2nd Progress Report: 2018-2019

3rd Reference Group Meeting

Water Research Commission

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

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

Reference group Meeting: 3rd Progress and planning report
Date: May 2019

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DEFINITIONS OF TERMS USED IN THIS REPORT

Climate Smart Agriculture:

CSA '…contributes to the achievement of sustainable development goals. It integrates the three dimensions of sustainable development (economic, social and environmental) by jointly addressing food security and climate challenges. It is composed of three main pillars:

1. Sustainably increasing agricultural productivity and incomes,
2. Adapting and building resilience to climate change and
3. Reducing and/or removing greenhouse gases emissions, where possible. (FAO, 2013[1])

Climate Change:

There is ample evidence of national and local changes in the temperature and rainfall climatology of South Africa over at least the past five decades and a high probability that this process may increase in the coming decades:

- Mean annual temperatures have increased by more than 1.5 times the observed global average of 0.65°C,
- Maximum and minimum temperatures have been increasing annually and in almost all seasons,
- Hot and cold extremes have increased and decreased respectively in frequency, in most seasons across the country, particularly in the western and northern interior,
- In almost all hydrological zones there has been a marginal reduction in rainfall for the autumn months. Annual rainfall has not changed significantly, but an overall reduction in the number of rain days implies a tendency towards an increase in the intensity of rainfall events and increased dry spell duration and
- Extreme rainfall events show a tendency towards increasing in frequency annually, and especially in spring and summer, with a reduction in extremes in autumn. (DEA, 2013[2])

Climate variability:

This term is used when community members indicate that there have been changes in their weather patterns, but where the trends are not necessarily clear. It includes and increased in extreme events such as storms, wind, and in season dry spells. It also includes and increased in drought conditions and variability in temperature, where temperatures are considered higher (or lower) then "normal" in a given month or season.

Resilience:

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[1] FAO, 2013*. Climate Smart Agriculture Sourcebook*. Food and Agriculture Organization of the United Nations. 2013

[2] DEA (Department of Environmental Affairs). 2013. *Long-Term Adaptation Scenarios Flagship Research Programme (LTAS) for South Africa. Summary for Policy-Makers*. Pretoria, South Africa.

Resilience is the ability of a system to anticipate, absorb, accommodate or recover from the effects of an extreme climate event in a timely and efficient manner.
Contextual vulnerability is locally focussed and considers the present as the departure point and considers socio-economic dimensions of vulnerability as a basis for assessing future vulnerability. This is largely a participatory process as opposed to modelling approaches that are applied at programme and policy scales. Vulnerability and adaptation needs are contextualised with the local context and will include factors that aren't necessarily directly linked to climate change or CSA (FAO, 2013).

1 Progress summary

1.1 Project aims

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

1.2 Deliverables

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

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

Deliverables 5,6 and 7 were undertaken in this reporting period

1.3 Overview of activities

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

- **Practices:** Collation, review, testing, and finalisation of those CSA practices to be included. Allows for new ideas and local practices to be included over time. This also includes linkages and reference to external sources of technical information around climate change, soils, water management etc and how this will be done;
- **Process:** Through which climate smart agricultural practices are implemented at smallholder farmer level. This also includes the facilitation component, communities of practice, communication strategies and capacity building and
- **Monitoring and evaluation:** local and visual assessment protocols for assessing implementation and impact of practices as well as processes used. This also includes site selection and quantitative measurements undertaken to support the visual assessment protocols and development of visual and proxy indicators for future use in inactive based support schemes for smallholder farmers

The table below provides a summary of progress towards outputs

Table 1: Summary of activities related to deliverables and outputs

	Deliverable 4	Deliverable 5	Deliverable 6	Deliverable 7
Practices Output 1	CSA practices summary updated	Agroforestry and livestock management practices included		
		1st round water productivity (wp) assessments: gardening	1st round wp, soil health run-off, assessments; field cropping (CA)	1st round community level resilience snapshots
Process Outputs 2,3	-CCA workshop 1 (2 villages – EC, KZN	-CCA workshop 1 (2 villages – EC, KZN	-CCA workshop 1 (2 villages – EC, KZN	-CCA workshop 1 (2 villages – EC, KZN
	-Collaborative activities	-Collaborative activities	-Collaborative activities	-Collaborative activities
	-CCA workshop 2 (3 villages EC, KZN)	CCA workshop 2 (1 village KZN, 2 villages Limpopo, 3 villages EC)	CCA workshop 2 (2 villages KZN)	
		-CCA workshops (1 village KZN, 1 village Limpopo)	-CCA workshops 3-5 (3 villages EC, 2 villages KZN, 1 village Limpopo)	-CCA workshops 3-5 (1 village KZN)
	-Individual experimentation	Individual experimentation	Individual experimentation	Individual experimentation
	CoPs established and meeting Food security learning groups– 4 (LimaRDF, MDF) CA learning groups-2 (MDF/AWARD) CA networking platforms KZN; (GrainSA/MDF/ KwaNalu/ LMs) Agroecology networking; AWARD/MDF	Continuation of CoPs; FS learning groups x 7 CA networking platforms Agroecology network Amanzi 4 Food Network	New CoPs – 2 new learning groups SKZN FS learning groups x9 CA learning groups x 5 CA networking platforms Agroecology network Amanzi 4 Food Network	
	DSS – 1st iteration		Modelling process 1st iteration (version 1	Modelling process-refined (version 2)
	-Quantitative measurement	-Quantitative measurement sites set up; CA, gardening		

Monitoring and evaluation Outputs 3,4	-CA indicators; -	-CA indicators; Soil fertility, soil health, run-off, infiltration, water productivity		
	-Gardening	-Gardening indicators; irrigation demand, growth, yield, water productivity		
	Impact indicators			Individual Impact and resilience questionnaires, Participatory impact assessment methodology

2. CoPs and demonstration sites established

Community level CoPs have been set up in 9 villages across 3 provinces. Stakeholder platforms have been developed for :

- Agroecology Network in association with AWARD – Limpopo (Hoedpsruit) and
- Conservation Agriculture in association with GrainSA and LandCare – SKZN (Madzikane)
- Imvotho Buboni Learning Network in association with Fort Cox College, ERLC – Rhodes University, MDF and farmers organisations – Eastern Cape (Alice)

3 Demonstration sites have been set up with the required instrumentation and sampling for monitoring of both Conservation Agriculture and gardening implementation (one in each province)

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

Province	Site/Area; villages	Demonstration sites	CoPs	Collaborative strategies
KZN	Ntabamhlophe	- CCA workshop 1 - CCA workshop 2 -CCA workshop 3 -CCA workshop 4 -CCA workshop 5 **- Monitoring and PIA**	-Farmers w NGO support (Lima RDF)	- Tunnels and drip kits - Individual experimentation with basket of options
	Ezibomvini/ , Eqeleni	- CCA workshop 1 - CCA workshop 2 - CCA workshop 3 - CCA workshop 4 (training) - Water issues workshops 1,2 -Water issues follow-up -CCA workshop 5 **-Water issues continuation** **-Monitoring, PIA** **- Fodder and supplementation learning process**	-CA open days, cross visits (LandCare, DARD, ARC, GrainSA), LM Agric forums, ….	- Tunnels (Quantitative measurements - CA farmer experimentation (Quantitative measurements) – case studies -Individual experimentation with basket of options; monitoring review and re-planning - Livestock integration learning group and experimentation focus
	Swayimane	- CCA workshop 1	-CA open days	- CA farmer experimentation

		-CCA workshops 2 and 3 **-CCA workshop 4** **- Monitoring, review and replanning**	-Umgungundlovu DM agriculture forum	- gardening level experimentation; tunnel, trench beds drip kits etc.
	Madzikane	-CCA workshop 1 **-CCA workshops 2-4**	-CA open days - Madzikane stakeholder forum	-CA farmer experimentation - gardening level experimentation; tunnel, trench beds drip kits etc
Limpopo	Mametja (Sedawa, Turkey)	- CCA workshop 1 - CCA workshop 2 - CCA workshop 3 - CCA workshop 4 -Water issues workshops 1-2 -Water issues follow-up - CCA workshop 5 - Poultry production learning and mentoring **-CA learning and mentoring** **- Monitoring, review and re-planning**	-Agroecology network (AWARD/MDF) -Maruleng DM	-Review of CSA implementation and re-planning for next season Tunnels (Quantitative measurements - CA farmer experimentation (Quantitative measurements) – case studies - Individual experimentation with basket of options -water committee, plan for agric water provision
	Lepelle	Water issues workshops 1-2	-	-water committee, plan for agric water provision
	Tzaneen (Sekororo-Lourene)	- CCA workshop 1 - CCA workshop 2 - Assessment of farmer experimentation	Farmers learning group	-Tunnels and drip kits
EC	Alice/Middledrift area	- CCA workshop 1 - CCA workshop 2 - CCA workshop 3 -CCA workshop 4 and 5 **- Monitoring, review and re-planning**	Imvotho Bubomi Learning Network (IBLN) - ERLC, Fort Cox, Farmers, Agric Extension services, NGOs	- Monitoring and review of implementation of CSA practices and experimentation - Training and mentoring _CA, furrow irrigation, …. -Planning for further implementation and experimentation and quantitative measurements

Details of these activities are outlined in the reports for Deliverables 5 (August 2018), 6 (January 2019) and 7 (May 2019). Brief summaries of progress with different aspects of the process are provided below.

3. CSA practices implemented

Below a brief summary is provided for each province

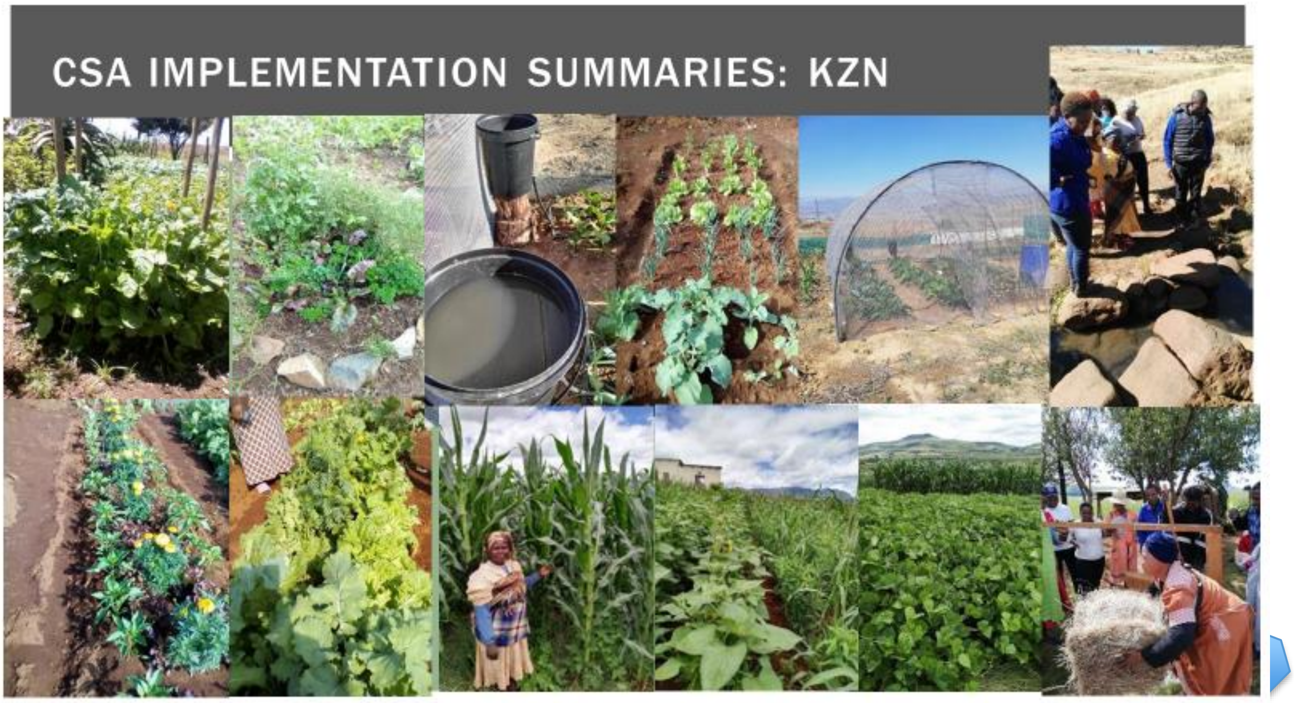
3.1 KwaZulu Natal

The table below shows all practices tried out in KZN. The grey highlights indicate practices that have allo been recommended in the 1st version of the computer-based model and the brown highlights indicate additional practices included in the 2nd version

Table 3: CSA practices implemented in KZN 2017-2016

Soil	Water	Crop (garden and field)	Livestock	Natural Resources	People
Making compost	Drip irrigation	Diversified crops in gardens; beetroot, Chinese cabbage, carrots, parsley, thyme,	Vaccinations		Savings
Use of goat and cattle manure	Mulching	Shade cloth tunnels	Dipping		Small businesses
Canopy cover and legumes (Lab-Lab)	Infiltration pits	Beds: raised beds, trench beds, eco-circles	Proper feed; including from fodder produced		Farmer centres
Diversified crops to hold soil and prevent erosion	Garden layout with shallow furrows for water harvesting and retention	Tower gardens – fertility and greywater management	Addition of supplements		Selling chickens
	Greywater management	Conservation agriculture; including management of residues	Limiting burning of veld		
	Improved irrigation practices	Inter cropping and crop rotation	Planting grass; ungwengwe and kikuyu		
	Rainwater storage in JoJo tanks and drums	Diversified crops in fields; different varieties of maize, sorghum, millet, legumes (e.g. cowpeas, beans, Lab-lab), cover crops			
	Spring protection	Use of Decis Forte (Pyrethrins) for pest control in fields			
	Buying JoJo tanks – and negotiating with water trucks to fill these	Liquid manure			
		Mixed cropping in gardens			

The photographs below provide a visual indication of these practice



1: Tower garden; using greywater for irrigation, planted to kale, spinach and tomatoes
2: Eco-circle with a 2litre bottle (with holes) used for in situ irrigation and planted to a mixture of herbs and vegetables
3: Bucket drip kits inside a shade cloth tunnel
4: raised bed with mixed cropping planted as a “normal practice control” when comparing with trench beds
5: A Shade cloth tunnel with 3 5x1m trench - beds
6: Inspection of a locally protected spring
7: A shallow trench bed planted to a mixture of green peppers, chillies and marigolds
8: A deep trench bed planted to a mixture of kale, rape, mustard spinach and Chinese cabbage
9: A maize and cowpea intercropped conservation agriculture (CA) plot
10: A CA plot planted to summer cover crops; sunflower, millet and sunnhemp
11: A CA plot planted to Dolichos beans
12: Making bales of hay with a small manual baler

3.2 LImpopo

The table below shows all practices tried out in LImpopo.

