A smallholder farmer level decision support system for climate resilient farming practices improves community level resilience to climate change

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Summary

The more extreme weather patterns with increased heat, decreased precipitation and more extreme rainfall events; increase of natural hazards such as floods, droughts, hailstorms and high winds that characterise climate change place additional pressure on smallholder farming systems and has already led to severe losses in crop and vegetable production and mortality in livestock. A significant proportion of smallholders have abandoned agricultural activities and this number is still on the increase. Smallholders are generally not well prepared for these more extreme weather conditions and experience high levels of increased vulnerability as a consequence.

It is becoming clear that climate change will have drastic consequences for low-income and otherwise disadvantaged communities. Despite their vulnerability, these communities will have to make the most climate adaptations. It is possible for individual smallholders to manage their agricultural and natural resources better and in a manner that could substantially reduce their risk and vulnerability generally and more specifically to climate change. Through a combination of best bet options in agro-ecology, water and soil conservation, water harvesting, conservation agriculture and rangeland management a measurable impact on livelihoods and increased productivity can be made.

Processes such as collaborative, participatory research that includes scientists and farmers, strengthening of communication systems for anticipating and responding to climate risks, and increased flexibility in livelihood options, which serve to strengthen coping strategies in agriculture for near-term risks from climate variability, provide potential pathways for strengthening adaptive capacities for climate change.

Mahlathini Development Foundation and our partners and collaborators (Universities, NGOs, CSI initiatives, District and Local Municipalities and Government Departments), have been working within the socio-ecological and social learning space to assist smallholder farmers in KZN, Limpopo and the Eastern Cape to

improve their resilience and adaptive capacity to climate change by designing and testing a participatory smallholder level decision support system for implementing climate resilient agricultural practices.

Within this process smallholder farmers explore and analyse their understanding of climate change and the impacts of these changes on their livelihoods and agricultural systems. They explore adaptive strategies and measures (local and external), prioritize appropriate practices for individual and group experimentation and implementation, assess the impact of these new practices and processes on their livelihoods and re-plan their actions and interventions on a cyclical basis.

This allows them to make incremental changes over time in soil and water management practices, cropping and livestock management and natural resources management, within the limits of their own resources, vision and motivation. This provides a viable model for CCA implementation and financing at smallholder level.

Recent participatory impact assessments have shown remarkable improvements in resilience in the space of just one to two years of focussed local action.

Introduction

A current Water Research Commission adaptive research process entitled "Collaborative knowledge creation and mediation strategies for the dissemination of Water and Soil Conservation practices and Climate Smart Agriculture in smallholder farming systems" is exploring best practice options for climate resilient agriculture for smallholders and evaluating the impact of implementation of a range of these practices on the resilience of agriculture based livelihoods. Alongside this, a decision support methodology and system has been designed to assist smallholders and the facilitators who support them to make informed and appropriate decisions about choices of a 'basket of options' for implementation at a local level.

The research process is broadly divided into three elements for purposes of clarity, although all three elements are tackled concurrently:

1. Community climate change adaptation process design
2. Climate resilient agricultural practices and
3. A decision support system.

Community climate change adaptation process design

This consists broadly of

1. Situation and vulnerability assessments; baselines and farmer typologies
2. Climate Change dialogues; Exploration of climate change impacts, adaptive strategies and prioritization of adaptive measures and
3. Participatory impact assessments: Resilience snapshots

1. Situation and vulnerability assessments

The model for vulnerability assessments used in this process provides for a combination of socio-economic (livelihood) and socio-ecological (access and utilization of natural capital) indicators, in a climate change context (wellbeing, adaptive capacity and governance). This is a new process design, built from elements of existing international best practice options.

The process consists of focus groups discussions, individual interviews (baselines) and household visits, or walkabouts as we call them – as they include a broad and initial assessment of the "lay of the land".

This information is pulled together into a database that has been put together to provide for a farmer segmentation/ farmer typology approach. Farmer typologies allow for differentiation between different levels of vulnerability in a community to target interventions/ practices more specifically

The three typologies developed within this process are shown in the figure below

Typology A (2,5 million)

- Female headed,
- Farm for food only,
- Very low incomes – mostly unemployed,
- Access to small plots of land (<0,1ha),
- No household level access to water,
- Lower education levels (Primary school)
- No access to formal markets,
- Belong to village savings and loan associations and
- Engage in other livelihood activities

Typology B (250 000)

- Male and female headed,
- Farm for food and sell surplus,
- Slightly higher incomes,
- Access to larger plots of land (0,1-1ha)
- Some access to hh level water,
- Somewhat higher education levels (High school),
- No access to formal markets and
- Belong to village savings and loan associations

Typology C (10 000)

- Male headed, Ffarm mainly for income,
- Much higher incomes from employment in the household,
- Good access to water at household and field level,
- Higher education levels (Matric nad post scholl qualifications),
- Acess to formal markets.
- Belong to cooperatives or farm individually

Figure 1: Smallholder typology for climate resilient farming decision support system

A typical participant is thus:

A 51 year old woman, who is the head of her household, has Grade 9-11 level of education, is unemployed, has an average monthly income of R2170, engages in field cropping, gardening and livestock husbandry, has no access to water in her household, engages in local markets only and belongs to a savings group

These typologies are one of the input categories into the decision support system.

