CONSERVATION AGRICULTURE IN AFRICA: CLIMATE SMART AGRICULTURAL DEVELOPMENT

Chapter X

CA INNOVATION SYSTEMS BUILD CLIMATE RESILIENCE FOR SMALLHOLDER FARMERS IN SOUTH AFRICA

Erna Kruger[1] *, Hendrik Smith [2], Phumzile Ngcobo[3], Mazwi Dlamini [4] and Temakholo Mathebula[5]

1 Mahlathini Development Foundation, Pietermaritzburg, KwaZulu-Natal, South Africa

* Corresponding author: info@mahlathini.org

2 Grain SA, 457 Witherite street, The Willows, Pretoria, Gauteng, South Africa

3 Mahlathini Development Foundation, Pietermaritzburg, KwaZulu- Natal, South Africa

4 Mahlathini Development Foundation, Pietermaritzburg, KwaZulu- Natal, South Africa

5 Mahlathini Development Foundation, Pietermaritzburg, KwaZulu- Natal, South Africa

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1.1 SUMMARY

Introduction of conservation agriculture (CA) and associated climate resilient agriculture (CRA) practices within an innovation systems approach and using farmer-level experimentation and learning groups as the primary learning and social empowerment processes has created a sustainable and expanding farming alternative for smallholders that is improving their resilience to climate change substantially.

Smallholder participants in the CA innovation system development process in the KwaZulu-Natal province of South Africa have built resilience to climate change and improved their livelihoods through substantial improvement in yields, productivity, and soil and water conservation parameters. They have improved their social agency and social and economic resilience through their involvement in innovation platforms, Village Savings and Loan Associations (VSLAs), farmer centres, development of cooperatives, as well as local sales and initiation of processing facilities.

Participatory design of a monitoring process using multiple system indicators (social, economic, physical, agronomic, and environmental) has provided a framework for assessing impact of community-level climate change adaptation.

1.2 INTRODUCTION

Sustainable and regenerative agricultural practices such as conservation agriculture (CA), that conserve and increase soil organic carbon (SOC) and improve soil health, are increasingly promoted in Southern Africa as an alternative to conventional farming systems (Smith, et al., 2017). CA depends on the simultaneous implementation of three linked principles: (1) continuous zero or minimal soil disturbance, (2) permanent organic soil cover, and (3) crop diversification (FAO, 2013). The latter usually entails crop rotation and the inclusion of legumes and/or cover crops.
Complementary practices supporting CA implementation in smallholder farming systems include appropriate nutrient management and stress-tolerant crop varieties, increased efficiency of planting and mechanization, integrated pest and disease and weed management, livestock integration, and enabling political and social environments (Thierfelder, et al., 2018).

The Maize Trust-funded CA Smallholder Farmer Innovation Programme (SFIP) in South Africa, as conceptualized and implemented through Mahlathini Development Foundation (MDF), has pioneered the use of agricultural innovation systems as a methodological approach for the promotion of an appropriate smallholder CA farming system, as well as awareness raising and adaptive research into specific elements of this system (Kruger & Smith, 2019). This approach takes cognizance of the complexity of introducing CA into a farming system, including working with smallholder farmers as partners in the knowledge co-creation process through on-farm research and experiential learning, as well as embedding the process into the existing socio-political environments and economic value chains. The overall goal of the CA SFIP is the mainstreaming of CA by grain farmers to ensure sustainable use and management of natural resources while enhancing national and household food security and income.

Specific objectives of the programme include also increasing the sustainability and efficiency of CA systems in the study areas giving specific attention to the value chain and incorporation into the broader agribusiness environment and strengthening and use different innovation platforms, such as social institutions as avenues to scale out sustained collective action and CA practices.

Figure 1 outlines the elements of the CA-SFIP in South Africa (2013-2019) (Smith & Visser, 2014).

