CLIMATE CHANGE ADAPTATION FOR SMALLHOLDER FARMERS IN SOUTH AFRICA

VOLUME 2 PART 2: CLIMATE RESILIENT AGRICULTURE. AN IMPLEMENTATION AND SUPPORT GUIDE: INTENSIVE HOMESTEAD FOOD PRODUCTION PRACTICES

E Kruger, MC Dlamini, T Mathebula, P Ngcobo, BT Maimela & L Sisitka

WATER RESEARCH COMMISSION

TT 841/3/20

Climate Change Adaptation for Smallholder Farmers in South Africa

Volume 2 Part 2: Climate Resilient Agriculture. An implementation and support guide: Intensive homestead food production practices

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Report to the

Water Research Commission

by

Mahlathini Development Foundation

Report No. TT 841/3/20

February 2021

Obtainable from
Water Research Commission
Private Bag X03
Gezina, 0031

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The publication of this report emanates from a project entitled *Collaborative knowledge creation and mediation strategies for the dissemination of Water and Soil Conservation practices and Climate Smart Agriculture in smallholder farming systems.* (WRC Project No. K5/2719/4)

This report forms part of a series of 9 reports. The reports are:

Volume 1: Climate Change Adaptation for smallholder farmers in South Africa. An implementation and decision support guide. Summary report. (WRC Report No. TT 841/1/20)
Volume 2 Part 1: Community Climate Change Adaptation facilitation: A manual for facilitation of Climate Resilient Agriculture for smallholder farmers. (WRC Report No. TT 841/2/20)
Volume 2 Part 2: Climate Resilient Agriculture. An implementation and support guide: Intensive homestead food production practices. (WRC Report No. TT 841/3/20)
Volume 2 Part 3: Climate Resilient Agriculture. An implementation and support guide: Local, group-based access to water for household food production. (WRC Report No. TT 841/4/20)
Volume 2 Part 4: Climate Resilient Agriculture. An implementation and support guide: Field cropping and livestock integration practices. (WRC Report No. TT 841/5/20)
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Volume 2 Part 8: Climate Resilient Agriculture learning materials for smallholder farmers in Sepedi. (WRC Report No. TT 841/9/20)

ISBN 978-0-6392-0229-7

Printed in the Republic of South Africa

ACKNOWLEDGEMENTS

The following individuals and organisations deserve acknowledgement for their invaluable contributions and support to this project:

Chris Stimie (Rural Integrated Engineering – RIEng)
Dr Brigid Letty and Jon McCosh (Institute of Natural Resources – INR)
Nqe Dlamini (StratAct)
Catherine van den Hoof (Researcher)
Dr Sharon Pollard, Ancois de Villiers, Bigboy Mkabela and Derick du Toit (Association for Water and Rural Development)
Hendrik Smith (GrainSA)
Marna de Lange (Socio-Technical Interfacing)
Matthew Evans (Web developer)
MDF interns and students: Khethiwe Mthethwa, Samukhelisiwe Mkhize, Sylvester Selala, Palesa Motaung and Sanelise Tafa
MDF board members: Timothy Houghton and Desiree Manicom

PROJECT FUNDED BY

WATER RESEARCH COMMISSION

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Abbreviations and acronyms

CA	Conservation Agriculture
CC	Climate change
CCA	Climate change adaptation
CRA	Climate resilient agriculture
EC	Eastern Cape
KZN	KwaZulu-Natal
MDF	Mahlathini Development Foundation
SOC	Soil organic carbon
SOM	Soil organic matter

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1 BACKGROUND AND INTRODUCTION

1.1 CLIMATE RESILIENT INTENSIVE HOMESTEAD FOOD PRODUCTION PRACTICES

1.1.1 *The current situation*

Homestead food production is an important aspect of the smallholder farming system. These are small (0,01-0,5 ha; or 100-5000 m^2) plots adjacent to homesteads where participants plant a range of crops and fruit trees, with or without access to water for irrigation. The homesteads also host small livestock such as poultry and in some cases kraals for goats and cattle. A limited number of people also keep pigs. These plots are usually fenced. The large majority of smallholders plant for household consumption and sale of surplus.

Production is constrained by infertile and badly structured soils. Often, the smallholders live in areas where soils are not ideal for cropping. This situation is worsened by repeated shallow tillage (with hand hoes and/or tractors), without addition of nutrients or organic matter, often for many years. The results are very low fertility soils, with many structural problems such as capping and compaction. This is now exacerbated by climate change, with alternating hot and dry conditions and heavy downpours adding extensive erosion of top soil to the list of woes. Productivity is generally extremely low.

In addition, access to water for irrigation is an enormous obstacle for most smallholders, who battle to have enough just for household use.

Diversity in cropping also tends to be low; with a focus generally on maize and pumpkins for field crops, as well as legumes in some cases. In terms of vegetables, planting consists mainly of cabbage, spinach, tomatoes and onions. In KZN and the Eastern Cape, participants may have a few un-grafted peach trees. In the subtropical areas of Limpopo lowveld, diversity is somewhat higher with more habitual planting of a wide range of trees (e.g. bananas, mangoes, avocadoes, paw-paws and citrus, as well as indigenous trees).

The challenge is thus to work with a combination of aspects; soil fertility, soil erosion control, water management, cropping, fruit tree production and livestock integration, to create a more productive and resilient, intensive homestead food production system, working within the confines of the local situation and resources.

The climate resilient agriculture (CRA) practices promoted through this study, encompass vegetable and fruit production as well as small livestock integration; practices that are undertaken within the boundaries of the homestead. Practices also include soil and water conservation, as well as microclimate management.

The potential of practices to have an impact on productivity in a changing climate depends on a number of criteria. These criteria have been developed and fine-tuned with learning group members. The most common criteria can be summarised as; productivity, water use, labour, cost, ease of implementation and income potential. Farmers were encouraged to try out new practices alongside their normal/ traditional practices to be able to compare these practices and clearly observe potential advantages.

Comments from farmers about the overall process:

- *"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 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."*
- *"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 grants is even worse, as the head of the household; farming makes it better because you farm for both consumption and making an income."*
- *"I have experienced harsh weather with no rain and no 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."*
- *"It's not easy to implement new things, but if results are presented and examples are shown to prove that the practice is being tried by other farmers and it's working very well, then it makes it easier for us to try."*
- *"It's not easy to move from traditional ways of doing things to something new, because we sometimes associate change with risk that we are not ready for."*
- *"Seeing results from other people's gardens motivates us to try these ideas ourselves."*
- *"We progress much faster when we work together in learning groups, discuss issues and visit each other's gardens."*

This document provides a description of different CRA practices tried out by smallholder farmers in their learning groups, some examples of implementation, comments from farmers, assessment of impact and an overall rating based on farmers' views and in some cases, measurements.

Rating

As a means of providing a quick qualitative and visual summary of the impact of each CRA practice on the resilience of the smallholder farming system, a rating has been devised as follows:

Criteria	**Descriptors**	**Score (1 point for each descriptor)**
Improved food provision	More food, increased diversity, increased continuity	3
Improved soil conditions	Improved fertility, improved organic matter, improved soil health	3
Improved water management	Improved water holding capacity, efficient use of water, improved access	3
Uptake of practice	Experimentation with practice (no of people), continuation of practice after experimentation, increased implementation of practice	3
Skills and resources to sustain practice	Use of own resources, knowledge to implement practice adequately, access to required/external resources	3

The stars are filled (black) for each point provided in the score in the following manner

★☆☆☆☆ Score 1 to 3

★★☆☆☆ Score 4 to 6

★★★☆☆ Score 7 to 9

★★★★☆ Score 10 to 12

★★★★★ Score 13 to 15

1.2 SITES AND PARTICIPANTS

Farmer level experimentation and demonstration of practices have been undertaken for three consecutive seasons. Sites have been chosen to be representative of different agroecological conditions within South Africa.

Table 1 summarises the sites, number of participants and farmer level experimentation undertaken with each village learning group, over a period of three years.

Table 1: Summary of farmer experimentation sites for this study.

		Number of participants			Climate Resilient Agriculture practices tried*										
					Water			Soil		Crop/ tree resilience				Livestock resilience	
Area	Village	2017/18	2018/19	2019/20	Harvesting	Retention	Use efficiency	Conservation	Improvement	Crop diversification	Mixed cropping	Drought and heat tolarant crops	Integrated weed and pest management	Fodder and supplementation	Livestock integration
Mametja, Limpopo	Sedawa, Turkey, Willows, Botshabelo, Santeng	108	78	65	x	x	x	x	x	x	x	x	x		x
Bergville, KwaZulu-Natal	Ezibomvini, Stulwane, Eqeleni, Mhlwazini,	65	68	50		x	x	x	x	x	x	x	x	x	
Southern KwaZulu-Natal	Madzikane, Ofafa, Spring Valley	32	25	22		x	x	x	x	x	x	x	x	x	
Midlands, KwaZulu-Natal	Gobizembe, Mayizekanye, Ozwathini	27	28	41		x	x	x	x	x	x	x	x	x	
Eastern Cape	Xumbu, Berlin, Qhuzini, Dimbaza	18	15	45			x		x		x		x		

* This is a simplified categorisation of pratices, as most contribute to several objectives

1.2.1 *Innovation system process*

The process started with an introductory workshop with each of the learning groups, to discuss climate change, impacts on their livelihoods and farming and potential adaptive measures. These workshops also provide a space to introduce concepts and potential practices and discuss inclusion of these into their present farming system, followed by practical demonstrations and setting up the farmer level experimentation trial plots.

Interested individuals in a local area or village come together to form a learning group. Several farmers in that group then volunteer to undertake on-farm experimentation, which creates an environment where the whole group learns throughout the season through observations and reflections on the implementation and results of the chosen trials. Farmers compare various treatments with their standard practices, which are planted as control plots.

The group assesses and reviews the CRA practices each season and, based on their observations and learning, make decisions regarding the next season's implementation and experimentation. In this way the farming system is continually improved and adapted.

The table below outlines the practices introduced that farmers chose to experiment with and include in into their farming system. It also gives a summary of the rating for each practice.

Table 2: Summary of CRA practices tried throughout this farmer level experimentation and learning process.