Climate change dialogues

A participatory methodology has been developed to allow groups of farmers to explore the impacts of climate change, potential adaptive strategies and to prioritize local adaptation measures. Seven community level workshops have been conducted across three provinces, involving around 250 participants. The table below provides a summary of this community level analysis

Table 1: Summary of climate change impacts from community level workshops (2018)

Climate change impacts on livelihoods and farming			
	KZN	**EC**	**Limpopo**
Water	Less water in the landscape; streams and springs dry up, borehole run dry, soils dry out quickly after rain	Less water in the landscape; streams and springs dry up, borehole run dry, soils dry out quickly after rain	Less water in the landscape; streams and springs dry up, borehole run dry, soils dry out quickly after rain
	Dams dry up	Dams dry up	Dams dry up

	Municipal water supply becoming more unreliable	Municipal water supply becoming more unreliable	Municipal water supply becoming more unreliable;
			Need to buy water for household use – now sometimes for more than 6 months of the year
			RWH storage only enough for household use.
Soil	More erosion	More erosion	More erosion
	Soils becoming more compacted and infertile	Soils becoming more compacted and infertile	Soils becoming more compacted and infertile
			Soils too hot to sustain plant growth
Cropping	Timing for planting has changed-later	Timing for planting has changed-later	Can no longer plant dryland maize
			All cropping now requires irrigation – even crops such as sweet potato
			Drought tolerant crops such as sorghum and millet grow- but severe bird damage
	Heat damage to crops	Heat damage to crops	Heat damage to crops
	Reduced germination and growth	Reduced germination and growth	Reduced germination and growth
	Seeding of legumes becoming unreliable	Seeding of legumes becoming unreliable	Seeding of legumes becoming unreliable
	Lower yields	Lower yields	Lower yields
			Winter vegetables don't do well - stress induced bolting and lack of growth
	More pests and diseases	More pests and diseases	More pests and diseases
	Loss of indigenous seed stocks		Loss of indigenous seed stocks
Livestock	Less grazing; not enough to see cattle through winter	Less grazing; not enough to see cattle through winter	Less grazing; not enough to see cattle through winter
	More disease in cattle and heat stress symptoms	More disease in cattle and heat stress symptoms	More disease in cattle and heat stress symptoms
	Fewer calves	Fewer calves	Fewer calves
	More deaths	More deaths	More deaths
Natural resources	Fewer trees; too much cutting for firewood	Fewer trees; too much cutting for firewood	Fewer trees; too much cutting for firewood
	Decrease in wild animals and indigenous plants	Decrease in wild animals and indigenous plants	Decrease in wild animals and indigenous plants
	Increased crop damage from wild animals such as birds and monkeys	Increased crop damage from wild animals such as birds and monkeys	Increased crop damage from wild animals such as birds and monkeys
	Availability of indigenous vegetables has decreased		No longer able to harvest any resources due to scarcity
			Increased population puts pressure on resources
Social	More diseases	More diseases	More diseases
	Increased poverty and hunger	Increased poverty and hunger	Increased poverty and hunger
	Increased crime and reduced job opportunities	Increased crime and reduced job opportunities	Increased crime and reduced job opportunities
			Increased food prices
			Increased conflict
			Inability to survive

Although the impacts discussed were similar across the three provinces, the severity of these changes are a lot more obvious in Limpopo.

From these impact diagrams community members discuss adaptive measures and strategies; what they have already tried and what they would like to try. Here the new ideas or innovations can then be introduced by facilitators, as they are requested by the community members. The table below is illustrative and are the adaptive measures suggested by the participants in Turkey village (Lower Oliphant's' Basin – Limpopo)

Table 2: An example of potential adaptive measures from the Turkey (Limpopo) climate change dialogue process

Turkey CC workshop; December 2017			
Impacts	**Description and linkages**	**Outcomes**	**Potential adaptive measure**
Reduced water availability	Dams dry out, boreholes provide less water, rivers dry out, less rain	Reduced production, hunger, diseases, no jobs, poverty, crime, death	More boreholes, more dams, water management, irrigation in evenings and early morning, mulching, trench beds (keep moisture in and soil cool)
Drying of environment	Soils are hotter and drier, drought, plants wilt, increased pests		Save plant residues for animals, buy fodder, control pests on animals
Reduction of resources	Deforestation, Fruit trees die, livestock, wild animals die		Planting of trees after they have been cut down; make use of paraffin stoves and electricity, government involvement in solving the problem,
Extreme heat	Early fruiting, trees wilt	Poor crop health	Shade netting
Shortage of water	Rivers dry out, municipal supply only once per week. Boreholes dry out	Lack of education towards saving water	NGOs and government to assist Trench beds, mulching, save water in dams, drip irrigation, irrigate in evening, boreholes, greywater
Reduction of resources	Less grazing, seed shortage, trees are removed, indigenous animals are no longer there	Increased vulnerability of the people, forced to move to urban areas	Donations for/of seed Rather use paraffin stoves than firewood. Only chop down mature trees to allow others to grow, planting trees, government intervention Taking care of indigenous plants Plant fodder for livestock
Soils	Poor cultivation practices, soil erosion, dry soils, sandy soils		Using crop residues and manure, conservation agriculture, mixed cropping
Social repercussions	Less or no food, health problems, no jobs	Burning of buses, divorce, separation of families, poverty, crime	Getting access to health care, parents must work
Shortage of implements			Setting up cooperatives for government support, use animal drawn traction-oxen and donkeys, improvise, make our own tools, make use of hand hoes

A list of specific practices is summarised from these discussions and categorized into the five climate resilient agriculture themes. An example is given below of this process conducted for a learning group from Ezibomvini Village in Bergville, KZN.

