to runoff				
	mm	CA trial	CA control	Conv control
Dec-18	64	9,38%	7,81%	10,16%
Jan-19	258,5	3,87%	5,03%	4,84%
Feb-19	254	5,00%	5,51%	4,92%
Mar-19	205,5	4,77%	4,14%	4,62%
Apr-19	67	5,97%	5,22%	6,72%
Average % runoff		**5,80%**	**5,54%**	**6,25%**

Predictably, the percentage rainfall converted to runoff in Ntobmakhe's plots is much higher as well. Runoff in her CA plots 9both the trial and the control) is lower than her conventionally tilled plot.

NDUNWANA; BONIWE HLATSWHAYO

Table 13: Run-off results or different cropping options within the CA trial; Ndunwana 2018-2019

Nduwane; Boniwe Hlatshwayo			
	Rainfall	**CA runoff (M+B)**	**Conventional runoff**
	mm	ml	ml
Dec-18	22	11	14
Jan-19	321	305	348
Feb-19	253	471	609
Mar-19	73	69	117
Apr-19	63	41	29
Average seasonal runoff		**179,4**	**223,4**

She is in her 4th year of CA implementation and still following the 400m^2 trial layout of 2 plots of M+B and M+CP intercrops. She has received good yields averaging around 9,6t/ha for her maize in the 2017-2018 season. For the CA trail plot the organic matter has been recorded at 2,9% and for her conventional control plot at 2,75%. Boniwe recorded very low runoff values, for both her CA and conventional control plots – with a lower average seasonal run-off value for the CA plots.

Table 14: Percentage rainfall converted to runoff for CA trial and conventional control plots in Ndunwana; 2018-2019

Percentage rainfall converted to runoff			
	mm	**CA trial**	**Conv control**
Dec-18	22	0,05%	0,06%
Jan-19	321	0,10%	0,11%
Feb-19	253	0,19%	0,24%
Mar-19	73	0,09%	0,16%
Apr-19	63	0,07%	0,05%
Average % runoff		**0,10%**	**0,12%**

Boniwe's percentage of rainfall converted to runoff results are very low and are similar to those for Phumelele in Ezibomvini. This provides some weight to the argument that in the longer term, hand tillage, followed by CA has led to stable, wel-l structured soils.

Conclusions

- Runoff for the 2018-2019 season was much lower than the runoff measured in the two previous seasons, despite the fact that the overall rainfall was not that different. This can be attributed mainly to the rainfall intensity and periodicity but also to slowly improving organic matter content in the soil
- Historical land management practices have a large effect on the localised soil structure and soil health. It may take many seasons to rebuild a living soil with good aggregate stability and the related characteristics of reduced run-off and improved infiltration. There is evidence that those smallholder farmers who have always practiced hand tillage have soils that are in a much better state than those who ploughed continuously prior to starting their CA implementation.
- Even within the CA trial plots (which are divided into $10m^2$ blocks), there can be considerable variation in soil quality, which again is related to historical management practices. It is considered that the differences in run-off between these blocks is related much more to the differences in historical land management practices than the different cropping options presently implemented.
- On average, the mixed cropped CA trial plots show less run-off than the CA control plots which have been mono cropped to maize.
- For this season, the conventional control plots (ploughed) have on average shown less run-off than the CA trial plots. Although there has been a steady, but slow increase in percentage Organic carbon (and %OM) in the CA trial plots, the comparison of these CA plots with newly ploughed conventional plots has been problematic. There may be a initial "flash" release of organic matter in the newly ploughed plots that was not accounted for. There may also be a slow decrease in organic matter in the CA trial plots – although this could in fact be more related to the procedures for measurement of organic carbon, the timing of taking the soil samples and the general drying trends in the soils over the last two to three seasons. These tests are to be repeated in the coming season in the hope that some of these aspects can be clarified.

WATER HOLDING CAPACITY

In the Bergville area, the WHC (water holding capacity) of the soil is naturally high, given the high clay content and reasonably high SOM content (2-4%). A study conducted with 5 of our smallholder farmers in Stulwane, by a Soil Science Masters student from the University of Pretoria – Palesa Motaung confirms these generalisations.

As in many of our present analyses, students, interns and fieldworkers battle to conceptualise the importance of control samples and also battle to find appropriate controls – as in many cases the farmers that we are now working with for these measurements have moved across to CA for their entire cropping areas and do not have conventional tillage control plots. In Palesa Motaung's study, given that she is focussing on soil health aspects, she used veld samples as her controls.

She has used both the Visual Soil Assessment methodology refined by our team as well as the Cornell comprehensive soil health assessment framework – which uses chemical, biological and physical soil measurements to provide indices[4] and scores for soil health.

Among the soil health tests that she conducted, she calculated available water holding capacity (AWC) for the following plots for five 5th year CA farming participants in Stulwane:

- CA maize only
- Ca maize and beans
- Veld

The results are shown in the small table below

Water holding capacity (g water per g soil)	Treatment average of 5 farmers (Stulwane)
0,58	CA maize only
0,58	CA maize and beans
0,62	Veld

The AWC is the amount of water available to plants – between the field capacity and wilting points for the particular soil. For the samples tested, the AWC is scored at 100% for all three treatments (CA maize only, CA maize and beans and Veld). This means that the water holding capacity of the soils in our study area are high. In addition, the water holding capacity of the CA trials are very close to the veld benchmark, indicating the benefit of the implemented CA system. The system consists of rotated plots of different combinations of mono-cropped maize, legumes and cover crops.

[4]B.N. Moebius-Clune, D.J. Moebius-Clune, B.K. Gugino, O.J. Idowu, R.R. Schindelbeck, A.J. Ristow, H.M. van Es, J.E. Thies, H.A. Shayler, M.B. McBride, K.S.M. Kurtz, D.W. Wolfe, and G.S. Abawi .2017. Comprehensive Assessment of Soil Health. The Cornell Framework. Third Edition. Cornell University, Ithaca New York.

Table 15: Soil quality scores provided by the Cornell soil assessment framework for 5 participants in Stulwane; 2018-2019

Treatment	**Overall Quality Score**	**Overall Biological Quality Score**	**Overall Chemical Quality Score**	**Overall Physical Quality Score**
Description		***Soil organic matter, active carbon, microbial respiration***	***Extractable P, K and pH***	***Available water capacity, wet aggregate stability***
CA Maize Only	60,7	48,2	62,6	76,7
CA Maize & Beans	54,7	43,2	51,2	77,3
Veld	63,0	56,4	61,1	75,9

Note: data compiled by Palesa Motaung for the M Soil Science study.

The differences in the scores between the CA maize only and CA maize and bean plots were to some extent artificial and related to sampling, rather than the treatments. Extractable P for example was extremely high for a few of the CA plots – but were likely due to recent fertilization – rather than an overall over supply of P in the soil, but led to much lower scores, as indicated in the pink shaded block of the table above.

For 3 of the 5 participants, the scores for biological properties were lower for their CA maize and bean plots than for their CA maize only plots – as indicated in the blue shaded block in the table above. A trend that has been noticed already in this research process is that soil quality within participants' fields can vary considerably and that microbial respiration and active carbon also varies considerably between the different treatments in a 10- block layout (10mx10m blocks). Treatments consist of monocropping and intercropping mixes, with cover crops, which are rotated. This variation is not directly related to the present crop combination in the block, or rather there have been no discernible trends in the data recorded to date. A trend that has been noticed, is that the participants who have used both intercropping and crop rotation in their experimental blocks, have higher average values for these biological properties. It is postulated here that the basic soil quality within these farmers fields differ markedly due to a combination historical management practices, and natural variability and that the CA management practices will even these differences out over time.

Conclusions

- The practice of CA has improved the physical properties of the soil over time, to the extent that both water holding capacity and aggregate stability for the CA fields are higher than for natural veld in the area (this is a high benchmark for comparison)
- The CA practices have also improved the pH and nutrient availability in the soil (extractable P and K) to levels equivalent to and higher than the natural veld benchmark

GRAVIMETRIC WATER

The intention of doing the gravimetric water calculations is twofold;

1. To gain a visual representation of water availability in the soil for different cropping options within the CA system and
2. To ascertain trends in water holding capacity in the soil, given the assumption that CA and specifically multi- cropping options within the CA system improves the water holding capacity of the soil.

Results from a gravimetric water content analysis in and of itself, cannot fully answer these questions, as there are numerous factors at play and a much more in-depth analysis would be required. This process has thus been exploratory in nature.

This process has been conducted for the last two seasons.

For the 2017-2018 season samples were taken for three participants (Phumelele Hlongwane, Ntombakhe Zikode and Zodwa Zikode), for different crop combinations within the CA trials (M, M+B, M+CP, SCC). The results were quite confusing and were only written up for one of the participants- Phumelele Hlongwane.

This season only one set of soil samples (Phumelele Hlongwane) were taken for gravimetric soil water assessments, given the time- consuming nature of this activity. These samples would give an indication of soil water content at different depths (30cm, 60cm, 90cm and 120cm), at different stages of crop growth, during the season. Samples were combined for her CA trial and were also taken for a CA control and a conventional control plot.

Right and Far Right:: Taking the gravimetric soil samples in Phumelele's CA trial plot, at planting (2018/11/07)

Below is Phumelele Hlongwane's 1000m^2 CA trial plot layout (2018/2019). Green shading indicates plots where gravimetric sampling was done.

Plot 5 M	Plot 4 M+B	Plot 3 M+CP	Plot 2 M+CP	Plot 1 SCC

Plot 6 M+B	Plot 7 M+B	Plot 8 M+B	Plot 9 M	Plot 10 LAB LAB

Phumelele took a risk and planted a lot earlier in the season than most of the other farmers in the area, who planted towards the end of November and early December only. Her crops suffered considerably from the continued lack of rain and high temperatures prevailing during November and December 2018.

Table 16: Gravimetric soil water sampling dates, compared to average monthly rainfall data

Gravimetric water samples taken	Date of sampling	Average rainfall for the sampling period
Planting (0 days)	2018/11/07	50
Establishment (4-6 leaf stage) (20-30 days)	2019/01/01	80
Vegetative growth (40-50 days)	2019/02/12	101
Productive stage (tasselling) (60-70 days) and	2019/03/14	212
Harvesting (physiological maturity) (80-110 days).	2019/04/25	150

The table above indicates the trend noticed by the farmers; that the rainfall during the establishment and early vegetative growth stages of the crop was not enough to sustain growth and rainfall towards the end of the season was unusually high, hampering maturation of the crops.

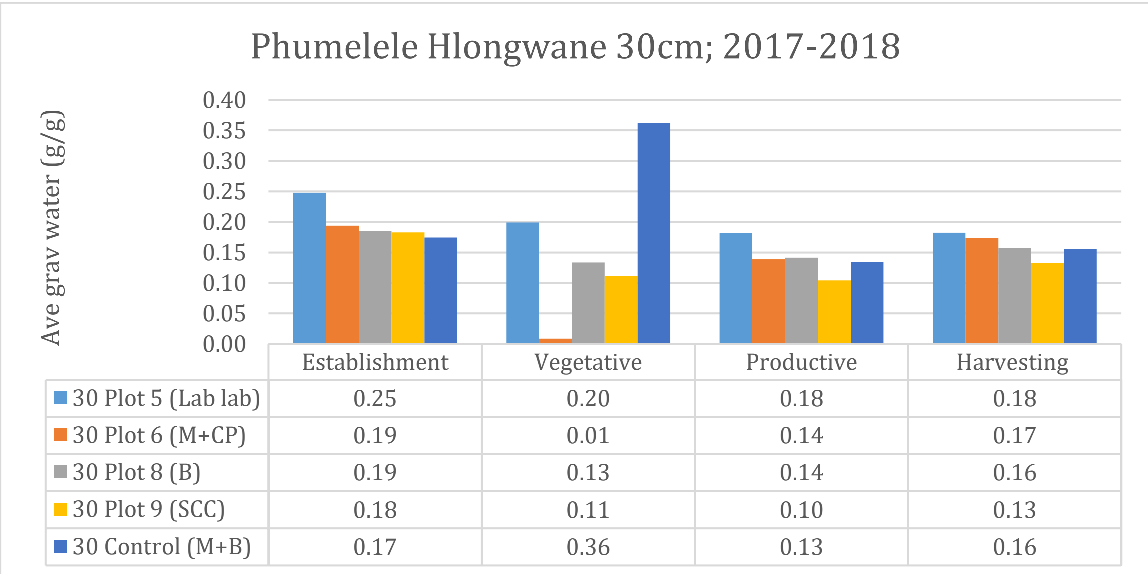
Germination and early growth were hampered, but maize growth in the later vegetative stages improved. Growth of the leguminous crops, specifically beans, was severely hampered, with almost zero harvests recorded. Lab-lab (Dolichos) and cowpeas survived well, even under these stressfull conditions. Of the summer cover crops the Sunnhemp and millet (babala) survived well, but sunflowers did not. The photos taken below for Phumllele Hlongwane are indicative.

Right to far-Right: Growth of different crops, towards the end of the productive phase (2019/04/11); Dolichos, Sunnhemp and millet (Babala)
Right: Cowpeas grew well, but because of heavy rains in the productive phase did not seed well

Far Right: Maize germination was patchy and growth was compromised. Late rains caused a lot of damage to cobs.

Comparison of gravimetric water content results for two seasons (Phumelele Hlongwane – Ezibomvini)
For the 2017-2018 season, calculations for gravimetric water content between the different cropping options were in fact very similar; meaning that the water content at the different depths were similar within each of the cropping options. There were some interesting differences between the cropping options.

The figure below indicates the results at 30cm depth.



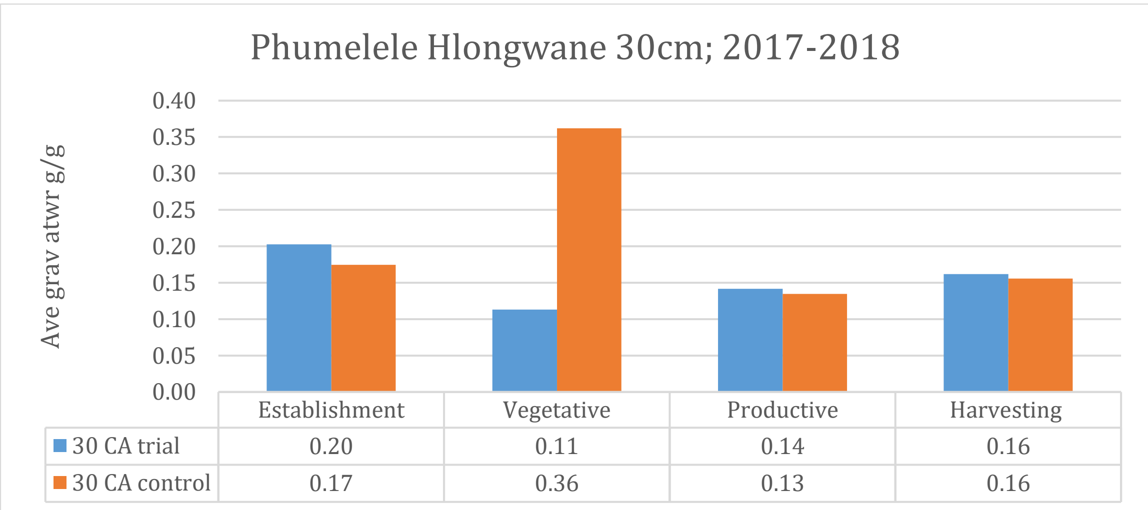
	Establishment	Vegetative	Productive	Harvesting
30 Plot 5 (Lab lab)	0.25	0.20	0.18	0.18
30 Plot 6 (M+CP)	0.19	0.01	0.14	0.17
30 Plot 8 (B)	0.19	0.13	0.14	0.16
30 Plot 9 (SCC)	0.18	0.11	0.10	0.13
30 Control (M+B)	0.17	0.36	0.13	0.16

Figure 9: Gravimetric water content at 30cm depth for different cropping options (Phumelele Hlongwane, 2017-2018)

From the figure above the following trends can be seen:

- At establishment, vegetative stage, productive and harvesting; for depths 30,60,90,120 the values are similar within each plot of the CA trial for 2017-2018, meaning the water content of the whole profile was similar in each plot (results for 60cm-120cm are not shown here)
- The water content for the plot planted to Lab-Lab beans (Dolichos) remained higher than the other plots for most of the season. The assumption here is that the mulching capability of the Dolichos reduced the evaporation and improved soil water content.
- The soil water content for the summer cover crops, Plot 9, was lower than for the other cropping options in the trial plots for the entire season. This provides a reasonably clear indication that the SCC used more water than the other crop combinations tested (Lab-Lab beans, maize and cowpea intercrop and beans). For the vegetative and productive growth period the measurements of 0,11 and 0,1 (g/g) of water to soil is considered suboptimal for unimpeded growth.
- Generally, the CA control and the CA trial plots had similar gravimetric water content readings for the season, indicating the water holding capacity of the soil is not changed greatly by the particular cropping options within the CA farming system.
- The gravimetric water content for the maize and cowpea intercrop (Plat 6), indicates a severe dip in water content in the soil during the vegetative growth phase. It is not clear why this would be the case, but it could be an indication of temporary competition for water between the maize and cowpeas in the vegetative growth stage – although the severity of the result (0,01 g/g) would rather indicate an error in sampling and analysis.

In general, these results indicate that the water holding capacity of these soils under the CA system of mixed cropping and crop rotation supported good growth of all crop combinations in this season. To compare the results of 2017-2018 with the present season (2018-2019), the results for all trail plots were combined and averaged and were then compared to the CA control and a conventional control (2018-2019 only). These results are shown in the two figures below.