Criteria	Improved food provision			Improved soil conditions			Improved water management			Uptake of practise			Skills and resources to sustain practise				
Climate Resilient Agriculture practices tried / **Descriptors**	More food	increased diversity	increased continuity	Improved fertility	improved organic matter	improved soil health	Improved water holding capacity	efficient use of water	improved access	Experimentation with practise (no of people)	continuation of practise after experimentation	increased implementation of practice	Use of own resources	knowledge to implement practise adequately	access to required /external resources	**Score**	**Rating**
1.3.1.1 Trench beds	1	1		1	1	1	1	1		1	1	1	1	1	1	13	★★★★★
1.3.1.2 Furrows and ridges	1			1	1		1	1		1	1	1	1	1	1	11	★★★★☆
1.3.1.3 Shallow trenches	1			1	1		1						1			5	★★☆☆☆
1.3.2 Composting	1			1	1	1	1				1		1	1		8	★★★☆☆
1.3.3 Liquid Manure	1			1						1	1		1	1	1	7	★★★☆☆
1.3.4 Shade cloth tunnels	1		1	1	1	1	1	1		1	1	1	1	1	1	13	★★★★★
1.3.5 Mulching	1			1	1	1	1				1		1			7	★★★☆☆
1.3.6 Eco-circles	1			1	1	1		1		1			1			7	★★★☆☆
1.3.7.1 Tower gardens	1	1		1				1			1		1			6	★★☆☆☆
1.3.8 Mixed cropping, crop diversification	1	1	1			1		1		1	1		1	1		9	★★★☆☆
1.3.9 Natural pest and disease control	1	1				1				1	1		1			6	★★☆☆☆
1.3.10 Seed Saving	1	1	1							1	1	1	1			7	★★★☆☆
1.3.11.1 Banana basins	1		1	1	1	1	1	1		1	1		1	1		11	★★★☆☆
1.3.11.2 Organic mango production	1	1		1	1	1	1	1		1	1		1	1		11	★★★☆☆
1.3.12 Stone bunds and check dams	1			1	1		1			1	1		1	1		8	★★★☆☆
1.3.13 Infiltration ditches (run-on ditches, diversion ditches)	1						1	1	1		1		1			6	★★☆☆☆
1.3.14 Rainwater harvesting (RWH)	1						1	1	1		1		1			6	★★☆☆☆
1.3.15 Small dams	1						1	1	1		1		1			6	★★☆☆☆

1.3 CRA PRACTICES

1.3.1 *Bed design*

The design of the garden and beds within the garden is central to incorporation of soil and water conservation principles and increase in soil fertility and soil organic matter into the intensive homestead food production system. Bed designs that provide for *in situ* composting are central to the process.

The learning process in garden and bed design includes aspects of siting, topography, water flow and run-off, wind protection and shading, to allow for well-planned inclusion of the different elements with the layout. Usually, the process starts with soil and water conservation activities (e.g. in-field rainwater harvesting; contours, swales, diversion ditches, etc.), leading on to placement of windbreaks and trees in the system, before careful consideration of placement of perennial crops and plants and layout of seasonal beds and paths.

1.3.1.1 Trench beds

To make trench beds, soil is dug out to a depth of 60 cm to 1 m and the resulting trench is filled with a layered mixture of organic matter and topsoil, before being finished off as a raised bed with an internal water holding basin and providing for water flow and infiltration pathways. They are basically underground composting beds that provide much improved soil fertility, organic matter and water holding capacity and provide for good yields.

Materials such as branches and old tins are added to the bottom of the trenches for aeration and further additions such as bones, bone meal and lime are suggested for ensuring a balance of nutrients in the resultant bed. During this learning cycle these beds have been made as 1 m x 5 m beds, to allow for implementation both inside and outside the shade netting tunnels that have also been introduced. Mulching, attention to management of irrigation and mixed cropping are routinely combined to provide for the best possible overall practice.

Generally, participants find the construction of these beds extremely labour and resource intensive, but the results speak for themselves. In the drier regions such as Limpopo, finding enough organic material to fill the trenches can be a challenge. It has been the most common practice taken on by participants, especially when introduced in combination with tunnels. Participants have constructed anything between 1 and 20 of the beds in their gardens.

Below are a few examples of construction of and growth in trench beds.

Figure 1: Above left; three 1 m x 5 m trench beds dug with collected tins for layering at the bottom of the trenches (Mametja, Limpopo).

Above middle; trench beds planted to tomatoes and leafy greens, clearly showing the built-up nature of trench beds, the indented beds for water holding, and a water flow path above the top-most trench (Turkey, Limpopo).

Above right; trenches planted to tomatoes, mustard greens and spinach, showing their placement in relation to existing mango trees and newly planted paw-paw trees in the left top corner (Sedawa, Limpopo)

Figure 2: Right; a mulched and mixed cropped trench bed in a tunnel, thriving, compared to

Far right; the same crops planted on the same day, in the conventional raised beds for Phumelele Hlongwane (Ezibomvini, KZN)

Comments by farmers

- "*Use of animal manure when planting successive crops in the trench beds helps to keep the fertility levels high and has also resulted in the presence of a larger number of earthworms in the beds."*
- *"Trench beds are the best. I now have 11 trench beds in my garden. The quality of crops from the trench beds is very good, but when you don't add compost or manure (chicken/goat/cow) every season, the quality decreases. I noticed that in one of the beds, and then started adding compost when planting."*

Assessment of impact

This practice is initially slow to be taken up, unless introduced alongside an incentive such as provision of a shade cloth tunnel. Trench beds have been extremely popular for the Limpopo based learning groups, where more than 80% of participants have included them into their gardening practice. Increase in productivity has been measured and is on average 2 to 3 times higher (200 to 300% increase) in trench beds, when compared to the normal beds. In KZN and the EC, the uptake has been a lot lower, in part because of better structured and more fertile soils that have reduced the initial wow effect of these beds. Here yield increases fall between 30% to around 120%, which is still significant.

Rating

Criteria	Descriptors	Score (1 point for each descriptor)
Improved food provision	**More food, increased diversity**, increased continuity	2
Improved soil conditions	**Improved fertility**, **improved organic matter, improved soil health**	3
Improved water management	**Improved water holding capacity, efficient use of water**, improved access	2
Uptake of practice	**Experimentation with practice (no of people), continuation of practice after experimentation**, **increased implementation of practice**	3
Skills and resources to sustain practice	**Use of own resources**, **knowledge to implement practice adequately**, **access to required/external resources**	3

★★★★★

1.3.1.2 Furrows and ridges

A traditional planting practice, furrows and ridges are used extensively in parts of Mpumalanga and Limpopo, where soil is ridged and crops are planted on the ridges. The furrows serve to lead water (irrigation and/or rain) to the crops. Adaptations made to this practice to improve on this design is the inclusion of organic matter (manure, weeds, compost, crop residues) into the ridges, mulching and placing these ridges on contour, to improve water flow to the beds and reduce the erosion potential.

The practice is particularly useful for growing sweet potatoes, but a range of crops can be grown. The effect is very similar to shallow trenches and can be used at any scale. Integrated into the garden design it also allows for channelling water and allowing for slow seepage into the surrounding beds for improved water management.

Below are a few examples.

Figure 3: Above left; A furrow and ridge meandering on a contour, planted to sweet potato and mulched, using maize residues, banana stems and tree leaves. In this case the furrow is also providing extra water infiltration for the mango trees in this garden. Above centre; Furrows and ridges planted to tomatoes, carrots, maize and spinach. The water flow paths are clearly visible, as is a trench bed under construction on the right-hand side of the picture. Above right; Furrows and ridges mulched with dry grass and planted to tomatoes. Flood irrigation is practiced, using the black irrigation piping seen in the foreground of the picture (Sedawa, Limpopo).

Comments by farmers

- *"Using manure and mulching in our traditional beds, the furrows and ridges, has helped to increase crop survival and yields."*

Assessment of impact

This practice is already widespread in Limpopo and introduction of the improvements to the system has been easy. It is much simpler for participants to improve on something they are already doing, than starting on a new practice. The practice is best suited to the conditions and soil types in Limpopo and the EC, but has not been introduced in KZN. Sandy-clay, low fertility soils with a tendency towards capping work well, while soils with a high proportion of loam and clay tend to become very hard and the ridges dry out fast and are difficult to re-wet. The capping of the sandier soils tends to 'lock' the moisture into the soil without reducing aeration – which the heavier clay soils do not. Generally, the water productivity (WP) of furrows and ridges is much lower than trench beds. Calculations have shown a 150% to 300% increase in water productivity for the trenches when compared to furrows and ridges, where increased fertility and mulching are not used, and an 80% to 160% increase in WP where they are.

Rating

Criteria	Descriptors	Score (1 point for each descriptor)
Improved food provision	**More food,** increased diversity, increased continuity	1
Improved soil conditions	**Improved fertility**, **improved organic matter,** improved soil health	2
Improved water management	**Improved water holding capacity, efficient use of water**, improved access	2
Uptake of practice	**Experimentation with practice, (no of people), continuation of practice after experimentation**, **increased implementation of practice**	3
Skills and resources to sustain practice	**Use of own resources**, **knowledge to implement practice adequately**, **access to required/external resources**	3

★★★★☆

1.3.1.3 Shallow trenches

The shallow trench is a variation on trench beds that can also be implemented at a larger scale, where a ditch 15 cm deep and 30 cm wide is constructed on contour and is then filled with organic matter; usually manure, grass and crop residues, and the top soil is replaced on top of this mixture. Crops are planted either in the sides of the ridge formed or on top.

Shallow trenches are much easier to construct than deep trenches, but the fertility does not last as long and thus these beds are re-constructed every 2nd to 3rd season. It is recommended that legumes are planted initially, as in the beginning stages Nitrogen can be a bit limiting for these beds.

Alongside are a few examples.

Figure 4: Right; digging a shallow trench in a homestead field cropping plot (Turkey Limpopo) and Far right; the beginnings of filling in a shallow trench (Mametja, Limpopo)

Assessment of impact

Although the practice is comparatively low in labour and resource requirements and is particularly good in terms of rehabilitating low fertility capped soils, participants have been slow in taking on this practice; partly due to deeply entrenched habitual practices, and partly due to the slow initial increase in fertility and crop growth.

Rating

Criteria	Descriptors	Score (1 point for each descriptor)
Improved food provision	**More food,** increased diversity, increased continuity	1
Improved soil conditions	**Improved fertility**, **improved organic matter,** improved soil health	2
Improved water management	**Improved water holding capacity,** efficient use of water, improved access	1
Uptake of practice	Experimentation with practice (no of people), continuation of practice after experimentation, increased implementation of practice	0
Skills and resources to sustain practice	**Use of own resources**, knowledge to implement practice adequately, access to required/external resources	1

★★☆☆☆

1.3.2 *Composting*

Composting consists of conscious piling and layering of a range of organic materials such as manure, crop residues, grass and leaves and managing such piles for improved decomposition of material to make compost for use in soil fertility enhancement in gardens and fields.

Branches and old tins are added to the bottom of the piles for aeration and further additions such as bones, bone meal and lime are suggested for ensuring a balance of nutrients in the resultant compost.

In smallholder farming systems, very few participants undertake composting. This is related to a number of constraints including availability of suitable manure, availability of water and availability of plant material. In addition, compost piles are often destroyed by livestock. In the piloting process and also related to training in organic mango production, a handful of participants in Limpopo have undertaken composting.

Figure 5: Right; Makibeng Moradyie (Sedawa, Limpopo), makes compost from manure, crop residue, grasses and leaves and

Far right; Meisie Mokwena's compost pile, covered with grass (Sedawa, Limpopo).