The following table outlines the practices and their categories

Table 3: Suggested practices for farmers, categorised into the 5 primary themes.

<table>
<tr><th></th><th>Natural RM</th><th>Soil</th><th>Water</th><th>Crops</th><th>Livestock</th></tr>
<tr><td>Shade cloth Tunnels</td><td></td><td></td><td style="background:#aaa"></td><td style="background:#aaa"></td><td></td></tr>
<tr><td>Bed design</td><td></td><td style="background:#aaa"></td><td></td><td style="background:#aaa"></td><td></td></tr>
<tr><td>Mulching</td><td></td><td style="background:#aaa"></td><td style="background:#aaa"></td><td></td><td></td></tr>
<tr><td>Natural pest and diseases</td><td></td><td></td><td></td><td style="background:#aaa"></td><td></td></tr>
<tr><td>Rainwater harvesting</td><td></td><td></td><td style="background:#aaa"></td><td></td><td></td></tr>
<tr><td>Trench bed</td><td></td><td style="background:#aaa"></td><td style="background:#aaa"></td><td style="background:#aaa"></td><td></td></tr>
<tr><td>Composting</td><td></td><td style="background:#aaa"></td><td></td><td style="background:#aaa"></td><td></td></tr>
<tr><td>Conservation Agriculture</td><td></td><td></td><td></td><td></td><td></td></tr>
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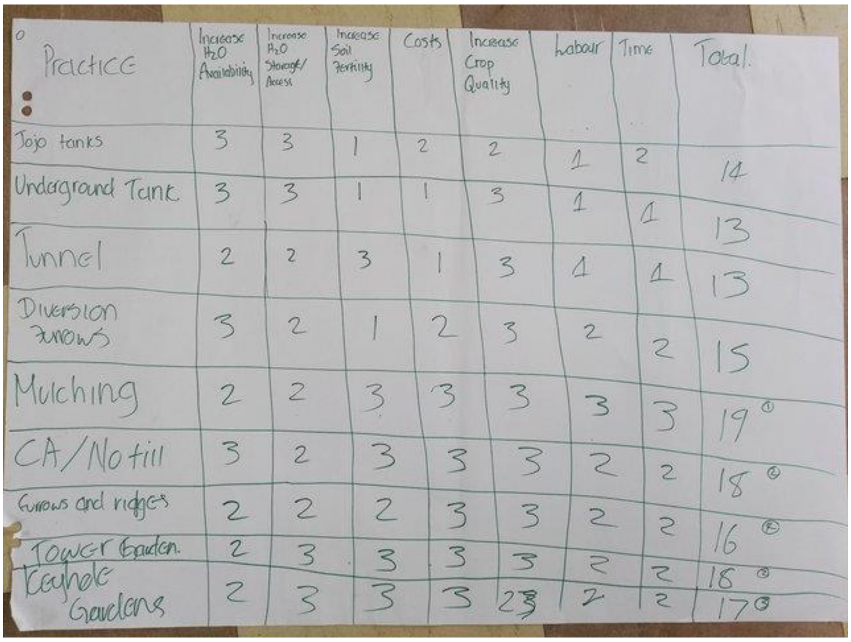
Fodder crops					
Underground water tank					
Mixed cropping					
Conservation of wetlands and streams					
Burying of disposable pampers					
Reducing burning of grazing veld					
Greywater use					

Participants then prioritize these practices in order of importance for implementation and change as a group. This depends on local conditions such as drought, harsh weather conditions and the like. The preference ranking for this group was as follows:

1. Underground rainwater harvesting tanks
2. Shade cloth tunnels
3. Trench beds
4. Mulching
5. Natural pest and disease control
6. Mixed cropping (fields and gardens)
7. Compost
8. Fodder crops
9. Conserving wetlands and streams

Right: Sylvester and Temakholo from MDF, facilitating the prioritization of practices

It is also possible here to do a matrix ranking exercise where you elucidate from the groups their criteria for prioritization of practices, which is a very important step in the community level decision making process.



Practice	Increase H2O Availability	Increase H2O Storage/ Access	Increase Soil Fertility	Costs	Increase Crop Quality	Labour	Time	Total
Jojo tanks	3	3	1	2	2	1	2	14
Underground Tank	3	3	1	1	3	1	1	13
Tunnel	2	2	3	1	3	1	1	13
Diversion furrows	3	2	1	2	3	2	2	15
Mulching	2	2	3	3	3	3	3	19 ①
CA/No till	3	2	3	3	3	2	2	18 ②
Furrows and ridges	2	2	2	3	3	2	2	16
Tower Garden	2	3	3	3	3	2	2	18
Keyhole Gardens	2	3	3	3	23	2	2	17 ③