Table 4: CSA practices implemented in Limpopo 2017-2016

Soil	Water	Crop (garden and field)	Livestock	Natural Resources	People
Making compost	Drip irrigation	Diversified crops in gardens; herbs	Planting fodder	Homestead nurseries	Water committees;

		(coriander, parsley, basil, rocket, time, rosemary) and vegetables; kale, rape, mustard spinach, leeks, baby marrows,	crops; ryegrass, summer cover crops, Lucerne		for installation of boreholes
Use of goat and cattle manure	Mulching	Shade cloth tunnels	Small livestock integration and feed production	Organic mango production	Organic marketing initiative for sale of herbs and vegetables
Canopy cover and legumes (Lab-Lab)	Infiltration pits, banana circles	Beds: raised beds, trench beds, eco-circles			
Diversified crops to hold soil and prevent erosion	Garden layout with shallow furrows for water harvesting and retention	Tower gardens – fertility and greywater management			
	Greywater management	Conservation agriculture; including management of residues			
	Improved irrigation practices	Inter cropping and crop rotation			
	Rainwater storage in JoJo tanks and drums	Diversified crops in fields; different varieties of maize, sorghum, millet, legumes (e.g. cowpeas, beans), cover crops			
	Underground RWH tanks	Liquid manure			
		Mixed cropping in gardens			

The photographs below provide a visual indication of these practice

1: Tower garden for use of greywater for irrigation planted to spinach
2: Diversion ditch leading to large underground rainwater harvesting storage structure (24 000l)
3: Shade cloth tunnel
4: Mixed crop bed; with maize, rape, basil and cassava
5: Ryegrass planted for fodder, being grazed by a small goat
6: Bucket drip kit, irrigating a trench bed which is planted to a mixture of vegetables and mulched
7: A stone line
8: Three 5x1m deep trench beds planted to a mixture of vegetables
9: A CA plot planted to maize that has been mulched
10: A CA mixed crop plot with maize and sorghum (bird resistant variety)

3.3 Eastern Cape

The table below shows all practices tried out in the Eastern Cape

Table 5: CSA practices implemented in the Eastern Cape 2017-2016

Soil	Water	Crop (garden and field)	Livestock	Natural Resources	People
Making compost	Drip irrigation	Diversified crops in gardens;			A4F agroecology network
Use of goat and cattle manure	Mulching	Shade cloth tunnels			
Diversified crops to hold soil and prevent erosion	Greywater management	Beds: trench beds, eco-circles			
	Improved irrigation practices	Tower gardens – fertility and greywater management			
	Furrow irrigation	Conservation agriculture; including management of residues			

	Underground RWH tanks	Diversified crops in fields; different varieties of maize, sorghum, millet, legumes (e.g. cowpeas, beans), cover crops			
		Mixed cropping in gardens			

The photographs below provide a visual indication of these practice

1: Tower garden for irrigation with greywater planted to spinach

2: Bucket drip kit installed, alongside a chameleon water sensor in a deep trench bed planted to spinach

3: Onions seeding planted on furrows and ridges and mulched in the furrows

4: An Eco-circle bed with mulching planted to a mixture of vegetables

5: Mint and nasturtiums (multipurpose plants in a garden)

6: Spinach and cabbage planted n trench beds inside a shade cloth tunnel

6: Raised beds planted to a mixture of vegetables and mulched.

4. The Decision Support System

Using a systemic approach and social learning from a socio-ecological perspective, the model consists of a number of layers of input parameters or filters used to define a basket of best bet CSA options for a specific smallholder farmer, using a combination of participatory processes linked to technical databases.

The process is designed to also support and assist the facilitator in their decision making, in support of the smallholder farmers; meaning that the facilitator accesses information such as the basic climate change predictions for the area, the agroecological characteristics including rainfall, temperature, soil texture etc) and an initial contextualised basket of CSA practices from which to negotiate prioritized practices with farmers. Practices are thus chosen by both facilitators and farmers.

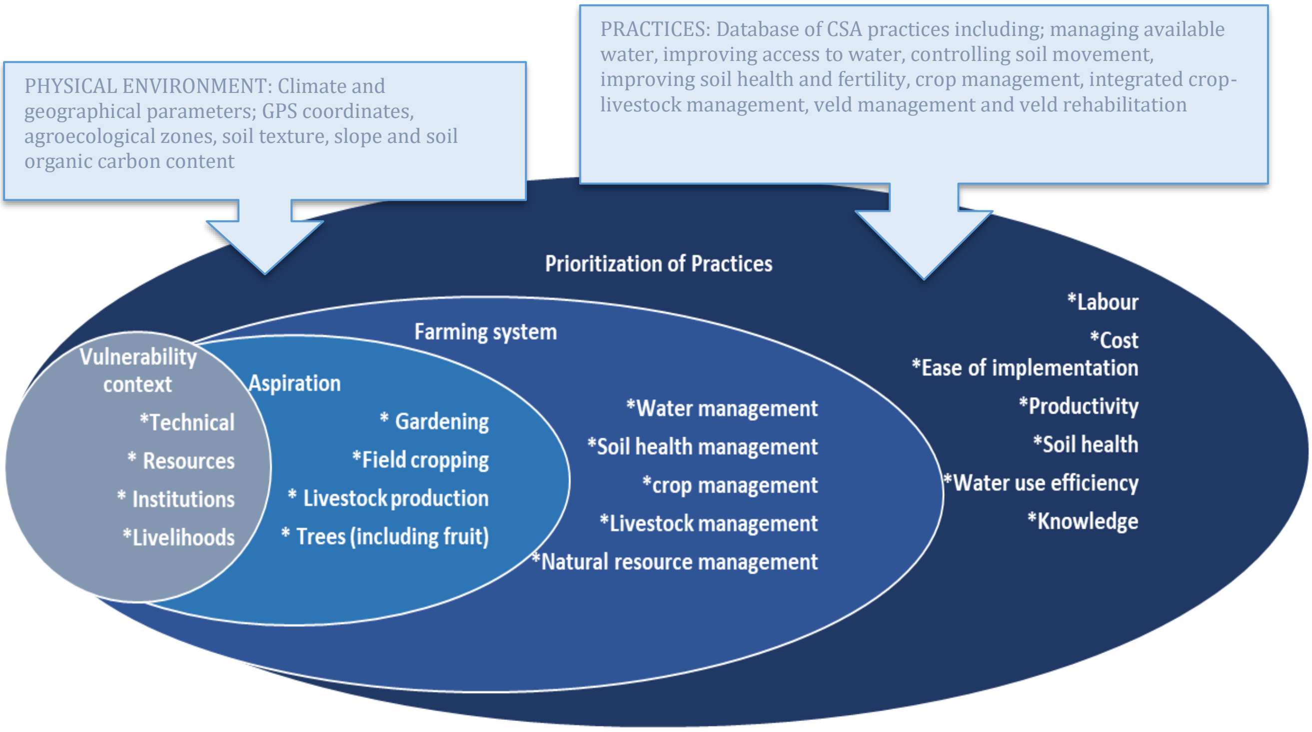


*Figure 1: **The Small- Scale Farmer Decision Support System***

The model is designed primarily as a participatory and facilitated process at community level. In support to this process a computer-based model can be used alongside this methodology to provide further information and decision support to the facilitator. It is also possible for a farmer to access this model independently to derive an initial basket of CSA practice options for themselves.

The computer model information flow is designed as shown in the figure below – and follows the same basic steps as shown in Figure 1 above.

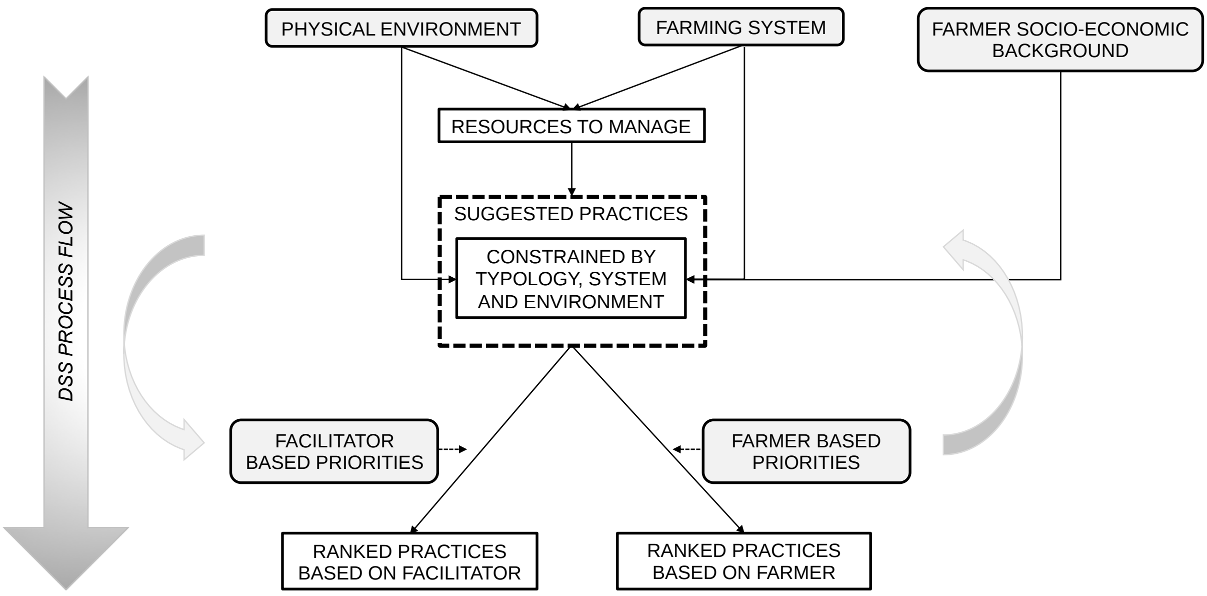


Figure 2: ***The computer- based model for the smallholder DSS***

In our case the set of criteria (proxies used as indicators for the complex reality) that helps to make informed decisions on management practices are:

- **The current farming systems;** gardening, field cropping, livestock production and natural resource management (NRM) (including trees),
- **The physical environment:** agroecological zone, soil texture, slope and organic soil carbon and
- **The socio-economic background of the farmer;** demographic information (gender HH head, age, dependency ratio), level of education, sources of income (unemployment vs. external employment, own business, grants, farm, etc.), total income, access to services, infrastructure, technology (Electricity, water (tap, borehole, rainwater harvesting, etc.), irrigation (buckets, standpipes, etc.), fencing and farming tools (hand vs traction/other), social organisation, market access (formal vs. informal), farm size and farming purpose (food vs. selling).

Besides this, the resources and related management strategies as well as a list of practices need to be provided as input to the system. All information, except the physical environment; i.e. climate, soil and topography, and the resources and management strategies, are derived through the use of a range of participatory processes. Data on the physical environmental conditions have been taken from datasets freely available online. This information can however be customised by the DSS user, in case more appropriate information is available for the specific farmer concerned.