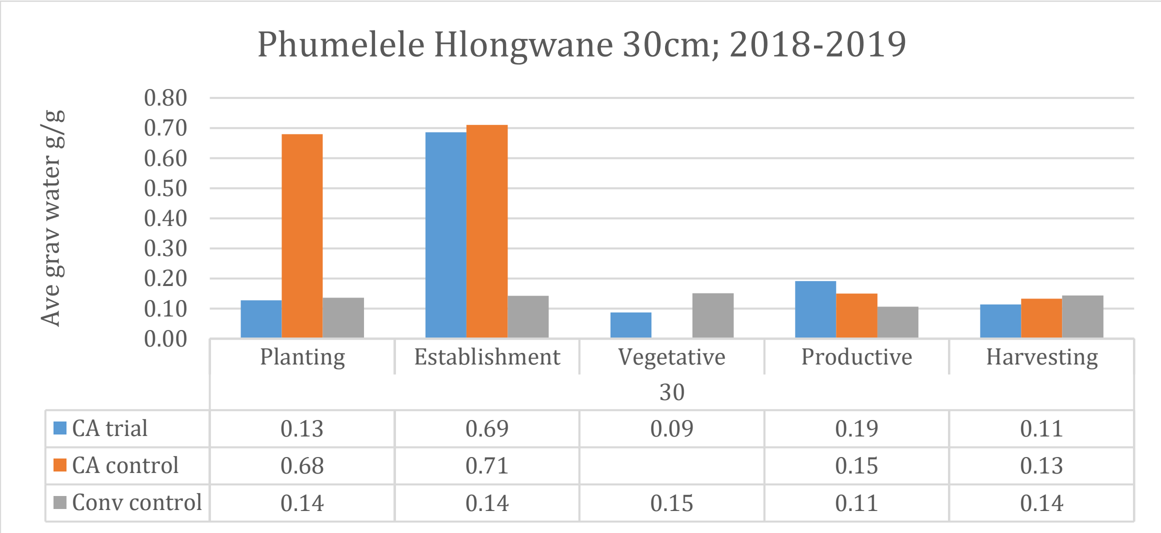
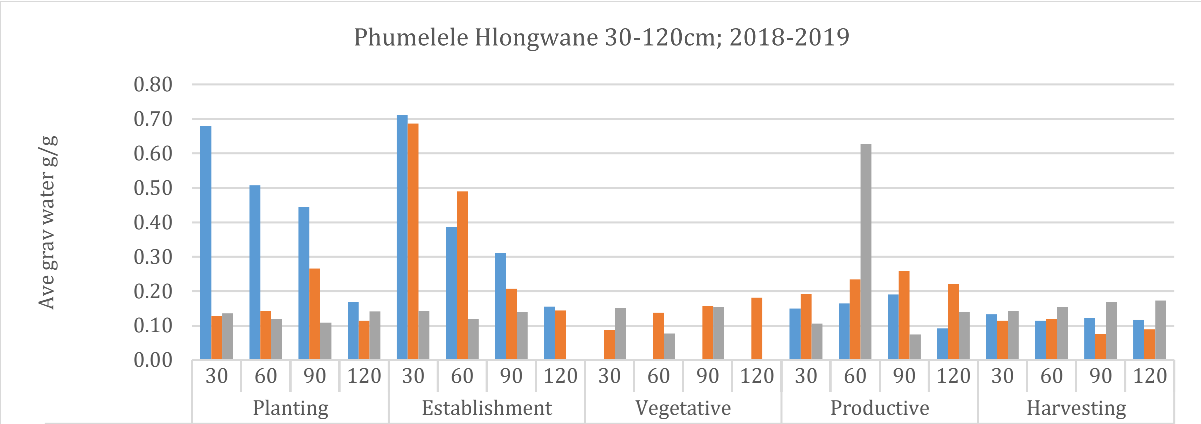


Figure 10: Comparison of gravimetric water content results between 2017-2018 and 2018-2019 season, for CA trial and control plots for Phumelele Hlongwane (Ezibomvini)

From the above figures the following observations can be made:

- Overall the water content was lower at the beginning of the season and higher at the end of the season for 2018-2019, when compared to 2017-2018. This trend follows the rainfall patterns and ETo for these two periods.
- For the 2018-2109 season the water content for the CA control for the planting and establishment phases is relatively high. It then dips sharply during the vegetative phase (result missing)
- For the CA trial plot water content during the establishment stage is high and dips sharply to a value below optimal growth during the vegetative growth stage.
- The gravimetric water content for the CA trial and CA control is higher during the productive phase than the conventional control for the 2018-2019 – indicating potential for better production from the CA plots.
- During the harvesting phase the water content for the CA trial plot for 2018-2019 is lower than the two control plots. This is likely an indication of continued active growth of the cover crops and lab-Lab beans planted in the trial.

The only conclusion that could confidently be drawn from these results is that the soil water content of the vegetative growth stage in 2018-2019, for the CA trial and CA control pots was well below the levels required for unimpeded crop growth. The high water content values are not congruent with the rainfall and ETo data gathered for this season and are hard to explain – unless per chance samples were taken very soon after rainfall events.



	Planting				Establishment				Vegetative				Productive				Harvesting			
	30	60	90	120	30	60	90	120	30	60	90	120	30	60	90	120	30	60	90	120
CA control	0.68	0.51	0.44	0.17	0.71	0.39	0.31	0.16					0.15	0.16	0.19	0.09	0.13	0.11	0.12	0.12
CA trial	0.13	0.14	0.27	0.11	0.69	0.49	0.21	0.14	0.09	0.14	0.16	0.18	0.19	0.23	0.26	0.22	0.11	0.12	0.08	0.09
Conv control	0.14	0.12	0.11	0.14	0.14	0.12	0.14		0.15	0.08	0.15		0.11	0.63	0.07	0.14	0.14	0.15	0.17	0.17

What can be seen from this figure is the following:

- There is a great reduction in water content in the soil, throughout the profile (30-120cm depth) moving from the vegetative to productive stages and in fact there is too little water in the soil during that period to sustain the crop growth as a gravimetric water content in clay-loam soils of 0,11 -0,14 (g/g) is required as a minimum prior to wilting point being reached
- The CA trial plots recovered well during the productive phase and indicate a higher soil water content than both the control plots throughout the soil profile. This points towards better water holding capacity in these soils linked to the multi cropping options and shows also that the potential competition during the vegetative growth phase did not continue into the productive phase
- Towards the end of the season (harvesting stage) the deeper soil levels have dried out considerable for the CA trial, more so than the control plots; indicating an increased drying in the lower levels of the soil profile for the multi-species CA trial. This is likely due to the continued growth of the Lab-Lab beans and cover crops, which were not present in the control plots.

Overall, for both seasons, the gravimetric soil water content of the CA trials are somewhat lower than the CA control plots. This indicates that the multi-cropping options used in the CA trial use more water than a monocropping option (such as used in the CA controls). This result is not unexpected. There is also an indication that the multi-cropping led to decreased water availability during the vegetative growth phase for the 2018-2019 season, which could in turn affect the maize yields for this season. The beans intercropped with maize died back during this period and no yields have been recorded. Cowpeas however, survived well. This provides a good indication of the drought tolerance of cowpeas. For the summer cover crop combination, sunflowers also died during this vegetative growth phase due to water shortages, but the millet and Sunnhemp survived well and seeded. Interestingly the water content is much improved for the CA trial when compared to the CA and conventional controls-indicating a good recovery for the CA trial plots in this phase

BULK DENSITY

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 17: Bulk density results for three CA participants

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

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

SOIL HEALTH

This season soil health analysis was undertaken for 10 participants across five villages in Bergville;

- Eqeleni (2) Stulwane (2); 6th year of implementation
- Ezibomvini (2); 5th year of CA implementation
- Mhlwazini (2); 3rd year of CA implementation
- Ndunwana (2); 3rd year of CA implementation

The intention is to compare the soil health characteristics for a number of cropping options within the CA trials, with conventionally tilled mono-cropped control plots, over time.

The soil health tests (as analysed by Soil Health Solutions in the Western Cape and Ward Laboratories in the USA) provides insight into microbial respiration and populations in the soil, organic and inorganic fractions of the main nutrients N, P and K, and assessment of organic carbon percentage organic matter (%OM). An overall soil health score (SH) is also provided for each sample.

Soil health tests parameters[5]

These analyses are benchmarked against natural veld for each participant, due to high local variation in soil health properties, measured at different times. The veld scores provide for high benchmarks to compare the cropping practices against.

Soil Respiration 1-day CO2-C: This result is one of the most important numbers in this soil test procedure. This number in ppm is the amount of CO2-C released in 24 hours from soil microbes after soil has been dried and rewetted (as occurs naturally in the field). This is a measure of the microbial biomass in the soil and is related to soil fertility and the potential for microbial activity. In most cases, the higher the number, the more fertile the soil.

[5] Haney/Soil Health Test Information Rev. 1.0 (2019). Lance Gunderson, Ward Laboratories Inc.

Microbes exist in soil in great abundance. They are highly adaptable to their environment and their composition, adaptability, and structure are a result of the environment they inhabit. They have adapted to the temperature, moisture levels, soil structure, crop and management inputs, as well as soil nutrient content. Since soil microbes are highly adaptive and are driven by their need to reproduce and by their need for acquiring C, N, and P in a ratio of 100: 10: 1 (C:N:P), it is safe to assume that soil microbes are a dependable indicator of soil health. Carbon is the driver of the soil nutrient-microbial recycling system.

Water extractable organic C (WEOC): Consists of sugars from root exudates, plus organic matter degradation. This number (in ppm) is the amount of organic C extracted from the soil with water. This C pool is roughly 80 times smaller than the total soil organic C pool (% Organic Matter) and reflects the energy source feeding soil microbes. A soil with 3% soil organic matter when measured with the same method (combustion) at a 0-3 inch sampling depth produces a 20,000 ppm C concentration. When the water extract from the same soil is analysed, the number typically ranges from 100-300 ppm C. The water extractable organic C reflects the quality of the C in the soil and is highly related to the microbial activity. On the other hand, % SOM is about the quantity of organic C. In other words, soil organic matter is the house that microbes live in, but what is being measured is the food they eat (WEOC and WEON).
If this value is low, it will reflect in the C02 evolution, which will also be low. So less organic carbon means less respiration from microorganisms, but again this relationship is unlikely to be linear. The Microbially Active Carbon (MAC = WEOC / ppm CO2) content is an expression of this relationship. If the percentage MAC is low, it means that nutrient cycling will also be low. One needs a %MAC of at least 20% for efficient nutrient cycling.

Water extractable organic N (WEON): Consists of Atmospheric N2 sequestration from free living N fixers, plus organic matter degradation. This number is the amount of the total water extractable N minus the inorganic N (NH4-N + NO3-N). This N pool is highly related to the water extractable organic C pool and will be easily broken down by soil microbes and released to the soil in inorganic N forms that are readily plant available.

Organic C: Organic N: This number is the ratio of organic C from the water extract to the amount of organic N in the water extract. This C:N ratio is a critical component of the nutrient cycle. Soil organic C and soil organic N are highly related to each other as well as the water extractable organic C and organic N pools. Therefore, we use the organic C:N ratio of the water extract since this is the ratio the soil microbes have readily available to them and is a more sensitive indicator than the soil C:N ratio. A soil C:N ratio above 20:1 generally indicates that no net N and P mineralization will occur. As the ratio decreases, more N and P are released to the soil solution which can be taken up by growing plants. This same mechanism is applied to the water extract. The lower this ratio is, the more organisms are active and the more available the food is to the plants. Good C:N ratios for plant growth are <15:1. The most ideal values for this ratio are between 8:1 and 15:1.

Soil Health Calculation: This number is calculated as 1-day CO2-C/10 plus WEOC/50 plus WEON/10 to include a weighted contribution of water extractable organic C and organic N. It represents the overall health of the soil system. It combines 5 independent measurements of the soil's biological properties. The calculation looks at the balance of soil C and N and their relationship to microbial activity. This soil health calculation number can vary from 0 to more than 50. This number should be above 7 and increase over time.

Some of the inter relationships between these variables are explored below

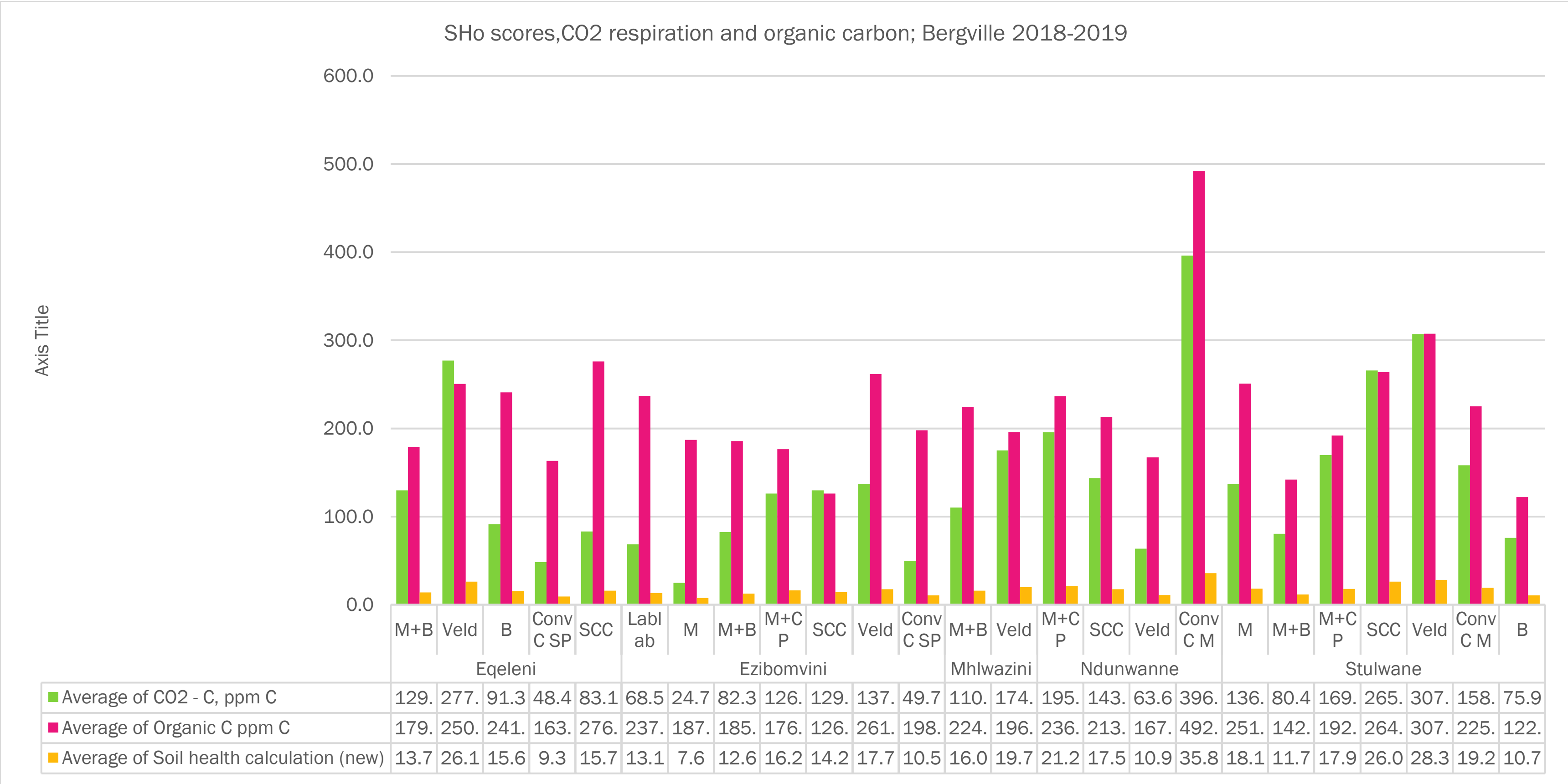


Figure 11: Comparison of the SH scores for Bergville participants (N=10) with microbial respiration and organic carbon.

The general assumption here is that if the level of organic C in a plot is high, then the microbial respiration will also be high, as will the soil health scores and vice versa. This is not always the case, as the relationship is not necessarily a linear one.

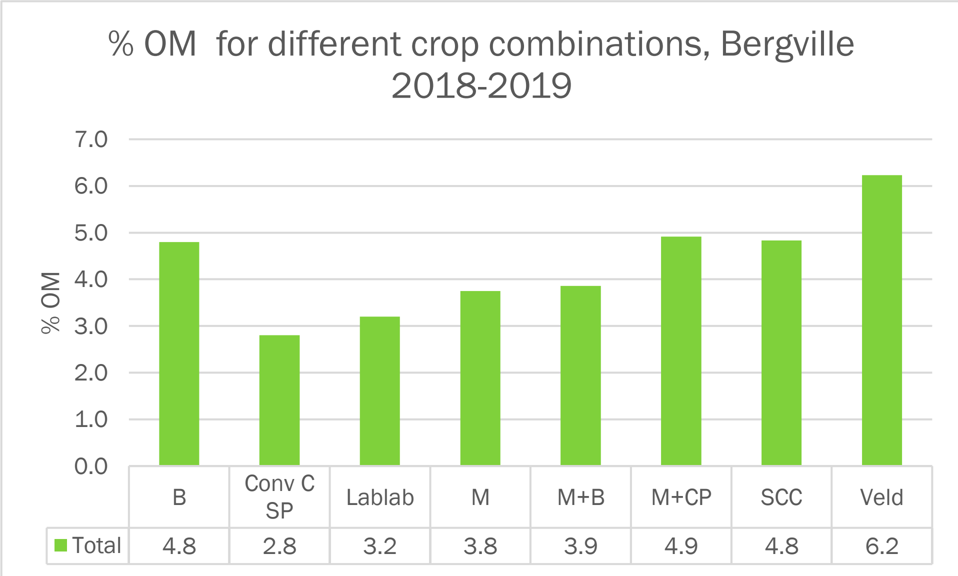
The CO_2-C respiration also gives and indication of the potential mineralisation of N for the soil as well as organic matter content. The small table below indicates these relationships.

Test results ppm CO_2-C	N mineralisation potential	Biomass
>100	High-N potential soil. Likely sufficient N for most crops	Soil very well supplied with organic matter. Biomass>2500ppm
61-100	Moderately-high. This soil has limited need for N supplementation	Ideal state of biological activity and adequate organic matter
31-60	Moderate. Supplemental N required	Requires new applications of stable organic matter. Biomass <1200ppm
6-30	Moderate-low. Will not provide sufficient N for most crops	Low in organic structure and microbial activity Biomass <500ppm
0-5	Little biological activity; requires significant fertilisation	Very inactive soil. Biomass<100ppm. Consider long term care

For the above figure the following trends can be seen:

- All the CA samples for all five villages fall within the >100ppm and 61-100ppm $C0_{2-}C$ respiration categories; indicating adequate to high levels of organic matter, an ideal state of biological activity and a moderate to high N- mineralisaton potential.