(Insert Figure 1)

Figure 1: Elements of the CA-SFIP innovation system

This chapter considers the building blocks of an innovation systems approach, issues of horizontal-or out-scaling and three different sets of indicators (innovation system indicators, soil health indicators and resilience indicators) that have been developed to monitor and track progress within the system.

In the smallholder context, introduction of CA into the farming system requires the design, introduction, and facilitation of a reasonably complex innovation system (IS) approach by the implementers, as well as practice, labour, and resources (including natural and financial resources) by the farmers that have system-wide implications. In the SFIP, on-farm, farmer-led research is the most central component of the IS, supported by learning, awareness raising and economic elements (Smith, et al., 2017) (Swanepoel, et al., 2017). Different activities are

undertaken within each of these elements. A strongly participatory facilitation process is required to ensure synergies across the activities and the knowledge co-creation that is crucial to the success of the process. To date the introduction of CA into smallholder farming systems has mainly consisted of researcher or extension led Ca trials and demonstrations and uptake has been extremely limited (Swanepoel, et al., 2017).

Interested individuals in a local area or village come together to form a learning group. Several farmers in that group then volunteer to undertake on-farm experimentation, which creates an environment where the whole group learns throughout the season through observations and reflections on the trials' implementation and results. They compare various CA treatments with their standard practices, which are planted as control plots. This provides an opportunity to explore all aspects of the cropping system, its socio-economic context and feasibility, as well as the grain and legume value chain in the area. Over a period of 4–6 years farmers develop their ability to define their own farm-level experimental processes, which increases in complexity and design to incorporate different aspects of the cropping system. They work together to share labour and equipment, set up Village Savings and Loan Associations (VSLAs), do bulk buying, set up farmer centres, and arrange for local processing and marketing options. They bring new farmers interested in CA on board throughout the process.

This process also allows for longer-term monitoring and research into biophysical and socio-economic changes in the areas of operation.

1.3 SMALLHOLDER FARMING SYSTEM AND PARTICIPANTS

The majority of smallholder farmers in South Africa live in scattered communal tenure communities, more often than not in agriculturally marginal production areas. They suffer under the yoke of extreme poverty, highly degraded natural environments, and are highly vulnerable to the effects of climate change.

Agricultural production is central to rural livelihoods and food production and is undertaken as a mixed farming system approach that typically includes vegetable production in small household gardens, field cropping in dryland fields of between 0,1–2ha and livestock rearing - mostly cattle, goats, and sheep in village-based commonages (De Wit M, et al., 2015).

There are an estimated 3 million smallholder farmers in South Africa, of whom around 72% fall within a non-commercial category consisting primarily of unemployed women who rely on social grants (89%), who farm for household food purposes on small plots (0,1–1ha), with very low household incomes (~R2,000/month), with low productivity (maize yields of between 0,1–2t/ha), and with negligible external support. A further 23% are considered semi-commercial, as they produce for both household consumption and sale and are slightly better resourced. Commercial smallholders make up the remaining 5% and are often supported through employment in the family (Cousins, 2015).

Though a focus on the rural poor, this programme has worked primarily with the non-commercial and semi-commercial smallholders in the Eastern Cape and KwaZulu-Natal provinces of South Africa. The focus has been on three distinct agroecological zones within KwaZulu-Natal: Bergville, in the Drakensberg mountain foothills with an average annual rainfall of between 650–750mm per annum, with high percentage clay soils; Southern KwaZulu-Natal and the northern reaches of the Eastern Cape (EC & SKZN), also in the Drakensberg foothills, but with more variable rainfall (450–750mm/annum) and much

sandier soils; and the Midlands, in the more coastal region of Southern KZN, with a higher average annual rainfall of between 750–850mm and a wide range of soil types.