For the Facilitator-Farmer DSS the resources and related management strategies are discussed and negotiated in the participatory process. For the computer based or Individual Farmer DSS these are provided as an input into the model using the following framework:

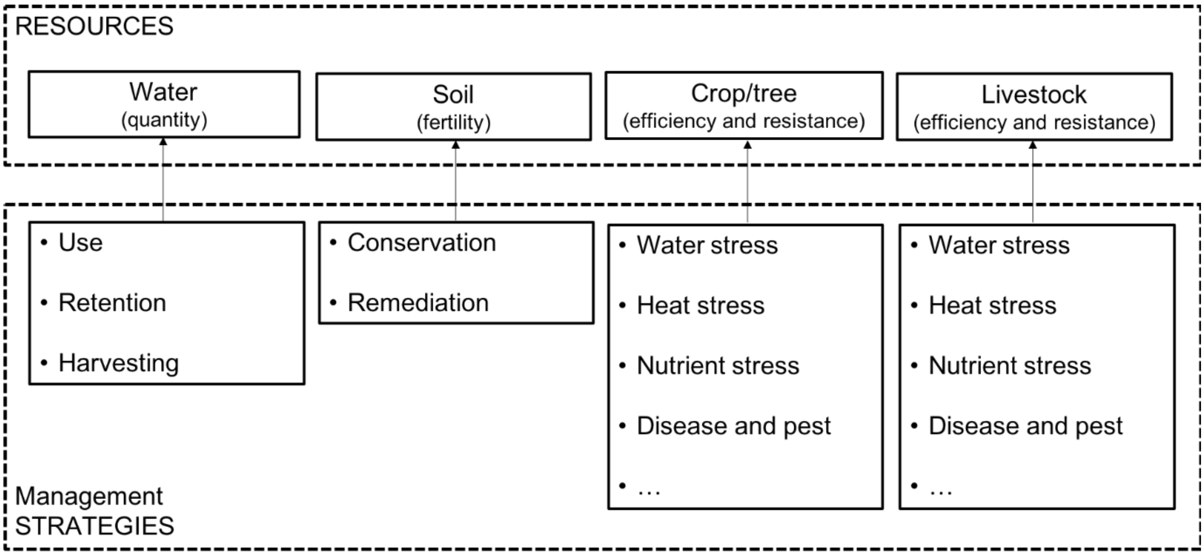
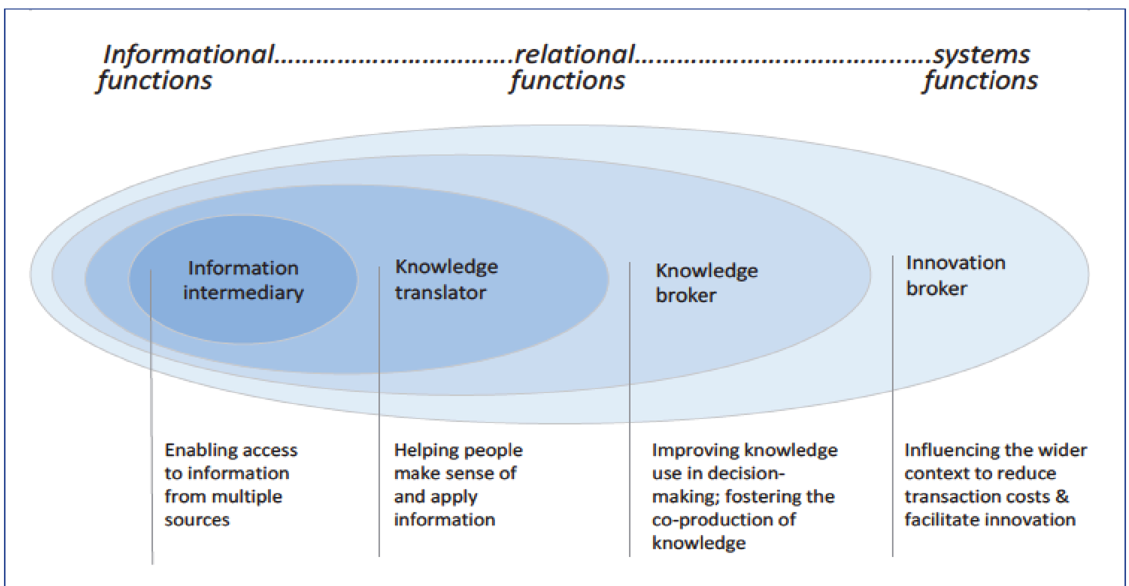


Figure 3: ***Resources to manage and their associated management strategies***

The practices have been identified by both farmers and experts; the latter based on experience in the South African context and desktop reviews.

4.1 How does the facilitator-farmer DSS work

In effect, the DSS discussed above is a way of providing and making sense of information. This information is contextualised in a social learning system (a group of people learning and implementing together) using the framework shown below.



	Local good practice	CC	Farmer level experimentation to test practices (CCA workshop 4)	CoPs and innovation platforms

Activities and processes	Best practise options	Impacts of CC (CCA workshop 1)	Introduction of new practices and ideas to try (CCA workshop 5)	Benchmarking for visual indicators
	Stakeholder engagements	Adaptive strategies (CCA workshop 2)	Learning and mentoring	
	Materials and information	Appropriate practices (CCA workshop 3)	Assessment of outcomes and impacts	
	internet based platform		Cyclical, iterative learning and implementation	
Facilitator-Farmer Decision Support System				

*Figure 4: **A systemic view of the Facilitator-Farmer DSS indicating associated activities and processes***

The DSS thus incorporates the whole system of social learning and innovation, in an iterative process that can lead to social change and agency in climate change adaptation, as depicted in Figure 5 below.

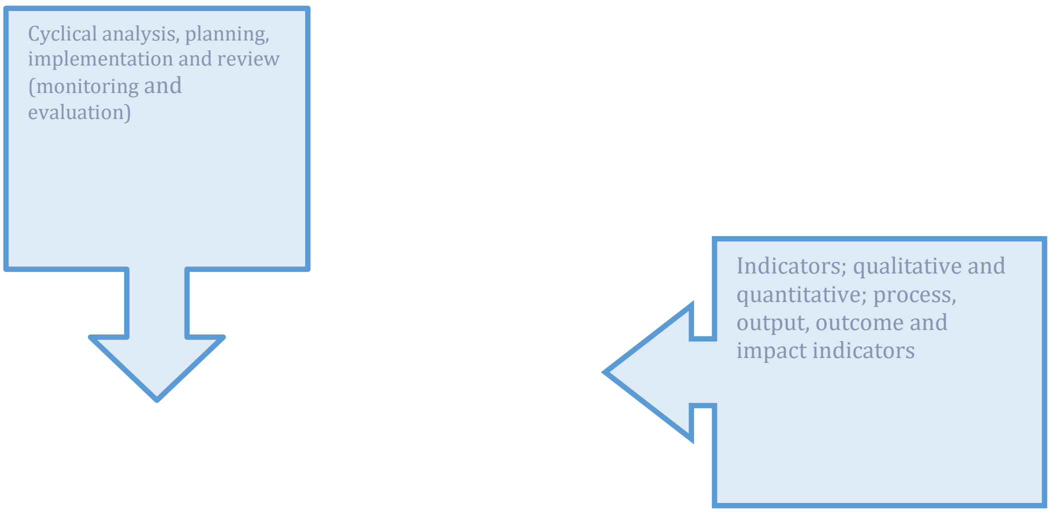


*Figure 5: **Social learning, innovation and building agency is an iterative process that includes careful monitoring and evaluation***

4.2 Refinement of the Individual DSS Model

All information, except the physical environment; i.e. climate, soil and topography, and the resources and management strategies, were derived through the use of a range of participatory processes. Data on the physical environmental conditions have been taken from datasets freely available online. This information can however be customised by the DSS user, in case more appropriate information is available for the specific farmer concerned.

The first round of modelling consisted of using the baseline information of 26 HH across KZN, EC and Limpopo to assess the fit of the model. The output of the model is a list/basket of practices for each farmer based on the physical environment, farming system and farmer typology.

Assumptions made

The justification for managing the different resources in our DSS is as follows:

- Semi-arid warm: in this environment water is limited and the temperatures can be hot. Water and heat stress are the main limiting factors. Pests and diseases in plants and animals are present.
- Sub-humid cool: in a more humid environment, weeds grow well and can create a competing environment for nutrients. Plants and animals are also more prone to diseases.
- Sandy soils: those soils have poor structures, with low water and nutrient holding capacity. They heat up fast. Certain practices are not suitable in sandy soils and more specifically sandy soils in semi-arid regions, where rainfed crops and trees can be difficult to establish and maintain.
- Clayey soils: high level of clay can increase the probability of erosion due to crusting, in particular under semi-arid environment. Water and OC retention in clay soils are important management principles.
- OC: soils with less than 1,5% OC are considered to be of low fertility. %OC in sandy soils is inherently lower and more difficult to build up than in high clay soils.
- Slope: above 5% sloping, agricultural production becomes sub-optimal due to erosion and run-off, in both semi-arid and sub-humid regions. Slope above 15%; agricultural production is not suitable under all conditions, due to water and nutrient run-off.

Table 3 allows us to identify, for each farming HH, the resources to manage and the related strategies within each farming system taking the environmental conditions into account. It thus combines the proxies for the physical environment, farming systems and management strategies.

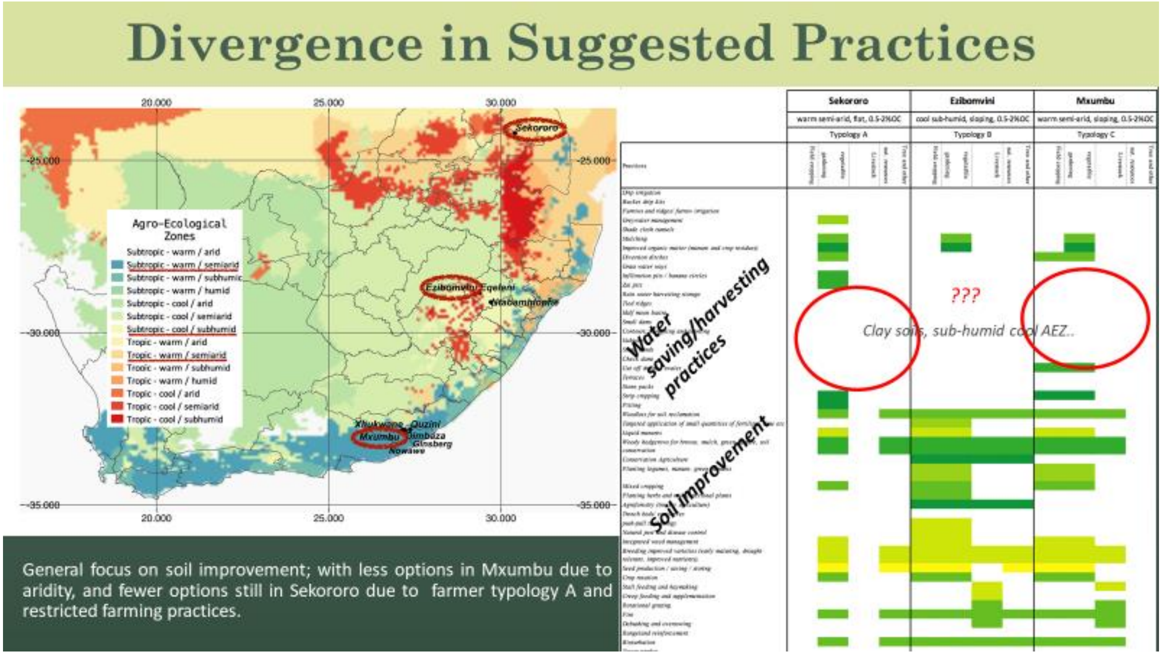
*Table 6:**Criteria to define the resources to manage and related strategies (version 1)***

Note: * (solely in semi-arid zone)

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

Practices recommended (Round 1) for 26 HH

Based on the above assumptions and proxies a list of practices were recommended for the initial 26 household baseline. These lists have been "reality tested" against the facilitation team's general experience in the areas. It was found that soil and water conservation practices were under represented when using this version of the model. This outcome is summarised in the slide below (as presented at the Agroecology Networking session in December 2018)



Refinement of the DSS model (Version 2)

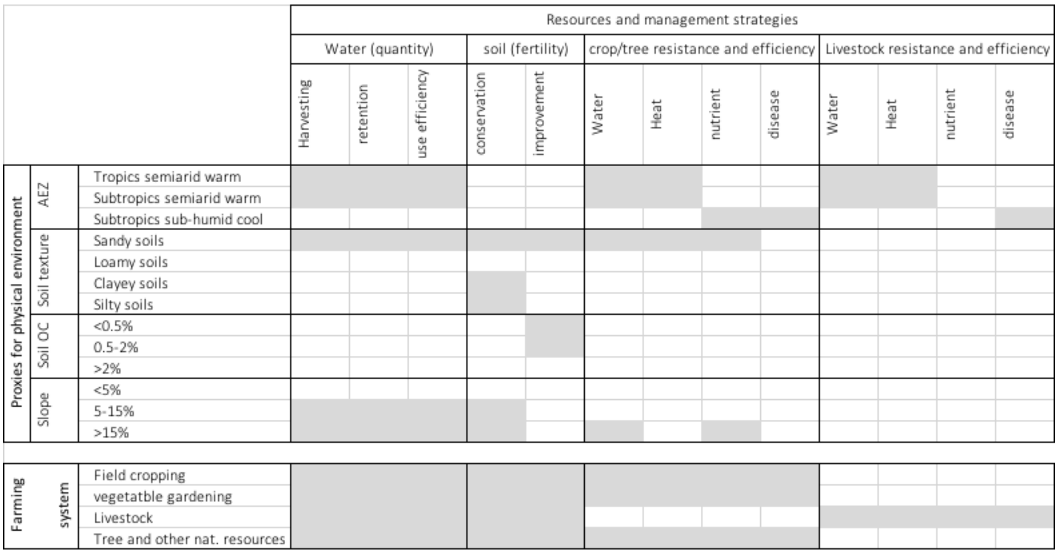
Three changes have been made:

1. It has been assumed that water (harvesting, retention and use efficiency) is important for all farmers (thus=1 for all)
2. It has been assumed that soil conservation is important for all farmers (thus=1 for all)
3. Certain restrictions for soil texture and slope have been removed. Water (harvesting, retention and use efficiency) and soil conservation are no longer restricted to the semi-arid zone only, as was the case in the first round.