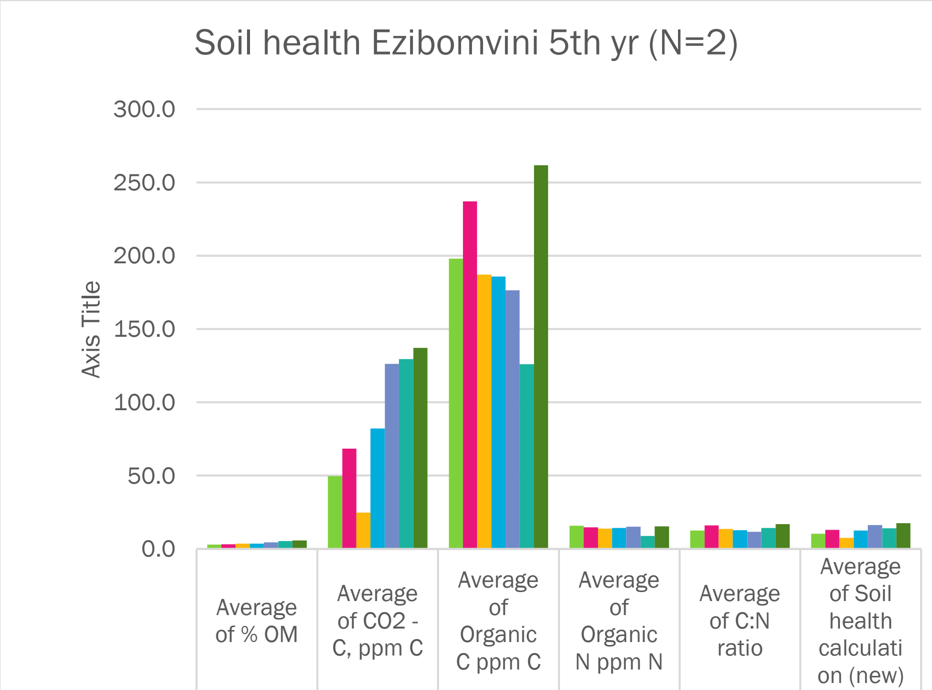
- The two Conventional tillage samples (sweet potato) fall within the moderate category where addition of organic matter is required as well as supplemental N. the Conventional maize control for Ndunwana however has extremely high respiration and organic carbon values – This value is somewhat of a mystery- as the benchmark veld samples for Ndunwana are quite low. The fact that it is a newly tilled plot, does not fully explain the result.



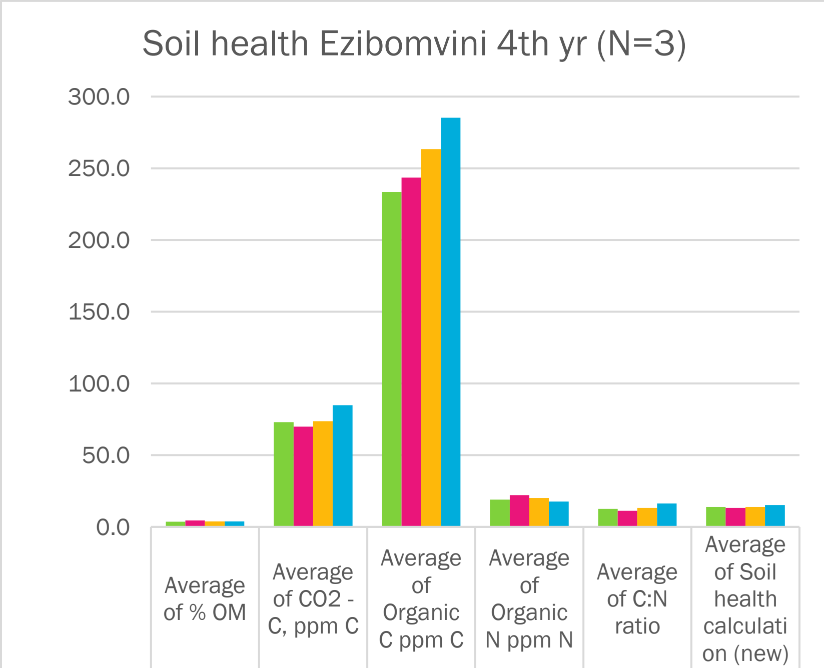
In conclusion the soil health status of the CA trial plots are moderately high to high, with good organic matter content and ideal states of biological activity, as indicated in the small figure alongside. The highest values for %Om are for the M+CP and SCC plots – which confirms the observations that these crop combinations are the bet at improving soil health in the short term.

Figure 12: % OM for different CA crop combinations in Bergville; 2018-2019

Below is a comparison of the soil health status for Ezibomvini across two seasons.



	Average of % OM	Average of CO2 - C, ppm C	Average of Organic C ppm C	Average of Organic N ppm N	Average of C:N ratio	Average of Soil health calculation (new)
Conv C SP	2.9	49.7	198.0	15.8	12.5	10.5
Lablab	3.2	68.5	237.0	14.7	16.1	13.1
M	3.6	24.7	187.0	13.8	13.6	7.6
M+B	3.6	82.3	185.7	14.4	12.8	12.6
M+CP	4.5	126.2	176.5	15.1	11.7	16.2
SCC	5.3	129.6	126.0	8.8	14.3	14.2
Veld	5.8	137.0	261.7	15.4	17.0	17.7



	Average of % OM	Average of CO2 - C, ppm C	Average of Organic C ppm C	Average of Organic N ppm N	Average of C:N ratio	Average of Soil health calculation (new)
Cont M	3.8	73.1	233.5	19.1	12.6	13.9
M+B	4.7	69.9	243.5	22.2	11.2	13.2
SCC	4.0	73.7	263.3	20.3	13.1	14.0
Veld	3.9	84.8	285.3	17.8	16.3	15.2

Figure 13: Comparison of Soil health indicators for Ezibomvini across two cropping seasons; 2017/18 and 2018/19

NOTE: CONV C SP ;conventional control sweet potatoes, LabLab; Dolichos beans, M;Maize, M+B; maize and bean intercrop, M+CP; Maize and cowpea intercrop, SCC; summer cover crop mix – millet, sunnhemp and sunflower)

When comparing the two graphs (4th and 5th year) above, it can be seen that the soil health scores (SH) are comparable for f the CA cropping options

- SCC (5th); SH=14,2 and SCC (4th); SH =14,0
- M+B (5th); SH=12,6 and M+B (4th); SH=13,2

The SH score for the veld samples however differ quite a lot; mainly due to a difference in measured Organic C and Organic N. In general, the Organic C and Organic N values for the 4th year are markedly higher than those measured for the 2018-2019 season. But the microbial respiration values for comparable CA samples (M+ and SCC) are markedly higher for the 5th year. While the flux and flow of organic nutrient availability and microbial growth are quite complex, with many interrelated parameters, the trends in decrease in organic C and N are considered to be related primarily to a slow, but definite drying of the soil profile over the last two years. The trend towards increased microbial activity in the multi-cropped (M+B, M+BP and SCC) and legume (Lab-Lab) plots in the 5th year clearly indicate the value of these practices for sustained soil health under conditions of climate variability (late onset of rain, variable rainfall and increased temperatures)

As mentioned above in the discussions around soil water content and water holding capacity, finding appropriate controls to compare the CA results against, has been a challenge. This season a conventional control plot was chosen where increased tillage and mono-cropping is practiced. The l=plot was planted to sweet potatoes. We however, did not take into account the historical land use of this plot, so while the lower % OM and microbial respiration was expected, the higher levels of organic N were not. We have not compared the Ca and conventional plots directly for this reason.

In addition, the CA maize plot for 2018-2019 (5th year), shows a very low microbial respiration rate, despite having reasonably high organic C and Organic N values. The understanding here is that there are localised differences in soil quality between the 10x10m CA plots in Phumelele Hlongwane's field that have reduced these values considerably. These differences are not directly related to the multi-cropping and crop-rotation practices for the CA trial, but are more likely due to a lower microbial count, or localised soil pathogens. This was reported on in the 2016-17 report, where a supplementary soil pathogen study conducted by the ARC showed high levels of root and crown rot fungal species in her CA plots; notably Fusarium and Phoma species.[6]. The data indicated that the severity of root rots is higher in the CA plots than the conventionally tilled plots.

This will be considered further under the PLFA result section. The table below indicates Phumelele's rotations in the last four years.

Plot no	**2015/16**	**2016/17**	**2017/18**	2018/19	**Run off plots**
1	M+B	M	M +WCC	SCC	Green squares indicate run-off plots
2	SCC	M	M+B	M+CP	Rotations have been done attempting to ensure a different crop/crop mix on each plot in each consecutive year. A further refinement of the schedule to be a 3-year rotation of; single crop – intercrop- cover
3	M+SCC+WCC	M+B	M	MCP	
4	M+B	LL	M	M+B	
5	LL	M	LL	M	
6	M+LL	SCC	M+CP	M+B	
7	M+CP	M	M+CP	M+B	
8	M+B	M+CP	B	M+B	
9	M+CP	M+B	SCC	M	
10	M+B	M+B	M	LL	
		CA Control: M	CA Control: M	CA Control M	

[6] Agricultural Research Council. Plant Protection Research Institute. P/Bag X134, Queenswood, Pretoria 0121. Preliminary Consultation Report-Analyses Of Soil borne Diseases Of Maize, Soybean And Sunflower – Soil Health Project. Prepared by: Dr Sandra Lamprecht and Thabo Phasoana. Tel: (021) 887 4690 Fax: (021) 887 5096. Email: lamprechts@arc.agric.za

					crop, will be adhered to into the future
	Control: M (CA)		CA Control: M+B (CA)	Conventional control: SP	

For 2018-2019 (5th year) the soil health results indicate the following trends:

- The average % OM is higher for all the CA cropping options when compared to the conventional control. The SCC CA plot has a value close to that of the natural veld sample, indicating the greatest build- up of organic carbon for this cropping option. This trend was also noticed for the 2017-2018 cropping season (4th year)
- The microbial respiration is highest for the SCC CA plot, followed by the maize and legume (cowpea, bean) intercropped plots and Lab-Lab beans and is lowest for the mono-cropped maize. A similar trend was noticed for the 2017-2018 cropping season (4th year).
- The average organic N is the highest for the three CA pots containing legumes (Lab-Lab, M+B and M+CP). And lowest for the SCC plot. A similar trend was noticed for the 2017-2018 cropping season (4th year).
- A low C:N ratio is considered beneficial for nutrient availability for crop growth. The lowest values are found for the CA intercropped plots (M+B and M+CP), followed by the CA maize plot. Again, the trend is similar to the 2017-2018 results

The Conventional control plot showed the highest average organic N value (15,8ppm).

Using the soil health test results, it is also possible to explore the composition of the microbial population in the soil, looking at the different types of microorganisms and their prevalence.

,

Volumetric Aggregate stability %				
0 - 15 %	15 - 30 %	30 - 45 %	45 - 60%	> 60%
Very low	Low	Average	Good	Excellent

Generally it is known that conventional tillage systems favour decomposer/saprophytic fungi, with small hyphal networks. These are important in soil fertility but play a very small role in carbon storage. Conservation Agriculture systems favour Mycorrhizal fungi which have large hyphal networks and play a major role in carbon storage. Mycorrhizal fungi get their energy in a liquid form, as soluble carbon directly from actively growing plants. They access and transport water - plus nutrients such as phosphorus, nitrogen and zinc - in exchange for carbon from plants. Soluble carbon is also channelled into soil aggregates via the hyphae of mycorrhizal fungi and can undergo humification, a process in which simple sugars are made up into highly complex carbon polymers. Aggregate stability is thus an important emerging quality of the soil under CA. It is measured as % volumetric stability, as shown in the small table alongside.

From the soil health, microbial respiration and organic carbon data for Ezibomvini and Ndunwana, the expectation is that aggregate stability will be good to excellent. This is indeed the case for Ndunwana (as shown in Figure 5), where the values % range from 45-46,5%. For Ezibomvini however, there is a range of values from low, through average to good. This would mean, among other things, that the Mycorrhizal fungi populations in the Ezibomvini soils are not building up as expected and shows high variation between plots (within on field).

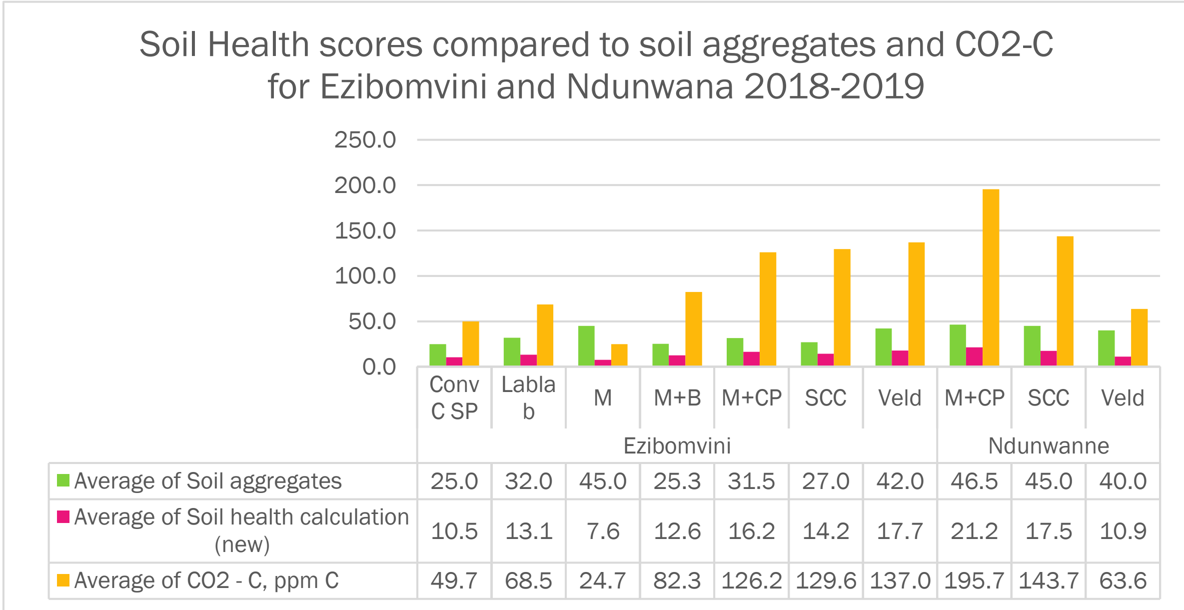
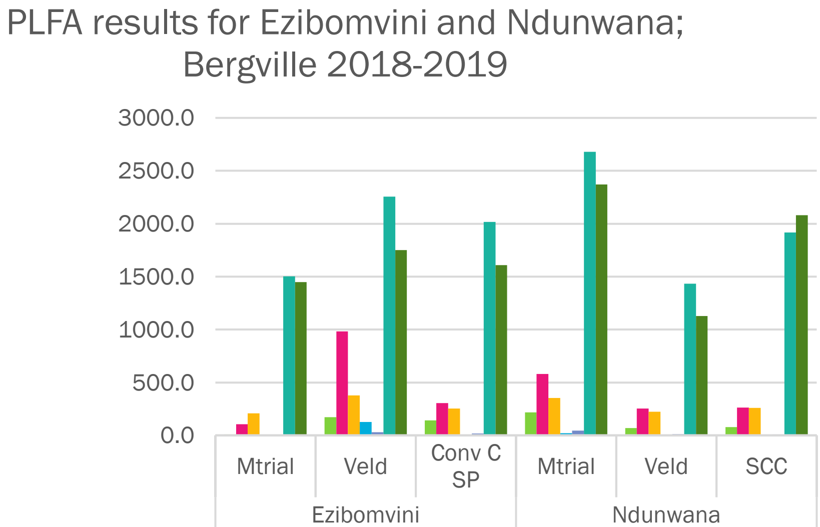


Figure 14: A comparison of % aggregate stability for soil health samples from Ezibomvini and Ndunwana

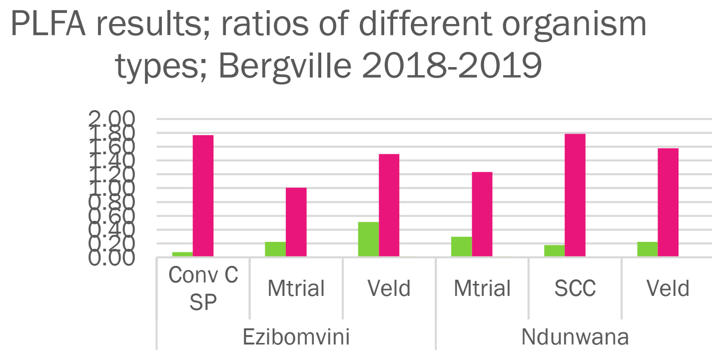
The PLFA analysis conducted and presented below, sheds some light on this.