Comments by farmers

- *"It is hard work to make compost and it is often destroyed before we can use it."*
- *"Including more organic matter in the soil helps to hold water and to protect plants from heat stress."*
- *"Compost needs a lot of water, which is difficult to find. We rather use the water we have in our households and for watering crops."*
- *"It is too much work. It is really hard to make enough compost."*

Assessment of impact

Although compost is central to organic and agroecological approaches to food production, smallholder farmers very seldom make compost. Labour, water and resource requirements are high. Thus processes with *in situ* organic matter decomposition and composting such as trench beds, shallow trenches, mulching and soil cover are promoted as alternatives.

Rating

Criteria	Descriptors	Score (1 point for each descriptor)
Improved food provision	**More food,** increased diversity, increased continuity	1
Improved soil conditions	**Improved fertility**, **improved organic matter, improved soil health**	3
Improved water management	**Improved water holding capacity,** efficient use of water, improved access	1
Uptake of practice	Experimentation with practice (no of people), **continuation of practice after experimentation**, increased implementation of practice	1
Skills and resources to sustain practice	**Use of own resources**, **knowledge to implement practice adequately**, access to required/external resources	2

★★★☆☆

1.3.3 *Liquid Manure*

Liquid manures are water-based extracts made from animal- and plant-based materials that are fermented and then diluted prior to spraying on plants or the soil around plants as an additional fertility enhancement measure. Liquid manures add and balance nutrients in plants and also add microbial mixes for increased disease and pest resistance in plants.

Common sources for liquid manure are animal manures (preferably fresh, still containing the urinary fraction) such as cattle, goat, horse, sheep and poultry manure, and/or plant materials such as dark green leafy weeds (for Nitrogen), banana stems (for potassium and phosphate), comfrey and stinging nettle (both provide silicon in addition to macro and micro nutrients for disease resistance in plants).

Below are a few examples of liquid manure prepared by participants

Figure 6: Left; Liquid manure tub for Meisie Mokwena (Sedawa, Limpopo)

Farmers' comments

- *"Liquid manure using comfrey – we have seen how comfrey fertilizes the soil and also assists with pest control and with bone problems."*
- *"Using liquid manure and mixed cropping means that I now do not need any other means for pest and disease control."*
- *"Liquid manure using chicken manure soaked in water for 10 days and diluting that before use, works the best. Liquid manure helps for soil fertility and also for chasing pests."*

Assessment of impact

Smallholder farmers find making and inclusion of liquid manures into their farming system easy and convenient to do. Issues arise however with; (i) renewing the liquid manure source every 14 to 21 days, (ii) putting lids on the liquid manure fermentation containers, meaning the loss of many more volatile elements, including nitrogen and (iii) making the more complex nutrient-dense fermented mixtures that also contain milk, molasses, lime and bone meal. For the latter, participants claim lack of access. Around 42% of participants have taken on this practice.

Rating

Criteria	Descriptors	Score (1 point for each descriptor)
Improved food provision	**More food,** increased diversity, increased continuity	1
Improved soil conditions	**Improved fertility**, improved organic matter, improved soil health	1
Improved water management	Improved water holding capacity, efficient use of water, improved access	
Uptake of practice	**Experimentation with practice, (no of people), continuation of practice after experimentation**, increased implementation of practice	2
Skills and resources to sustain practice	**Use of own resources**, **knowledge to implement practice adequately**, **access to required/external resources**	3

★★★☆☆

1.3.4 *Shade cloth tunnels*

Microclimate management is considered an important adaptive measure to climate change. Shade netting and tunnels are mostly out of reach for smallholder farmers, both in terms of cost and in terms of technical skills to construct these structures.

In this regard we have collaborated with Socio-Technical Interfacing, a rural development consultancy and implementation team, who have specialised in designing and providing at scale, kits for construction of micro-shade netting tunnels (6 m x 4.2 m, 2 m high), with three bucket drip kits included in the package. Participants are trained in the construction of these tunnels and they in turn assist new participants as they come on board.

In our process, these micro tunnels have been provided to the participants free of charge, but based on a strict set of criteria which include that each prospective participant is required to dig and pack three 1 m x 5 m trench beds, over which the tunnel is to be constructed. In our case, we have also specified prioritization of active farmers, women headed households where all members are unemployed, and households where participants can prove they can access the required labour and water to effectively manage the tunnel. The demand for these tunnels has far outstripped our present capacity to provide them to participants.

The tunnels are constructed with 40% grey shade cloth, cut into the correct sized panels, sewed onto and attached to the galvanised steel conduit arches, and anchored using ski rope (see overleaf for construction process).

Farmers, more specifically in Limpopo, where the shade cloth tunnels have been extremely popular, have extended their shade netting by themselves. The original idea that participants would buy further tunnel kits to expand, proved to be unnecessary.

Figure 7: Above; Spinach in Sarah Mohlale's tunnel, Right and Far Right; Spinach and onion beds outside and inside Mtashego and Florence Shaai's tunnels. Insert: Florence dried her coriander, as it matured prior to the sales arrangements being in place. She sells this dried herb by the teaspoon-full.

Figure 8: Makibeng Moradiye used netting that she found lying around discarded by commercial fruit estates in the vicinity, and poles cut locally to extend her shade netting area, after seeing good results in her shade netting tunnel.

Below are some pictures outlining the construction process.

Figure 9:

Line 1 Above left to right: Using a rope template to mark out the tunnel and arch position; Using a hollow metal bar to make the holes for the metal arches; Bending the arches using a jig; and joining the bent halves of the arches with a standard connector.
Line 2 Above left to right; 'Planting" the arches in their holes; Sewing the netting for the end panels onto the two end arches before putting them up; Pulling and tightening the netting over all arches once they have been put up; then anchoring the arches and putting the final touches to the structure once the netting around the bottom the edges have been buried for added structural protection against wind forces.
Line 3 Above left and right: Examples of completed tunnels, with the three bucket drip kits installed.

The learning also includes the construction and installation of the bucket drip irrigation kits – one for each trench bed.

Figure 10:
Above Line 1 Left to Right; making a hole in the bottom of a 20 litre bucket to be able to attach the elbow and pipe fitting for the down pipe of the drip kit and placing this bucket on top of a 'pedestal' to provide a 'head' for the water to flow out along the dripper lines
Above Line 2 Left to Right; making the string drippers in the pipe and ladies from The Oaks attempting to make their own drippers after being taught how
Above Line 3 Left to Right: laying the two 5 m long dripper lines in the trench bed, 60 cm apart, closing off the ends of the pipes with a home-made clamp and testing the drippers for flow.

Some participants have already adapted the bucket drip system to accommodate for their own priorities and to expand their use of drip kits.

Figure 11:
Right Christinah Thobejane adapted the system to accommodate a much larger 200 L container, to allow her to irrigate less often

and

Far right; Makibeng Moradyie from Mametja (Limpopo), bought some piping that she connected to and old 50 L container to make up her own drip kit.

These buckets can also be adapted to include sand filters to filter greywater and or dirty warty irrigation water. In this case a layer of gravel is placed in the bottom of the bucket, followed by a layer of rinsed, clean river sand. The sand is placed inside a muslin bag to avoid mixing when the buckets are filled with water. These ‘filters’ need to be replaced from time to time as the flowrate from the bucket drip systems starts slowing down. The drip irrigation pipes also need to be ‘flushed’ by opening the end clamps and allowing the flow of water to wash out any accumulated silt and debris

Figure 12: Above Left to Right; gravel and rinsed, clean sand wrapped in a muslin ’bag’ make up the filter for the drip irrigation system.

Farmers’ comments

- *“The drip irrigation helps to reduce evaporation and saves water.”*
- *“The shade net tunnels work very well to reduce heat and water stress and there are fewer pests.”*
- *“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.”*
- “*The cool season crops such as Chinese cabbage, spinach and beetroot do a lot better inside the tunnels than outside, as they are not stressed by the high variability in temperatures and excessive wind inside the tunnels.*”
- *“Evaporation of water is substantially higher outside the tunnels than inside, even during the winter months. This is the biggest advantage of the tunnels – reducing water and wind stress for the crops.”*
- *“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 Resilient 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 terms of water management for irrigation"*
- *"We have added further shade-netting structures in our gardens, as they work very well".*

Assessment of impact

Participants with tunnels have all commented on the increased productivity inside the tunnels, due to a combination of increasing water use efficiency reducing evaporation, reducing pest incidence, reducing heat and reducing plant stress due to wind.

If use of tunnels is combined with trench beds and mulching, productivity can easily be twice as high as the productivity outside the tunnels; more especially in areas of Limpopo where this was implemented, where heat and drought has made vegetable production outside tunnels all but impossible for extended periods of the year.

More than 80% of participants with tunnels have also extended the size of their vegetable gardens; having been convinced that it is possible to produce despite difficult weather conditions. Sales from these small gardens have averaged around R400 to R800/ month.

Surprisingly, a large percentage of the bucket drip kits provided have been used extensively by participants. They have also replaced the gravel and sand filters, once these became clogged up.

Rating

Criteria	Descriptors	Score (1 point for each descriptor)
Improved food provision	**More food,** increased diversity, **increased continuity**	2
Improved soil conditions	**Improved fertility**, **improved organic matter, improved soil health**	3
Improved water management	**Improved water holding capacity, efficient use of water,** improved access	2
Uptake of practice	**Experimentation with practice, (no of people), continuation of practice after experimentation, increased implementation of practice**	3
Skills and resources to sustain practice	**Use of own resources**, **knowledge to implement practice adequately**, **access to required/external resources**	3

★★★★★

1.3.4.1 Water Productivity

Water productivity; the amount of crop produced per unit of water, is a very good indicator for increased resilience and productivity. However, accurate measurements of the amount of water added and the yields obtained are required.

This experiment has been undertaken for three participants in KZN and Limpopo respectively, for two to three growing seasons of six months each. The experiment itself consisted of planting 1x5 m trench beds inside and outside the tunnel to the same crop, at the same time, with or without mulching.

Davis weather stations were installed in both sites to obtain accurate rainfall and evapotranspiration data and participants were provided with record keeping forms and books to record all irrigation and harvesting.

Water productivity (WP) experimentation in KZN

This has been undertaken in the Bergville region for; Phumelele Hlongwane (Ezibomvini), Ntombakhe Zikode (Eqeleni) and Nombono Dladla (Ezibomvini).

Crops used for each experimentation cycle were as follows

1. Spinach (July- November 2018)
2. Chinese cabbage and green pepper (February- May 2019)
3. Spinach and green pepper (September 2019-February 2020)

Below are a few photographs of production inside and outside the tunnels

Figure 13: Right; Spinach in Phumelele Hlongwane's trench bed inside her tunnel (2018), is greener and larger than Far right; spinach in the trench bed outside her tunnel.

Figure 14: Above left; Phumelele Hlongwane's green pepper and Chinese cabbage bed inside her tunnel (Feb-May 2019).

Above centre; spinach and green peppers newly planted in September 2019 inside Phumelele's tunnel.

Above right; Phumelele's trench beds outside her tunnel in September 2019.