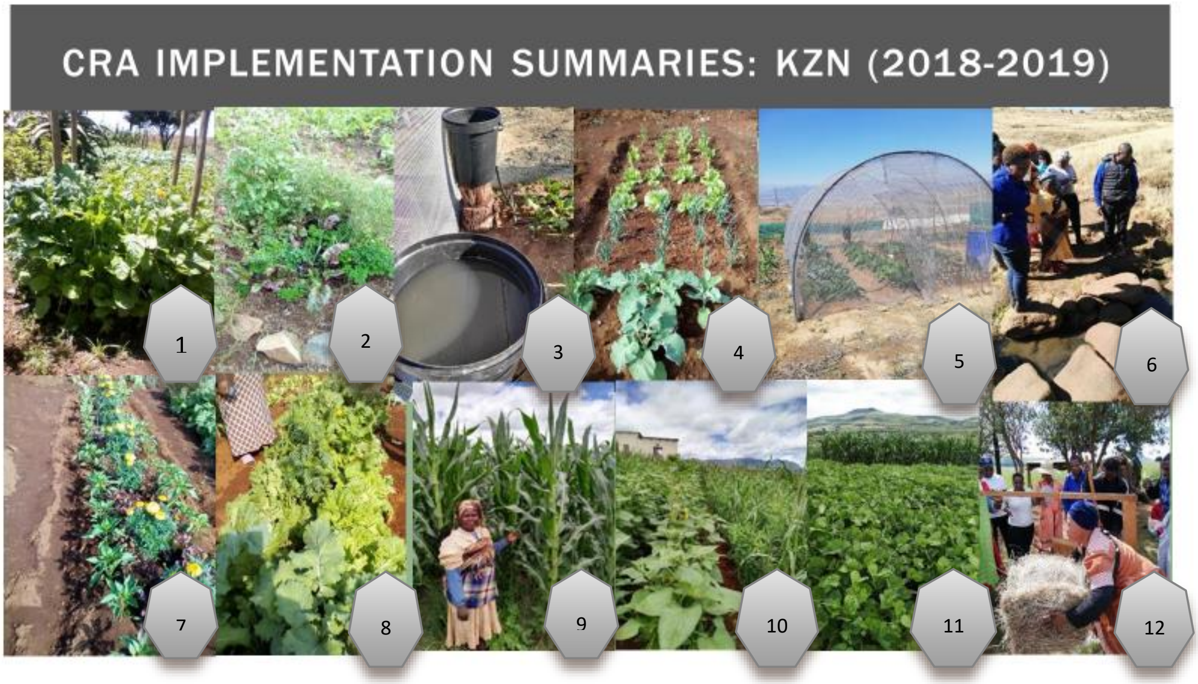
Right: A group level matrix using community defined criteria for prioritizing climate smart/resilient agricultural practices to be tried out (Thabamhlophe village, Estcourt, KZN, 2018)

This provides a broad action plan for implementation, which is developed further into an individual farmer level experimentation plan. Participants choose from these prioritized practices which ones they will try out in their own homesteads and devise a broad plan of how to intervene in the communal activities such as conservation of wetlands. This process also provides a good agenda for securing external support from role players in the development sector (government Departments, Municipalities, CSI and NGO funded projects)

3. Participatory Impact Assessments

After a cycle of experimentation with the basket of CRA practices (one season/ 6 months), the process is reviewed and a participatory impact assessment process is conducted with the learning group members. Again, it is important for community members themselves to develop the impact indicators/criteria

The diagram below provides a summary of all the practices that were tried out for the KZN learning groups for the 2018-2019 season



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

Community members worked in small groups to analyse for themselves the impact of the climate resilient agricultural practices they have been implementing.

Right: Participants from 4 learning groups work together in assessing the impact of their implementation

Below is the result of a matrix ranking exercise conducted during this session. The research team were incredibly impressed with the depth of analysis participants undertook and with the impact indicators participants developed. It also indicates that smallholder farmers use integrated and systemic indicators to make their decisions and not just production and income data, commonly used in agriculture.

Table 4: Participatory impact assessment of CRA practices by Ezibomvini participants, March 2019.

IMPACT INDICATORS → PRACTICES ↓	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**

Positive impact of CRA and associated practices in order of importance: Conservation Agriculture, gardening (tunnels, agroecology), small businesses (farmer centres, poultry), savings, livestock (integration – fodder, health)

The resilience snapshot put together from individual interviews of these same participants, gives a very strong indication of the benefit of CRA to the livelihoods of the rural poor. Climate change adaptation for these participants has resulted in increased availability of food, incomes and social agency and has provided hope for a more positive future for these participants.

Table 5: Resilience snapshot for Ezibomvini participants, March 2019.

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%	Based on increase in yields

	Livestock – 25%	
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

Climate resilient agriculture practices for smallholders

The approach is to work directly with smallholders in local contexts to improve practices and synergise across sectors. The emphasis is thus at farm/household level. Here CSA aims to improve aspects of crop production, livestock and pasture management, natural resource management, as well as soil and water management as depicted in Figure 2 below.