PLFA ANALYSIS

PLFA (Phospholipid – fatty acid) analysis of the microbial populations in the samples provides a breakdown of the type of organism present; bacteria, fungi and protozoa, as well as their relative abundance. This is based on the different and distinguishable biochemical structures and processes for these organisms. Although this analysis can get very complex two simplified snapshots of the process are provided in the figures below



	Ezibomvini			Ndunwana		
	Mtrial	Veld	Conv C SP	Mtrial	Veld	SCC
Average of Arbuscular Mycorrhizal	9.4	170.8	140.9	217.4	68.1	79.4
Average of Saprophytes	104.6	982.4	305.3	581.5	253.7	264.1
Average of Actinomycetes biomass	208.4	376.7	253.2	352.8	223.5	259.4
Average of Rhizobia	0.0	126.0	0.0	21.3	0.0	0.0
Average of Protozoa biomass	0.0	29.7	17.9	44.7	13.0	8.8
Average of Bacteria biomass	1504.0	2257.3	2015.7	2679.2	1433.2	1917.0
Average of Undifferentiated	1448.4	1750.2	1610.1	2369.3	1128.5	2081.4



	Ezibomvini			Ndunwana		
	Conv C SP	Mtrial	Veld	Mtrial	SCC	Veld
Average of Fungi:Bacteria	0.08	0.22	0.51	0.30	0.18	0.22
Average of Gram(+):Gram(-)	1.77	1.00	1.49	1.24	1.79	1.58
Average of Predator:Prey	0.00	0.01	0.01	0.02	0.00	0.01

Figure 15: PLFA results for microbial populations from Ezibomvini and Ndunwana soil health samples; Bergville 2018-2019

From the above figures on PLFA results the following trends can be seen:

- Mycorrhizal fungi populations for the CA maize (Mtrial) in Ezibomvini as extremely low, when compared to the veld sample and the samples from Ndunwana; although the Mycorrhizal populations are quite small when compared to the overall microbial populations present in these sites.
- For the Ezibomvini samples the total microbial biomass for the Mtrial sample is lower than the Conventional control sample. This low microbial mass is not reflected in the %OM (3,65) or the organic carbon (187ppm) and organic nitrogen (13,8ppm) content of the plot; these values being quite high.

This means that the microbial biomass in this particular plot is being dampened for another reason, the most likely being disease, shown in the 2nd graph in Figure 6 above. Here the proportion of gram -bacteria in the soil is higher than any of the other plots tested and the reasonably high proportion of fungi:bacteria (0,22) when compared to the other samples, points towards a possibility of disease causing fungal species. From this and other analyses done, it would appear that this situation is specific to this plot (and perhaps 2 others) in Phumlele Hlongwane's CA trail.

- Mycorrhizal fungi populations in the CA trail plots (Maize and SCC) are considerably higher than the veld benchmark, indicating the expected build-up of these fungi in the CA cropping system

NITROGEN

In the dryland cropping system around Bergville, as in most other dryland cropping areas in South Africa, supplementation with inorganic Nitrogen is considered an important strategy for optimal crop growth. In our CA study different crop combinations and cropping options are being explored to assess the potential of providing this nitrogen through improvement of natural nutrient flow cycles. Inorganic N, besides being expensive, also has been shown to dampen the natural microbial activity in the soil and can also be partially ineffective under extreme conditions of drought and heat.

An analysis of immediate release N has been done, as well as an estimation of the rand value of inorganic nitrogen saved /ha for different cropping options under CA. The immediate release N- is the water extractable organic Nitrogen, which is immediately available to the next crop.

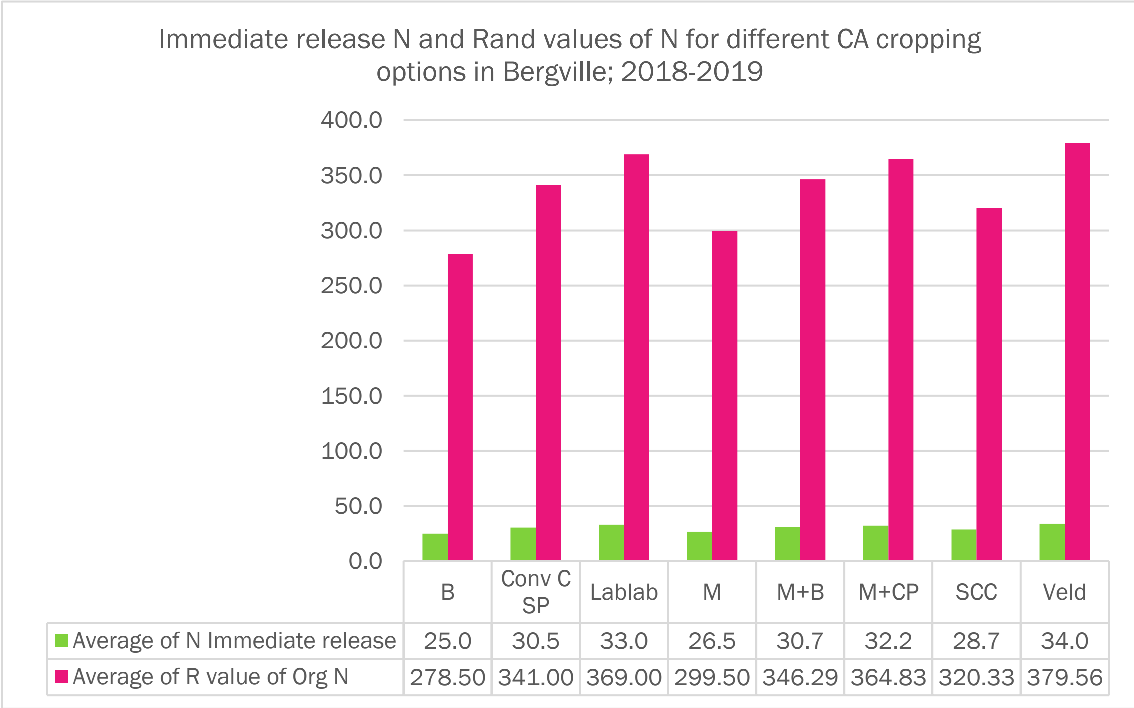
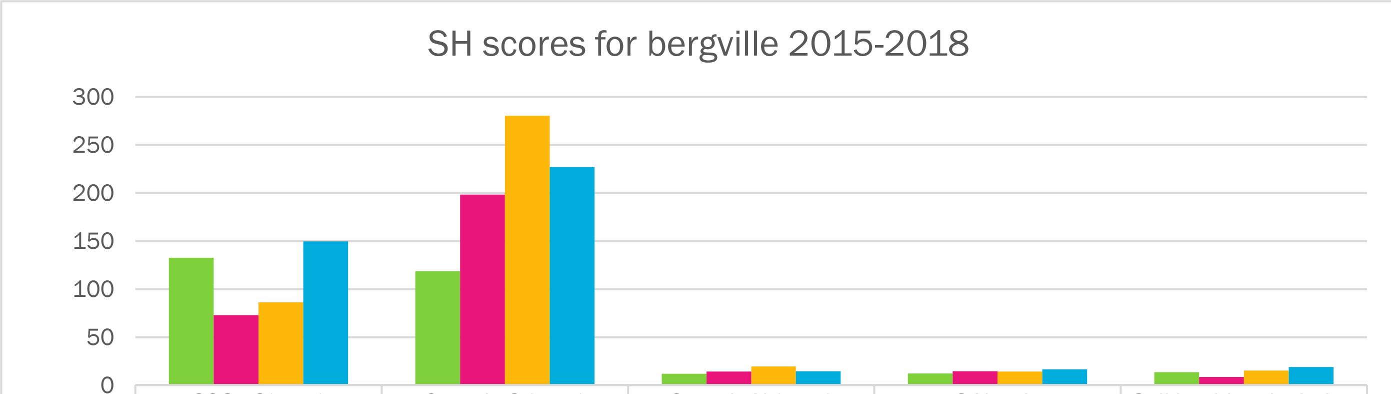


Figure 16:Comparison of immediate release N and Rand value of inorganic Nitrogen substituted for organic N for 5 villages in Bergville; 2018-2019

From this figure the expected progression of increase in available N from a CA maize monocrop – a summer cover crop mix to a maize and bean intercrop – a maize and cowpea intercrop is clearly visible. The CA beans only plot has a somewhat unexpectedly low result. On average the rand value of inorganic N saved in this process is R318/ha. If a recommendation of 60Kg/ha of N is used, this equates to a saving of around 47% on inorganic fertilizer – more specifically for the plots that integrate legumes (M+B, M+CP and Lab-Lab beans). The average rand value for inorganic N saved in the previous season (2017), was R393. It is assumed that this value is higher because of the higher soil water content (better soil water distribution in the soil profile throughout the season). This indicates the effect of heat and dry soil profiles on the ability of the soils to process and maintain nutrients.

COMPARISON OF SH TEST RESULTS 2015-2018

One can compare the soil health data for the different participants over time to track improvement in soil health scores. The assumption is that soil health will improve over time with CA implementation. The figure below summarises the data for five participants between 2015/16 to 2018/19



	CO2 - C(ppm)	Organic C (ppm)	Organic N (ppm)	C:N ratio	Soil health calculation
2015	132.7	118.5	11.65	12.1	13.6
2016	72.95	198.55	14.025	14.55	8.525
2017	86.2	280.5	19.4	14.0	15.2
2018	149.68	227.02	14.62	16.58	18.74

Figure 17: Soil health data for 5 participants from Bergville;2015-2018

From the above figure the following trends are visible:

- Soil health scores have increased between 2015-2018 and the average SH score for 2017/18 is 18,74.
- Despite the fluctuations in Co_{2_C} (microbial respiration) organic carbon and organic nitrogen in the four years of measurement, the overall values have increased substantially since 2015.
- Interestingly the C:N ration has been systematically increasing – rather than the expected reduction. It indicates a higher proportional increase in organic nitrogen in the soil, as compared to organic carbon through the CA practices employed in the programme. It is likely also an effect of a somewhat reduced ability to improve organic carbon in the soil through the traditional practice of livestock grazing on crop residues.
- ,The extreme climatic conditions in the area, including heat and dry soil profiles, reduces the soil health impact of the CA practices and also increases variability in the results for different seasons.

2.4 Alice/King Williams Town- EC

Written by Mazwi Dlamini

2.4.1 Introduction

For the past season there have been challenges in data collection from the tunnel experimentation site at Zingisa in Berlin, mainly due to the unavailability of dedicated personnel at the training garden where the process was set up. The student from Fort Cox ATI to whom this responsibility was given, was unable to focus sufficiently. The personnel would oversee the watering and maintenance of the experimental as well providing readings on a regular basis. The sensors were mainly to be used as a tool to determine watering needs on the experiment.

More recently Nompumelelo Mendwana has since joined Zingisa and will be based on site as an intern (from Fort Cox ATI). Some duties assigned to her are that of making sure that experiments on site are maintained, records of both rainfall events and watering patterns noted and data uploaded. Nompumelelo has also agreed to a monthly report on the progress of crops; growth, replanting, harvests, pests and diseases and any other comments worth mentioning. She was also assisted in setting up her phone to connect to the sensors and has been provided with 500MB of data monthly for her to upload data on a weekly basis.

2.4.2 Progress thus far

The tunnel has been doing quite well, the structure is still intact with no holes around it and crops in the tunnel are growing well with cooler soil. Crops in the tunnel have been requiring less water when compared to crops outside the tunnel. For a very long period, the sensors were showing beds to be dry, despite the insistence of the interns that they were watering these beds. A decision was taken to double the amount of water provided from 20L to 40L every three days. Since this, sensors on the VIA website have been positively responding to the increased amount of water on the beds. Soil samples were also taken for chemical analysis and showed what we suspected; these are hydrophobic infertile grey soils with a tendency to compaction and are extremely hard when dry. No specific problems in the soil chemistry have been noted.

A summary of the chameleon readings for the three beds (raised bed outside tunnel, trench bed outside tunnel and trench bed inside the tunnel) indicate that finally enough water is being provided to the beds (April-July 2019). During July, irrigation has stopped, as the broccoli planted has now been harvested and the beds are being prepared for the next cropping season.

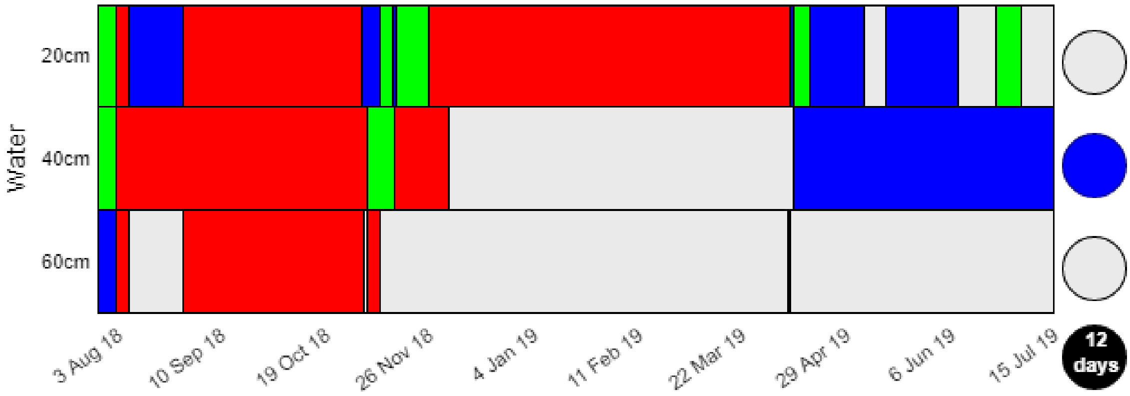


Figure 18: Chameleon data for the trench bed inside the tunnel: EC July 2019

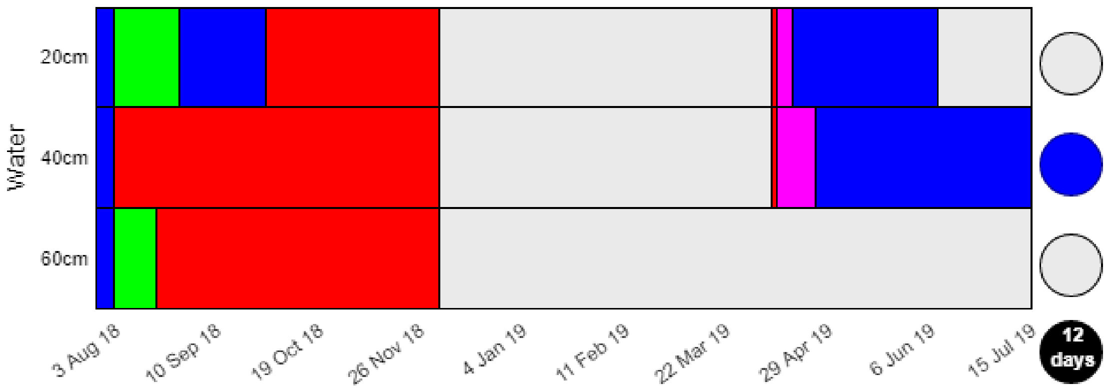


Figure 19: Chameleon data for the trench bed outside the tunnel: EC July 2019

The purple colour indicated in the trench bed outside the tunnel is due to high levels of humic acids, due to organic matter decomposition and were due to a new trench bed being made for the purposes of this experiment.

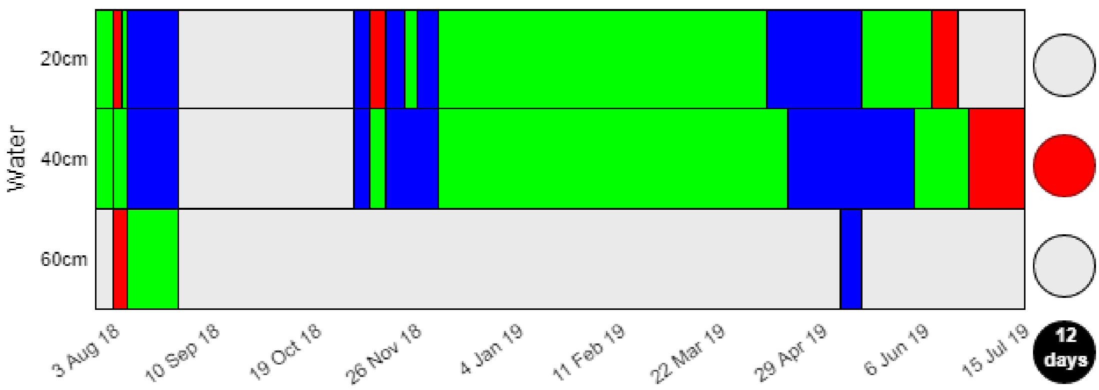


Figure 20: Chameleon data for the raised bed outside the tunnel

Growth comparisons inside and outside the tunnel have not been made in any coherent manner, but the student did not notice much of a difference – as indicated in the two photographs below. He photographs indicate broccoli plants form which the heads have already been harvested. The process of monitoring crop growth and yields has again been inconsistent.

Figure 21: Comparison of crops outside (left) and inside (right) the tunnel

2.5 Sedawa, Turkey, Mametja - Limpopo

Written by Erna Kruger, Mazwi Dlamini and Betty Maimela

Most of the fieldwork and monitoring are conducted under the AWARD AgriSi programme. Below a snapshot is provided of some of the CCA related aspects pertinent to this process. The adaptation impact assessment and resilience snapshot methodology designed under this research process was used to get an indication of impact for 6 participants in the Limpopo learning groups.

Learning processes for the Limpopo learning groups conducted are summarised in the table below.

Table 18*: Summary of learning sessions conducted: May-July 2019*

Turkey 1 and 2, Sedawa, Mametja, Botshabelo,	**Dated**	**Activity**	**No of participants**	**Comments**
Turkey, Sedawa, Mamejta, Botshabelo	2019/05/08-12	Individual garden monitoring	21	Assessment of integration of CSA learning into gardening and field cropping implementation
Turkey, Sedawa, Lepelle	2019/05/16	Organic mango production post training monitoring	10	To assess how well participants have been implementing their organic mango production – working towards a PGS and marketing strategy
Turkey	2019/05/23	Natural pest and disease control workshop	11	To assist the group with garden management and pest control issues in their shade cloth tunnels

Sedawa, Turkey,	2019/05/07/09, 2019/06/07 and 2019/07/02	S&W conservation and small dam construction	11, 8, 12, 15	Construction of check dams, stone lines, swales and shallow trenches as well as small dams sealed with bentonite- with planning for inflow and overflow
Sedawa, turkey	2019/06/10-13	Resilience snapshots	6	Individual interviews, to test the impact assessment methodology in Limpopo
Willows	2019/06/27, 07/04, 07/07	Crop management and soil health workshop, trench bed construction with CWP team and garden monitoring follow up	12,16	These were essentially revision workshops to re-introduce CRA practices to new members in the learning group
Sedawa, Turkey	2019/06/28	Cropping calendar	16	Betty and the group worked through this process- to assist with record keeping and planning for plating
Turkey	2019/06/29	Provision of 20 layers for small layers unit in Turkey	9	The Phedisang Turkey DIC group and a few members of learning group, Mazwi Dlamini
Turkey, Sedawa	2019/06/28	Proposal writing for community level water proposals	15,18	Water committees were assisted to write proposals to the US embassy for funding their cooperative development of boreholes for irrigation

2.5.1 Resilience snapshots

6 participants from Sedawa and Turkey in Limpopo were interviewed. The results are summarise below.