Note: These three changes have been made based on the experience of the project team in the field and in rural areas across South Africa. Lack of access to water is a very real and vey common constraint among rural dwellers in KZN, Limpopo and Eastern Cape and although commonly known is in fact not well documented in the literature. Attempts will be made in the next iteration of this model to provide acceptable academic evidence for these changes.

The table 3 above has thus been changed as shown in table 4 below. Basically the *s have been removed

*Table 7: **Criteria to define the resources to manage and related strategies (version 2)***



Minor changes were also made to some of the excel formulae used in the model.

These changes have broadened the practices recommended for most of the participants, as shown in the examples below; one participant each from KZN, Limpopo and Eastern Cape. The practices highlighted in brown are new practices included in version 2 of the model, a further 9 practices related to soil and water conservation. This version is considered a better fit for conditions on the ground. This is outlined in table 10 below.

*Table 8: **Basket/list of practices recommended for version 1 and 2 of the DSS***

Province	KZN		Limpopo		EC	
Village	Ezibomvini		Sekororo		Mxumbu	
Name and Surname	Phumelele Hlongwane		Chenne Mailula		Xolisa Dwane	
DSS versions	Version 2	Version 1	Version 2	Version 1	Version 2	Version 1
Drip irrigation	0	0	0	0	0	0
Bucket drip kits	0	0	0	0	0	0
Furrows and ridges/ furrow irrigation	0	0	0	0	0	0
Greywater management	1	0	1	0	0	0
Shade cloth tunnels	1	0	1	0	0	0
Mulching	1	1	1	1	0	0
Improved organic matter (manure and crop residues)	1	1	1	1	1	1
Diversion ditches	1	0	0	0	0	0
Grass water ways	0	0	0	0	0	0
Infiltration pits / banana circles	1	1	1	1	0	0
Zai pits	1	1	0	0	0	0
Rain water harvesting storage	1	0	1	1	1	1

Tied ridges	0	0	0	0	0	0
Half moon basins	0	0	0	0	1	1
Small dams	0	0	0	0	0	0
Contours; ploughing and planting	1	0	0	0	0	0
Gabions	0	0	0	0	1	1
Stone bunds	0	0	0	0	0	0
Check dams	0	0	0	0	1	1
Cut off drains / swales	0	0	0	0	1	1
Terraces	0	0	0	0	0	0
Stone packs	1	0	0	0	0	0
Strip cropping	1	0	0	0	0	0
Pitting	1	0	1	1	0	0
Woodlots for soil reclamation	1	1	0	0	0	0
Targeted application of small quantities of fertilizer, lime etc	1	1	0	0	0	0
Liquid manures	1	1	1	1	0	0
Woody hedgerows for browse, mulch, green manure, soil conservation	1	1	0	0	0	0
Conservation Agriculture	1	1	0	0	0	0
Planting legumes, manure, green manures	1	1	0	0	0	0
Mixed cropping	1	1	0	0	0	0
Planting herbs and multifunctional plants	1	1	0	0	0	0
Agroforestry (trees + agriculture)	1	1	0	0	0	0
Trench beds/ eco circles	1	0	1	0	0	0
push-pull technology	1	1	0	0	0	0
Natural pest and disease control	1	1	0	0	0	0
Integrated weed management	1	1	1	1	1	1
Breeding improved varieties (early maturing, drought tolerant, improved nutrients),	1	1	1	1	1	1
Seed production / saving / storing	1	1	1	1	1	1
Crop rotation	1	1	1	1	1	1
Stall feeding and haymaking	0	0	0	0	0	1
Creep feeding and supplementation	1	1	0	0	0	0
Rotational grazing	1	1	0	0	1	1
De-bushing and over sowing	1	1	0	0	1	1
Rangeland reinforcement	1	1	0	0	1	1
Bioturbation	1	1	1	1	1	1
Tower garden	1	1	1	1	0	0

Keyhole beds	1	1	1	1	0	0
No of practices recommended	**35**	**26**	**16**	**13**	**14**	**15**

For the KZN participant, this means that around 88% of the overall list of practices (in the practices database) have been recommended for her. She already had the largest number of recommendations (in version1) being a farmer in Typology B (fewer restrictions) and engaging in gardening, cropping and livestock production. Although this is quite high, it is understood that the farmer level ranking is still to take place and these practices can then be prioritized and narrowed down further. For the Limpopo and EC participants, around 1/3 of practices have been recommended in their basket of options.

A general analysis of practices for the 41 households shows that only 5 practices have been recommended for all (opposed to 4 in version 1):

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

And a number of practices have been recommended for none of the 41 HH:

- Drip irrigation
- Bucket drip kits
- Furrows and ridges/ furrow irrigation
- Stone bunds
- Terraces
- Tied ridges
- Grassed waterways
- Stall feeding and haymaking

These practices are constrained by land size, typology and slope for the most part, but are not considered inherently unsuitable for smallholder farmers. They could still be presented to learning groups in special cases, where their applicability is considered suitable.

Ranking of suggested practices based on score provided by the facilitator

Based on scores provided by the facilitator (the generic score used in the DSS) the basket of practices can be ordered by preference. In the table below, a ranking based on facilitator's scores, is provided for the farming HH 'Phumelele Hlongwane' located in Ezibomvini, KZN. According to the facilitator, improving organic matter, pitting, Conservation Agriculture and Agroforestry are the most appropriate interventions (having the highest score). are the most appropriate practices suggested by the DSS for this HH. This is followed by keyhole beds, tower gardens, woody hedgerows, Zai pits and infiltration pits.

*Table 9: **Ranking of suggested practices by 'the facilitator' for Phumelele Hlongwane (DSS version 2)***

E. Score provided by facilitator for suggested practices that are not constrained				
Field cropping	vegetable gardening	Livestock	Tree and other nat. resources	Practices
0	0	0	0	Drip irrigation
0	0	0	0	Bucket drip kits
0	0	0	0	Furrows and ridges/ furrow irrigation
0	5	0	0	Greywater management
0	8	0	0	Shade cloth tunnels
0	9	0	0	Mulching
11	11	0	11	Improved organic matter (manure and crop residues)
9	9	0	9	Diversion ditches
0	0	0	0	Grass water ways
0	10	0	0	Infiltration pits / banana circles
10	10	0	0	Zai pits
9	9	9	9	Rain water harvesting storage
0	0	0	0	Tied ridges
0	0	0	0	Half moon basins
0	0	0	0	Small dams
0	0	0	0	Contours; ploughing and planting
0	0	0	0	Gabions
0	0	0	0	Stone bunds
0	0	0	0	Check dams
0	0	0	0	Cut off drains / swales
0	0	0	0	Terraces
9	9	0	9	Stone packs
11	0	0	0	Strip cropping
11	0	11	11	Pitting
9	0	9	9	Woodlots for soil reclamation
8	0	0	0	Targeted application of small quantities of fertilizer, lime etc
0	7	0	0	Liquid manures
10	0	10	10	Woody hedgerows for browse, mulch, green manure, soil conservation
11	11	11	11	Conservation Agriculture
8	8	0	8	Planting legumes, manure, green manures
9	9	0	0	Mixed cropping
9	9	0	0	Planting herbs and multifunctional plants
11	11	11	11	Agroforestry (trees + agriculture)
0	9	0	0	Trench beds/ ecocircles
7	0	0	0	push-pull technology
7	7	0	7	Natural pest and disease control
7	7	0	7	Integrated weed management
7	7	7	7	Breeding improved varieties (early maturing, drought tolerant, improved nutrients),
6	6	0	6	Seed production / saving / storing
9	9	0	0	Crop rotation
0	0	0	0	Stall feeding and haymaking
0	0	7	0	Creep feeding and supplementation
0	0	9	0	Rotational grazing
0	0	9	0	Debushing and oversowing
0	0	9	0	Rangeland reinforcement
9	9	9	9	Bioturbation
0	10	0	0	Tower garden
0	10	0	0	Keyhole beds

Ranking of suggested practices based on score provided by the farmer

A participatory impact monitoring process for the KZN participants (Bergville and Tabamhlophe) provided an assessment of practices **actually tried out and prioritized for impact on livelihoods**. This gives us an opportunity to compare the outcomes of the computer based DSS with a real case study.

The table below summarises the practices according to those recommended through the DSS, but not yet tried, those not recommended but tried and practices tried out that are not in the DSS list of practices.

*Table 10: **Analysis of CSA practices implemented in KZN (Bergville, Tabamhlophe) – 2017-2019***

Practices recommended not yet tried	Practices tried, not recommended	Not in recommendations

Zai pits	Bucket drip irrigation	Making compost
Contours; ploughing and planting		Improved irrigation practices
Stone packs		Spring protection
Strip cropping		Limited burning of veld
Pitting		Vaccinations and dipping
Agroforestry		
Natural pest and disease control		
Breeding improved varieties		
Seed saving		
Integrated weed management		
Rotational grazing		
De-bushing and over-sowing		
Rangeland reinforcement		
Keyhole beds		

The facilitated DSS process is designed to be cyclical and seasonal, to allow smallholder farmers to prioritize and experiment with a couple of prioritized practices at a time and to build on these, over time. The results above indicate the work to date over 2 seasons. Practices blocked in green are those that have already been planned into the coming growing season. These include strip cropping, natural pest and disease control, seed saving and keyhole beds.

The practices not recommended by tried out by farmers, are those that should still be included in the DSS and will be considered in the 3rd and final version of this model

Overall there is a very good coherence in practices recommended by the computer- based model and those recommended through the facilitated process.

5. Participatory impact assessment (PIA)

For this process the PIA framework has been used to outline the indicators used at community level and provide for a qualitative assessment of increased resilience by community members. A group process has been designed and tested, as has an individual survey instrument. Both will be reported on here.

In PIAs there are three basic questions:

1. What changes have there been in the community since the start of the project/process
2. Which of these changes are attributable to the projects
3. What differences have these changes made to people's lives

5.1 PIA Workshop outline

. Recap climate change impacts

- Explore what people have noticed about impacts and make lists under headings: natural, physical, economic, human and social
  Group level brainstorming of ideas; written on cards under the headings given, with arrows for increase or decrease

  2. Recap adaptive strategies/ practices
- What have people been doing to adapt to this, fix the problems, make things better?
- What can be done? (first look at hat has been done and then any further ideas of what can be done)
- Elucidate adaptations for each category: natural, physical, economic human, social
  *Group level brainstorming; write on different cards (those done and those thought of) and place next to the impact, indicate with a * which of these have been facilitated or introduced (and by whom) – this can be other farmers, projects, extension officers….*

  3. Practices: Recap 5 fingers and list all practices under each category
- Re-introduce the 5 fingers concept – and include a further category of the whole hand – which is the social and personal
- Which practices have been implemented (introduced and other)?
  Go around in the circle and each person mentions what s/he has done (productive, economic, social, personal actions) and what she would still like to try
- Add these practices to the five fingers diagram
  Make an A1 diagram of the five finger and then add practices on cards
- Go through practices recommended through the DSS
  Use cards with ranked practices from the DSS- describe and show the ones that people are not familiar with.
- Rank practices for next round of implementation
  Rank the list of practices by a show of hands.

  4. What have been the changes or benefits from each practice
- What changes have there been?
  Brainstorming changes – an interrogate to get to the more
- How important are these changes to your lives? How do you decide? Which criteria would you use to decide?
  Do a matrix ranking: changes (in columns), criteria (in rows) – Use proportional piling, working down each column by asking "how important is this practice for the criteria" and comparing the practices with each other (to an extent) as you go down the list…. Exercise is done in small groups of 5-8 participants
  Below is an example of how this could look

	food	income	Soil, water	Access, ease,	knowledge
Trench beds					
Tunnels					
CA					
Cover crops					
Legumes					

Other crops; potatoes, sweet potatoes					
Savings					
Subsidised inputs					
Saving for inputs					
Farmer centre					
Small businesses					
Learning group					
Water committee					

6. Expanding on practices

- Introduce new practices for each of five fingers
- Participants assess each practice (after deciding on criteria for how you decide this practice is useful?)

Eventually the whole exercise can be summarised in the table below

	Natural	Physical	Economic	Human	Social
CC impacts					
Adaptive strategies					
Actions/ practices					
Changes due to practices					
Importance of these changes to your livelihood					

5.2 Participatory Impact assessment; Bergville, Ntabamhlophe (April 2019)

Attendance

30 participants were invited; A selection of participants from learning groups in 8 villages: Stulwane (8 participants), Thamela (1 participant), Nthabamhlophe - Estcourt (2 participants), Eqeleni (4 participants), Ezibomvini (10 participants), Emazimbeni (3 participants) and Emabunzini (2 participants).

These participants represent those in the villages actively pursuing and experimenting with some of the CSA practices introduced and those most engaged in the mixed farming systems typical in the area.

Right Above and Below: Bergville and Ntabamhlophe participants in the PIA workshop

Facilitators; Lindelwa Ndaba (from Lima-RDF) joined the MDF team with one of her local facilitators from Ntabamhlophe, to learn about this process, for incorporation into her work in Food Security in her organisation.

Climate change

Here participants summarised their observations as an introduction into the process of assessing the impact of CSA practices:

- Less rainfall
- Late rains
- Greater intensity of storms and strong winds
- Increased heat in spring, summer and autumn

Climate change impacts on farming and livelihoods

This exercise was repeated, partly to assess whether people's perception of changes and impacts have shifted, now that they are more aware to the issues at hand. It also provided an opportunity for participants across villages and from different areas to engage with each other around their understanding and perceptions. This exercise was conducted at the beginning of the process as well.