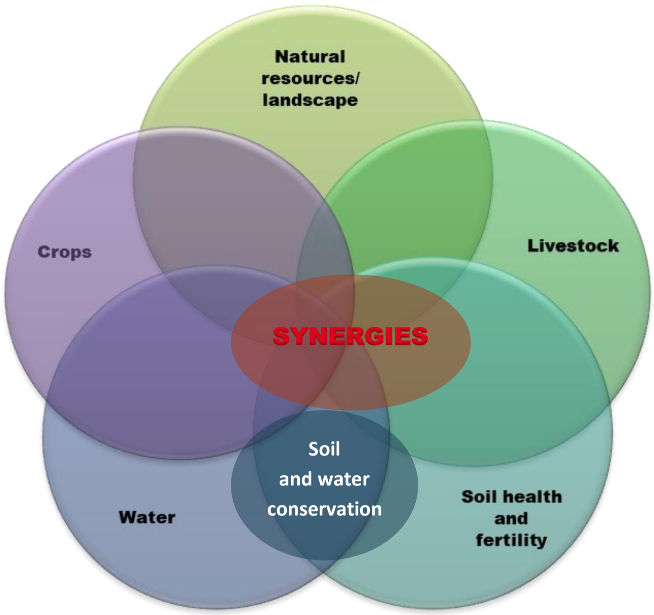


Figure 2: Household level implementation of CSA integrates across sectors (adapted from Arslan, 2014)

A database of 66 different practices falling into the categories mentioned in the figure above has been compiled, based on local suggestions and best bet options from experience and literature.

For each practice, a 1-page summary has been put together, that can be presented to smallholders in the climate change adaptation workshops, for consideration by the smallholder farmers as a new idea or innovation to experiment with. Below are two illustrative examples

Tower Gardens

- Greywater management
- Gardens
- <0,1ha,
- Low -medium cost, low-medium skills, including learning and mentoring, local resources
- Low maintenance – but bags will need to be replaced after some time (3-5 years)

DESCRIPTION

- Tower gardens are built up from the ground by using four poles and wrapping a tube of 80% shade cloth around these poles.
- In the centre of the bed, a stone column is built up using a bottomless bucket as a ring
- The bed is filled in with a pre-prepared mixture (1/3 soil, 1/3 manure, 1/3 ash (It needs a lot of ash to clean the greywater used)
- Small holes are made in the side of the bag and seedlings are planted vertically into these small holes- usually spinach or another leafy vegetable
- The top of the bed can be used for planting other crops – tomatoes are good as they can be staked to the poles.
- The bed is watered by pouring the greywater onto the stone column in the middle

Making the soil, manure ash mixture for filling the tower garden

Placement of the stone column – in the small bottomless bucket in the middle of the bed

Building up the tower- filling in the soil mix around the stone column and moving it up

A 'mature' tower garden planted to spinach and tomatoes

Watering into the central stone column

Making the small holes in the side of the bag for planting seedlings

Stone bunds

- Rainfall: >150mm/year
- Temperature: >5°C
- Topography: 0,5%-5%
- Soil: all types – where stones and rocks are easily available

- Gardens, fields
- <0,1ha, 0,1-1ha, >2ha
- Low cost, local resources,
- Labour intensive

DESCRIPTION

-Pack stone lines on contours to control water movement

- The stones are keyed into a shallow ditch and larger stones are packed downslope from the smaller stones to avoid stone lines form breaking and allow slow movement of water though the stone lines

-Planting can be done below the stone line as more water accumulates there, or just above the stone line in the accumulated silt and soil

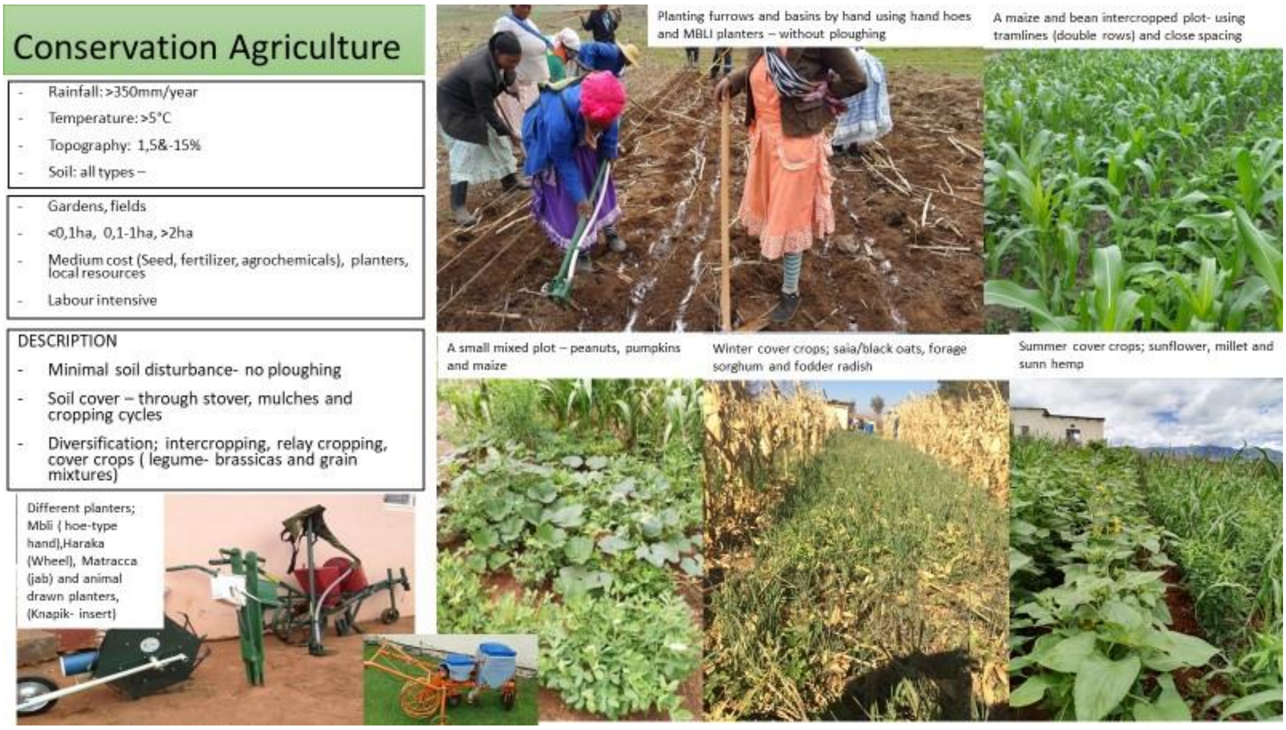
Stone lines are constructed on contour and can be done at any scale.