Calculations for Water Productivity

Note: A crop coefficient of 1,0 was used for spinach, Chinese cabbage and green pepper and was gleaned from the scientific literature[1]

WP was calculated as kg produce/m^3 of water. Water use is calculated by multiplying reference evapotranspiration (ET_0) with the crop coefficient to find the actual evapotranspiration (Etc), which is the volume of water (m^3) used to produce the yield (kg). In our case the 'Scientific method' uses Etc for calculating WP and the 'Farmers' method' uses water applied. The latter was used as farmers felt they could not think in terms of concepts they did not know, but could think in terms of how much water they apply.

To this end Chameleon soil water sensors were installed in the beds inside and outside the tunnels, to assist farmers to manage the amount of water they applied. These sensors use blue, green and red lights to indicate the soil moisture content at different soil depths (in our case we used three depths, namely 20, 40 and 60 cm deep). The idea was that participants could use these sensors to decide when and how much to irrigate.

This turned out to be a much more complicated process than anticipated, and in effect the Chameleons did not help participants much to plan and manage their watering processes. The example below is for Phumelele Hlongwane. The readings from June 2018 to January 2019 are shown. It indicates that she over-watered her bed inside her tunnel from June until September (blue colour), after which a more ideal water content was only reached again towards the end of December 2018 (blue and green colours). The readings actually provide a much clearer indication of access to water and rainfall than it does of irrigation management. The readings also indicate that Phumelele reduced the amount of water she used for irrigation from September 2018 onwards. The grey colour indicates either soil that is too dry to afford a reading, or a sensor that is not working. In addition, the humic acids released by beds with high organic matter content (pink colour on the graph), slowly (or more quickly in some cases) dissolve the gypsum covering of the underground sensors over time, leading to the sensors no longer being accurate or active. It was very difficult to discern whether the lack of readings was due to the soil being dry or sensors being inactive.

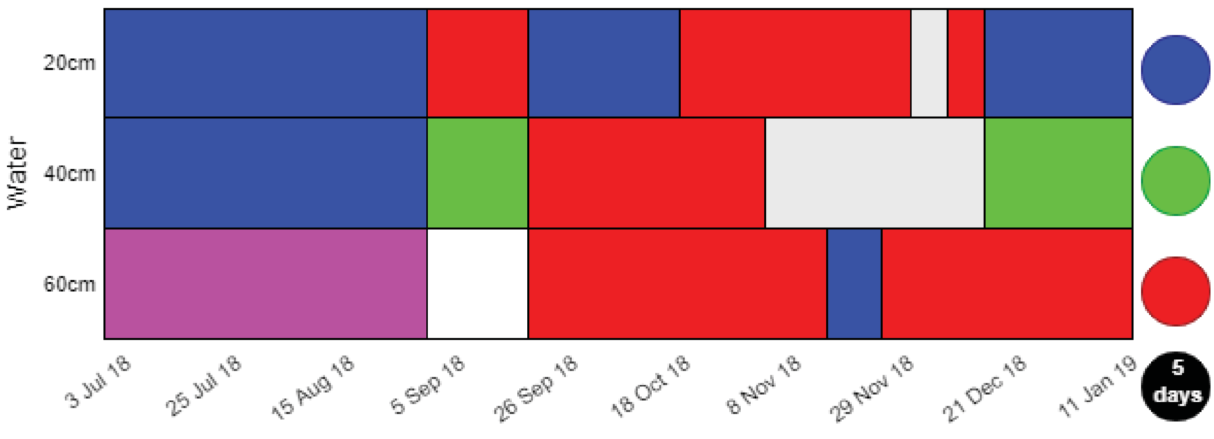

Figure 15: Chameleon sensor readings for Phumelele Hlongwane (Bergville) between July 2018 and January 2019; measured at depths of 20 cm, 40 cm and 60 cm respectively.

Another trend that has been noticed is that water productivity increased substantially for the 2nd and 3rd rounds of the experimentation. Participants reduced their amount of irrigation by more than 60% after the first season; partly because they realized they were over-watering their beds and partly due to decreased access to water for irrigation. The three small tables below compare the WP for Phumelele Hlongwane's experiments across three seasons. She consistently achieved the best WP results across the three seasons.

[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.

Table 3: Water productivity calculations for Phumelele Hlongwane, growing spinach in trench beds inside and outside her shade cloth tunnel (June-Sept 2018).

Plot	**Crop**	**Simple scientific method (ETc)**			**Farmers' method (Water applied)**		
		Yield per plot (5x1 m) (kg)	Water use (m^3)	**WP (kg/m^3)**	Yield per plot (5x1 m) (kg)	Water use (m^3)	**WP (kg/m^3)**
Trench bed inside tunnel	Spinach	21,06	1,65	**12,8**	21,06	1,85	**11,4**
Trench bed outside tunnel	Spinach	5,32	0,83	**6,5**	5,32	1,75	**3,0**

Table 4: Water productivity calculations for Phumelele Hlongwane, growing Chinese cabbage and green pepper in trench beds inside and outside her shade cloth tunnel (Feb-May 2019).

Plot	**Crop**	**Simple scientific method (ETc)**			**Farmers' method (Water applied)**		
		Yield per plot (5x1 m) (kg)	Water use (m^3)	**WP (kg/m^3)**	Yield per plot (5x1 m) (kg)	Water use (m^3)	**WP (kg/m^3)**
Trench bed inside tunnel	Chinese cabbage	60,5	0,5	**122,0**	60,5	0,6	**100,9**
Trench bed outside tunnel	Chinese cabbage	34,7	0,5	**72,1**	34,7	0,6	**57,9**
Trench bed inside tunnel	Green Pepper	3,7	0,5	**7,2**	3,7	0,5	**7,2**
Trench bed outside tunnel	Green Pepper	2,9	0,5	**5,8**	2,9	0,5	**5,6**

Table 5: Water productivity calculations for Phumelele Hlongwane, growing spinach and green pepper in trench beds inside and outside her shade cloth tunnel (September 2019-March 2020)

Plot	**Crop**	**Simple scientific method (ETc)**			**Farmers' method (Water applied)**		
		Yield per plot (5x1 m) (kg)	Water use (m^3)	**WP (kg/m^3)**	Yield per plot (5x1 m) (kg)	Water use (m^3)	**WP (kg/m^3)**
Trench bed inside tunnel	Green pepper	30,1	0,7	**46,5**	30,1	0,5	**37,8**
Trench bed outside tunnel	Green pepper	24,6	0,7	**34,5**	24,6	0,5	**31,1**
Trench bed inside tunnel	Spinach	49,0	0,7	**73,7**	49,0	0,5	**62,4**
Trench bed outside tunnel	Spinach	19,6	0,7	**29,1**	19,6	0,5	**26,4**

Observations for these three tables can be summarised as follows:

- WP calculations using the scientific method are between 10% and 20% higher than those calculated using the amount of water applied (irrigation, plus rainwater) only
- WP for crops grown in the tunnels (under shade cloth – 20%, grey) is higher than the same crop grown under similar conditions in open field conditions. Water productivity is on average 24-35% higher inside the shade tunnels, for all crops tested thus far (spinach, green pepper, Chinese cabbage)
- Yields for crops grown under shade cloth are often considerably higher than the yields for equivalent open field conditions; between 22% to 250% higher
- Yield differences for cool season leafy crops such as spinach (swiss chard) and Chinese cabbage are the most pronounced inside and outside the shade cloth tunnels. These crops yield much better within the more protected environment of the tunnels. These differences are also the most pronounced in the hot summer months

- WP for spinach was initially calculated as 12,8 kg/m^3 for the 2018 winter season. (trench inside tunnel). The WP shot up to 73,7 kg/m^3 for the summer growing season going into 2020. For the same crop. This is considered to be due to more effective irrigation and increased fertility in the trench beds as they “mature”. These values however are not directly comparable, given that
- one crop was produced during the winter season and the other during the summer season

Water productivity (WP) experimentation in Limpopo

This has been undertaken in the Mametja region for Christina Thobejane (Sedawa), Norah Mahlaku (Sedawa) and Makibeng Moradiya (Mametja).

Crops used for each experimentation cycle were as follows:

1. Spinach (April-July 2018)
2. Spinach, chilli and leek (June-September 2019)

Participants with chameleons undertook to record irrigation and harvests for a 2nd season, (June-September 2019), but most stopped their record keeping around June-July 2019 due to severe water shortages in the villages. They stopped watering their beds outside the tunnels and focused on keeping small quantities of crops inside their tunnels alive. It was thus not possible to do a second round of water productivity calculations. One participant however made a brave attempt and her calculations are presented below. During the 2nd season participants planted their own crop combinations and used crops for selling through the organic marketing system set up in the area and for household consumption.

Below, the WP calculations are presented for two participants for April-July in 2018. They both planted spinach in trench beds inside and outside their tunnels and used the traditional furrow and ridges planting method as a control.

Table 6: Water productivity calculations for two participants, growing spinach inside their shade cloth tunnels, in trench beds with and without mulch, and outside the tunnel on furrows and ridges with mulch (Sedawa, Limpopo); April-July 2018

Plot	**Crop**	**Simple scientific method (ETc)**			**Farmers' method (Water applied)**		
		Yield per plot (kg)	Water use (m^3)	**WP (kg/m^3)**	Yield per plot (kg)	Water use (m^3)	**WP (kg/m^3)**
Christina Thobejane, inside tunnel, trench bed with mulch (5 m^2)	Spinach	48,9	0,8	**61,7**	48,9	1,1	**56,7**
Christina Thobejane, outside tunnel, furrows and ridges with mulch (3,5 m^2)	Spinach	24,5	0,5	**44,0**	24,5	3,9	**5**
Nora Mahlako, inside tunnel, trench bed without mulch (5 m^2)	Spinach	19,6	0,8	**24,7**	19,6	9,5	**5**

Note 1: Both participants stopped irrigating some of their beds due to a lack of water and these results could not be included.

Observations from the table can be summarised as follows:

- For Christina; the WP for the trench bed inside the tunnel is ~70% higher than the furrows and ridges control planting, when looking at the scientific method of calculation. Yields inside the tunnel were double that of the traditional planting method of furrows and ridges, which were outside the tunnel.
- Christina mentioned that she changed the way she does watering, based on her Chameleon readings and opted for deep watering once or twice a week, rather than using small amounts of irrigation on a daily basis.

- For Norah's tunnel the situation is quite different. She did not do mulching and she kept to the 'traditional' watering practice of a little in the morning and a little in the evening every day. She has used a lot more water than Christina did inside her tunnel (9,5 m^3 vs 1,1 m^3), but her process was significantly less productive (19,6 kg of spinach vs 48,9 kg of spinach). This indicates that her practices greatly increased the required amount of water, without increasing the efficiency of use of this water. This is a significant difference in yield brought about by a number of factors, as observed and discussed with the farmers:
    - Mulching and deep watering inside the tunnel vs no mulching and repetitive shallow watering
    - Harvesting practices; another aspect mentioned by farmers when analysing these results is that it is possible that Norah overharvested her spinach, with the outcome that regrowth and further harvesting was reduced
    - Farmers also mentioned that there is generally more shade from trees, in Christina's garden, even her tunnel is provided with some shade during the day, while Norah's tunnel has no shade
    - Different planting times; this could in fact have played a large part in the WP differences in the two tunnels as Norah planted at the end of February (when it was very hot) and Christina planted at the beginning of April (when it was much cooler).