For this exercise the impacts were divided into the 5 livelihood categories and is summarised in the table below.

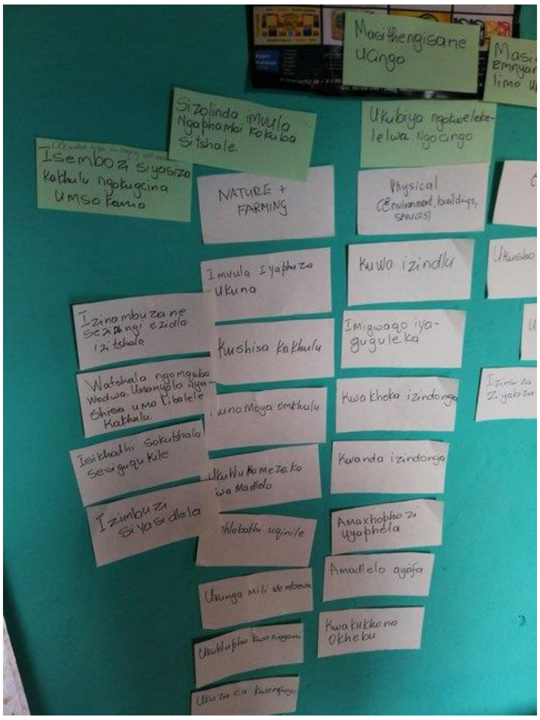
Table 11: Impacts of practices according to livelihoods resrources

<table>
<tr><th>Natural (environment and farming</th><th>Physical (infrastructure, environment)</th><th>Economic</th><th>Human (Skills, knowledge, agency)</th><th>Social (organisation, cohesion)</th></tr>
<tr><td>Earthworms disappear</td><td>Water shortages; reduced flow in streams and springs, boreholes dry up</td><td>Food shortages</td><td>Increase in diseases in humans</td><td>No progress here</td></tr>
<tr><td>Degradation of veld and reduced grazing</td><td>Severe erosion of roads and damage to houses by heavy rainfall</td><td>Water shortages at household level</td><td>Farming is done by older people; the younger people are lazy</td><td>People don’t work together</td></tr>
<tr><td>Livestock break into fields and eat crops</td><td>Dongas are increasing in number and size</td><td>Farming inputs and services are very expensive</td><td>Water borne diseases from drinking dirty water</td><td>Traditional leadership is no longer respected</td></tr>
<tr><td>More diseases in cattle, requiring purchase of medication and vaccines and more deaths</td><td>Damage to wetlands from people building there, overgrazing and other uses.</td><td></td><td></td><td>Other community members steal farmers’ produce</td></tr>
<tr><td>Contours in the fields, that were made many years ago have not been maintained and now there is erosion in the fields</td><td>Severe erosion due to denuding of land, followed by heavy rainfall</td><td></td><td></td><td>Learning groups; some conflict in some of the learning groups has reduced participation.</td></tr>
<tr><td>More crop damage from birds than before</td><td colspan="4" rowspan="9">SOME GENERAL ADAPTIVE MEASURES PROPOSED
- Savings
- Rotational group saving for buying and putting up fencing
- Small businesses
- Buying fencing
- Request support for fencing and ask Government support as well – although with the latter participants are aware that Government support is unlikely.

COMMENTS ON PLANTING DATES
-People who planted in November- have struggled with lack of germination
- More germination for those who planted in December
- Spraying with Decis (pesticide against cutworms and stalk borer) helped with germination and growth (more pests were present) and reduced eating of seed by birds
- A few participants even planted in January – and this worked quite well in this last season
- One participant in Thamela mulched her whole field and planted in November and has had promising germination and growth from this
-Participants also noted that beans did not grow at all, but the cowpeas have done reasonably well, even under these difficult conditions.
It is difficult to make decisions about planting dates now that the climate is more unpredictable.
The importance of crop residues to maintain soil moisture cannot be under-estimated</td></tr>
<tr><td>Dry soil</td></tr>
<tr><td>Seeds don’t germinate</td></tr>
<tr><td>Extreme winds that damage vegetation and crops</td></tr>
<tr><td>More veld fires</td></tr>
<tr><td>More pests in crops and new pests that were not present in the past</td></tr>
<tr><td>Fertilizer is ineffective in hot, dry conditions</td></tr>
<tr><td>Planting times for crops are changing in unpredictable ways</td></tr>
<tr><td>There are small water sources in some people’s homesteads, which they refuse to share with others</td></tr>
</table>

General comments about this discussion:

1. The participants'' understanding of the contribution of CC to the erosion issues in their villages shows a good grasp of the process. They have commented on the process of denuding of the environment due to heat, drought and grazing pressure, followed by heavy storms and the increased damage caused to the environment due to this. They are also aware of the reduction in water from boreholes, wetlands and springs and how the climate variability, along with bad management practices have exacerbated this process.



Right: An outline of CC impacts put together by the participants

2. Participants discussed the fact that there are only about 30% of community members in each of the villages who are farming. The rest of the inhabitants do not respect people's efforts and do not cooperate in terms of managing their livestock. They have even been known to take their cattle to the fields to graze and to steal some of the crops. The traditional authorities and Local Municipality are not focused on peoples' problems and do not seem to care. They do not assist. This has now led to an increased feeling for the need to fence their fields. Round 23% of participants present, have already fenced their fields.
3. Fencing is expensive and people suggested joint savings and implementation options to spread this burden. They would also like to request assistance, but know that they are unlikely to find support in the short term. They do however believe that they can ask for assistance form the department of Agriculture. A further suggestion is that they club together to fence one large piece of land and then work there together – as this should be cheaper than fencing each person's field separately.
4. There was a long discussion on the merits of soil cover from crop residues and how this can assist with the problem of deciding on a planting date related to weather variability. One person went a far as mulching her whole field- which has had very promising results for her- given that her November planting of field crops was successful, whereas it was not for others. This also links into the discussions held about production of fodder crops and fencing of fields, as management of crop residues for soil cover will then become a possibility.
5. Participants do not believe that the lack of interest in farming is because of climate change, but is a broader societal issue; where people and especially the youth have become lazy, with high expectations of support and prefer not to be active at all, than to put in effort into activities with low returns.

CSA practices

Here participants described practices they are using under the five fingers (soil, water, cropping (gardening and field cropping, livestock and natural resource management. We decided also to include a further category - social agency, or what they described as people management

Table 12:CSA practices implemented in Bergville and Nthabamhlophe

Soil	Water	Crop (garden and field)	Livestock	Natural Resources	People
Making compost	Drip irrigation	Diversified crops in gardens; beetroot, Chinese cabbage, carrots, parsley, thyme,	Vaccinations		Savings
Use of goat and cattle manure	Mulching	Shade cloth tunnels	Dipping		Small businesses
Canopy cover and legumes (Lab-Lab)	Infiltration pits	Beds: raised beds, trench beds, eco-circles	Proper feed; including from fodder produced		Farmer centres
Diversified crops to hold soil and prevent erosion	Garden layout with shallow furrows for water harvesting and retention	Tower gardens – fertility and greywater management	Addition of supplements		Selling chickens
	Greywater management	Conservation agriculture; including management of residues	Limiting burning of veld		
	Improved irrigation practices	Inter cropping and crop rotation	Planting grass; ungwengwe and kikuyu		
	Rainwater storage in JoJo tanks and drums	Diversified crops in fields; different varieties of maize, sorghum, millet, legumes (e.g. cowpeas, beans, Lab-lab), cover crops			
	Spring protection	Use of Decis Forte (Pyrethrins) for pest control in fields			
	Buying JoJo tanks – and negotiating with water trucks to fill these	Liquid manure			
		Mixed cropping in gardens			

From this table it can be seen that participants have implemented a wide range of practices in cropping and gardening and have also started to focus on livestock production and management. They have given no attention to natural resources management, erosion control, or soil and water conservation in grazing management.

Right: An analysis of practices related to the "five fingers' concept

In addition, participants specifically mentioned the benefits of trench beds:

- These beds produce very high yields
- They keep the soil fertile for a long time and
- They hold a lot of water – saving on irrigation needs.

In addition, although agro-ecology is promoted and organic gardening demonstrated and promoted, the use of pesticides such as Blue Death (Carbaryl) and Bulala Zonke (Malathion) in the gardens, is common.

In addition, in the Conservation Agriculture experimentation process participants have been using Decis Forte (pyrethrin) to control both cut worm and stalk borer. Contrary to expectations that the need for this pesticide would reduce over time, participants feel that it is becoming more important with the changing weather conditions as the stalk borer load in their fields has increased. They also believe that spraying this pesticide reduces the incidence of birds feeding on their seed.

Changes and benefits from CSA practices

This exercise consisted of doing a matrix ranking of practices farmers have used in the past year; incorporating gardening, field cropping, livestock management, soil and water conservation and water issues (access, availability).

Impact indicators for this exercise were developed in 2 small groups by asking participants to outline how they make decisions about which practices to use and what changes they would observe.

Below is a summary of the Matrix for each of the 2 small groups. A process of proportional piling was used for the scoring of each practice and indicator – where 100 counters were provided for each indicator and the small group decided how these would be placed proportionally for each practice. In this way participants can comment on; more or less, and how much more or less. The outcome of the exercise is quantifiable in terms of gauging percentages.

The 3rd group conducted an exercise in comparing different water saving practices

Matrix 1

For this matrix the practices were conflated to encompass all specific practices within that category.

- ❖ Conservation agriculture; minimal tillage, soil cover, crop diversification
- ❖ Savings: Village saving and loan associations, rotational saving in small groups towards specific infrastructural needs, personal savings
- ❖ Livestock; fodder production, vaccinations, dipping, supplementation
- ❖ Gardening; bed design (trench beds, eco-circles, raised beds, tower gardens, tunnels, mulching, mixed cropping, crop diversification, inclusion of herbs, infiltration pits and water conservation furrows.
- ❖ Crop rotation; 3-4 crop rotations in field cropping
- ❖ Intercropping: grain-legume and grain -cover crop intercropping options in field cropping
- ❖ Small businesses; including agricultural and non- agricultural businesses; sale of snacks in schools, sewing, baking, poultry production, maize milling etc.

The impact indicators developed by this group are of particular interest as they are multi-dimensional talking at least two different aspects for each indicator Additionally, the exercise was run so that each practice is compared with the other practices when considering one of the indicators or criteria. This greatly increases the value and reliability of the scores provided by the group.

Table 13:Impact indicators and assessment form the Bergville PIA, April 2019

	Soil; health and fertility	Money; income and savings	Productivity; acceptance of practice, saving in farming – equipment, labour	Knowledge; increased knowledge and ability to use	Food; how much produced and how healthy	Water; use and access	Social agency; Support, empowerment	Total
Conservation Agriculture	22	21	26	28	18	23	18	156
Savings	6	15	14	15	12	11	15	88
Livestock	19	11	18	7	5	12	11	83
Gardening	14	15	12	13	15	17	21	107
Crop rotation	16	12	13	12	12	15	10	90
Intercropping	12	13	15	12	11	11	9	83
Small businesses	11	17	15	10	20	11	9	93

Comments:

- ➢ The overall impact on livelihoods (which is seen as the combination of the indicators chosen by the group) is shown under the 'total" column. From this, the participants clearly consider the Conservation Agriculture (CA) process as the most significant, followed by gardening, small businesses, savings and livestock – in decreasing order
- ➢ The practices of crop rotation and intercropping fall under the ambit of CA. the comparison of these two practices by community members has shown some very interesting learnings and conceptions;
  - o Crop rotation is considered to be better at increasing soil health and soil fertility than intercropping – showing an internalisation by the group of the positive effects of rotation of the main grain crops with legumes and cover crop combinations, as

well as an observation that this works better than intercropping by itself. This observation is clearly supported by academic evidence.

- Income, savings and productivity are considered to be somewhat higher for intercropping; again, a very astute observation from the group. Generally, participants prefer crop rotation over inter-cropping, but are able to appreciate the increases in productivity and potential income due to intercropping options.
- Water use and access is considered by this group to be quite a bit better for crop rotation, when compared to intercropping. They have noticed the potential of intercropped grain and legume plots as well as grain and cover crop plots to show signs of water stress and competition for water (and potentially nutrients) between the crops. Although, academically this is not the case in well managed fields, it is quite likely in more infertile plots.
- Regarding social agency; group participants are more easily able to relate to the concept of crop rotation as they find crop management in the single cropped blocks a lot easier (including weeding and harvesting) and do not have difficult decisions to make in terms of choices of timing of harvesting and extended harvesting periods.

Matrix 2

	Money	Food	Fertility	Saving water	Total
Mulching	8	13	26	23	**70**
CA; Maize and bean intercrop	11	23	20	15	**69**
Pipes for channelling water to households	17	24	6	12	**59**
Trench beds	19	7	18	19	**63**
Using animal traction	13	19	6	15	**53**
CA; crop rotation	23	11	18	9	**61**
Tower gardens	9	4	6	7	**26**

Matrix 3; water practices ranking

This group Ranked the practices, rather than the criteria and discussions revolved primarily around water management in gardens.

Practice	Ranking	Criteria
JoJo tanks	5	Good healthy food, water supply, safe clean water, increased moisture holding, reduced conflict among neighbours, and reduced costs
Grey water	1	
Infiltration pits	1	
Mulching	1	
Comment: The JoJo tanks assist the most, but in winter, they need to be filled from water tankers supplied by the Municipality, which can be expensive.		