A view showing the stones keyed into a ditch with larger stones downslope of the smaller stones.

Small stone lines are used to control run-off form a road and channel water into the gardens

Brinjals planted in accumulated silt above a garden level stone line

Bananas planted below a substantial stone line



This database provides a resource to farmers and facilitators to choose appropriate climate resilient agricultural practices for their area and their particular situation. It is one of the input parameters for the decision support process.

In addition, qualitative and quantitative indicators have been explored to Physically assess the impact of these practices. These have included for example run-off, infiltration, water holding capacity in the soil profile, and water productivity as well as a number of soil based parameters such as organic matter content, soil fertility and microbial activity.

As an example, a farmer level experimentation process consisting of production in trench beds, inside and outside of shade cloth tunnels was conducted. The control for this experiment was the farmer's 'normal' gardening practice – in this case raised beds.

Above left to right: Spinach grown in a trench bed inside a tunnel, in a trench bed outside a tunnel and in a control bed (raised bed), by Phumelele Hlongwane

Farmers kept careful records of the amount of water applied (irrigation) and their harvests (yields), alongside the research team who worked with local weather stations and soil moisture measurements to assess the water productivity of these practices.

The table below outlines the resultant water productivity calculation for this experiment. Both conventional WP calculations and a simpler format suggested by farmers that only uses their water applied were used.

Table 1: Water productivity for production of spinach inside and outside shade cloth tunnels for 2 smallholder farmers in KNV, Bergville

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

The control plots are not included here, as the two farmers realised quite early in the season that their normal production methods required too much water and opted to focus only on the trench beds. Water productivity is 60-100% higher for trench beds inside the tunnels when compared to trench beds outside the tunnel – using the more scientific approach that also takes into account evapotranspiration and leaching. This is a highly significant result, indicating the potential of micro-climate control in adaptation.

Water productivity calculate only from yields compared to water applied, shows a larger variation in results for the two participants. They both applied more water to their trench beds outside their tunnels, than inside; working on the assumption that the reduced growth for the crops outside the tunnel was due to water stress. This experimentation process assisted in their learning that plant stress also includes other factors such as temperature, wind and insect damage.

The smallholder climate change adaptation decision support process

The decision support process focusses on a bottom -up approach, where individual farmers in a locality make decisions regarding the 'basket' of CSA/CRA approaches and practices most suited to their specific situation. To do this in a way that also includes the concepts of social learning, innovation and agency the following decision support concept has been developed.

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.