1.4 ASPECTS OF THE CA-SFIP INNOVATION SYSTEM

In broadening the introduction of CA beyond the scope of researcher-managed trial plots and commercial cropping advice, the following aspects have been included in the agricultural innovation process:

- Collaborative and participatory research for knowledge co-creation in terms of applying CA principles to smallholder farming systems,
- Farmer-level experimentation,
- Introduction of crop rotation, intercropping, cover crops and fodder crops into the smallholder farming system,
- A focus on livestock integration.
- A focus on new cover crops and planting options; such as strip cropping,
- Inclusion of quantitative research elements into the experimentation process - soil fertility, soil health (including carbon sequestration), run-off, infiltration, and water productivity,
- Adaptive and localized research into aspects such as soil and water conservation, spacing, varieties, herbicide and weeding regimes, pest control, and local breeding options,
- A maize commodity value chain focus; including relationships with agribusiness, bulk buying, farmer centres, and local marketing initiatives,
- Support for microfinance and small business development in the CA system.
- Learning and mentorship - for community-level facilitators and lead farmers, internships for agriculture and rural development studies graduates, postgraduate (MSc and PhD) opportunities in CA, and short learning programmes for stakeholders, including other NGOs, research organizations, and government.
- Development of visual and proxy indicators suitable for local-level implementation.
- Cost-benefit and livelihoods improvement analysis for the CA systems at local levels.
- A focus on post-harvest aspects, storage, threshing, and milling.
- Brokering of partnerships in agribusiness, research, and implementation.
- Exploration of alternative financing models, including payment for ecosystem services and climate change adaptation incentives.
- Production of a CA manual for smallholder farmers (in English and isiZulu).
- Production of articles, conference papers, and presentations by all members of the implementation team and
- Setting up of innovation platforms and forums that include all role players.

The combination of all these aspects have provided for a coherent CA implementation process for smallholder farmers. The primary organisational structure through which all the aspects of learning, experimentation, implementation and value chain development are negotiated are village-based farmer learning groups. Individual farmers undertake experimentation suited to their own needs and farming process. Sub-groups of farmers undertake different experiments, for example new crop varieties and cover crop combinations and the results are fed back into the learning groups and innovation platforms, allowing for a cyclical increase in complexity of the system.

1.5 HORIZONTAL SCALING

This aspect of the process relies on verbal communication between smallholder farmers as the basis for awareness raising and spread of CA in and between these communal tenure villages. It is based on communication in learning groups and also on open days and stakeholder forums, given that smallholders rarely rely on printed information for their farming decisions (Smith, et al., 2017).

This section outlines the uptake of the CA process across the three areas for the six years of implementation. The numbers indicated, are those participants within the learning groups who undertake the farmer-level experimentation. For the CA trial, each farmer signs a contract indicating their willingness and ability to undertake the trial as well as the control. Participant farmers plant a CA trial (100 m^2, 400m^2, or 1000m^2) alongside their normal maize plantings (controls). Their control plot has to be at least the same size as their trial.

Table 1: Participants in the CA farmer-level trails for the CA-SFIP (2013-2018)

	2013–2014	**2014–2015**	**2015–2016**	**2016–2017**	**2017–2018**	**2018–2019**	**Area under trials (2018)**	**Total area planted ***
	Yr. 1	Yr. 2	Yr. 3	Yr. 4	Yr. 5	Yr. 6		
Bergville	19 (12)	59 (27)	81 (55)	106 (115)	270 (252)	291 (207)	17,4ha	49,4ha
EC + SKZN	23 (22)	48 (16)	43 (29)	68 (54)	120 (84)	111(83)	3,6ha	8ha
Midlands				30 (18)	75 (47)	85 (82)	2,2ha	4,6ha
TOTAL	**42**	**107**	**124**	**204**	**383**	**487**	**23,2ha**	**62ha**

*Control plot sizes have been measured accurately only for a proportion of the participants. This value is thus an estimate.

The numbers in each column are the number of smallholders registered each year (at the beginning of the season) to do their farmer level trials. The numbers in brackets are the farmers who managed to plant and harvest their trials. Reasons provided by farmers for not planting have included:

- Season too dry and opted not to plant,
- Waited too long and then could not plant,
- Lack of labour,
- Cattle not sent into the mountains for summer grazing in time to plant,
- Non-payment of subsidy amount,
- Ill-health, migration of family members, and
- Inability to plant the control plots as per the agreement.