These results give a clear indication of the productive advantage of using tunnels in these hot, dry conditions and further show the added yield and water productivity advantages of mulching and deep watering as crop management practices. Chameleon sensor readings further demonstrate the above analysis.

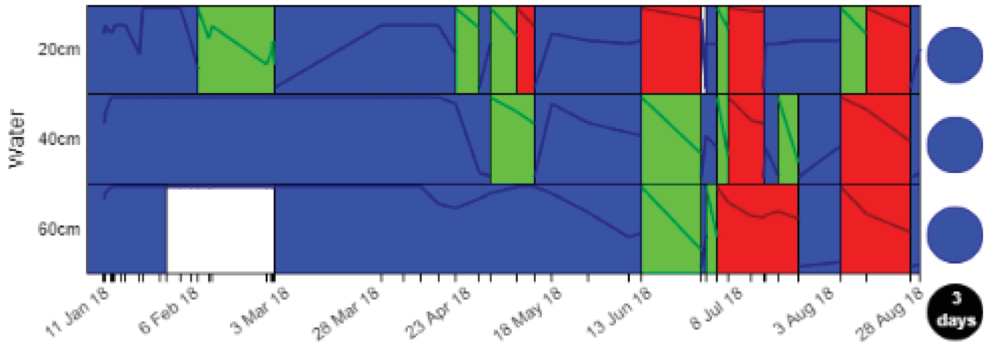

Figure 16: Chameleon sensor readings for Christina Thobejane's trench bed inside her tunnel between January and August 2018

This data indicates 58% blue, 15% green and 17% red readings throughout this period and is a good example of reasonable irrigation management. The data set for the furrows and ridges look similar, as shown below, but she had to use 3,5 times more water on the furrows and ridges, when compared to the trench inside the tunnel to achieve this result

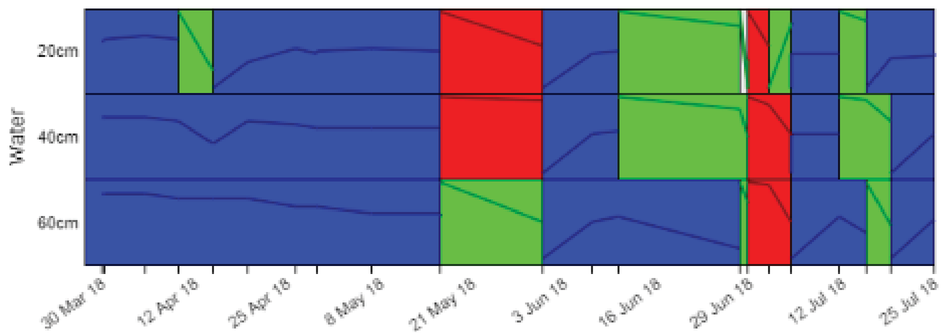

Figure 17: Chameleon sensor readings for Christina Thobejane's furrows and ridges outside her tunnel between March and July 2018

Norah Mahlaku's Chameleon sensor readings for her trench bed inside her showed under watering (26% blue, 4% green and 70% red) during the same period despite the fact that she used 8,6 times more water than Christina did in her tunnel trench bed.

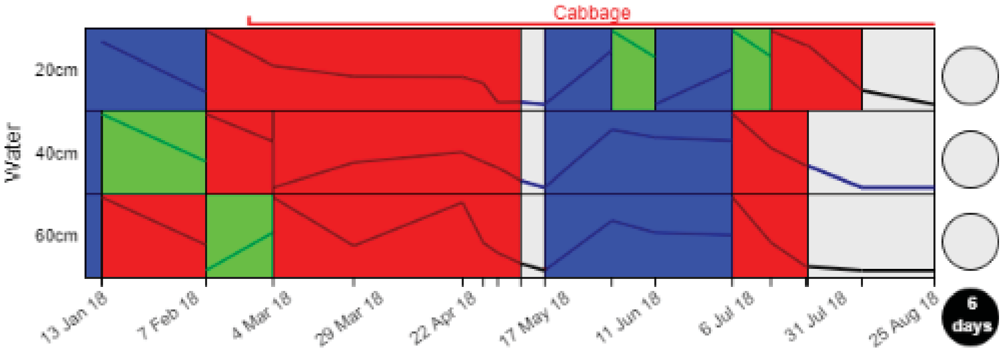

Figure 18: Chameleon sensor readings for Norah Mahlaku's trench bed inside her tunnel between January and August 2018

Christina has made the following comments about the chameleons:

- ➢ Applying water until the chameleon changes colour (goes blue) seems to be a good idea as this saves her some water and means that she only has to irrigate once a week (every 7 days).
- ➢ She has thus now changed her irrigation practice of watering a little every morning and afternoon, to a deep watering every 5-7 days. Even though this was discussed in the learning workshops, she was not convinced until she managed to work it out for herself.
- ➢ The chameleon in the tunnel stays blue (indicating enough water in the soil) for longer than in the other beds.
- ➢ She appreciates the ease of using the chameleons – by just checking the colour.
- ➢ She felt that all the weighing and recording of water applied was time consuming and unnecessary, since she could visually see the difference in the plants.
- ➢ Another difficulty lay in the reading the data from the chameleons, as this was often frustrated by small wires coming loose in the chameleon array. Uploading this data was also a bit problematic, given that it required a sizeable amount of data, along with good cell phone reception.

Figure 19:
Right; An example of a Chameleon sensor in this case indicating blue, green and red for the three different soil depths (20, 40 and 60 cm respectively)
Far right; Sylvester Selala in Christina's tunnel checking the sensor.

A further interesting adaptation was employed by Makibeng Moradiya. She observed that the shading in the tunnels has a very beneficial effect on crop growth. She then moved her outside beds to be either in the shade or surrounded by shade-cloth to reduce the effect of heat and wind. She has thus already internalised the principles inherent in the advantages that tunnels can provide and have applied these to the rest of her garden.

Figure 20: Above left; spinach and leeks inside the tunnel, in the bed Makibeng used for her record keeping. In the foreground are peas and parsley. Above Right; A trench bed outside the tunnel with beetroot and spinach – planted slightly later in the season, planted in an area with shade and surrounded by shade cloth, to emulate the effects of the tunnel.

The WP calculations for her trench beds inside and outside her tunnel thus do not show such a high degree of difference, as shown below, using the farmer method of calculation.

Table 7: Water productivity calculation for Makibeng Moradiya, Limpopo, June-September 2019

	Farmers' method (Water applied)		
Name of farmer **Crops; leeks, chilli and spinach**	Water use (m^3)	Total weight (kg)	**WP (kg/m^3)**
Trench bed inside tunnel (4,5 m^2)	1,7	17,4	**10,3**
Trench bed outside tunnel (4,5 m^2)	1,8	14,9	**8,3**

From the above table it can be seen that Makibeng's water productivity inside her tunnel was around 24% higher than outside the tunnel.

1.3.4.2 Cost-benefit analysis

The cost-benefit analysis serves to indicate the effect of payment for irrigation on the potential profitability of producing crops in the shade net tunnels. Payment for water is by far the most significant cost to smallholders.

Water costs have been estimated using the common cost of R35/210 litre drum in Limpopo and R300/ 2 200 litre JoJo tank in KZN. The table below indicates the potential profit of producing inside and outside tunnels related to payment for water. The improved financial benefit of planting in tunnels is a very compelling reason why they are so popular with the smallholder participants.

Table 8: A cost-benefit analysis of planting inside and outside tunnels; with and without paying for irrigation water.

Cropping practice	**Water (litres/5 m^2 bed)**	**Cost of water (R/m^2)**	**Yield (Kg/m^2)**	**Sales (R/m^2)**	**Profit (R/m^2)**
KZN: Trench inside tunnel	700	**R0,00**	2,6	R26	R26,00
KZN: Trench inside tunnel	700	R4,90	2,6	R26	R21,20
Limpopo: Trench inside tunnel	1100	**R0,00**	6	R60	R60,00
Limpopo: Trench inside tunnel	1100	R18,70	6	R60	R41,30
KZN: Trench outside tunnel	700	**R0,00**	1,6	R16	R16,00
KZN: Trench outside tunnel	700	R4,90	1,6	R16	R11,10
Limpopo: Trench outside tunnel	2926	R48,80	4,2	R42	-R6,80
Limpopo: Furrows and ridges	3913	R130,40	2,4	R24	-R106,40

1.3.5 *Mulching*

Mulching is an oft-mentioned climate resilient agriculture practice that has obvious benefits in reducing evaporation, decreasing soil temperature and to some extent improving soil fertility and soil health.

It is a practice that smallholders are generally well aware of, but do not implement often, despite the obvious benefits. Smallholders cite increased pest and disease incidence along with difficulty in obtaining material for mulching as the two main reasons.

The important longer-term benefits of mulching in increasing soil health and fertility are generally not realised, given that farmers stop using the practice after lack of a major impact in the short term. Around 32% of smallholders who have been introduced to this practice continue to use it as an ongoing practice in their gardens.

Farmers' comments

- *"I use dry leaves for mulching to reduce evaporation. This is good because I have to fetch water with a wheelbarrow and now I do not need to do this every day." (Rackson Makgobatlou, Turkey, Limpopo)*
- *"Mulching also adds to soil fertility."*
- *"Although the mulching assists in weed control, some weeding is still required- especially in summer and the main advantage of the mulch is to keep the soil moist and cool"*
- *"I experienced pest problems, ants feeding on the mulch and damaging my crops, when using mulching, so I do not use mulch anymore." (Sarah Madire, Turkey, Limpopo).*

Rating

Criteria	**Descriptors**	**Score (1 point for each descriptor)**
Improved food provision	**More food,** increased diversity, increased continuity	1
Improved soil conditions	**Improved fertility**, **improved organic matter, improved soil health**	3
Improved water management	Improved water holding capacity, **efficient use of water**, improved access	1
Uptake of practice	Experimentation with practice, (no of people), **continuation of practice after experimentation**, increased implementation of practice	1
Skills and resources to sustain practice	**Use of own resources**, knowledge to implement practice adequately, access to required/external resources	1

★★★☆☆

1.3.6 *Eco-circles*

These are small circular, double-dug beds with addition of manure or compost, as well as mulch. They are drip irrigated using a 2-litre bottle with small holes drilled into the sides, which is 'planted' in the centre of the bed.

Eco-circles are appropriate for small gardens and also as a practice to introduce the benefits of increased soil depth for rooting, organic matter, mulch and irrigation management. A few participants have incorporated these concepts into their overall gardening practice and around 31% of participants to whom this practice has been introduced continue to use it in an ongoing manner in their gardens

Below are a few examples.