1. Learning and change

Question 1: What have you learnt about dealing with CC and climatic extremes?

- I have learnt that practices such as trench beds and tunnels provide good growth and yields, despite difficult weather conditions. Also, these practices are cheap. Although it is initially a lot of work, the increased yields make a big difference. We get more food than we did before and will now be able to continue farming

- Tunnels also help in reducing heat and water stress in plants and this leads to much better production
- Tunnels help in this extreme heat by protecting our vegetables from heat and pests. Climate smart practices enable us to continue with farming activities even in this difficult climate change.
- Having a tunnel and mulching inside the tunnel is the best in water management for irrigation.
- Irrigation management, such as using drip kits help a lot as there is less evaporation and water is saved. It also saves time.
- Working with mixed cropping and crop rotation has decreased the incidence of pests and diseases, although there are still problems.
- Including more organic matter in the soil helps to hold water and to protect plants from heat stress.
- Working with the five fingers principles [manage soil movement, manage soil fertility, manage water, manage crops and manage natural resources) (tool) helps to keep in mind all different aspects to include in changing practices
- Using liquid manure and mixed cropping means that I now do not need any other means for pest and disease control.
- I have learnt about practices that will help me continue with farming activities even though water is a struggle and the sun is too hot for any vegetable to survive in our environment, the little we have been given is better than nothing.
- Leaving the soil exposed to heat and rain and turning over the soil to plough and plant has destroyed the soil making it infertile and very hard. Improving the soil takes time, but makes a big difference in growth of crops.
- I learnt to conserve water, by using grey water and mulching in my garden. I also learnt a lot on the importance of soil health.
- I have learned the importance of saving water and the conserving our soil.
- I have experienced harsh weather with no rain and harvests using our traditional ways of farming, which affected our livelihood as we had to buy all vegetables instead of growing them myself. Now I know how to deal with changes of climate, since I met Mahlathini and AWARD, and they taught us practices that changed my life. I don’t buy vegetables that I need every day, I pick from my garden.

Question 2: What is your experience regarding the impact of CC on your life?

- Climate change has been hard on us, especially on our farming activities. Farming seems impossible in this condition, especially with no rain. Being unemployed and relying on old age grant is even worse, as the head of the household; farming makes it better because you farm for both consumption and making an income

Question 3: Do you share your knowledge and experiences with the learning group or community members?

- Yes, I talk to my neighbours about the gardening practices, so that they can also try and revive their gardens
- Yes, I share my experiences and knowledge with community members at the workshops and my neighbours; by telling them what we do and how the knowledge is helping us in terms of making things better
- Yes, I share my knowledge, especially with unemployed members of the community because I am making a living and I don't go hungry with my small garden

Question 4: How do you share the knowledge gained with other members of your community?

- Discussions at savings meetings, at the springs when we collect water
- By inviting them to join us on our meetings and sharing experiences
- Always have meetings where we invite community members to join and we share all knowledge and experiences
- I invite people community members to attend meeting with us and also allow community members in my household
- I share my experiences and knowledge learned from working with Mahlathini with the community and I also recruit new members to join and learn like am learning.
- I do visits community members selling them vegetables and share with them what I have learned and how it is helping me, to encourage them to see what we are benefiting to better our finance and was of farming

Question 5: What helps you to learn more about new innovations and information?

	No (N=6)	**Comments**
Listening to other farmers experiences and experiments	5	
By doing and experimenting in own garden	5	
Motivated by other farmers work and experiences	4	This helps to motivate me to try out some of the ideas myself
Learning workshops	5	

Question 6: What new things have you added into your practices? How has it worked?

- The shade net tunnels work very well to reduce heat and water stress and there are fewer pests. We have added further shade- netting structures in our gardens
- I have made my own version of a drip-kit using and old bucket and piping. This saves water and time

- We dig small dams in our gardens during the summer months, so that the added water can penetrate into the soil and there is enough moisture in the soil to grow our dryland crops such as maize, cowpeas, peanuts and sweet potatoes
- Using manure and mulching in our traditional beds- the furrows and ridges has helped to increase crop survival and yields
- The tower gardens are very productive and this is a nice, clean way of using greywater, which is sometimes the only water for gardening we have access to.

2. Climate smart practices

Section 1: Impacts and lessons learnt

Past Issues	Past practice	Present practice	Impact	Lessons
Drying fast, wilting of plants, having to irrigate often	Exposing the soil	Cover the soil by mulching and farming inside the tunnel	Less evaporation and my vegetables don't dry out quickly	Learned the importance of covering the soil and good water management
Poor quality vegetables	Not fertilising the soil and disturbing the soil	Adding organic material to the soil and minimum soil disturbance	Good soil condition and healthy vegetables	I have to look after my soil in order to continue with my farming activities because I love farming
Pest and disease problems	Used ash -which is only effective for certain pests	Use liquid manure made from weeds and cow manure, I also use mixed cropping for pest and disease control	Very good and effective	We don't need chemicals to fight pests and disease in our garden as they will affect our soil and our health
Pest problems	Using blue death	Use liquid manure for both soil fertility and pest and disease control	Healthy vegetables and good soil conditions	We can use organic materials from our household to treat pests and diseases without using chemicals
Soil erosion	Turning the soil when planting maize and cover crops.	Minimum soil disturbance when planting maize (CA)	Softer soil that holds more water, better yields	I learned that I have to conserve my soil, always cover my soil.

Section 2: Assessment of impact for CSA practices tried out using local indicators

Scale:

-1 = worse than normal practice
0=no change
1=some positive change
2=medium positive change
3= high positive change

	Name of practice	Soil	Water	Productivity	Labour	Pest and disease control	Cost and maintenance	Livelihoods	Adaptation to extreme weather conditions
1	Trench beds	2	2	2	-1	0	2	2	2
2	Tunnels (w trench beds)	2	3	3	-1	2	1	3	3
3	Mulching	1	1	2	1	2	2	1	1
4	Mixed cropping and crop rotation	0	1	1	1	2	2	1	1
4	Tower gardens	2	3	3	2	0	0	2	2
5	Planting basins	0	2	2	0	0	1	1	1
7	Raised beds, with mulch	1	2	2	1	0	1	0	1
8	eco-circle	2	3	2	-1	1	0	1	1
9	CA; w intercropping, legumes, cover crops	3	2	3	1	1	0	2	2
1o	Using goat manure (composted in a kraal)	3	1	2	0	1	0	1	1

Section 3: Resilience snapshot

This section was compiled from a combination of all 6 interviewee responses.

Resilience indicators	Rating for increase	Comment
Increase in size of farming activities	Gardening; 1% Field cropping; – 98% Livestock; 6%	Cropping areas measured, no of livestock assessed Dryland cropping has reduced significantly due to drought conditions and infertile soil
Increased farming activities	No	Most participants involved primarily in gardening, with some field cropping and livestock management
Increased season	Yes	For field cropping and gardening- autumn and winter options

Increased crop diversity	Crops: 21 new crops Practices: 11 new practices	Management options include; drip irrigation, tunnels, no-till planters, JoJo tanks, RWH drums,
Increased productivity	Gardening; 120% Field cropping: 15% Livestock: 6%	Based on increase in yields (mainly from tunnels and trench beds for gardening CA for field cropping
Increased water use efficiency	45%	Access, RWH, water holding capacity and irrigation efficiency rated
Increased income	13%	Based on average monthly incomes, mostly though marketing of produce locally and through the organic marketing system
Increased household food provisioning	Vegetables; 7-10kg/week Fruit; 5-10kg/week Dryland crops (maize, legumes, sweet potatoes); 5-10kg/week	Food produced and consumed in the household
Increased savings	Not applicable	Participants are not formally involved in saving activities
Increased social agency (collaborative actions)	2	Learning groups and local water committees
Increased informed decision making	5	Own experience, local facilitators, other farmers, facilitators, extension officers
Positive mindsets	2-3	More to much more positive about the future: Much improved household food security and food availability

4. Conclusion

This resilience snapshot process provides a very clear indication of the contribution of agroecological and climate smart practices in gardening and field cropping to the resilience of local livelihoods for these households. Participants have increased their productivity; by more than doubling their household food provisioning and increasing their monthly incomes by 13%.

2.5.2 **Monitoring of field cropping and CA in Limpopo**

It has been 4 years since farmers in the Lower Olifants' Basin have had enough rain to harvest their dryland crops at the end of the summer season. This season started like the previous years, with rain only properly starting in early January 2019. Despite this late start farmers in the RESILMO Agricultural Support Initiative took to their fields with enthusiasm. They included experiments in field cropping, using the Conservation Agriculture principles introduced; namely, minimal soil disturbance (no ploughing), keeping the soil covered (mulch and crop residues) and crop diversity (intercropping and planting of legumes and cover crops).

Figure 22:Above and alongside) are examples of maize planted using CA principles in Sedawa and Turkey villages.

With all the changes in rainfall patterns and extreme heat, farmers are acutely aware of the impacts of climate change on their environment and their farming patterns. The effects on their ability to produce food under rainfed conditions have been significant, as besides not being able to farm for the past four seasons, this time period has also meant that many smallholders have lost their seed stock for planting. In pockets, individuals with the ability to provide some supplementary irrigation have managed to keep seed stocks of groundnuts, jugo beans (Bamabara groundnuts, cowpeas and sorghum, alongside their traditional cucurbits, pumpkins, butternut and watermelons. They have been supported to re-introduce maize and a range of cover crops such as sugar beans, cowpeas, sunflower, Sunnhemp, millet, black oats, fodder rye and fodder radish) on the understanding that the increased water use efficiency allowed through CA could sustain these crops, or some of them at least, in the lower rainfall years. Although maize is not a particularly drought resistant crop, the farmers were determined to plant maize, despite the potential of low yields and crop failure.

Below are a few snapshots of the farmers' cropping and learning process for 2018-2019. Around 50 farmers from 3 villages in the Lower Olifants (Sedawa, Botshabelo and Turkey) participated. They all planted a range of crops; maize, legume (cow-peas, groundnuts, sugar beans) and cucurbits (butternut, Mokopu (traditional gourds), pumpkin, water melons), from which they managed to harvest – even though in some cases crops did not survive. Some farmers planted in their household plots, while others took a chance and planted in their larger fields.

Potential advantages of CA that participants observed in their fields include:

- Increased water holding capacity of the soil
- Reduced erosion
- Reduced heat stress for crops
- Improved soil health and soil fertility
- Reduced pest attacks

Figure 23:Above left: Mpelesi Sekgobela's (Turkey) CA intercropping plot (maize and bambara groundnut), planted across a slope for erosion control and water retention and Above right: Her field with maize, cowpea and pumpkin intercropping

Farmers also noticed other differences between their local system and the CA experiments. For example, they noticed that the narrow spacing of crops in the CA system worked a lot better than the preferred wider spacing in the area. They worked on the understanding that the wider spacing reduces water stress, as does monocropping, but found that the intercropping and close spacing increased the potential of survival of their crops considerably. They realised that the cover provided by the closely spaced grain-legume intercrop improves water holding and reduces the effect of extreme heat.

Farmers also combined their traditional practices of making furrows and ridges, with the use of compost and manure to good effect.

Figure 24: Above Left: Meisie Mokoena's (Mametja) conventionally planted maize and cowpea plot; most of the maize didn't germinate and Above right; a maize, cowpea and pumpkin intercrop planted in furrows and ridges, with addition of compost

Figure 25:*Above: In Meisie's field she tried a number of different practices; different planting times, intercropping and monocropping, mulching, stone lines and furrows and ridges.*

In this way, and despite a high stalk borer load in the maize, farmers managed to harvest a range of crops, including maize. For their conventionally planted plots, most farmers suffered crop failure again. Yields in the CA plots have still been rather low, at around 80kg/ 1000m^2 (~1,5t/ha). In good seasons, in the past, farmers remember averaging around 240kg (~6,5t/ha) for similar sized plots. The maize harvested is used to make maize meal locally, at a cost of R50 for 12,5kg of maize. Although these yields are only around 25% of the locally understood yield potential, farmers remain determined to produce maize.

Miriam Malepe (Botshabelo)

Mariam Malepe is the local facilitator for Botshabelo. She didn't follow the CA principles in her household when she was planting maize and cover crops, opting instead to have a young boy plough for her. She had zero harvest from this plot, where a combination of run-off damage and heat destroyed her crops. She then decided to follow the CA principles in her big field, a small distance from her homestead and here she harvested of water melons, pumpkins, ground nuts, cow-peas, Mokopu (traditional gourd) and maize.

Figure 26: Right above: Miriam's watermelon yield. She sells them at R10/ melon in her village and will make around R700, to use towards household needs. Right below: Miriam drying and preparing her maize.

Maria Morema (Sedawa)

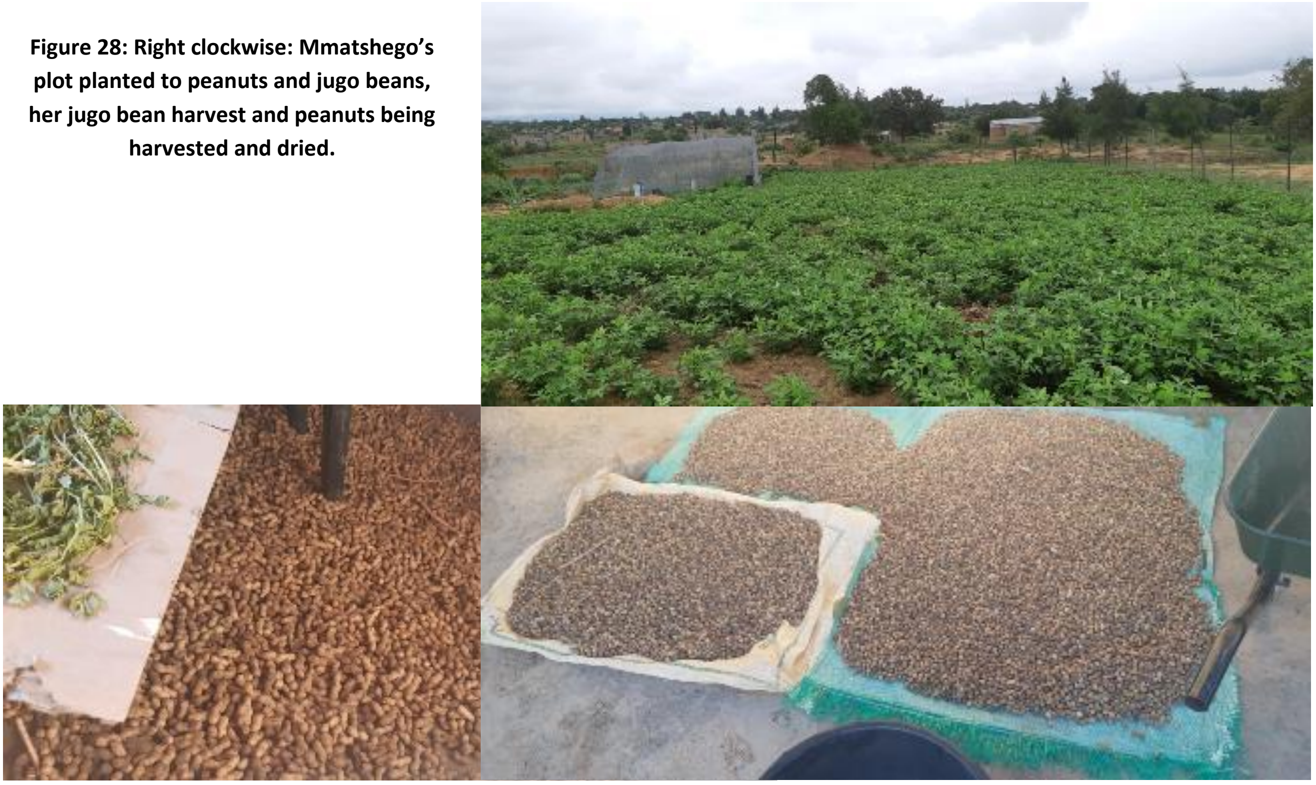
She planted maize, sorghum, pumpkins, cow-peas, watermelons and ground nuts both in her field which is in the mountains and her house hold plot. She sells both pumpkins and watermelons locally for R10 each and they are also eating them.

Figure 27:Right clockwise: Maria's maize and pumpkin intercrop, a watermelon and some of her sorghum harvest

Mmatshego Shaai (Turkey)

Mmatshego Shaai from Turkey planted ground nuts and Bambara nuts in her household plot. She did not plant maize, due to the dryness of the season. She has received a good harvest and has sold both the peanuts and the jugo beans locally, making around R600 to supplement household use and also has kept seed for future planting.

Figure 28: Right clockwise: Mmatshego's plot planted to peanuts and jugo beans, her jugo bean harvest and peanuts being harvested and dried.



4. Conclusion

These smallholder farmers have shown a remarkable ability to adapt to their changing conditions through using a combination of traditional and introduced climate resilient practices and through planting a variety of drought tolerant crops alongside their maize.

Even though maize didn't grow all that well, farmers have found ways to incorporate and keep this crop going in their farming system, despite the rainfall still being far below optimal at around 380mm for the summer rainfall period (October 2018-April2019)

Figure 29: Above left: A good stand of CA maize in Abridge Tshetlha's field in Sedawa and Above right: Makibeng Moradiya providing some green maize to her friend and local facilitator Christina Thobejane

2.5.3 Soil and water conservation at homestead level

A workshop was held in Turkey 1, at Lucas Makawane's household on the 7th of May 2019. This was upon request form the learning group participants and the household members; who were primarily concerned with seepage from a spring in the homestead above.