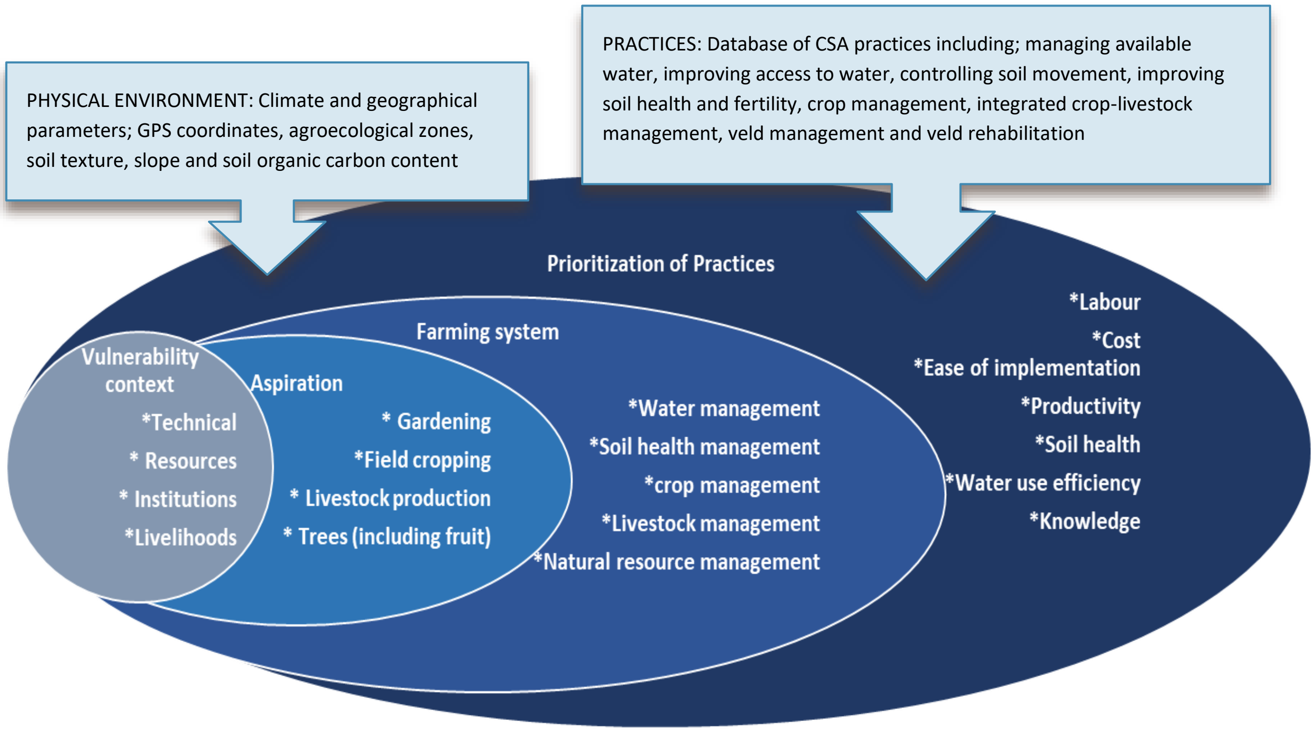


Figure 3: The smallholder CSA/CRA decision support model

The model is designed primarily as a participatory and facilitated process at community level. In support of this process, a computer-based model can be used alongside this methodology to provide further information and decisions 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 the facilitated model shown in Figure 4 below.

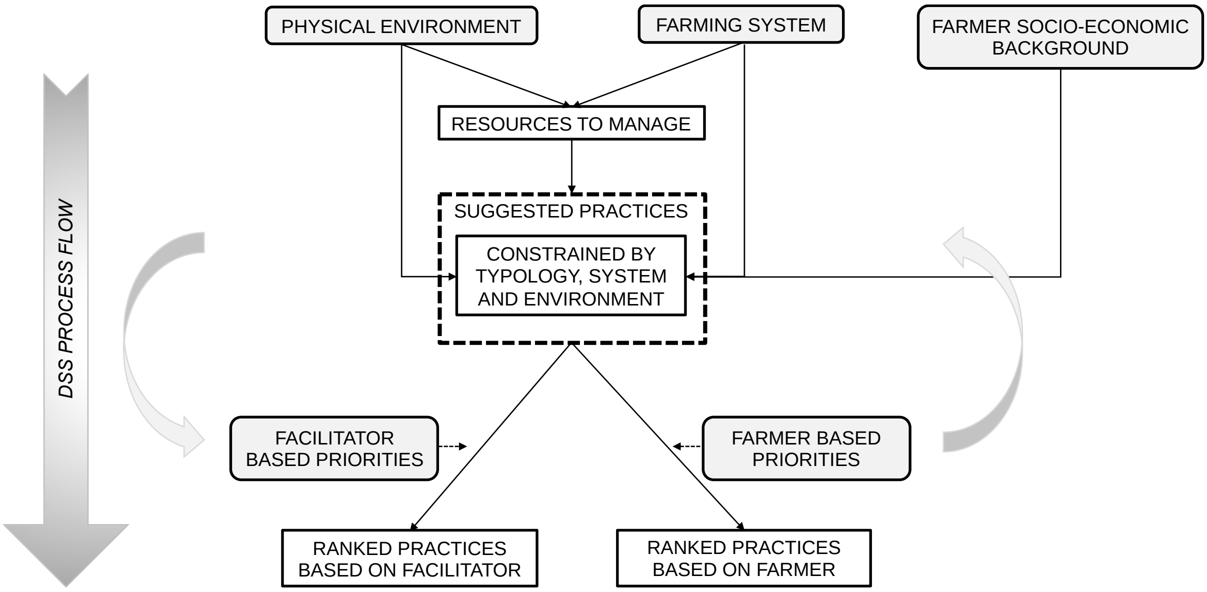


Figure 4: The computer-based model for the smallholder DSS

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:

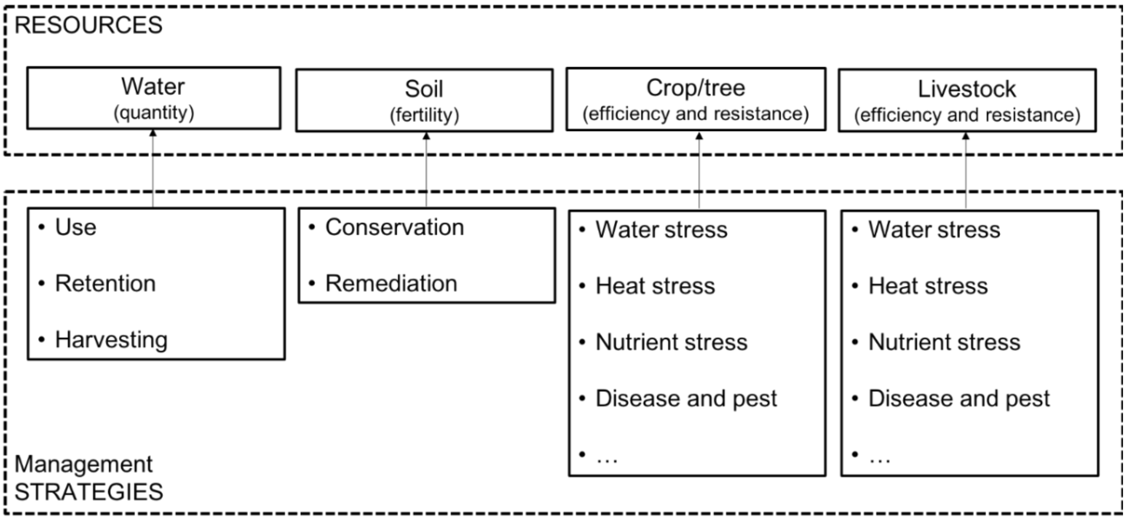


Figure 5: Resources to manage and their associated managements strategies

Once all the information is inputted into the model an initial list of practices is suggested for each individual farmer. The model has been tested and refined, through comparison of this computed based process with the participatory process and assessing how closely these two processes are aligned.