Figure 21: Above left; Double digging the 1 m diameter circle for the bed, Above centre; A completed eco-circle with a stone border (Gobizembe, KZN) and Above right; Mulching and 2 litre bottle drip system adapted for use in a larger trench bed (Bergville, KZN).

Farmers' experiences

- *Portia Shai implemented the eco-circles in her garden and found that they improved crop growth and yields substantially, as long as one has water for irrigation. Magdalena and Lydia Shaai also added to Portia they have planted spinach, green beans and herbs in the eco-circles and they are very happy with the results.*

Rating

Criteria	Descriptors	Score (1 point for each descriptor)
Improved food provision	**More food,** increased diversity, increased continuity	1
Improved soil conditions	**Improved fertility**, **improved organic matter, improved soil health**	3
Improved water management	Improved water holding capacity, **efficient use of water**, improved access	1
Uptake of practice	**Experimentation with practice (no of people),** continuation of practice after experimentation, increased implementation of practice	1
Skills and resources to sustain practice	**Use of own resources**, knowledge to implement practice adequately, access to required/external resources	1

★★★☆☆

1.3.7 *Greywater management*

Greywater is water used for washing in a household (clothes, dishes, people), but does not include blackwater (toilet water, sewage). Greywater is generally high in soap content of various types and organic matter. Dangers in use include microbial contamination, nitrification from soap and crusting on top of the soil if it is used in the same place often. Management for safe use and disposal of greywater is important. Mostly this consists of using ash and other substances such as moringa seed to bind and flocculate some of the soap, and irrigation practices that avoids the greywater from touching the leaves of the crops.

Greywater is not considered suitable for use by smallholders in vegetable gardens in KZN and the Eastern Cape, but is generally used to water fruit trees and shrubs. In Limpopo, there is a practice of settling soaps with ash, prior to using greywater in gardens.

In this process, specific bed-designs were introduced to maximise the benefits of greywater. These include tower gardens and keyhole beds. Keyhole beds are above ground beds, constructed with stone walls and have a central composting basket where greywater is applied. Access to enough stone has been a severely limiting factor and participants have not undertaken this practice after the initial demonstrations

1.3.7.1 Tower gardens

Tower gardens are built-up beds; a constructed tube of shade cloth and poles with a central core of gravel to filter out and bind some of the soaps in greywater. The medium is made of a third each of soil, compost or manure and wood ash. The wood ash also binds the soaps.

They provide a small, intensive, easy to manage raised bed that can be placed close to the home, in circumstances where there is a shortage of water and a safe way to use greywater.

The materials required can be limiting for some gardeners, and includes 2x3 m 80% shade cloth, 4x 1,8 m poles, 5 kg gravel, a 5-litre bottomless bucket and a wheelbarrow full of wood ash. Construction of the bed is easy, once demonstrated.

Below are some examples of tower gardens constructed by participants in KZN.

Figure 22: Above left; a tower garden self-constructed by Mrs Mncanyana from Gobizembe (SKZN), planted to leek, kale, parsley and spinach.

Above centre left Mrs Xasibe's tower garden (Gobizembe) planted to spinach, kale, and marigolds.

Above centre right; A tower garden constructed by Mrs Msele from Stulwane (Bergville), from a large feedbag, planted to cabbage and spinach.

Above right; Mrs Hlongwane's tower garden in Ezibomvini (Bergville), planted to mustard spinach, kale, spring onions and cabbage.

Below are some examples of tower gardens constructed in the EC and Limpopo

Figure 23: Above left and centre; tower gardens for Aviwe Biko (Dimbaza) and Phindiwe Msesiwe (Qhuzini) in the EC, planted to spinach, cabbage, onions and beetroot Above right: Nkhurwane Shaai's tower garden in Turkey (Limpopo,) planted to spinach only.

Comments by farmers

- *"We do not have easy access to the materials required to build these towers."*
- *"It is a convenient way of growing crops as it was easy to maintain and to manage and did not require extensive weeding."*
- *"These towers provide a good way to use greywater, which otherwise would be wasted and crops grow very well."*
- *"As simple as it looks to do a tower garden, for us (Turkey 1, Limpopo) it was too much. Although trench beds are even more work, we found the results a lot more impressive in terms of improved yields and water usage and thus prefer these beds."*
- *"I have now planted three tower gardens, so that I have spinach all the time."*
- *"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."*

Assessment of impact

Despite the fact that these beds are highly productive and a good option for easy household production and safe use of greywater, the practice is not readily taken up by learning group participants. Participants have a tendency to make the towers too big and to provide too little water and they tend to forget to flush the bed with clean water from time to time. They are also reluctant to plant into the sides of the towers, which diminishes the usefulness of the structures substantially. As a result, the potential advantages of using tower gardens have not been well realised. Around 46% of learning group participants use greywater, but only about 5% of those participants have incorporated the use of tower gardens.

Rating

Criteria	Descriptors	Score (1 point for each descriptor)
Improved food provision	**More food, increased diversity**, increased continuity	2
Improved soil conditions	**Improved fertility**, improved organic matter, improved soil health	1
Improved water management	Improved water holding capacity, **efficient use of water**, improved access	1
Uptake of practice	Experimentation with practice,(no of people), **continuation of practice after experimentation**, increased implementation of practice	1
Skills and resources to sustain practice	**Use of own resources**, knowledge to implement practice adequately, access to required/external resources	1

★★☆☆☆

1.3.8 *Mixed cropping, crop diversification*

Mixed cropping in a gardening context, is a combination of inter-cropping, crop rotation and companion planting. The intention is to have as many different types of crops (including medicinal, pest repellent and multi-purpose plants) in your vegetable and fruit production systems as possible, throughout the year, to ensure a healthy food supply, improve pest, disease and weed management and reduce risk of shortages due to crop failure.

The choice of crops is based on the following:

- Being able to harvest food from a garden for household use throughout the year. This means a focus on crops that can be harvested for extended period such as leafy greens, leaf lettuces, and spring onions and leeks, and de-emphasising crops such as cabbage and onions that have long waiting periods without producing food.
- Crops high in Vitamin A; such as dark green leafy vegetables (such as spinach, mustard, rape and kale), carrots, traditional greens (such as Amaranthus and pumpkin leaves) and herbs (such as parsley).
- Pest-repellent crops such as coriander, garlic chives and other herbs such as rosemary and thyme.
- Legumes and protein rich vegetables such as beans, peas and turnips.
- Perennial multipurpose plants such as wormwood, lemongrass, bulbinella and comfrey.
- Flowers such as marigolds and calendula.

In addition, attention is given to not planting crops of the same family together in one bed to reduce the spread of common diseases and nutrient competition. Thus, tomatoes, brinjals, potatoes and peppers are not planted together, neither are brassicas such as cabbage, broccoli, cauliflower and kale, or chards such as swiss chard and beetroot.

Crop rotation is introduced both in terms of alternating heavy feeders such as cabbage with light feeders such as swiss chard and lettuces, as well as the well-known rotation of leaf-root-legume-fruit.

Cropping calendars are developed to suit localities and changing climatic conditions.

Below is a cropping calendar jointly designed with participants from Limpopo, which experiences warm winters and hot summers. In KZN and the Eastern Cape where winters are cool to cold, standard cropping calendars are still mostly appropriate.

When can I plant vegetables?										Too hot to plant!		
	Mrch	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb
Baby marrows						■	■	■	■			
Basil	■	■	■			■	■	■				
Beetroot	■			■	■	■						
Brinjal						■	■	■				
Cabbage	■	■	■	■	■	■						
Carrots				■	■	■	■					
Chilli						■	■	■	■			
Green beans	■	■					■	■	■			
Green pepper						■	■	■				
Kale and other morogo e.g. amaranthus	■	■	■	■	■	■	■	■				
Lettuce	■	■	■	■	■	■						
Leeks, sping onions	■	■	■	■	■	■	■					
Mustard spinach	■	■	■	■	■							
Onions	■	■					■	■	■			
Parsley	■	■	■	■	■	■	■					
Peas	■	■	■	■	■							
Tomatoes	■	■	■	■	■	■						

Figure 24: Vegetable cropping calendar developed with participants in Limpopo (2019)

Mixed cropping concepts have been easily internalised and adapted by learning group participants in all three provinces. They have now included *a mixed cropping regime* as their standard practice. This consists of planting 2-5 different crops per bed for each planting cycle of around 4 months, and rotating these with different crops in the following season; e.g. rotating root crops with leaf crops, or cabbage with spinach. They explain that the actual planting mixes are chosen depending on whether they are heavy feeders or not, and on crops belonging to different crop families. It is clear that they are now using some of the principles of mixed cropping and crop rotation that were introduced, in their cropping cycles.

Participants have been encouraged to grow their crops from seed and for most learning groups, participants have also worked together to buy commercial or locally produced seedlings.

Figure 25: Seedlings of vegetables and herbs being sold to participants in the learning group from the farmer centre in Ezibomvini; spinach, beetroot, cabbage, Chinese cabbage, onions, and herbs (parsley and coriander).

The advantages of mixed cropping are much more apparent when combined with mulching, soil fertility practices and soil and water conservation techniques.

The pictures below provide examples of what participants have implemented.

Figure 26: Clockwise from Top left: Mrs Mcanyana (Gobizembe) – broccoli, Chinese cabbage, spinach, coriander and marigolds; Magdelina Malepe (Sedawa), marigolds, thyme, parsley, spinach and kale; Christina Thobejane (Sedawa) – maize, okra, tomatoes kale and marigolds; Alex Makgopa (Sedawa)- spring onions, spinach, carrots and marigolds and Phumelele Hlongwane (Ezibomvini) – beetroot, mustard spinach, spring onions and parsley

Herbs are not very common in community gardens as they are generally known to be for medicinal uses and not consumption, hence the general belief is that if required, they must be purchased from a traditional healer or collected from the nearby bush. Growing herbs was a way to introduce and create awareness about other types of herbs and their uses. The team discussed the various uses of the herbs with participants when planting, e.g. use of parsley and rocket in salads, thyme in meat dishes, coriander in curry, etc.

Figure 27; Centre; Mrs Ngobese's garden with leeks, sprig onions marigolds and basil incorporated, Right; Herbs growing in an eco-circle, parsley, coriander and rocket by Mrs Xasibe in Gobizembe, KZN

However, participants tend to decrease their mixed cropping efforts when planting larger areas and or when they are planting for sale. It is here that intercropping and crop rotation come to the fore. This has been most evident in Limpopo, where a handful of participants have accessed larger fields and irrigation.

Figure 28: Above left: Matsehgo Shaai with mono-cropped beds of coriander and spinach in her tunnel, *Above centre; Mrs Maphori with mono-cropped cabbage in his irrigated field.* *Above right; Obridge Tsethla's mono-cropped tomatoes in his irrigated field.*

Comments by farmers

- *"I planted Chinese cabbage for the first time, but it attracted too many snails."*
- *"We like crops that we can harvest multiple times in our vegetable gardens."*
- *"Some of the practices such as mixed cropping is good; one can see the results you are working towards."*
- *"Working with mixed cropping and crop rotation has decreased the incidence of pests and diseases, although there are still problems"*

Assessment of impact

Mixed cropping and crop diversification are reasonably easy practices to introduce into the smallholder household food gardening process, despite participants' initial reluctance in growing crops that they don't know and don't habitually consume.