OUTLINE OF AGENDA

1. Brief review of 5 fingers implementation in Turkey; highlight lack of activities in soil and water management
2. Discuss issues of waterflow in the homestead – where waterflows, issues with erosion, runoff, water logging, water from roofs, present RWH activities, damp in household, problems with water from the road etc
3. 2 Small groups do a diagram of waterflow in the HH and their suggestions for management.
4. Recommended actions summarised – linked to input on contours and using line-levels awa options: stone lines, swales, check-dams, Planting trees (Legumes)
5. Work together in small groups, to demonstrate these actions

INTRODUCTION

Organising workshops this close to the elections caused some local level confusion, as the LFs assumed people would not be available, but also went ahead and told some of the workshop. MDF decided to continue with the workshop as there were around 17 people present and also mentioned to participants as this process is location specific, it can be repeated again, if participants come forward and ask for more of these workshops. The workshop planned for Sedawa had to be cancelled as the LF did not invite participants.

Autumn is a good time to put in place S&W conservation measures in households, as it is still close enough to the rainy season to give clear indications of waterflow and issues in the yard and participants are not too busy with field cropping or gardening (in between seasons)

5 FINGERS AND S&W CONSERVATION INPUT

Participants briefly summarised their actions as follows:

Soil fertility: Compost, trench beds

Crop management: CA, natural P&D control, liquid manure (Banana stems manure, weeds)

Soil erosion control: mulching, stone lines

Figure 30: Right: the ditch draining water away from houses at the top-end of the yard
Far right: Run-off problems caused at the side of the house due to lack of gutters -small ditches have been made in an attempt to divert water from the donga forming lower down.

Householders comments about their homestead

- There is a non-perennial spring in the year of the homestead above and when it rains a lot then water seeps down into the top of their yard in a continuous sheet along the fence line. They have dug a ditch to drain that water away from their yard, as it causes damp issues in their house, which is quite close to the fence line. They have never considered using this water or planting there, as the water only is there for a month or so after the rain stops and the soil there is water logged- so that plants can not grow easily.
- There are no gutters on house
- There is a donga that has formed at the top of the garden/field, where they put bags filled with sand and other garden wastes and branches to try and control this. It has only partially helped and every year there is more damage. The household does not know what next to try there, as it washes away their crops when it is raining.

- Generally, the soil in the yard and garden/field is very bad, it is gritty, shallow, extremely hard and infertile. It is very difficult to dig in this soil and crops do not do well.

The household owners provided the team and participants with permission to do the construction of various S&W conservation structures in their household. It is important to always negotiate these with the owners, to ensure they are OK with changes being made in their homestead. In addition, organic material (5-10x50kg bags), manure (5x50kg bags) and stones (1 bakkie load) had been collected prior to the workshop.

Participants were encouraged to look closely as water flow, run-off, erosion, water harvesting, damp in the houses and all related soil and water management issues they could observe and were tasked to make a diagram in 2 small groups. They were to discuss their ideas about options for improvement in each small group and then report back to plenary.

Figure 31: Right and Far right: the two small groups of participants busy with their water flow maps and discussing suggestions for improvement.

Suggestions from the participants can be summarised as:

1. As the general slope of the plot, including the house is down hill towards the small field at the bottom a small dam should be constructed at the bottom of the field and all run-off channelled into there.
2. Householders should make ridges and furrows and plant in those structures; the soil in the field is hard and infertile and this will help
3. Householders should fertilize the soil using trench beds
4. Householders should make furrows and ridges across the donga on the one side and plan sugar cane there, to utilize the increased water there
5. A small dam should be made next to the house, where the washing line presently is, as this will reduce the run-off to the donga just below that and provide water that can be channelled into the garden/field

INPUTS PROVIDED BY THE TEAM

There are handouts (Translated into sePedi available)

1. What are contours, why are they important, how to measure contours
2. Making and using a line level to mark contours
3. Check dams – what are they, how and where re they constructed?
4. Using stone lines for erosion control and water flow management in the household

5. Planting multipurpose plants on these structures, to use increased water available and hold soil. (Pigeon peas and Sesbania Sesban
6. Making shallow trenches – a variation on furrows and ridges, with more organic matter, made on contour

Below a short summary of each practice is provided with a few photographs form the workshop process

MARKING CONTOURS WITH LINE LEVELS.

Contours are imaginary lines across a slope where each point along the line is at the same height or level. The important part about contours is that they are level and not straight necessarily. It is important to make water and soil conservation structures ON these contour lines, to slow down water, deposit silt and allow for infiltration If they're not level, water will still flow and potentially cause other damage.

Line-levels are used to measure contour lines in a large garden/field situation. The lines between the poles can be made to suite from between 2-10m long. A small builder's level is hung along the line in the centre between the poles. It is important that the line is tied to the two poles at exactly the same height.

Figure 32: Right: One of the sub groups of participants busy constructing their line level

STONE LINES

These are stone lines packed along a contour to reduce run-off, increase sedimentation and infiltration in the soil they will eventually form s mall terraces.
These lines have to be keyed in by first digging a shallow ditch 30cm wide to place the stones in. They are built up using flattish even stones starting with larger stones at the bottom and should be stable enough for someone to walk over them once they are done,

It is possible also to plant deep rooting plants, shrubs and trees along these stone lines. In this case leguminous fodder trees were focused on, as this provides high nitrogen mulch as well as fodder for chickens, goats and cows, but do not grow into large trees

Figure 33: Right: A stone line constructed as close as possible to the top of a slope as a starting point, note that it is keyed in and "slants" slightly uphill. Manure has been worked into the soil above the stone line, for planting. Far Right: Two stone lines constructed around 2 meters apart and planted to Sesbania sesban seedlings

CHECK DAMS

These are similar to stone lines, but require a bit more "construction' as they are built across small gulleys and drainage lines. Soil will build up behind the check dams. They need to be built roughly in the shape of a banana, to have the lowest point in the gulley so that water can still flow over them, with an apron of stone below the check dam wall to ensure that this water does not cut into the soil. They need to be securely keyed into the banks of the gulley by digging a ditch 30cm wide and 30cm deep within which the first line of stones is to be placed. These structures need to be very stable and should support people walking across them easily.

Figure 34: Right: Putting in the final completion touches to a check dam built across a gulley forming at the top end of the garden/field

SHALLOW TRENCHES

This is both a soil erosion control and soil fertility enhancement technique for fields. To start contours are marked using a line level. Then 30cm wide and 15cm deep ditchers are dug along this line with the soil placed below the ditch. The ditches are lined with a layer of mulch or dried plant material around 10cm deep and then a layer of manure that covers this; approximately 2-5cm deep. The soil is then placed back over this mixture to make a small ridge. Crops, such as sweet potatoes can be planted on this ridge and other crops such as beans and grains, just above or below, depending on the season.

Figure 35*:* Right: Digging the furrow for the shallow trenches on a contour marked using a line level and Far right; the packed and planted (orange fleshed sweet potato) shallow trench line in the field.

SEED DISTRIBUTION AND DISCUSSION ON FODDER TREES

Using the pictures shown alongside, the planting of and uses for leguminous fodder trees were discussed with the ground.

All 17 participants received sample packets of pigeon pea and Sesabania sesban seeds and were keen to plant these in their gardens and fields.

For Pigeon peas, preplant treatment consists of soaking them overnight in water and only planting those seeds that have swollen up, during soaking. This shows that the seeds are still viable.

Sesabania, is a fire acclimatised pioneer species. As such seed need to be soaked in boiling water for 10min prior to removing form the hot water and being planted. They are unlikely to germinate without this heat treatment. They are to plant them in basins or seed beds first creating small seedling trees, that are transplanted to bags when about 10cm high and finally transplanted into a field situation when they are around 30cm high.

2.5.4 **Small earth dams; Turkey, Sedawa**

It is a traditional practice in the area to dig small earth dams in the gardens and fields during the rainy season. These dams hold water for a short period only, but also help to increase the water content of the soil as the water slowly drains into the surrounding profile.

Matshego Shaai (Turkey2) constructed such a dam in her garden, but had trouble during March-April of this She requested assistance with design of her dam, to manage the inflow and over-flow aspects. A workshop was held for the learning group participants, and including Esinah Malepe from Sedawa, who had a similar request, in early Maydam overflowing and causing damage to her trench beds.

Figure 36 Right: The breach in Matshego's small earth dam caused by heavy rains and Far Right; deposited on top of her trench beds built below the dam wall. Damage was also caused in the tunnel

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OUTLINE OF AGENDA

1. Discuss issues of waterflow in the homestead – where waterflows, issues with erosion, runoff, water logging, water from roofs, present RWH activities, damp in household, problems with water from the road etc
2. Lay out possible options for placement of diversion ditches to channel water to the small dam site
3. Assess small dam for structural integrity and experiment with use of bentonite as a dam sealing option.

WORKSHOP 1 IN TURKEY

This workshop was planned specifically for Matshego Shaai as she requested assistance with layout of diversion ditches to lead water to her small dam and also to provide an effective and safe overflow option for this small dam, as some damage has been caused below this dam in the past. As Esinah Malepe from Sedawa has also tried constructing small dams in her homestead, as well as a few others in Turkey, this ended up being a small specialised workshop for these participants.

PROCESS

The process consisted of doing a 'walkabout" around the yard, closely observing the waterflow from different sources, such as the road, her house courtyard structures etc, to find the best places for diversion ditches and also ideally for placement of the small dam.

Matshego mentioned that she has asked for assistance as she had found after digging this structure that the water seeped into the ground around the dam – which in some ways was positive as it helped her field crops to be well irrigated, but caused some problems for a few vegetable beds directly below the dam – which were waterlogged for a few weeks and the parsley planted there died. During the rainy season he tunnel which is about 2m below the small dam was also too wet. And then the water did not remain in the dam for long after the rains ended 9it dried out completely within 2-3 weeks.

Participants suggested that Matshego plant trees or crops such as bananas and sugarcane directly below her dam, to soak up the extra water there during the rainy season. These plants do not mind having "wet feet" and will dry the soil enough for the other crops not to be waterlogged.

Matshego has spent a lot of time and effort already in managing waterflow in her homestead; she has gutters and Jo-Jo tanks installed and has make small terraces and stone lines. She has also planted lines of trees and hedges and has thus managed to reduce any damage caused by run-off to a minimum.

A diversion ditch was constructed by the learning group participants to more effectively channel the water to her small dame. A silt trap was dug into this ditch and an overflow was planned at the bottom end of the small dam.

Discussions were held as to the construction of small dams- whether they should be round or square and the advantages and disadvantages of having perpendicular or angled walls. It was also discussed that sealing the dams is not a requirement; having small dams that provide for increased infiltration of water and underground water availability in season is also a very good strategy. Ways to seal the dams were also discussed. Plastic is easy, not very expensive and generally very inefficient -as dams still tend to leak a bit and the plastic tends to disintegrate in the sun. As these dams are not full all the time, plastic was considered inappropriate. It is possible to do a ferrocement lining. These are quite easy as long as one lines the inside of the dam properly with mesh priori to plastering and then repair any cracks or problems that ensue. This method has the advantage that the dam can be any shape and also that it can work around obstacles such as bid boulders that could not be removed. It is more expensive than using bentonite, but possible a lot more forgiving of inaccuracies than working with bentonite.

Bentonite has the advantage that not further inputs are required and this can be done at home, with the help of some labour. The average small dam sizes for participants present meant they would need 12-14 x 25kg bags each and thus the process would cost around ~R1 500.00

USE OF BENTONITE TO SEAL EARTH DAMS

NOTE: Mr Chris Stimie from RIEng assisted with procurement of reasonably prices bentonite (~R100/25kg) from Benoni (Gauteng) and also with advice and specifications for using bentonite

Bentonite is a very fine clay, which is used for sealing earth dams, where the intrinsic soil structure does not allow for longer term water holding.

There are a few different ways in which this is done:

- Pouring the bentonite into the water of such a small dam, to settle and seal is perhaps the least effective and most wasteful process- although it could be considered the easiest
- Generally the best procedure is:
  - To ensure that the dam is empty and the soil of the dam wall and floors is dry
  - To mix bentonite with the top 10cm layer of the dam floor and the dam wall, very evenly to about 10% in weight. This comes to using around 12,5kg (1/2bag) for every 1m^2 of the dam area.
  - The walls need to constructed or shaved to be at a 30-45 degree angle, so that the bentonite can be worked into the dam wall material

- The soil which the bentonite is mixed with needs to be finely worked, with not large clods or stones, so that one has the sense almost of making a plaster mix (for construction)
- The evenly mixed soil-bentonite walls and floor have to be tamped down to be as level and stable as possible and then covered with 30cm of soil

Below is a series of photographs showing the team's experiment with using bentonite. Only a section of the wall was used. This means the household will need to re-do this small patch when they do the whole dam – which they readily agreed to.

Figure 37: Above left to right: Measuring out a circle – to change the dam shape from a rectangle and then shaving the perpendicular walls to be at an angle of roughly 35 degrees. Marking out a m^2 area and then evenly distributing 12,5 kg of bentonite over the are and carefully mixing in the bentonite into the top 10cm of the soil on the bank

Figure 38: Right: Tamping down the finalised mixture on the wall and Far-right. Replacing a layer of soil over this bentonite mixture. This layer in our case was only about 5-10cm deep - and not 30cm as recommended, as this would reduce the volume of this very small dam dramatically.

It was decided that Matshego would use a pipe to very slowly and carefully fill her dam after construction, to check whether the walls will hold as is and what the sealing effect to of this process is. The group was aware that we were trying to find a way of using bentonite that would suite their purposes and that this initial experiment may not work.

Below is a picture showing the result. At this point the dam had been filled two weeks prior to the picture taken – which is a good indication of the bentonite working well. Matshego still has to give more attention to the overflow however.

WORKSHOP 2 IN SEDAWA

A similar workshop was held in Sedawa, at Esinah Malepe's home on the 7th of June 1029. Esinah had already constructed her diversion ditches and was in the process of shaping the dam for addition of bentonite.

Figure 39: Right; Esinah's dam after the bentonite was worked into the walls and floor of the pond

Participants here were in favour of this idea, although some were worried about having open bodies of water in their homesteads. They suggested to make the dams smaller, so that they could be covered.

Four participants volunteered to construct small dams and to be involved in the bentonite experimentation process (Magdalena Malepe, Triphina Malepe, Koko Maphori and Mmakopile Malepe).

Workshop 3 in turkey 2

After the first two workshops, despite the immediate positive results, we were still a little concerned about the process of applying bentonite in the most effective manner. Thus, a third workshop was initiated, where Chris Stimie from Rural Integrated Engineering joined the process to fine tune the method.

INTRODUCTION

Small dams/ponds present an opportunity for farmers to harvest rain water and collect water from nearby springs for those closer to the mountains. Water is an everyday struggle for dwellers in the village of Turkey and other surrounding villages where people buy drinking water and crops struggle a lot under high temperatures. Rackson Makhobatlou is a farmer in the area who thought a small pond may be of help for his farming prospects for irrigation as they almost never see any rain. He is hopeful that the dam will hold enough water for his crops and chickens.

SMALL DAM CONSTRUCTION

The workshop started at about eleven o'clock at Mr Makhobatlou's homestead in Turkey. The hole that had been dug needed to be re-shaped and water was needed to be brought on site. Water was very important for the mixing of bentonite and soil as the dam lining to prevent water from seeping through. Four individuals were commandeered to collect 400l of water from a nearby borehole while the rest of the groups altered the deep hole into a more open bowl to create a more even and gentle slope that would make sure the soil-bentonite mixture stayed along the wall and did not slide down.

At the point depicted by the picture above, the team dedicated to collect water had made their way back and we officially started the day with a proper introduction. Chris delivered the talk and Betty translated for locals in their vernacular. Chris had drawn and photocopied all steps into making the dam from start to finish and we had already covered step one; digging; and the importance of the

slope of the dam. Step two was to then measure out the dam into 1m x 1m grids allowing for the calculation of bentonite to be used. The calculation is to apply 1x25kg bag of bentonite to every 2m². The following step 3 was to evenly spread the bentonite all over the dam. Step 4 saw us mix the bentonite into the soil starting from the bottom of the dam; these were mixed until the colours evened out. The walls also had to be mixed in without moving the soils and here slope played a crucial role in stabilizing soils, the less steep the better. The mixing was done twice to ensure an even mix of soil and bentonite. The soil-bentonite mix was compacted making sure that it stuck on the wall.

Figure 41: Left, marking out grids, top right; bags placed on grids & bottom right, bentonite spread.

Step five; was sprinkling water all over the dam using a watering can, the watering can apply water well enough without moving the soil and this allows the bentonite to expand across the wall. We continued this process slowly until we started noticing a change in the soil texture. After about an hour so, we put in another layer of soil to protect the bentonite mix after which more water was applied to help seal the dam completely. 400L of water was then poured carefully into the dam using bags to stop the top layer from running away to the bottom of the pond. A mark was made where the water sat along the wall and was continuously checked on; our dam was waterproof!

Figure 42: Left, compacting the dam & right, water siting in the dam.

The group was very excited seeing water sit on top of sandy soils and only then they appreciated the bentonite and stared enquiring about. The bentonite is not available at local hardware outlets and is twice the price of cement. Bentonite used on the day was bought and collected from Benoni, outside of Johannesburg.

CONCLUSION

Mr Makhobatlou will be digging a furrow from his gate to the dam, where the furrow approaches the dam, he will excavate a small slit trap. This depression will also serve as an overflow when the dam is full; water will push out the dam via the silt trap and be directed along the outside of the dam to the garden. He was also advised to look into buying shade cloth to protect water from evaporating as he could easily see huge losses of water in the Limpopo heat.

2.5.5 **Continuation of water issues in Sedawa**

Here, a similar situation unfolded as was experienced in Bergville. The water committees lost traction as participants' hope for support by government was raised again by the elections. This made the participants reluctant to contemplate the additional contributions required to make the local situation work.

This led to smaller splinter groups forming and some people making their own arrangements with private individuals supplying water in the area.

The water committees were subsequently assisted to write funding proposals to the US Embassy.

2.5.6 **Follow -up on organic mango production training**

A learning group meeting was held in Turkey to review learnings from the Organic Mango production training and inform all learning group members about these learnings. The intention was also to discuss implementation of new ideas and practices from this training.