Comments:

- JoJo tanks are considered a good investment for increased water security at household and gardening level, much more so than any of the in- situ water conservation practices such as infiltration pits and mulching.
- Interestingly, participants from both Bergville and Estcourt mentioned that they have persuaded the operators for the water tankers from the municipality to fill up their JoJo tanks for a fee. This is a win-win situation for both the participants, who can now have

access to a lot more water than is usually supplied to them through the municipality and the municipalities themselves, who can now offer water to selected households and feel that they are "doing their work".

- At a systemic level however, this is an extremely alarming trend. The water tankers are meant to be a back-up plan for municipalities where their water supply falls short in terms of servicing people and for emergencies. It has however become the main way in which water is provided and is unfortunately part and parcel of the broader defrauding of government coffers and state capture. It is possibly the most expensive way to supply water that was ever conceived and allows certain interests to benefit disproportionately- namely the companies providing and maintaining these tankers, which predictably are linked to the government officials themselves. One tanker is said to cost around R35 000/ day to run and maintain, but only carries around 20 000l of water- and if used to fill up JoJo tanks, can only supply around 5-10 people in a day. The fees paid to the tanker operators are also bribes, rather than an official process, making the entire procedure extremely questionable.

Expanding on CSA practices

Participants have suggested that they will continue expanding the CSA practices and have outlined strategies for each of the villages. What this shows is that there is substantial potential for horizontal expansion and learning within the communities themselves and that if a careful, fully participatory process is used for introduction and support of CSA practices, that quite complex processes can be talked. The community members who are still engaged in farming have a "hunger for farming systems that are more productive and that would better support their livelihoods and take on new ideas."
It also indicated the clearly that farmers learning from other farmers is the most successful and the most likely to build a sustainable framework of implementation that the participants can build on.

Table 14: CSA practices still to be tried out in Bergville:2019-2020

Village	New practices	COMMENTS
Stulwane	-Fencing of fields -Grazing management -Making hay bales -Fodder production - Supplementation with protein in winter (licks, pre-mixes and liquids) -Saving for shade netting tunnels	There is a lot of interest in the tunnels and participants have agreed to save towards buying shade netting and putting up their own structures- as the provision of further tunnel kits through this process is not possible. Interest in fodder production, making of hay and supplementation for livestock is high and interestingly also something that a number of women have volunteered to become involved in – especially in Ezibomvini and Eqeleni. Emazibeni and Emabunzini are areas where participants have come across the work done in other villages and have asked to be brought on board.
Eqeleni	-Fodder production- Continue with planting different fodder types -Making of hay bales -Supplementation -Saving for shade netting tunnels	
Ezibomvini	-Spring protection -Making of hay bales -Supplementation -Saving for shade netting tunnels	
Thamela	-Eco-circle -Saving for shade netting tunnels	
Emazimbeni	-Fencing of fields - Tower gardens	

	- Planting pottoes in bags -Saving for shade netting tunnels	They are learning about CSA from these groups and individuals.
Emabunzini	-Trench beds -Saving for shade netting tunnels	

Evaluation of the workshop

Some significant comments made in closing by participants included:

- We learnt a lot by bringing people from different areas together
- We have been provided with information on how to implement different practices such as different types of beds in the garden and water management
- We have also seen the proof of these practices here in Phumelele's garden
- We are grateful that Mahlathini has not forgotten the farmers

6. Resilience snapshots

Individual impact assessment questionnaires have been designed and linked to a resilience snapshot questionnaire. These have been tested for 6 participants per province. As a result, the impact assessment questionnaire has been streamlined and can now be more widely use. The questionnaire is presented in Attachment 4 to this report.

Below a case study for the 6 KZN participants is presented.

6.1 Resilience snapshot case study for KZN

Summaries of the responses to specific questions are summarised in bullet point and tables.

Learning and change

(a) What have you learnt about dealing with CC and climatic extremes?

- I have learnt that practices such as trench beds and CA provide good growth and yields, despite difficult weather conditions. Also, these practices are cheap. We get more food than we did before and will now be able to continue farming
- Adaptive practices like mulching help to deal with increased heat and water stress
- Practices such as trench beds, eco-circles, mulching and mixed cropping enables the soil to hold moisture for longer and withstand the heat and dry spells.

(b) What is your experience regarding the impact of CC on your life?

- This season we had drought; the beans did not grow and maize is stunted. I fear will not have enough food
- Cattle have been negatively impacted- more disease and deaths as grazing diminishes
- The climate is changing; low rainfall during the planting season and high temperatures are affecting farming activities

- I have not experienced climate change – I do not have water issues (participant in Midlands of KZN)
- Climate change has destabilised our planting patterns and has created a lot of uncertainty about planting dates for both summer and winter crops

(c) Do you share your knowledge and experiences with the learning group or community members?

- Yes, I talk to my neighbours about the gardening practices, so that they can also try and revive their gardens
- Yes, I have talked to neighbours, some come and visit to see the garden and experiments and some have even taken pictures.
- Yes, I talk to my neighbours and friends and invite them to the learning group sessions if they are not members yet.

(d) How do you share the knowledge gained with other members of your community?

- Discussions at savings meetings, at the springs when we collect water
- When people visit, I show them my garden

(e) What helps you to learn more about new innovations and information?

	No (N=6)	Comments
Listening to other farmers experiences and experiments	6	I get motivated by other farmers' work, get new ideas such as planting potatoes in bags
By doing and experimenting in own garden	4	This helps me to know how good the practices area, have tried a no of experiments and included my own ideas
Motivated by other farmers work and experiences	5	Learnt about raised beds in Msinga
Learning workshops	5	I find them useful because I always hear new information and experiences form the facilitator and farmers

(f) What new things have you added into your practices? How has it worked?

- I have not tried anything else new, outside of the practices we were taught; CA, trench beds, mulching, mixed cropping, RWH, greywater management, seedling production
- I have tried a u-shaped garden which helps to collect water, helping plants to grow better.
- I have used some of the maize and sunflower seed I grew in the CA trials to feed my indigenous chickens; this has helped for a better survival rate and even the ability to sell a few.

Climate smart practices

(g) Impacts and lessons learnt

	Past issues	Past Practice	Present Practice	Impact and lessons
Livestock	Low production	Bartered indigenous chickens	Selling indigenous chickens locally	
	Feed too expensive to buy	Fed chickens' scraps	Feed of sunflower and crushed maize seed from own production	More chickens survive and grow well making sales possible

Gardening	Low yield and dry beds	Raised beds	Trench beds and raised beds	Better growth and yield, increased water holding, beds remain moist during hot periods, beds hold water for a long time fewer pests and diseases,
		Fetched water from communal taps and springs	Also RWH and grey water use (unfiltered)	Saves water and time in fetching water to irrigate
			Mulch (dry grass)	Mulch retains moisture, but can encourage termites
		Buy seedlings	Seedling production	Increased number and types of crops;
		Standard veggies	New veggies and herbs	There is demand in the village for the new crops; kale, Chinese cabbage, carrots, More and different food for longer periods in the year
		Short season for planting, or no planting due to lack of water	Winter planting	Grow crops in garden and in the fields (sweet potatoes, potatoes)
Field cropping			CA	Increased water holding and less run-off, increased ability to withstand drought
			Intercropping	Increased availability of more types of food,
			Legumes	Increased yields
			Cover crops	Increased soil health, Feed availability for livestock

(h) Assessment of impact for CSA practices tried out using local indicators

-1 = worse than normal practice

0=no change

1=some positive change

2=medium positive change

3= high positive change

Note: It has been decided subsequent to this initial piloting of this exercise to make the scale more symmetrical -3through to 3

	Name of practice	**Soil**	**Water**	**Productivity**	**Labour**	**Pest and disease control**	**Cost and maintenance**	**Livelihoods**	**Adaptation**
1	Trench beds	2	2	3	-1	2	0	2	3
2	RWH	0	3	1	-1	0	-1	1	3
3	Mulching	2	2	3	0	3	0	1	2
4	Tower garden	2	3	3	2	0	0	2	2
5	Planting basins	0	2	2	0	0	1	1	1
7	Raised beds, with mulch	1	2	2	1	0	1	0	1
8	eco-circle	2	3	2	-1	1	0	1	1

9	CA; w intercropping, legumes, cover crops	3	2	3	1	1	0	2	2
1o	Using goat manure (composted in a kraal)	3	1	2	0	1	0	1	1

6.2 Resilience snapshot

A summary table of the results for all 6 participants is presented below, followed by the more in-depth

Resilience indicators	Rating for increase	Comment
Increase in size of farming activities	Gardening – 18% Field cropping – 63% Livestock – 31%	Cropping areas measured, no of livestock assessed
Increased farming activities	No	Most participants involved in gardening, field cropping and livestock management
Increased season	Yes	For field cropping and gardening- autumn and winter options
Increased crop diversity	Crops: 12 new crops Practices: 8 new practices	Management options include; drip irrigation, tunnels, no-till planters, JoJo tanks, RWH drums,
Increased productivity	Gardening – 72% Field cropping – 79% Livestock – 25%	Based on increase in yields
Increased water use efficiency	25%	Access, RWH, water holding capacity and irrigation efficiency rated
Increased income	13%	Based on average monthly incomes
Increased household food provisioning	Maize- 20kg/week Vegetables – 7kg/week	Food produced and consumed in the household
Increased savings	R150/month	Average of savings now undertaken
Increased social agency (collaborative actions)	2	Villages savings and loan associations and learning groups
Increased informed decision making	5	Own experience, local facilitators, other farmers, facilitators, extension officers
Positive mindsets	2-3	More to much more positive about the future: Much improved household food security and food availability

RESILIENCE SNAPSHOT		(6 participants)					
Date	Feb-19						
Province	KZN	Bergville, Midlands					
Village	Ezibomvini, Eqeleni and Gobizembe						
Increased in farming (Size)		**Before (Size in sqm)**	**Now (Size in sqm)**	**Comment: Percentage increase**			
	Gardening	76	93	18%			
	Field cropping	1400	3767	63%			
	Livestock	22	32	31%			
	Trees nat resources	4	4	0%			

		Y/N before	Y/N now		Comment:			
Increased diversity in farming	Gardening	1	1		Most participants undertake activities in all four farming categories			
	Field cropping	1	1					
	Livestock	1	1					
	Trees, nat resources	1	1					
Increased diversity (1)		**Management and practices before**	**No b4**	**No now**	**What has changed; new crops**	**What has changed; new practices**		**What has changed; , new management**
	Gardening	raised beds; use of ash and kraal manure	1	4	Kale, chinese cabbage, carrots, mustard spinach, Coriander	mulching, trenches, seedling production, more crops, tower gardens, eco circles, raised beds, planting basins,		RWH (Jojo tanks and drums), greywater and organic gardening, tunnel, drip irrigation,
	Field cropping	traditional planting of maize	1	4	Maize, beans, cowpeas, Lab-Lab, sunflower, sunnhemp, millet, potatoes, sweet potatoes	CA, intercropping ,legumes, cover crops, rotation		
	Livestock	extensive foraging	1	1	sunflower, maize	Feeding of poultry - crushed maize and sunflower		
	Trees nat resources							
		Types	**BEFORE: Quantity (KG, No)**		**NOW: Quantity (KG,No)**	**Percentage increase**		
Increased productivity	Gardening	Spinach	7,8		15,3	49%	(Amount in kgs/tonnes, 10,20,50kg bags/containers, no of meals (for a family)	
		Cabbage	5		8	38%		
		Potatoes	10		20	50%		
		Carrots	0		10	100%		
		Green pepper	0		30	100%		
		Chinese cabbage	0		8,5	100%		
		Chilli	5		7	29%		
		Onions	5		8	38%		
		Beetroot	4,3		11,3	62%		
		Kale	0		15	100%		

		Mustard spinach	0	30	100%		
		Coriander	0	30	100%	**72 %**	
	Field cropping	Maize	99,3	257,8	61%		
		Beans	4	16,8	76%		
		Cowpea	0	5	100%	**79 %**	
	Livestock	Chickens	15	20	**25%**		
	Trees nat resources						

	Increase Access	**Inc RWH**	**Inc water holding**	**incr water productivity (irrigation)**	**SCALE**
Increased water use efficiency (incl RWH, water holding, water access, water productivity)	1	1	2	1	0= same or worse than before; 1= somewhat better than before, 2= much better than before

	Income before (ave monthly in Rands)	**Income now (Ave monthly in Rands)**	**Comments**
Increased livelihood security (income)	1433	1650	

	Food types (staples, veg, livestock, fruit)	**Quantity/ week (kg)**	**No of times/ week (1-7)**	**Sales/week (in Rands)**	**Comments**
Increased livelihood security (Household provisioning and food security)	maize	20	7	0	6 of 6
	Veg (Spinach, chillies, green pepper)	10	5	225	2 of 6
	Veg(spinach, chinese cabbage, tomato	10	3	0	6 of 6
	Veg (beetroot, chilli)	1	1	0	6 of 6
	Chicken	2	2	0	1 of 6
	Pigs (kg of meat)	10	1	2500	1 of 6
	Cattle (no sold/yr)	1		10000	1 of 6
	Fruit	1	1		1 of 6

	Income options Before	**Income options Now**	**Comment; name new options e.g. which crops, etc**	**Scale**
Increased livelihood diversity/options	1,4	1,3,4	Small incomes form farming now possible	1=social grants; 2= remittances; 3=farming income;4= small business

	Amount per month Before	**Amount per month Now**	**Use of savings**	**Scale**

Savings (safety, security, achievement)	0	R150	2,3,4	1=food; 2=household use; 3=education; 4= production; 5=other
Increased growing season		**Yes/no Before**	**Yes/no Now**	**Comment**
	Gardening	0	1	Now grows crops in winter in garden and fields
	Field cropping	0	1	
	Livestock	0	0	
	Trees nat resources	0	0	
Collaborative actions/social agency	**Activities in groups Before-name**		**Activities in groups Now**	E.g. savings, church, learning groups, coops, farmers associations, work teams, selling, inputs, farmers centres water committees …
	Stokvel		VSLA	
			Learning group	
Informed decision making	**Information used to choose activities Before**		**Information used to choose activities Now**	E.g. Other community members, learning in groups, written info, radio, facilitators, extension officers, etc
	Own experience		Own experience	
	Extension officer		Extension officer	
			Learning group members	
			Local facilitator	
			Facilitator	
Positive mindsets	**Rate your mindset Before**	**Rate your mindset now**		**SCALE:0=less positive about the future; 1=the same; 2=more positive about the future; 3=much more positive**
	0	2-3		Much improved household food secuirty and food availability.