When the initial introduction of the new crops is done by providing seed, seedlings and plants as samples, it has been found that by the second or third season, participants have included some of these into their cropping system and have grown or bought their own stock.

Crop diversification is crucial for building resilience to climate change and farmers have commented repeatedly on the benefits of increased availability of a diverse range of food from their gardens. They have mentioned that they have saved money and that their children are healthier.

Rating

Criteria	**Descriptors**	**Score (1 point for each descriptor)**
Improved food provision	**More food, increased diversity**, **increased continuity**	3
Improved soil conditions	Improved fertility, improved organic matter, **improved soil health**	1
Improved water management	Improved water holding capacity, **efficient use of water**, improved access	1
Uptake of practice	**Experimentation with practice (no of people), continuation of practice after experimentation**, increased implementation of practice	2
Skills and resources to sustain practice	**Use of own resources**, **knowledge to implement practice adequately,** access to required/external resources	2

★★★☆☆

1.3.9 *Natural pest and disease control*

Natural pest and disease control in an intensified homestead food production system context consists of a combination of the following four approaches:

- ✓ Improvement of soil fertility, soil health and soil water holding capacity to produce vibrant, healthy plants, working form the assumption that stressed plants are more susceptible to pest and disease attacks.
- ✓ Mixed cropping and garden sanitation; to reduce the concentration of pests and diseases that occur in mono cropping systems as well as the potential for re-infestation and infection through safe removal of diseased plant material and removal of breeding grounds for pests. And to promote the presence of pest predators and bees.

Figure 29: Onion and leek flowers attract wasps, which are natural predators of common garden pests.

- ✓ Planting of multi-purpose species, both annual and perennial, to include plants that have pest repellent and pest control properties. These include for example;
  - o flowers such as marigolds and calendula;
  - o herbs such as lavender, rosemary, coriander, parsley, thyme, fennel, basil, rocket, lemon grass and garlic chives;
  - o medicinal species such as wormwood bulbine and bulbinella species, aloe *spp*, comfrey, stinging nettle; and
  - o leguminous trees such as Sesbania sesban, moringa, pigeon pea and Acacia *spp.*
- ✓ Making of brews/ teas with pest and disease control properties. Here common household recipes include combinations of chilli, garlic, onion and green bar soap (for soft bodied insects such as aphids), paraffin and onion (for hard bodied insects such as beetles and grasshoppers) and tobacco (only for pernicious and very heavy pest infestations). There are however many other options as well.

It is common for participants to wish to be provided with a chemical that can kill all their pests and gardeners often use pesticides such as 'blue death' and 'bulala zonke' in their gardens. The concept of a balanced ecosystem, which can in and of itself reduce pest and disease problems, is a difficult concept to internalize. Smallholders tend to be somewhat uninformed about different crop diseases and pay very little attention to this.

In addition, many smallholder farmers are very reluctant to plant anything that does not directly provide food for themselves and their livestock or a commodity that can be sold. For these reasons, introduction of a few new, carefully selected species into the smallholders' cropping system, is advised.

There are however some localised practices that participants report using. These include for example:

- ➢ Use of wood ash to deter cutworms and aphids.
- ➢ Use of salt, chilli, garlic and or onion mixed with soap and water to kill snails.
- ➢ Use of pig manure, indigenous garlic, garlic chives and 2 litre bottles half-filled with water, to deter moles.
- ➢ Burning of cow manure and marigolds; the smoke chases insects away.
- ➢ Spraying of a mixture of water in which cow hides have been soaked for some days to chase away locusts from crops and trees.

Phindiwe Msesiwe from Qhuzini (EC) explained that she uses the soap, chilli and garlic spray on her tower garden and in her beds. She sprays early in the mornings. She has replaced the garlic with onion, as garlic is expensive to buy. She also mixes in other "smelly" plants such as garlic chives and Khaki-weed (a Tagetes species). Below are a few pictures.

Figure 30: Phindiwe Msesiwe's tower garden that she sprays with a mixture of soap, chilli, onion, garlic chives and Khaki weed to deter pests.

Farmers' comments

- *"We learnt about promoting pest predators such as the lizard hotel."*
- *Portia Shai has been planting spinach and garlic on the same eco-circle; she plants spinach in the middle and on the outside, she plants garlic to help with pest control.*
- *Lydia Shai has been planting herbs (coriander and parsley) together with vegetables; the smell of the herbs helps control pests and diseases.*
- *In terms of pest and diseases control they use ash and a brew made from chilli and soap.*
- *Other participants said nothing; they normally don't use any practice for pest control even when they have pest problems in their garden, and they understand that materials used to make brews for pest control are easily accessible, some they can find in their garden but they don't have time to make the brew.*

Impact assessment

Participants have consistently mentioned the increase of pest and disease infestations in their crops due to the changing climate. They have also observed new types of pests becoming more prevalent. Although most participants are very enthusiastic about the presentations of a more natural garden eco-system that includes pest predators such as lizards and frogs, very few change their gardening practices substantially to accommodate these principles. They also enjoy the pest control brews and the many options available, but again very few participants actually experiment with these options. Only around 18% of participants introduced to these concepts have continued to try any of them out.

Mixed cropping however, including the use of strong smelling and pest repellent crops and herbs is taken on enthusiastically and around 82% of participants incorporated some of these practices in their gardens. Use of liquid manure and greywater as pest repellents is also quite common.

Rating

Criteria	Descriptors	Score (1 point for each descriptor)
Improved food provision	**More food, increased diversity**, increased continuity	2
Improved soil conditions	Improved fertility, improved organic matter, **improved soil health**	1
Improved water management	Improved water holding capacity, efficient use of water, improved access	0
Uptake of practice	**Experimentation with practice (no of people), continuation of practice after experimentation**, increased implementation of practice	2
Skills and resources to sustain practice	**Use of own resources**, knowledge to implement practice adequately, access to required/external resources	1

★★☆☆☆

1.3.10 *Seed Saving*

Seed saving is both a common practice among smallholders and a dwindling one. Seeds are kept from one year to the next and due to increasingly difficult growing conditions, many participants have reported losing most of their seed stock. Increasingly, smallholders will buy seed and attempt to keep seed from those crops when harvested; meaning a substantial attrition in the availability of seed of traditional crops.

Participants keep seed in drums, grass jars and bottles and plastic packets, usually in their homes. Some will add ash to their seed to control post-harvest pests such as weevils.

Upon introduction of new open pollinated and untreated seeds into the gardens, participants have enthusiastically started keeping seed of those crops. In Bergville for example, participants have kept and shared the following seed varieties; coriander, parsley, rape, kale, mustard spinach, leeks, maize, sugar beans, cowpeas, sunflower, sorghum, Sun hemp, pumpkins and millet. In Limpopo the list includes; Mustard spinach, carrots, onions, leeks, butternut, brinjals, chilli, kale, tomatoes, peas, green beans, moringa, basil, rocket, fennel, coriander, parsley, maize, cowpeas, sugar beans, white beans, sunflower, Sun hemp, jugo beans, groundnuts and pumpkins.

Figure 31: Above left; seed display at a farmers' exchange in Limpopo for bartering and sale; including for example beetroot, yarrow, mint, brinjal, Lucerne, pumpkins, chillies and marigolds and Above right: Seeds that have been saved by group members (Ezibomvini, Bergville) and that are shared among the learning group members; including coriander, parsley, rape, mustard spinach and kale.

Figure 32: Left; Sarah Madire (Turkey, Limpopo), kept seed for kale, mustard spinach and spinach, and replanted them in trench beds for food and sale, and Right; Odinah Mayibela (Mametja, Limpopo), kept jam tomato and kale seeds for replanting.

Impact assessment

Around 76% of the programme participants have kept and replanted seed. Seed exchange workshops are very popular and a few participants have been selling seed to their neighbours.

Seed from bi-annual crops and crops that need very specific attention to produce viable seed, or cross easily, such as onions, carrots, peppers, cabbage, broccoli and Chinese cabbage, have not been kept very successfully. Part of the issue with these crops is that one has to be able to demonstrate to the farmers what the correct practices are and the timing needs to be precise, which is tricky to manage with many far-flung participants.

Rating

Criteria	Descriptors	Score (1 point for each descriptor)
Improved food provision	**More food, increased diversity**, **increased continuity**	3
Improved soil conditions	Improved fertility, improved organic matter, improved soil health	0
Improved water management	Improved water holding capacity, efficient use of water, improved access	0
Uptake of practice	**Experimentation with practice, (no of people), continuation of practice after experimentation**, **increased implementation of practice**	3
Skills and resources to sustain practice	**Use of own resources**, knowledge to implement practice adequately, access to required/external resources	1

★★★☆☆

1.3.11 *Fruit Production*

Most smallholders will have at least a few fruit trees in their yards, the type depending on where they are located. In KZN and the EC participants primarily have peaches, some oranges, paw-paws and bananas. In Limpopo smallholders plant a range of sub-tropical fruit including mangoes, avocados, bananas, paw-paws and citrus. Fruit such as grapes, plums and apples are grown, but is not common.

In Limpopo, traditional fruit such as Marula and Mokgogoma are grown within the homesteads. Marula in particular has a good local market for beer and nuts.

On the whole, smallholders plant the trees and then expect them to self-manage thereafter. Irrigation, fertilisation and pruning are not commonly undertaken. The potential for improvement in production is substantial.

Figure 33: Above left; A mixed homestead orchard of banana, mango and avocado in Lepelle (Limpopo).

Above middle; A Mokgogoma tree in fruit.

Above right; Marula being harvested for beer and nuts

Two focus areas in Limpopo, have involved the promotion of a traditional practice in the area – banana basins; and promotion of improved production practices for mangoes, with a view to create certified organic mango producers who can sell into lucrative fresh and dried mango markets in the area.

1.3.11.1 Banana basins

This practice consists of planting the bananas in large square or circular basins filled with organic matter and stepping these basins down along a water flow course within the yard.

Banana basins have improved the survival of bananas substantially during the four- to five-year drought that has gripped the Lower Olifants region of Limpopo. Around 18% of participants who have been exposed to this practice have implemented it in their homesteads.

Figure 34: Right; A banana basin recently planted to young banana trees in Sedawa (Limpopo) and

Far Right; stepwise design of banana basins in a water flow channel in Botshabelo (Limpopo).

1.3.11.2 Organic mango production

Mangoes are extremely hardy fruit trees that can survive extreme heat and long dry spells. Most smallholders in Limpopo have at least a few trees in their homesteads and many have between eight to twenty trees. A few individuals, with some access to supplementary irrigation have planted sizeable orchards. Predominantly participants plant the 'wild' or 'fish' mango as it is locally known – which is un-grafted and produces reasonably small, fibrous fruits. These are mainly suitable for sale green, into the atjar value chain. Due to reasonably easy access to the fruit estates in the region, many of these participants also have a number of the more 'modern' varieties planted; namely Keitt, Kent, Tommy Atkins and Shelley, all with large fruit and low in fibre.