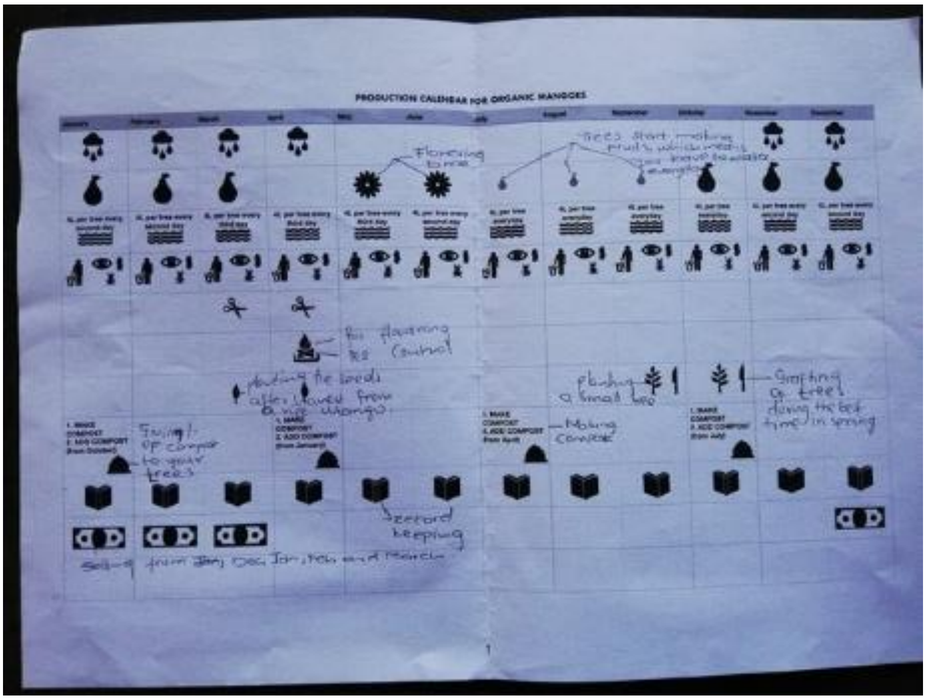
Figure 43: Right: Clonecia discusses with the learning group members what she remembers from the Organic Mango Production training at Hoedspruit Hub.

The local practice around Mango trees, is not to prune them. People believe this reduces production and are thus reluctant to try it out. Although the farmer experimentation idea has been introduced to deal with just such examples – where the "habitual" practice and the suggested practice are at odds, some of the farmers are reluctant even to try the new ideas on a small scale to see the outcome. In such cases new learning is unlikely to take place.

Farmers discussed some of their learnings including; planting seed correctly, making irrigation basins around the trees, pruning for improved fruiting, burning of leaves below the tree during flowering to reduce pest attacks and making compost. The organic PGS was introduced to the group, explaining the need for this peer review system to ensure organic production for marketing and quality control purposes.

Mr Malatji, the LF for the area suggested to the group that they set up a marketing cooperative, to ensure everyone who is interested can be involved and that they work together rather than competing. This would also help them to work at a commercial scale. He emphasised also that community members should stop expecting handouts (seed etc) from the MDF facilitators, as their job is to help people learn. The community needs to work towards being independent, so that they can continue when MDF leaves the area.

A monitoring process was conducted for a selection of the participants who attended the course, to assess experimentation with the new ideas and progress with mango production. They were all provided with another copy of the annual mango production planning cycle (shown right), to assist with their production cycle.



Below is a selection of photographs showing actions around mango production.

Norah Tshethla (from Turkey): She has 8 mango trees (Tommey, peach and sugar), all are old and have grown tall. Others died due to lack of watering.
She undertook pruning of her trees, built basins for watering and addition of compost around the trees, is now watering her trees on a weekly basis and is producing compost

Figure 44: Right: Norah's mangoes – pruned, with water harvesting basins and compost added.

Matshego Shaai (from Turkey): She has 15 mango trees and is continually propagating more. She has also undertaken pruning, made water harvesting basins and is producing compost for her trees. Mmatshego explained that she didn't have a problem with her harvest as she is used to pruning her trees, she only has a problem of pests and rotten mangoes. She believes that with the knowledge she gained from the workshop she will be able to control pests that decrease her harvests. She managed to sell her mangoes to achar company in Sekororo making an income of R6 000, and she believes she could have made more if she managed pest problem in time.


Figure 45: Above and alongside: Matsehgo's compost pile and mango tree prunings. A pruned tree with water harvesting basin, and mulching of tree leaves.

Mpelesi Sekgobela (Sedawa): She pruned 12 of her 21 trees as an experiment to compare harvests form pruned and un pruned trees. She has now been irrigating trees since the mango training, and no further trees have died. She also started a small nursery of mango trees from her own pips and she sells the seedling for R20. 00 each, and has sold 10 seedlings to date.


Figure 46: Right: Mpelesi's mango nursery and Far right: a hard pruning done for an old unproductive mango tree

Christina Thobejane (Sedawa): Shedidn't attend the training workshop but farmers who attended the workshop shared shared some information with her. She has 27 mango trees of a number of varieties (Kent, peach, sugar, Tommy, Kiet and L1). She irrigates her trees twice a week. She sells mangoes for both Archar (green) and in the community (ripe). In total, she has made R6 000 this season and has bought a blender from her profits to make mango juice.

Figure 47: Near right: A pruned mango tree, here incorporated into a trench bed design for inclusion of organic matter, mulching and water harvesting. Middle right: A bottle of home-made mango juice and Far Right: Christina's mango nursery.

3 DECISION SUPPORT SYSTEM

Written By Erna Kruger and Matthew Evans[1]

[1]*Final year computer programming student at University of Pretoria.*

With the completion of the refinement step of the DSS computer modelling process, Matthew Evans was brought on board to assist in designing an online survey process that could integrate the various components and steps of the modelling process.

3.1 Development of the decision support tool/survey

Written by Matthew Evans

A brief summary of the design specifications and process is provided below.

Technologies used

- Angular 7: Angular is an industry-standard JavaScript framework developed and maintained by Google. It is widely-supported and provides a solid foundation for web-based applications.
- Openlayers**:** Openlayers is a free, open source map layer rendering system. It is efficient and powerful, and provides the necessary functionality to render and interact with the map in the system.
- Custom GIS systems
- html2canvas, jspdf

3.2 Implementation details

Design considerations

User interface – to maintain a consistent styling that is approachable, easy to read and modern, Angular's Material design has been used. This provides a formalized design and interaction system based on Google's Component Dev Kit. Smooth animations provide a better user experience

The web application has been designed to be primarily client-side. Client-side calculation and rendering provides instantaneous feedback to the user – an important part of this system.

Input fields are grouped such that relevant fields are grouped together, or at least within close proximity. This helps the user cognitively shift subject-matter fewer times, reducing cognitive load.
Information that is difficult for the user to input, such as soil texture, soil organic carbon content, slope percentage and agro-ecological zone are automatically derived from GIS database data. This allows the user to focus on parts of the survey that are more relevant to the user (such as demographic details) and easier to fill in.
While the system automatically finds these values, the system is designed to be flexible for the user, and allows them to change the values if they believe the data the system uses for their location is incorrect/inaccurate.

The map uses hybrid tiles, rather than purely vector road maps or raster satellite tiles. This enables the user to find locations easily by being able to see place labels and roads, while still showing natural elements. Users can find the location they are looking for through steps of increasingly fine-grained control by using the search box, looking for roads or place names, and then looking at the satellite imagery to find an exact location, respectively.

Rather than requiring exact number/value inputs (aside from a few exceptions), the input has been reduced to multiple choice where possible. This makes input easier and faster for the user, and reduces the chance of user error. It also exposes the underlying functionality of the decision support system, showing which variable boundaries affect the system, which might help inform the user. Exceptions include dependency ratio calculation, where the number of adults and children fields are numeric inputs – dependency ratio is a difficult concept for users to understand and is calculated for them.

Skeleton loading screens have been implemented for both before the Angular application is bootstrapped, and before the page loads. This helps increase the perception of performance.

GIS

Reliance on external APIs has been kept to a minimum for this system. If a third party were to shut down or start charging for their previously-free services, it would require developer time before the system could become operational again. As such, as much data as possible is stored and delivered from the server to the client.

Two external APIs are being used:

1. OpenStreetMaps Nominatim – provides a simple API for querying locations by name, allowing the user to search for map locations.
2. Google Maps Satellite tiles – hybrid (photo with vector overlay) map tiles for the map

- Implementation of GIS

Server-side computation is very expensive, but storage and delivery of files is not. To deliver GIS information for a set of coordinates, large raster files must be traversed until the correct pixel coordinate is found, and then return the value at that pixel. These raster files can easily reach 3GB for South Africa alone for each variable (one for altitude data, one for soil texture, etc.).

Since no server-side calculations are happening, these large raster files are split up using custom software on the desktop. The files are converted into ASC format (geographical ASCII text format) which is a human- and computer-readable format. The tile is then split up into a user-defined number of smaller tiles, and an index is built to determine which tiles correspond to an area of coordinates.
When a set of coordinates is queried by the system, the index is loaded, finds the cell in which those coordinates fall, and then loads the tile that cell points to. This results in a reduced download size of multiple gigabytes to only a few hundred kilobytes, making the system significantly faster and using a fraction of the bandwidth.

In addition to partitioning of the map data, it is also compressed using gzip, giving a significant reduction in storage usage and bandwidth cost to the client.

Services implemented for reading ASC files automatically categorise z-values from the ASC files into enumerations defined in the system source. An exception is the SRTM Shuttle Radar Topology Mission data which automatically samples z-values from an area the size of the farm selected to find the slope of multiple points, rather than assuming the entire farm is on one slope percentage.

PDF Export

PDF export was accomplished using the html2canvas and jspdf libraries. Each practice's information to be rendered is created in an invisible element, converted to a canvas using html2canvas (special care is taken to ensure that all css is compatible with html2canvas's limited specification). The canvas is then converted to a png, and added to a pdf object created using jspdf. Page breaks are programmatically created when images will not fit on the same page.

System Flexibility

The DSS input data is simply stored in an Excel spreadsheet. This makes it easy for maintainers to add new practices or update existing ones in an interface that is familiar to them. Practice information can be easily added and updated, and is stored in a simple JSON format defined in a JSON schema file.

Due to the use of enumerations, the values used in the survey questions are the exact values used in calculations. The values can be changed at any time and will not affect the rest of the system, making it easy to make changes.

Angular provides a modular framework, meaning more features can be added or changed at a later stage.

Implementation process

Below is a point form summary of the steps in implementing the tool/survey.

- The DSS was provided in an Excel xlsx spreadsheet format with documentation in Word docx format. Powerpoint pptx presentations were provided containing individual practice information. Some of the GIS data was provided which would be used for production, namely AEZ data. Other data was a subset of the full datasets, and not of the entirety of South Africa.
- Designs were created by hand, and multiple iterations considered.
- Research was done to find GIS data and APIs. After not finding sufficiently stable or open APIs, the decision was made to host all data server-side.
- Interfaces and enumerations were created for data present in the excel dss. This allows for future flexibility and easy changing of visual values without affecting underlying implementation.
- Application state representation was derived from the input values, represented as an interface passed throughout the calculation process.
- Resource and typology calculations were implemented. These were implemented as services in a strategy-like design pattern, allowing mock data through dependency injection and ease of maintenance.
- Services for reading ASC files and “indexed” ASC files (detailed above under GIS) were implemented. It then followed that GIS services for soil texture, AEZ, etc. were implemented.
- The DSS calculator was implemented as a service.
- DSS practice information was extracted manually from the Word document and put into JSON format with images. A service was created to read this data and cache it.
- A service was created to convert html to canvas images, and then export to PDF to render the practice information PDF export.

3.3 The draft interface of the decision support tool

ON the web platform (still to be decided once finalised, but presently available on the MDF website at https://dss.mahlathini.org , is introduced as follows:

Introduction

The more extreme weather patterns with increased heat, decreased precipitation and more extreme rainfall events; increase of natural hazards such as floods, droughts, hailstorms and high winds that characterise climate change, place additional pressure on smallholder farming systems and has already led to severe losses in crop and vegetable production and mortality in livestock.

It is possible for individual smallholders to manage their agricultural and natural resources better and in a manner that could substantially reduce their risk and vulnerability generally and more specifically to climate change. Through a combination of best bet options in agro-ecology, water and soil conservation, water harvesting, conservation agriculture and rangeland management a measurable impact on livelihoods and increased productivity can be made.

Under the auspices of the Water Research Commission, our research team (Mahlathini Development Foundation, Environmental Learning Resources Centre, Institute of Natural Resources, and Rural Integrated Engineering) has designed a process to assist farmers to decide which climate resilient agriculture practices would be more suitable for them.

This process uses information on your location, the agroecological zone where you are farming, including aspects such as rainfall, temperature, slope, soil type and organic matter, as well as specific information on your farming practices to select a range of best bet options for you related to gardening (vegetable production), field cropping, livestock and natural resource management.

In addition, some basic information on what the practice is and how it can be implemented is provided. We hope this will be useful to you in your adaptive management strategies for dealing with increased climate variability.

The survey

This online survey below needs to be completed, by answering all the questions, so that your specific recommendation of practices can be generated.

You will be able to save and print your results, which will include basic information on the practices that have been selected by you. You also have the opportunity to prioritize some of these practices for yourself, before finalising your recommendation.

Some of the fields in this survey will be pre-populated with information that is derived from scientific databases. If you have your own information for these aspects, you can change the information in these fields. If for example the database recommendations that your soil type is 'clay", but you know from your own analysis that it is a "sandy-loam", then you can write in your own information. The same will go for aspects such as slope and organic matter.

Please try and fill in all the fields in this survey. The more information you provide, the more accurate your recommended practices are likely to be.

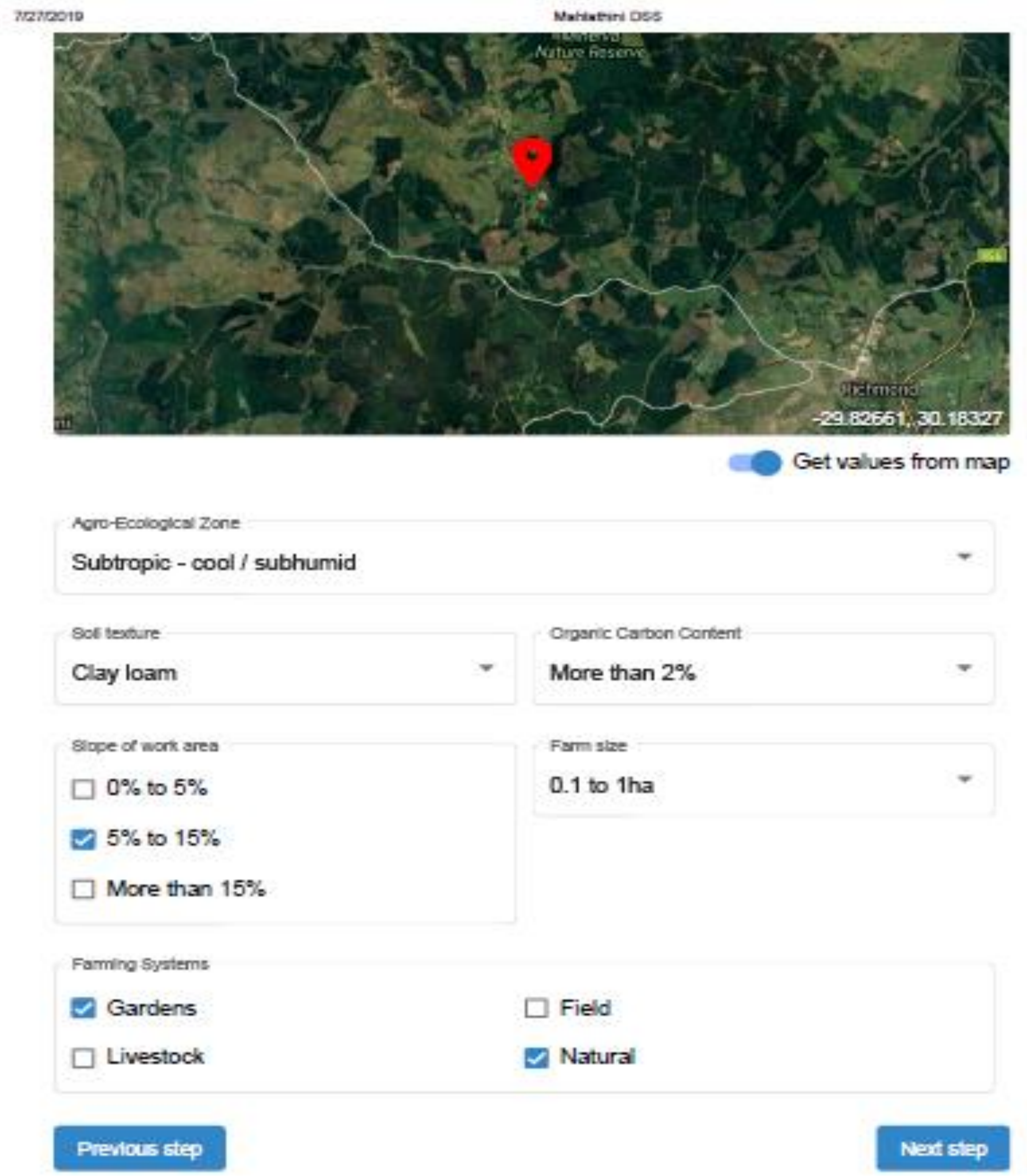
We would also welcome any questions and suggestions that you may have.

Enjoy!