Table 1 indicates that there is a gradual yearly increase in the number of participants practising CA, despite adverse weather conditions and the many constraints smallholder farmers face.

Monitoring of the number of participants who continue with CA implementation after their first year indicates different trends for the three different regions in the province (Bergville, EC and SKZN, and Midlands), as shown in Table 2 and depends to a large extent on a

positive outcome for their first season of experimentation, which in turn is related both to the local climatic and soil conditions and the farmer's own practice.

Table 2: Horizontal scaling for the CA-SFIP programme between 2013-2018/19

No of years CA	No of participants	% who continued	No of participants	% who continued	No of participants	% who continued
	Bergville		EC&SKZN		Midlands	
1	291		180		102	
2	291	100%	86	48%	52	51%
3	247	85%	34	40%	18	35%
4	101	41%	4	12%		
5	59	58%				
6	18	31%				

For Bergville, 31% of participants who started CA experimentation have continued for 6 consecutive years, 58% have continued for 5years, 41% for 4 years, 85% for 3 years and 100% for two years. This is not a linear process of uptake, which again is influenced by climatic conditions, as some farmers opt not to plant if seasonal rainfall is very late, but will take up the practise again in more conducive seasons. In all three areas the numbers also indicate that there is increased uptake in an area after two to three years of farmers being active in CA; jumping from 24 to 180 participants in the EC&SKZN and from 18 to 102 participants in the Midlands, for example.

Soil type and adverse weather conditions play a large part in longer-term adoption of CA and uptake is predictably lower in areas with very sandy soils, low soil organic matter (SOM) and high weather variability (hot, dry conditions interspersed with high-intensity storms). Favourable institutional arrangements and social organization have also been important contributing factors. Similar trends have been noted in recent reviews (Thierfelder, et al., 2018), (Swanepoel, et al., 2017), (Giller, et al., 2009).

What is significant is that every year new participants are brought on board and that, overall, the number of farmer participants undertaking trials and continuing with the CA is growing steadily.

SYSTEM INDICATORS

On a project level, an intensive monitoring process is undertaken by the MDF teams in the three different areas, using a participatory monitoring and evaluation (PM&E) framework that includes social agency (social and organisational), value chain (socio-economic) and productivity (agricultural and environmental) indicators.

Table 4 indicates the values for some of these indicators between 2013 and 2018.

The information for this dashboard is gleaned from several sources. There are planting and growth monitoring forms that are filled in for a selection of individuals undertaking the CA farmer experimentation process (30% of total participants) - mostly for the production indicators, such as size of field, inputs used, crops planted, weeding, growth, soil cover, soil fertility, soil health, and yields. The more social indicators are gathered through focus group

discussions (yearly review sessions with each learning group) as well as individual questionnaires.

Table 2: Innovation system indicators for the CA-SFIP (2013-2018)

CA innovation system indicators for smallholder farmers in KZN; 2013 and 2018			
Social Agency indicators			
Indicator	**Unit 2013/14**	**Unit 2018/19**	**Description/ comments**
Participants	41	487	No of CA experimentation participants, from farmer registration lists across all three areas
Learning groups	4	31	Count of no of village-based learning groups
Gender	89%	75%	Percentage of women undertaking CA experimentation. Obtained from farmer participation lists across all three areas
Local savings and loan associations	0%	58%	Percentage of all learning group members involved in VSLAs (Village savings and loan associations); from savings groups registers and learning group membership lists
Innovation platforms	0	6	No of platforms set up that include farmers and external stakeholders
Value chain indicators			
Months of food provisioning			No of participants, shown as a percentage who can provide enough maizemeal for their family for different month-based categories; from annual review interviews for an average of 50 participants annually.
1 to 3	100%	8%	
4 to 6	0%	39%	
7 to 9	0%	38%	
10 to 12	0%	15%	
Local sale of crops	0%	15%	No of participants, shown as a percentage who sell maize, beans, cowpeas and sunflower produced, locally; from annual review interviews for an average of 50 participants annually.
Saving for inputs	0%	28%	No of VSLA members who used their savings and small loans for agricultural inputs, shown as a percentage; from savings group records for 150 participants, averaged for a 3-year period
Farmer centres	0	6	No of farmer centres set up for sharing CA equipment, providing advice and sale of agricultural inputs and produce between 2013 and 2018
Cooperatives	0	3	No of cooperatives registered for CA smallholders between 2013 and 2018