Below is an example for 1 farmer in each of the three provinces where the model has been tested.

Table 6: Basket/list of practices recommended for version 2 of the DSS

Province	KZN	Limpopo	EC
Village	**Ezibomvini**	**Sekororo**	**Mxumbu**
Name and Surname	**Phumelele Hlongwane**	**Chenne Mailula**	**Xolisa Dwane**
Drip irrigation	0	0	0
Bucket drip kits	0	0	0
Furrows and ridges/ furrow irrigation	0	0	0
Greywater management	1	1	0
Shade cloth tunnels	1	1	0
Mulching	1	1	0
Improved organic matter (manure and crop residues)	1	1	1
Diversion ditches	1	0	0
Grass water ways	0	0	0
Infiltration pits / banana circles	1	1	0
Zai pits	1	0	0
Rain water harvesting storage	1	1	1
Tied ridges	0	0	0
Half- moon basins	0	0	1
Small dams	0	0	0
Contours; ploughing and planting	1	0	0
Gabions	0	0	1
Stone bunds	0	0	0
Check dams	0	0	1
Cut off drains / swales	0	0	1
Terraces	0	0	0
Stone packs	1	0	0
Strip cropping	1	0	0
Pitting	1	1	0
Woodlots for soil reclamation	1	0	0

Targeted application of small quantities of fertilizer, lime etc	1	0	0
Liquid manures	1	1	0
Woody hedgerows for browse, mulch, green manure, soil conservation	1	0	0
Conservation Agriculture	1	0	0
Planting legumes, manure, green manures	1	0	0
Mixed cropping	1	0	0
Planting herbs and multifunctional plants	1	0	0
Agroforestry (trees + agriculture)	1	0	0
Trench beds/ eco circles	1	1	0
push-pull technology	1	0	0
Natural pest and disease control	1	0	0
Integrated weed management	1	1	1
Breeding improved varieties (early maturing, drought tolerant, improved nutrient utilization),	1	1	1
Seed production / saving / storing	1	1	1
Crop rotation	1	1	1
Stall feeding and haymaking	0	0	0
Creep feeding and supplementation	1	0	0
Rotational grazing	1	0	1
De-bushing and over sowing	1	0	1
Rangeland reinforcement	1	0	1
Bioturbation	1	1	1
Tower garden	1	1	0
Keyhole beds	1	1	0
No of practices recommended	**35**	**16**	**14**

For the KZN participant, this means that around 88% of the full list of practices have been recommended for her. She has a wide range of recommendations 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.

Ranking can be undertaken first by the facilitator, or can be done directly by the farmer depending on the circumstances. Below is the ranking exercise undertaken for Phumelele Hlongwane (Ezibomvini, KZN).The practices shown in green are those that Phumelele are already implementing. This ranked list then provides options for inclusion of further ideas and practices

Table 7: Ranking of CRA practices recommended for Phumelele Hlongwane

(KZN; Bergville)Phumelele Hlongwane: List of practices scored by facilitator				
Practices	**Field cropping**	**Vegetable gardening**	**Livestock**	**Natural resources and trees**
Shade cloth tunnels		8		
Mulching		9		
Improved organic matter	11	11		11
Diversion ditches	9	9		9
Infiltration pits		10		
Zai pits	10	10		
RWH storage	9	9	9	9

Stone packs	9	9		9
Strip cropping	11			
Pitting	11		11	11
Woodlots for soil reclamation	9		9	9
Targeted fertilizer application	8			
Liquid manure		7		
Woody hedge rows	10		10	10
Conservation agriculture	11	11	11	11
Planting legumes, manure, green manures	8	8		8
Mixed cropping	9	9		
Planting herbs and multifunctional plants	9	9		
Agroforestry (trees + agriculture)	11	11	11	11
Trench beds/ eco circles		9		
push-pull technology	7			
Natural pest and disease control	7	7		7
Integrated weed management	7	7		7
Breeding improved varieties (early maturing, drought tolerant, improved nutrients),	7	7	7	7
Seed production / saving / storing	6	6		6
Crop rotation	9	9		
Stall feeding and haymaking				
Creep feeding and supplementation			7	
Rotational grazing			9	
De-bushing and over sowing			9	
Rangeland reinforcement			9	
Bioturbation	9	9	9	9
Tower garden		10		
Keyhole beds		10		

Below are a few indicative photographs of Phumelele's CRA practices.





Above clockwise from top left: A view of Phumelele Hlongwane's vegetable garden, a newly constructed tower garden, trench beds planted to a mixture of vegetables in her shade cloth tunnel, a plot of Dolichos in her CA field and a plot of summer cover crops- sunnhemp and millet.

Conclusion

The decision support system for climate resilient agriculture implementation by smallholder farmers is an important new innovation in the field of community-based climate change adaptation and can be scaled up as a framework in research, learning and implementation in this field.