7. Quantitative measurements

Initial site selection for the 2018-2019 period is shown below (as reported in Deliverable 3)

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

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

*Table 15: **Participants in quantitative measurements for trials; KZN and Limpopo***

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

*Table 16: **Measurements taken for the gardening trials***

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

*Table 17: **Measurements taken for the field cropping trials***

Parameter	Instruments	Dates
Evapotranspiration (Et_0)	Davis weather station	ongoing
Soil moisture	Gravimetric soil water samples	4x in growing season
Bulk density	Sampling	Once towards the end of the season
Soil fertility	Sampling for analysis at CEDARA soil Lab	End of growing season
Soil health	Sampling for analysis by Soil Health Solutions	End of growing seaosn
Rainfall	Rain gauges installed in 5 sites	On going
Infiltration	Single and double ring infiltrometers	Once during the season

Run-off	Run-off plots installed in three sites	On going
Weighing of the harvest	Weighing scale, including grain and biomass (lab analysis)	At the end of the growing season- for Mazie only
Rand value of the harvest	Local market price	At harvest

Data for a number of the quantitative measurements were rereported on in detail in Deliverables 5 (Limpopo) and 6 (KZN). In this report we will provide a focus on the water productivity results only.

7.1 Water Productivity in Conservation Agriculture

Due to crop failure in Limpopo (for both seasons 2017 and 2018), water productivity was calculated for the Bergville (KZN) sites only.

Data collection in this season provided a few challenges:

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

As a result, the data collected in this season was not adequate to run a model to allow us to compare simulated and observed values of evapotranspiration (ET) and water productivity (WP). The results presented in this section were observed values and were computed manually following the equations presented in the methodology section. Detail of the data and equatiosn used are provided in Deliverable 6 of this project.

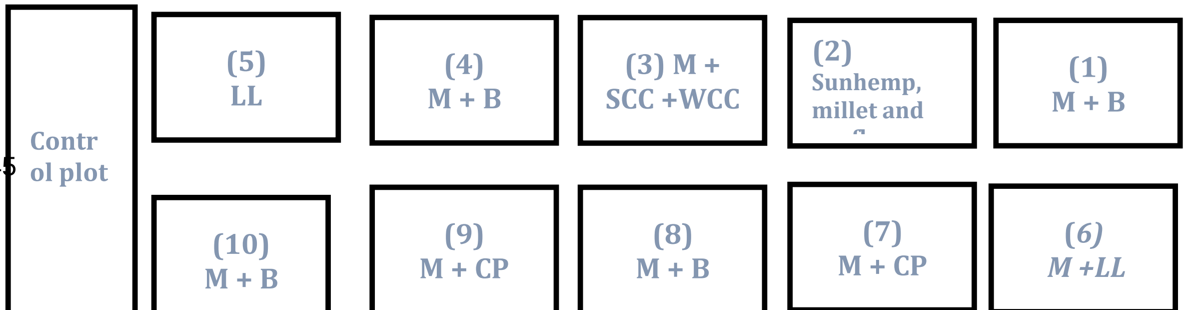
Our assumption for this farmer level experiment, or the hypothesis, is that water productivity of an intercropping system will be better than that of a monocropping system under CA.
Enough data was collected for two of the three sites and participants; Phumelele Hlongwane from Ezibomvini (PH) and Ntombakhe Zikode from Eqeleni (NZ).
Note: These participants have provided express permission to the research team to use their trial information in reporting and in publications. This is in lieu of a formal academic ethical clearance, which is still pending from UKZN and UWC. Both submissions were made almost two years ago, but expediting of these clearances have not been possible to date, despite numerous attempts.

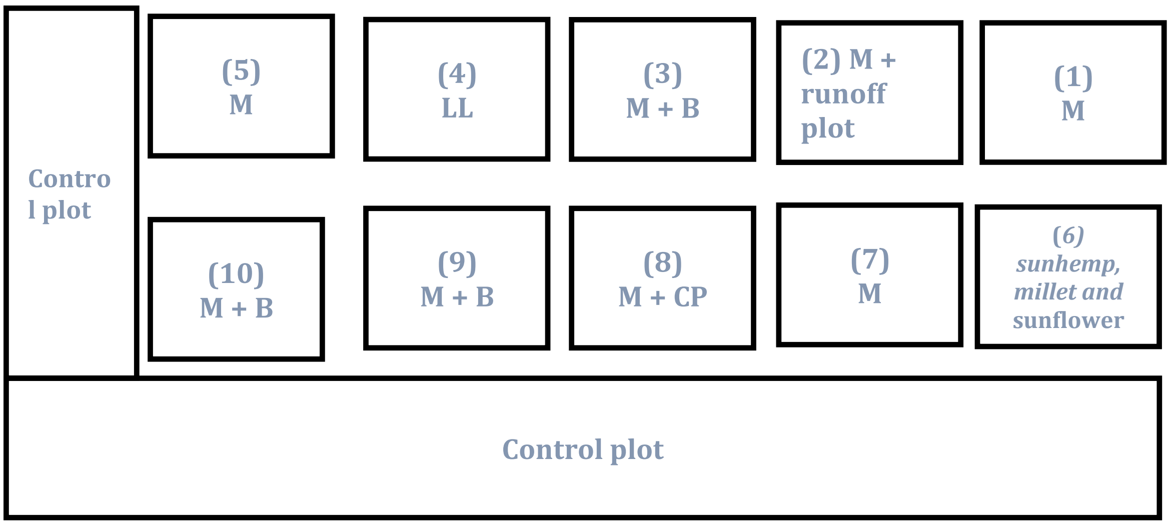
Trial and Control layouts and parameters

Phumelele Hlongwane (Ezibomvini- Bergville)

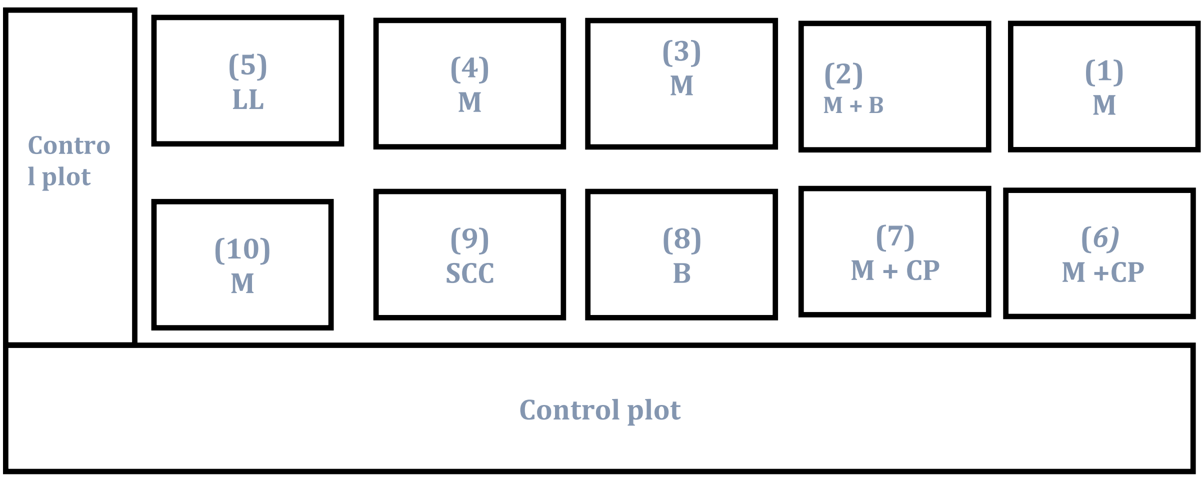
Experimentation

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





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



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

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

*Table 18: **Table outlining rotations undertaken in Phumelele's trial and control plots over the last three seasons, including an indication of installation of runoff plots.***

Plot no	2015/16	2016/17	2017/18	Run off plots
1	M+B	M	M +WCC	Grey squares indicate run-off plots
2	SCC	M	M+B	

3	M+SCC+WCC	M+B	M	Rotations have been done attempting to ensure a different crop/crop mix on each plot in each consecutive year.
4	M+B	LL	M	
5	LL	M	LL	
6	M+LL	SCC	M+CP	
7	M+CP	M	M+CP	A further refinement of the schedule to
8	M+B	M+C		
9	M+CP	M+B		
10	M+B	M+B		
		Cont		
	Control: M (CA)			

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

Ntombakhe Zikode (Eqeleni)

Experimentation

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

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

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

Water Productivity results and discussion; Method 1

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

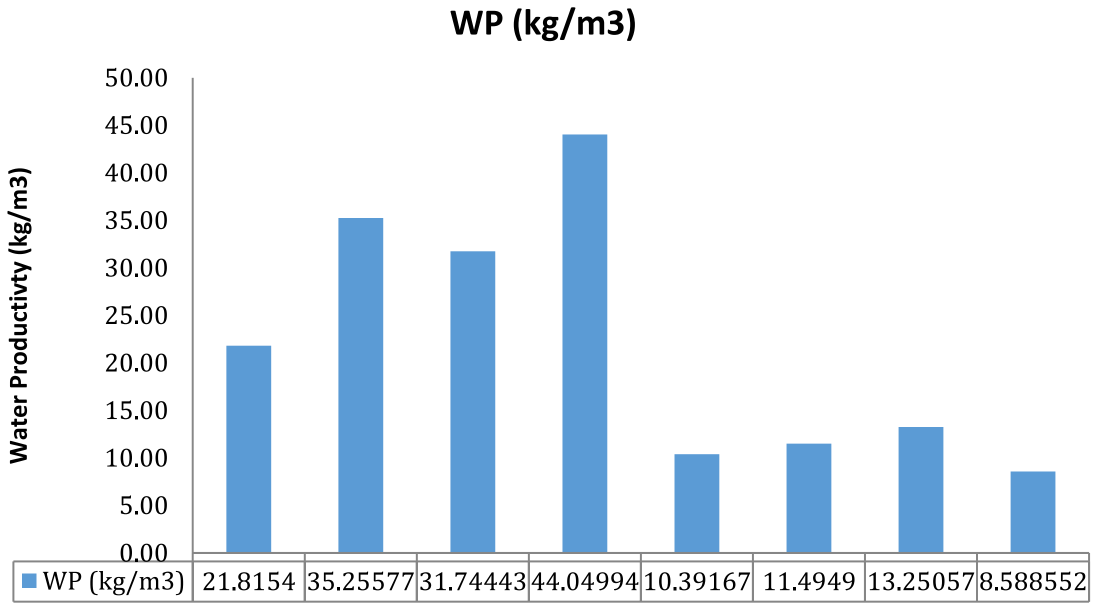


Figure 6: ***Water productivity results using weather station data for dryland field cropping using CA***

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

- Phumelele’s water productivity for all her plots is substantially higher than Ntombakhe’s. This is expected, as her soil fertility and soil health results are also substantially higher. This means that her soil has a much higher nutrient and water holding capacity, despite the fact that both participants have bene practising CA for 4-5 years. It points also to the fact that her management practices within the CA system are improving her soils more substantially than those that Ntombakhe have been using. Crop rotation by itself improves soil health and water holding capacity much more slowly than a combination of rotation and intercropping. Larger crop diversity is also important.
- For both participants the water productivity for their maize and bean intercropped plots is higher than for the maize only and the maize and cowpea plots. This trend has been noted also in the soil health test results and is interesting as it does not hold with the assumptions made by the implantation team that the maize and cowpea intercropped plots would out-perform the maize and bean intercrops.
- For both participants the water productivity of the mono-cropped maize plots is higher than that of their maize and cowpea intercropped plots. This points to a certain level of competition from the cowpeas intercropped with the maize
- For Phumelele, water productivity for her CA control mono-cropped maize is quite a bit higher than her CA trial mono-cropped maize. Her management practices for the two plots are very similar (using the same procedures, fertilizers and maize varieties), pointing to different water productivity potentials in her plots. This variability has been noted also in measurements of soil characteristics, water holding capacity and yields.