Co-financing of local infrastructure	0	3	No of learning groups who took advantage of the matching grant funding to finance local mills, threshers and water infrastructure or supplementary irrigation
Productivity indicators			
Reduced labour in CA plots	0%	78%	No of participants, shown as a percentage who indicated a reduction of labour throughout the cropping season; from annual review interviews for an average of 50 participants annually, across all three areas.
Reduced weeding in CA plots	0%	39%	No of participants, shown as a percentage who indicated reduced weeding in CA plots compared to conventionally cropped plots; from annual review interviews for an average of 50 participants annually, across all three areas.
Use of CA planters			
Hand hoes	97%	26%	No of participants, shown as a percentage using different CA planters introduced through the programme; from planting and crop monitoring forms, completed for between 50-200 participants annually, across all three areas
Hand planters	0%	69%	
Animal-drawn planters	3%	5%	
Tractor-drawn planters	0%	0,50%	
Maize yield for CA plots (t/ha)	2,3	3,3	Yield data measured and averaged for between 50 to 200 participants annually across all three areas.
Crop rotation	0%	20%	No of participants, shown as a percentage who practised intercropping of maize and beans; from planting and crop monitoring forms, completed for between 50-200 participants annually, across all three areas
Intercropping - maize and beans	0%	92%	No of participants, shown as a percentage who practised intercropping of maize and beans; from planting and crop monitoring forms, completed for between 50-200 participants annually, across all three areas.
Intercropping maize and other legumes	0%	17%	No of participants, shown as a percentage who practised intercropping of maize and other legumes such as cowpeas and Dolichos beans; from planting and crop monitoring forms, completed for between 50-200 participants annually, across all three areas.
Winter cover crops	0%	31%	No of participants, shown as a percentage who undertook planting of a winter cover crop mixes (Saia oats, fodder rye, fodder radish, vetch, fodder peas) from planting and crop monitoring forms, completed for between 50-200 participants annually, across all three areas.

Cover crops: summer mix	0%	26%	No of participants, shown as a percentage who undertook planting of a summer cover crop mixes ((sunflower, millet, sun hemp, sorghum) from planting and crop monitoring forms, completed for between 50-200 participants annually, across all three areas.
Seed saving	0%	11%	No of participants, shown as a percentage who undertook seed saving of OPV maize, legumes and cover crops; from planting and crop monitoring forms, completed for between 50-200 participants annually, across all three areas.
Fodder: provisioning for livestock: through cut and carry, hay	0%	5%	No of participants, shown as a percentage who cut and baled hay from their CA plots and veld grass for winter feeding of livestock; from planting and crop monitoring forms, completed for between 50-200 participants annually, across all three areas.
Reduced run-off in CA plots	0%	92%	No of participants, shown as a percentage who saw less run-off in their CA plots when compared to their control plots; from planting and crop monitoring forms, completed for between 50-200 participants annually, across all three areas.
Increase in percentage organic carbon			Percentage organic carbon measured and calculated for 5 participants from each area, annually, after being averaged across all CA plots for each participant.
Midlands (2017 to 2018)	0%	0%	
SKZN (2016–2018)	0%	24%	
Bergville (2015–2018)	0%	1%	

In this way, the programme is able to track and analyse the impact of the CA farmer-level experimentation process on the whole livelihood system of these smallholder farmers. Trends in the last few years are discussed below.