The intervention consisted of providing a learning session in making compost, deep mulching and manuring of trees, creation of irrigation basins for each tree and irrigation schedules for mangoes. It also included learning on correct pruning of trees for maximum fruit bearing capacity. Around 15% of participants involved have implemented these practices in their small orchards and have increased their harvestable, high quality fruit production by between 30-76%. This has allowed them direct access to packhouses in the area that receive fruit for drying and fruit rolls and provides for an average income potential of around R500/tree per annum.

Figure 35: Above Left; A pruned mango tree pushing out new growth, with compost added in the irrigation basin and mulching (Matshego Shaai).

.Above centre left; Pruning, composting and irrigation basins added for an old mango tree to bring it back into production (Mpelesi Sekgobela),

Above centre right; Shakes Searane's mango orchard in Lepelle, being inspected by a mango estate manager.

Above right; Mango juice produced by Christina Thobejane (Sedawa).

Comments from farmers

- *"I already knew how to prune the mango trees, but these new practices have reduced the pest and disease problems in our trees and with continued practice I think I will make a lot more money than the R6 000 I made this year (from 15 trees) (Matshego Shaai, Turkey)."*
- *"I have realized that it is important to irrigate the trees, as the ones I did not water have died back in this drought. Also, if you water the trees, then the small fruit don't drop off due to stress (Norah Tsetlha, Sedawa)."*
- *"We always believed that there was nothing we could do to improve the yields of our mangoes and wondered why the trees in the commercial estates look so good. Now we can produce beautiful mangoes, just like them (Christina Thobejane)."*

Rating

Criteria	Descriptors	Score (1 point for each descriptor)
Improved food provision	**More food,** increased diversity, **increased continuity**	2
Improved soil conditions	**Improved fertility, improved organic matter, improved soil health**	3
Improved water management	**Improved water holding capacity**, **efficient use of water**, improved access	2
Uptake of practice	**Experimentation with practice (no of people), continuation of practice after experimentation**, increased implementation of practice	2
Skills and resources to sustain practice	**Use of own resources**, **knowledge to implement practice adequately,** access to required/external resources	2

★★★☆☆

1.3.12 *Stone bunds and check dams*

Stone lines or bunds are a soil and water conservation practice that is appropriate for large sloped, eroded areas. The stones are keyed into the slope, along contours, to reduce erosion caused by overland flow of water. Often small gullies/dongas start forming on such denuded areas in the natural water flow channels and then check dams are constructed either separately or into the lines of stones.

The intention is to slow the flow of water, so that the silt and soil load can be dropped. The outcome is the formation of small benched terraces of fertile soil for plant growth.

This practice has been the most appropriate for Limpopo, where in the Lower Olifants' region there are large tracts of denuded soil in and around the homesteads, easily erodible top soil and long periods of heat and drought followed by intense rainfall events. Coupled to the local practice of clearing homestead plots completely and sweeping or raking the dirt to keep the yards clean, many homesteads have a high level of erosion. Stone bunds/ lines are a traditional practice in the area that was further promoted and also slightly improved upon in terms of placing the stone lines along contours and keying them into the soil to ensure greater stability. Around 61% of participants exposed to this 'improved' practice implemented stone lines in and around their yards.

Below are some examples.

Figure 36: Left; Sand bags used, where stones were not available to reduce overland flow and erosion caused by water running along a road in Willows (Limpopo), Centre: Small stone lines along a fence line in the Oaks (Limpopo) and Right; A large stone bund also acts as a water holding structure for a line of bananas planted directly below the line in Lepelle (Limpopo).

Figure 37: Above left; a close-up of a keyed in stone line, *Above centre left; a group of participants constructing a stone line.* *Above centre right; the resultant stone line structure upon completion* *Above right; revegetation of the denuded slope around four to five months later (Lepelle, Limpopo).*

Figure 38: Right: Two small stone lines with young pigeon pea trees planted above the lines in a homestead and Far Right; constructing a check dam to reduce gulley erosion in a participant's garden (Turkey, Limpopo).

Rating

Criteria	Descriptors	Score (1 point for each descriptor)
Improved food provision	**More food,** increased diversity, increased continuity	1
Improved soil conditions	Improved fertility**, improved organic matter, improved soil health**	2
Improved water management	**Improved water holding capacity**, efficient use of water, improved access	1
Uptake of practice	**Experimentation with practice (no of people), continuation of practice after experimentation**, increased implementation of practice	2
Skills and resources to sustain practice	**Use of own resources**, **knowledge to implement practice adequately,** access to required/external resources	2

★★★☆☆

1.3.13 *Infiltration ditches (run-on ditches, diversion ditches)*

These are shallow ditches (30 cm wide and 15-30 cm deep) that are dug either to channel water to a specific area (diversion ditches) or to catch water and allow it to sink into the soil in a cropping area (run-on ditches); the latter are dug along contours.

These ditches increase access to and availability of water in intensive food production.

Below are a few examples.

Figure 39: Left; A diversion ditch leading water from the road and fence line into a homestead garden (Botshabelo), Centre; a cut-off drain or run-on ditch intercepting water flowing from a house down into the garden (Sedawa) and Right; a diversion ditch leading to an infiltration pit into which crops will be planted, dug as a demonstration at Aviwe Biko's homestead Dimbaza, EC).

Figure 40: Above Left: A run-on ditch with sweet potatoes planted on the ridge below the ditch (The Oaks),

Above centre; A diversion ditch channelling water from the fence line and road to trench beds and banana basins in the garden (The Oaks).

Above right: A group of participants digging another diversion ditch in a homestead garden (Willows).

Farmers' comments

- ***"****Here in Gobizembe (SKZN), some of us have* ***a****dapted the diversion ditches to direct greywater to our gardens. Infiltration ditches do help over time to improve the condition of the soil; as organic matter collects in these ditches and use of greywater in these ditches improves yields substantially."*

Impact assessment

It can be tricky to decide where to place diversion ditches and run-on ditches in a landscape, as it requires a practiced eye in terms of water flow patterns. Participants who have been assisted to place and construct these ditches generally make good use of them, but very few participants undertake to dig these ditches for themselves. Only around 5 to 7% of participants have undertaken this practice.

These ditches can have a significant impact on reducing localised soil erosion due to water flow and in increasing available water in the soil for crop production.

Rating

Criteria	Descriptors	Score (1 point for each descriptor)
Improved food provision	**More food,** increased diversity, increased continuity	1
Improved soil conditions	Improved fertility, improved organic matter, improved soil health	
Improved water management	**Improved water holding capacity, efficient use of water, improved access**	3
Uptake of practice	Experimentation with practice (no of people), **continuation of practice after experimentation**, increased implementation of practice	1
Skills and resources to sustain practice	**Use of own resources**, knowledge to implement practice adequately, access to required/external resources	1

★★☆☆☆

1.3.14 *Rainwater harvesting (RWH); from roofs and yards*

Rainwater harvesting is a common practice undertaken in all three provinces (Limpopo, KZN and EC), although it is more prevalent in the water stressed communities in Limpopo, where 100% of participants avow to using the practice. It consists mainly of using basins and drums to catch water off roofs and structures.

The number of households who have large tanks; such as 2200 litre and 5000 litre Jo-Jo tanks is much lower, about 5% of all participants.

Figure 41: Above Left and Centre; examples of drums and basins used for RWH collection and Right; a 2200 litre JoJo tank for roof rainwater harvesting (Limpopo).

Underground RWH tanks can take advantage of both rainwater off roofs as well as overland flow from hard surfaces around homesteads. In these cases, large underground structures between 25 and 40 m^3 have been constructed. The resource and technical requirements for these structures are high and mostly they cannot be undertaken without dedicated funding and support.

Figure 42: Right; an underground RWH tank (24 m^3) made from ferrocement, with a brick wall to support the roof (Sedawa) and Far Right; a similar underground tank constructed using bidim cloth and sealant (Botshabelo). Below; another example of an underground tank (18 m^3), with a removable metal roof (Acornhoek).

Impact assessment

For the most part, the enormous potential for RWH is not realised, for both roof RWH and underground tanks. Both funding and technical expertise is required.

Rating

Criteria	Descriptors	Score (1 point for each descriptor)
Improved food provision	**More food,** increased diversity, increased continuity	1
Improved soil conditions	Improved fertility, improved organic matter, improved soil health	
Improved water management	**Improved water holding capacity, efficient use of water, improved access**	3
Uptake of practice	Experimentation with practice, (no of people), **continuation of practice after experimentation**, increased implementation of practice	1
Skills and resources to sustain practice	**Use of own resources**, knowledge to implement practice adequately, access to required/external resources	1

★★☆☆☆

1.3.15 *Small dams*

Digging of small dams, for seasonal supply of water during the rainy season, that also increases the soil water in the surrounding area of the garden is a traditional practice still used in both the EC and Limpopo. In KZN it is generally only used as a practice to utilize small localised springs in or close to people's homesteads.

Figure 43: Right; Mrs Msesiwe from Qhuzini, EC, has constructed a small dam and planted bananas on the edge and

Far Right; Esinah Malepe from Sedawa (Limpopo) has dug an oblong pond/dam in her garden, which she uses for supplementary irrigation during the summer months.

As an adaptive measure, we experimented with lining these ponds with bentonite, to increase their water holding capacity and also to allow for increased availability of water into the winter growing season. Attention was also given to design of these small dams to ensure that the inflow and the overflows are well placed and constructed, to avoid damage to the gardens due to over-topping of these structures.

A few examples are shown below.

Figure 44: Above Left; tamping down the layer of bentonite which was added after the dam walls and bottom were dug out to provide a wall angle of around 45-60° and Right; careful filling of this pond for the first time to allow for the bentonite to swell evenly and seal the pond (Sedawa, Limpopo).

Figure 45: Above left; fixing the wall angles for a small dam in Turkey, Limpopo and Right; the pond filled after attention was also given to the inflow and overflow for the pond.

Impact assessment

The use of bentonite is a cheap and technically easy way to extend the water holding capacity of small dams. A major drawback however is the seasonality of access to water. Once the bentonite dries out, it is unlikely to rehydrate properly to provide a full seal when water is once again available. It is thus only really an option if there is a way to keep these small dams full and thus the application is limited. Participants have not extended this practice after the initial piloting phase.

Rating

Criteria	Descriptors	Score (1 point for each descriptor)
Improved food provision	**More food,** increased diversity, increased continuity	1
Improved soil conditions	Improved fertility, improved organic matter, improved soil health	
Improved water management	**Improved water holding capacity, efficient use of water, improved access**	3
Uptake of practice	Experimentation with practice, (no of people), **continuation of practice after experimentation**, increased implementation of practice	1
Skills and resources to sustain practice	**Use of own resources**, knowledge to implement practice adequately, access to required/external resources	1

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