Below is a step by step example of the survey; for a participant living close to Richmond in KZN

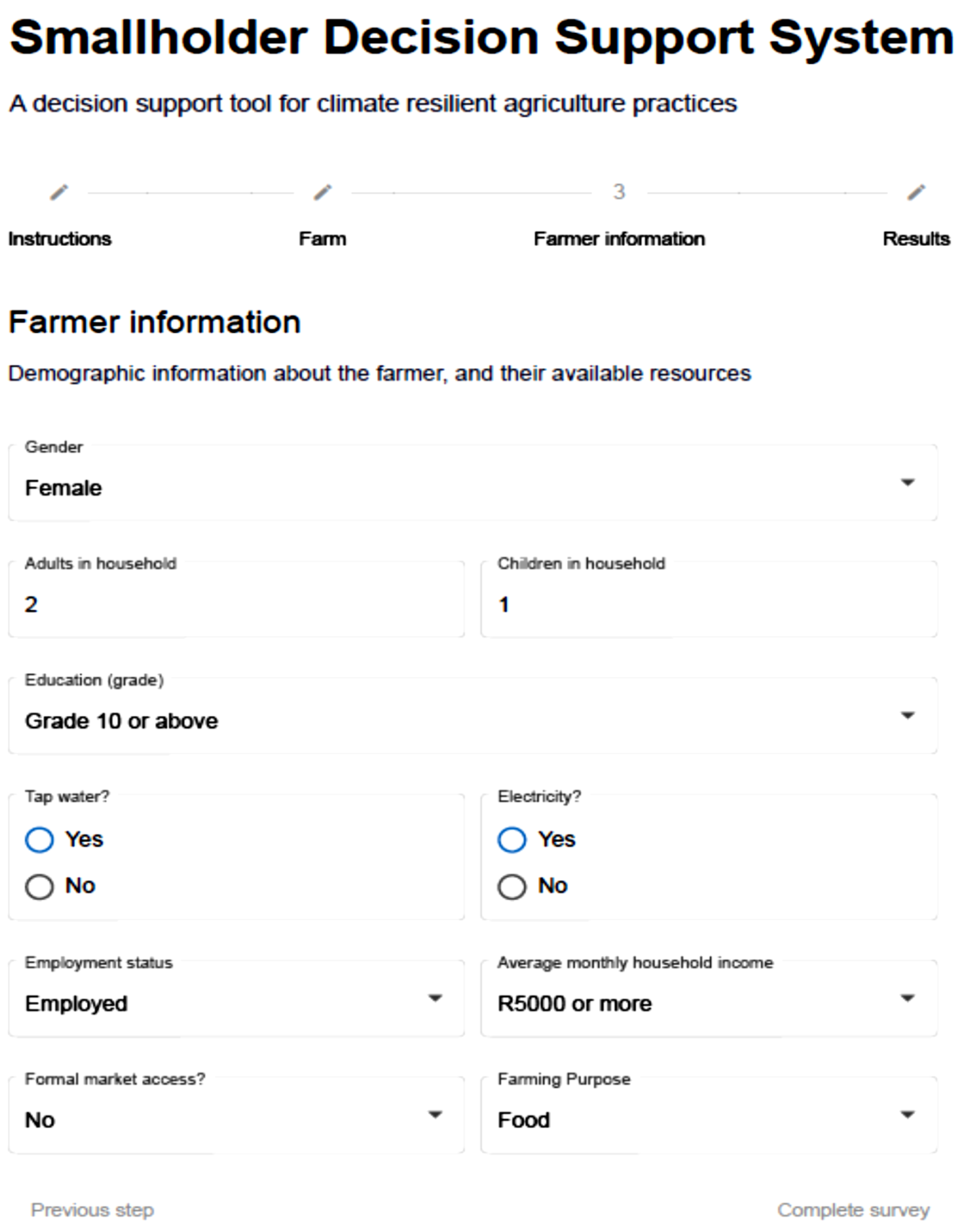
FARM INFORMATION

The blue boxes indicate choices made by the participant. Other choices were from drop down lists in the survey.



FARMER INFORMATION

This is the next step in the survey



Smallholder Decision Support System

A decision support tool for climate resilient agriculture practices

Instructions — Farm — 3 Farmer information — Results

Farmer information

Demographic information about the farmer, and their available resources

Gender
Female

Adults in household
2

Children in household
1

Education (grade)
Grade 10 or above

Tap water?
Yes
No

Electricity?
Yes
No

Employment status
Employed

Average monthly household income
R5000 or more

Formal market access?
No

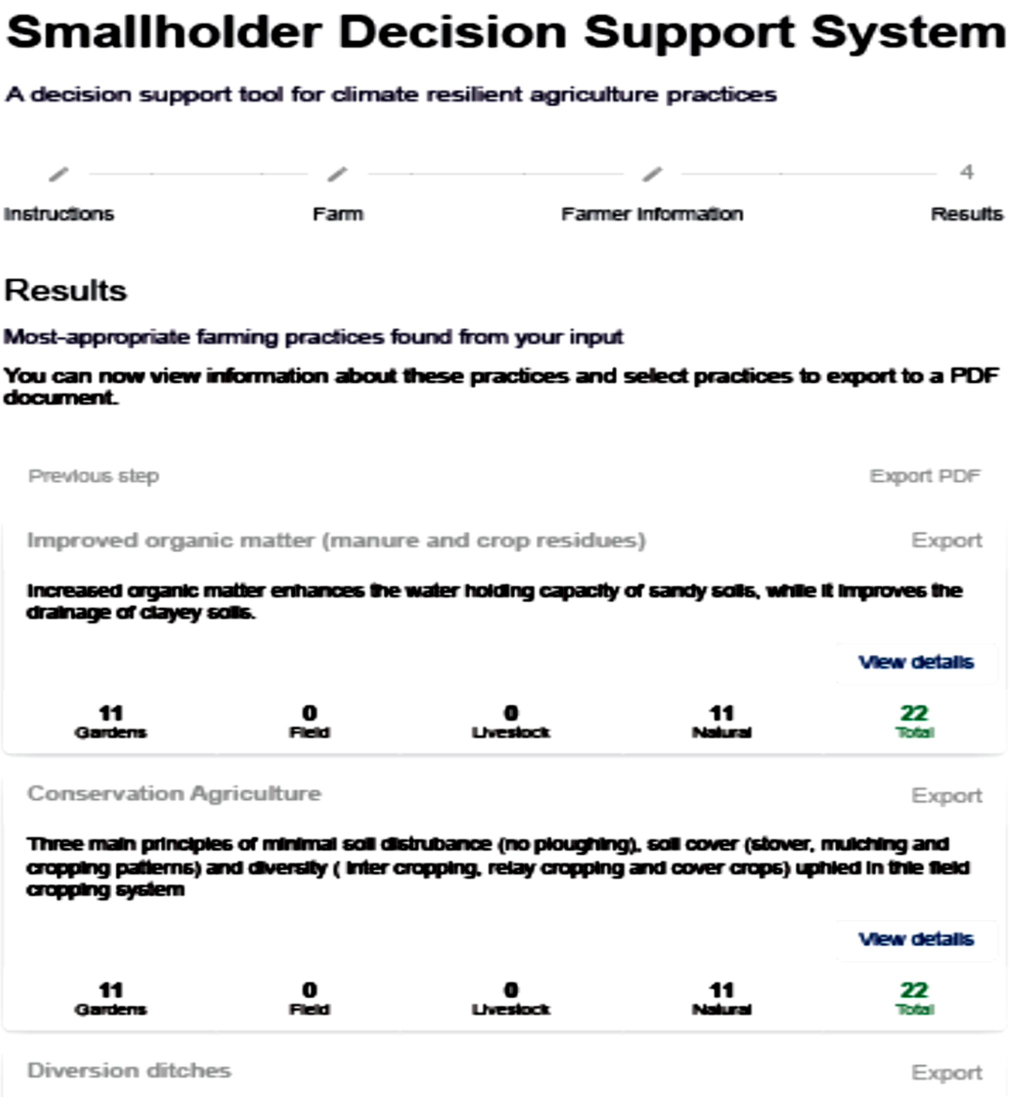
Farming Purpose
Food

Previous step

Complete survey

RESULTS

Thi page of the survey summarises the practices selected, in a ranked order from highest to lowest. In the example below the first two practices are shown.



It is then possible to select each practice for more information on that practice- as shown for "Conservation Agriculture" above. And then to export this information as a pdf document.

Conservation Agriculture

Three main principles of minimal soil distrubance (no ploughing), soil cover (stover, mulching and cropping patterns) and diversity (inter cropping, relay cropping and cover crops) uphied in thie field cropping system

This practice is appropriate under the following conditions												
Agroecological Zone			Soil Texture				Organic Carbon			Slope		
Subtropic - warm / semiarid	Tropic - warm / semiarid	Subtropic - cool / subhumid	Sand	Loam	Clay	Silt	Less than 0.5%	0.5% to 2%	More than 2%	0% to 5%	5% to 15%	More than 15%
		Y		Y	Y	Y		Y	Y	Y	Y	

Farming System				Farmer Category (based on access to resources)		
Gardens	Field	Livestock	Natural	A	B	C
Y	Y	Y	Y	Y	Y	Y

This practice is appropriate for the following resource management aspects												
Water (quantity)			Soil (fertility)		Crop resistance and efficiency				Livestock resistance and efficiency			
Harvesting	Retention	Use efficiency	Conservation	Improvement	Water	Heat	Nutrient	Disease	Water	Heat	Nutrient	Disease
	Y	Y	Y	Y	Y	Y	Y	Y			Y	

This survey will now be tested as extensively as possible in a range of practical situations. In addition all one page descriptions with photographs are to be completed and the survey updated.

4 CAPACITY BUILDING AND PUBLICATIONS

Capacity building has been undertaken on three levels:

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

Community level and organisational capacity building have continued within this reporting period and have been reported upon in detail in the above sections.

4.1 Post graduate students

A further postgraduate student has withdrawn from this process:

- Samukelisiwe Mkhize has withdrawn her recent registration for a PhD in Social Sciences (Policy and Development Studies). She has cited personal reasons for this decision and has also left MDF's internship position.

This has been a huge blow for our research process, as we now do not have enough time to canvas for another student to replace her. The work she was doing towards the research will now have to be shouldered by a much smaller team. MDF will appoint another intern in the coming months to assist.

Progress with ongoing studies:

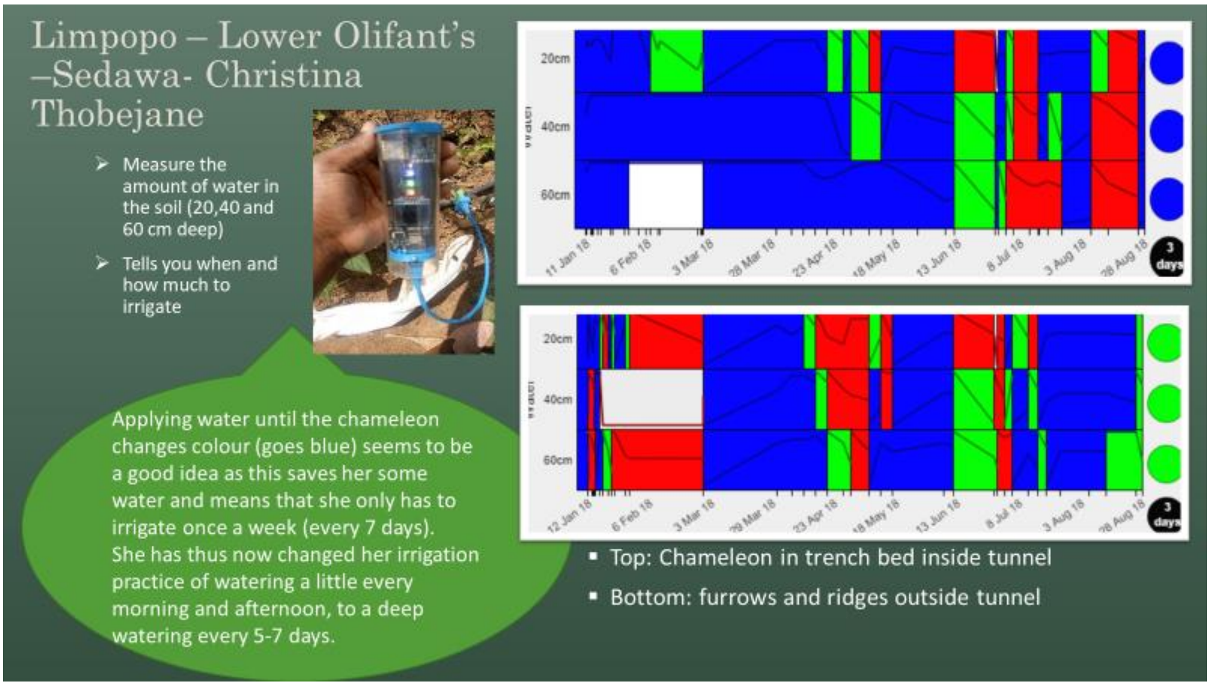
- Palesa Motaung: (M Soil Science- UP) has successfully conducted her fieldwork and is in the process of finalising her results and starting her write-up.
- Mazwi Dlamini: MPhil - UWC_PLAAS. He has conducted his first round of focus groups and interviews, has written these up and is in the process of conceptualising his second round of interviews. His progress has been slow, but he has another year to complete this part-time study at UWC

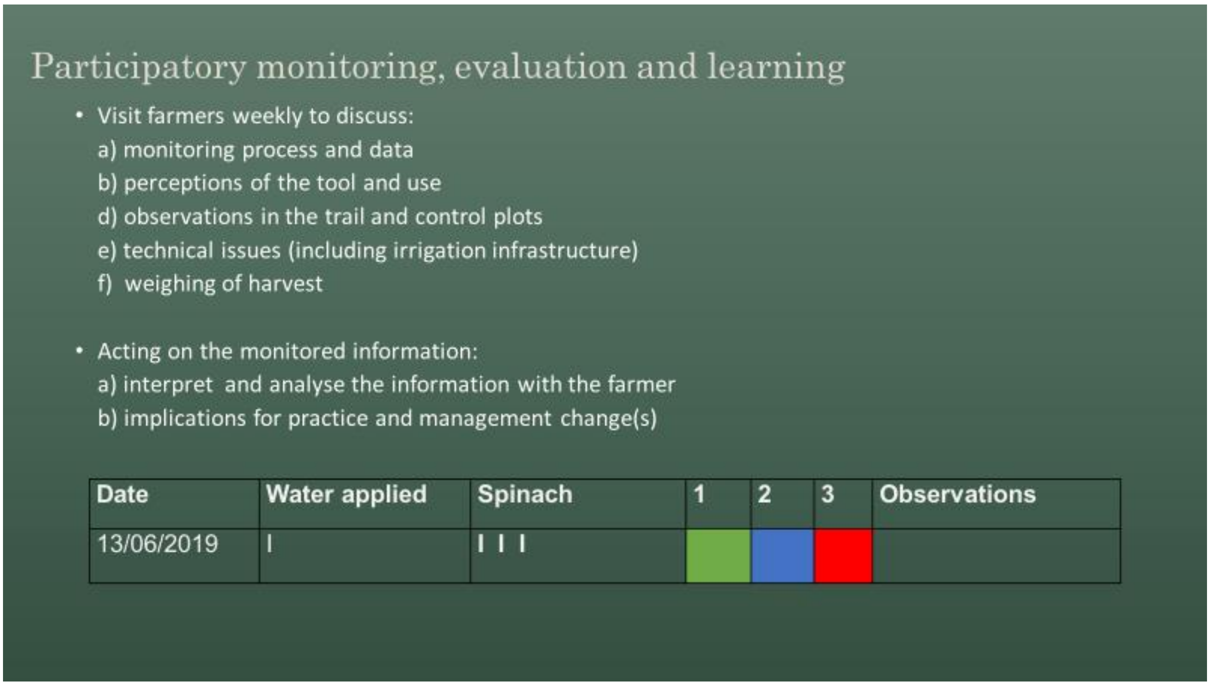
4.2 Networking and presentations

4.2.1 VIA conference

The Virtual Irrigation Academy (VIA) held a conference for partners and interested stakeholders on the 13th of June at the Future Africa centre at the University of Pretoria. Here MDF (Erna and Samukelisiwe) presented some of the work around irrigation scheduling and water productivity that has been done as a part of the smallholder climate resilient agriculture being undertaken under the auspices of the WRC. This event provided a great platform for outlining the use of the chameleon water sensors in the farmer level experimentation process.

Below is an illustrative slide from the presentation as well as a slide outlining the participatory monitoring and evaluation process used with the smallholder farmers





4.2.2 **Maize Trust Board visit to Bergville**

5 Members of the Maize Trust Board, journeyed from Pretoria to the cathedral Peak area in Bergville for a smallholder conservation agriculture day hosted by the MDF team. The intention was to provide information and practical examples of the innovation development approach used for adaptive and participatory research into smallholder CA systems. Both this approach to research and the emphasis

on livelihoods and adaptation were new to these important decision makers in the maize industry. The day was designed also to showcase some of the work smallholders have undertaken.
Below are a few illustrative photographs of the farmer visits.

Figure 48: Above Clockwise from top left: Visiting Ntombakhe Zikode's field in Eqeleni where a plot of winter cover crops is seen in the fore ground; Her maize crop maturing; the farmers' meeting with the board members and a view of a portion of the farmer centre for the village.

4.2.3 **QCTO preparation workshop for Agroecology curriculum**

A pre-scoping workshop was held with a number of different agroecology stakeholders and a representative from the QCTO (Quality Council for Trade and Occupations) at the University of Johannesburg on the 4th of July 2019

SAFL (Southern Africa Food Lab) and SKA (Kruger, Swart Assocaited) worked in close collaboration with the Hoedspruit Hub in designing the structure of the event. The main aims of the event were defined as:

- Introduce participating stakeholders to the structure and requirements of the QCTO.
- Determine the willingness of the sector to continue with the development of the qualification.
- Identify key development partners as required by the QCTO process.
- Convene a preliminary discussion on the cost of the development of the qualification and identifying possible funding sources to support the development.

To ensure that the sector was well represented, SAFL, SKA, and HH drew on their networks to develop an initial invitation list which was then circulated to all invited stakeholders for review and identification of additional stakeholders. In total, 62 sector stakeholders were invited, and 27 participants attended the event, of which MDF was one.
It was decided to continue with the curriculum development process and MDF is to be involved in the joint action group in this regard.

4.3 Publications

A series of three articles has been submitted to the Water Wheel magazine for publication in upcoming editions.:

- CCA community process,
- The impact of CRA on rural livelihoods and
- The smallholder farmer CRA decision support system