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

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

*Table 19: **Maize yields per plot in Phumelele Hlongwane's rotation system:2015-2017***

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

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

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

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

Biomass water productivity results

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

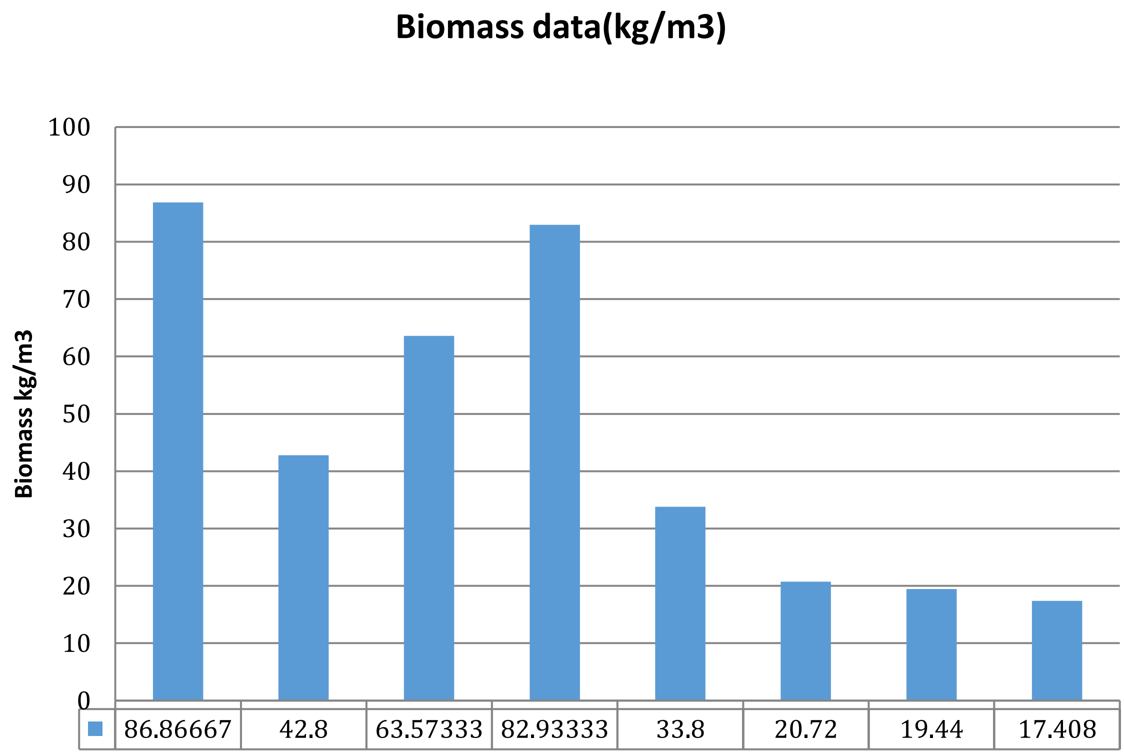


*Figure 7: **Biomass water productivity results using weather station data for dryland field cropping using CA***

From the graph above the following comments can be made:

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

In summary the WP results indicate the following:

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

7.2 Water productivity for gardening systems

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

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

They both planted spinach for this experiment which ran from 2nd of July November 2018. In both cases chameleon water sensors were installed in all three beds for participants to explore their irrigation scheduling and participants also recorded amount of irrigation and harvests.

In the end, only the crops in the two trench beds (inside and outside the tunnel) were compared, as both participants abandoned their normally planted beds mid-season due to lack of growth and difficulties with access to water for irrigation.

The table below outlines WP determined using both the weather station data and the simpler version of water applied that farmers prefer.

*Table 20: **Water productivity for gardening practices for two participants from Bergville; July-Aug 2018***

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

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

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

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

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

*Table 21: **Water productivity for gardening practices for two participants from Limpopo (Sedawa); April -July 2018***

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

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

Cost-benefit analysis for the Gardening systems in Limpopo and KZN

Bergville cost-benefit

A cost-benefit analysis for the trench beds in and outside tunnels for the Bergville area is shown in the table below. The calculation was done by comparing the cost of the water applied with income earned from sales.

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

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

The photos below are indicative.

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

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

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

Sedawa Cost benefit

AA rough estimate of cost nad benefit for Christinah thobejane in Limpopo is shown below. This small table assumes payment for water, as this has been the case in Limpopo.

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

From a water use efficiency point of view, planting in a trench bed without shading (microclimate management) requires 2.9 times the amount of water required in a deep trench under shade cloth.

The quantities of spinach produced in the tunnel are much higher than those produced outside the tunnel. The cost-benefit analysis above indicates, that if water needs to be bought, it would only be profitable to plant inside the tunnel. The profit is however not very high in this context (~R620/tunnel fully planted (15m^2)), for a season. Obviously, if cheaper water can be accessed, this would be a lot more.

7.3 Visual /Qualitative Assessments

This methodology has been tried each year in the Bergville area, as a potential peer review system for assessing soil quality. Below is the scoring sheet that has been designed for this assessment. This assessment has been altered slightly in terms of indicators used when compared to similar processes employed[3,4], to accommodate for tests that are seen to be very similar in the original forms. An example is surface ponding and infiltration, which in our version has been changed to infiltration only.

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

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

It also included some new techniques, mostly ones from a visual scoring index for soil compaction developed by Prof. Dr Thomas Weyer from Westphalia University in Germany[5] . These are soil surface texture, root growth, soil colour, bulk density and Coarse pore content.

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

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

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

*Table 22: **New redesigned VSA Indicator sheet for 2018***

Visual indicator of Soil Quality	Visual Score (VS)	Weight	Comments
Soil Structure (clods, aggregates)	0 = Poor conditions; 1 = Moderate conditions;	× 4	Shatter test
Soil porosity (macro pores, clods)		× 5	Coarse pore content
Soil colour (dark, average, light and uniformity (mottles)		× 3	Incl mottles and organic matter

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3 Sheperd G. 2010. Visual Soil Assessment Field Guide: Part 1: Maize. FAO, Rome

4 Sheperd G, Bailey J, Johnson P. 2012. Visual Soil Assessment. SMI and Vaderstad. New Zealand.

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

Soil surface (crusting, siltation, runoff)	2 = Good conditions	x 3	Assessment of soil surface texture
Earthworm counts		× 2	
Soil cover (0-15%;15-30%; >30%)		× 3	Revised scale, using quadrant
Soil depth (penetration resistance to rod into soil)		× 2	
Bulk density		× 2	Using knife tip penetration in a small pit.
Root growth and development		× 2	New scale
Ranking Score (sum of VS rankings) Max =52			

Piloting of the new VSA methodology.

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

The assessments were done for 5 participants in Stulwane, who have been participating in the CA programme for 4-5 years: Thulani Dlamini, Khulekani Dladla, Makhethi Dladla, Cuphile Buthelezi and Mtholeni Buthelezi

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

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

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

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

*Table 23**: VSA scores using the new methodology for 5 participants in Stulwane, November 2018.***

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

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

The score ranges are:

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

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

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

8. Work Plan

Deliverables Still to to be completed in the forthcoming years (2019-2021) are summarised below

Table 24: Work plan for 2019-2021

FINANCIAL YEAR 2019/2020			
8	Report: Appropriate quantitative measurement procedures for verification of the visual indicators.	Set up farmer and researcher level experimentation. Link proxies and benchmarks to quantitative research to verify and formalise. **Explore potential incentive schemes and financing mechanisms.** *Conduct survey of present knowledge mediation processes in community and smallholder settings???*	1 August 2019

9	Interim report: results of pilots, season 2	Pilot chosen collaborative strategies for introduction of a range of CSA and WSC strategies, working with the CoPs in each site and the decisions support system. **Create knowledge mediation productions, manuals, handouts and other resources necessary for learning and implementation**.	31 January 2020
FINANCIAL YEAR 2020/2021			
10	Final report: Results of pilots, season	Pilot chosen collaborative strategies for introduction of a range of CSA and WSC strategies, working with the CoPs in each site and the decisions support system. Create knowledge mediation productions, manuals, handouts and other resources necessary for learning and implementation.	1 May 2020
11	Final Report: Consolidation and finalisation of decision support system	**Finalisation of criteria and practices, introduction of new ideas and innovations, updating of decision support system**	3 July 2020
12	Final report - Summarise and disseminate recommendations for best practice options.	**Summarise and disseminate recommendations** for best practice options for knowledge mediation and CSA and SWC techniques for prioritized bioclimatic regions	7 August 2020

In addition, the following activities are to be given attention

Theme	Activities
Practices	Inclusion of more practices in the 1pagers
	Initial web design and online survey for the DSS
	Exploration of potential practices (more expertise and refinement required); spring protection, furrow irrigation, improved irrigation practices, windbreaks, fodder production, crop calendars, seed saving, drought and bird resistant varieties,
	Knowledge mediation products: Manuals, learning materials, participatory video
Process	Ongoing facilitation (learning, mentoring and monitoring) process to be conducted with the 7 established learning groups across three provinces
	Strengthening of stakeholder CoPs. Set up of learning and sharing events. Dissemination workshops
Monitoring and Evaluation	Participatory impact assessments in all provinces, with the next round of CSA implementation Continue write up monitoring results (Quantitative and qualitative); summer (CA and winter (gardening) Final assessment of appropriate visual indicators Recommendations; including Pes systems,

9. Capacity building

Capacity building has been undertaken on three levels:

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

9.1 Community level learning

This has been discussed at length in previous sections. In summary, learning workshop have be~~n~~en conducted in 9 villages across three provinces (EC, KZN and Limpopo) with a total of 250 participants including a number of topics ~~including~~; scientific and community level understanding of climate change and weather variability, impact of climate change on production, adaptive measures, introduction to a range of CSA practices, farmer level experimentation and practical learning for a range of CSA practices. Some of the themes for learning workshops and demonstrations were:

- Tunnel construction and installation, use and maintenance of bucket drip kits (Bergville, Madzikane, Turkey)
- Use of measurements in tunnel experimentation process; including rain gauges and chameleon water sensors and procedures for measuring amounts of irrigation and harvests (Sedawa, Ezibomvini, Mhlwazini)
- Soil fertility management using trench beds, shallow trenches and eco-circle beds (Bergville, Swayimane, Turkey
- Building and maintaining tower gardens for greywater management (Turkey, Dimbaza, Swayimane, Ezibomvini, Mhlwazini, Thamela)
- Spring protection and reticulation of water form springs and boreholes (Lepelle, Sedawa, Turkey, Ezibomvini and Eqeleni) and
- Fodder production and management (incl fodder species, supplementation, making and baling hay) (Stulwane, Ezibomvini and Eqeleni)

9.2 Organisational capacity building

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

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

9.3 Post graduate students

Two students that have been registered under this project have left:

1. **Sylvester Selala:** PhD in Hydrology (UKZN). He never completed his concept proposal and after two years of re-conceptualising his concept opted not to register for a doctorate. He felt that his topic of developing proxy and visual indicators and benchmarks for monitoring of CSA processes was too risky as an option and may not easily be completed within 1-2 years. He left the employ of MDF to pursue a business opportunity in financial management services.
2. **Khethiwe Mthethwa:** She was registered for an MSC in rural resource Management, but left the programme after her first year, having received full time employment under the Umgeni Resilience Programme, managed by UKZN. In addition, UKZN only provides 1 year of bursaries for Masters degrees and she did not want to continue with the study without a full bursary. She did not accept the payment of fees and support for field work offered through this project.

Progress with theses: Field work and initial reporting

1. **Palesa Motaung:** M Agric -University of Pretoria. Evaluating the restorative effect of conservation agriculture on the degraded soils of the upper Drakensburg area of Bergville, KwaZulu-Natal using qualitative versus quantitative soil health indicators
2. **Mazwi Dlamini: MPhil - UWC_PLAAS**. Factors influencing the adoption and non-adoption of Conservation Agriculture in smallholder farming systems, and the implications of these for livelihoods and food security in Bergville, Kwazulu-Natal

Progress: Initial proposals and research methodology

1. **Samukhelisiwe Mkhize: PhD Human Sciences – UKZN**; January 2019. An investigation into the factors limiting and promoting the adoption of CSA in smallholder systems in South Africa.

10. Publications and networking

Publications

- SA Grain Newsletter; CA SFIP, 1 smallholder case study (Swayimane)

Cross visits

- PACSA – small livestock production interventions in the Umgungundlovu DM
- INR_ Agroforestry implementation and progress

Attendance

- No-Till Club Annual Conference- 4-6 September 2018
- KZN CA Forum
- Introduction of Agricloud app (www.rain4africa.org) for smallholder farmers – ARC

Presentations

- Land Rehabilitation Society of South Africa: Annual Conference 13-15 August 2018. Presentation of a paper “Learning CA the Innovation Systems Way” – E Kruger
- 8th Biennial LandCare Conference; 25-27 September “CA Innovation Systems; progress and successes” – T Mathebula
- 2ACCA: Learning Conservation Agriculture the Innovation Systems way _E Kruger (2 October 2018) and Soil Health improvements in smallholder CA systems _E Kruger (3 October 2018)
- Agroecology Network: Decision Support System for CSA for smallholder farmers in SA _Catherine van den Hoof (22 November 2018) and Best practices in community based climate change adaptation _E Kruger (22 November 2018)
- National Climate change Committee Stakeholder Meeting: Community based climate smart agriculture _E Kruger (11 November 2018)
- Farmers Days: Joint open day events for Conservation Agriculture with LandCare and KZNDARD in Nokweja (SKZN), Stulwane- Bergville (KZN), Swayimane and Appelbosch (Midlands-KZN)
- Agroecology network: Farmer level CSA practices cross visit, demonstrations and presentations (12 March 2018)

Awards

- 2ACCA conference; Conservation Agriculture Champion award
- LandCare; Best Civil Society Organisation in LandCare award.