1 SOCIAL AGENCY INDICATORS

1.1 The total number of participants in the CA experimentation process has increased from 51 between 2013/14 to 487 between 2018/19. This indicates that the horizontal scaling process of bringing in new participants from existing and neighbouring villages in each successive season has worked extremely well as a process for introducing CA into the smallholder sector, as does the increase from 5 to 31 villages in this five-year period. The innovation systems model provides a solid foundation for the learning and co-creation function in an out scaling process and also provides a foundation for upscaling through the multi-stakeholder innovation platforms (Herman, et al., 2013).

This model has the potential to double the number of smallholders implementing CA on a yearly basis.

1.2 The number of female farmers has declined from 89% of the total number of participants to 75%. This indicates that the number of male farmers has increased from around 12 to 58 in total. Within the socio-cultural context of the rural Zulu population

in KwaZulu Natal, this means that the community is taking the CA process - specifically it's potential to provide an income over and above food provision - more seriously. The pattern is for men to only become involved in agricultural activities that provide an income, as the women's role in household food production activities is still very dominant.

1.3 Village Savings and Loan Associations (VSLAs) have been introduced for learning groups that have shown an interest, to assist participants in consumption smoothing, cash flow management and procurement of inputs for productive activities. In the five-year period of implementation, 58% of participants have joined VSLAs. And 28% of all participants are now saving and taking out small loans for agricultural inputs. ***VSLAs are central to ensuring continuity and sustainability of CA implementation and are crucial for improving resilience of smallholder households.***

1.4 The learning groups are considered to be local innovation platforms, where innovation is the result of a process of networking, interactive learning, and negotiation among a heterogeneous set of actors (Hellin, et al., 2014). Learning group members plan, implement, and review their progress together. These learning groups also host farmers' days and bring together community members from their own and neighbouring villages for these events. They invite local stakeholders such as the traditional authorities, local municipal officials, and extension officers to these events and with support from MDF a wide range of other external stakeholders also participate - including, for example, CBOs, NGOs, farmers' unions, universities (lecturers and students), input and mechanization suppliers, national and provincial government officials, and research organizations. In this way six innovation platforms have been built across KZN. Around 3,000 people have been involved in these awareness-raising and information-provision events to date. These platforms have also provided for negotiation of funding opportunities and support for the farmers and introduction of new ideas into the CA farming systems in these areas and have provided the learning groups with enough exposure to allow them to be included in the local economic development agendas for their regions. ***Innovation platforms are crucial for awareness raising, development of social agency, and inclusion in local and regional development initiatives.***

2 VALUE CHAIN INDICATORS

2.1 Food production for household consumption is the primary aim of these smallholder farmers. At the start of the programme, 100% of participants were able to produce only enough of their staple maize to feed their families for 1–3 months of the year. After five years, 38% of participants have produced enough maize to last their families for 4–6 months and 53% have produced enough to last their families for 6–12 months. Ten percent of participants have produced enough to feed their families and sell surplus produce. They have done this by improving the productivity in their existing fields, as very few have increased the size of their fields. ***CA can improve food production by between 200–400% over a period of 4–5 years.***

2.2 Local farmer centres have been introduced to provide the functions of coordination of shared equipment, an advice centre for CA implementers, and a local input-supply option for ease of access to inputs in small quantities. Decisions about the ownership and management processes of these centres were left to the learning groups. All four centres presently in operation are being managed by one or two individuals and all have managed to make a small profit of around R400/month. In all four centres the owners have opted to include a range of products to accommodate for the lack of input sales in the off-season. Secondary cooperatives - linked to these farmer centres - have been registered. ***Farmer centres play an important role in building social agency and local***

economic development options in the villages and are crucial to supporting the CA implementation process.

2.3 A matching grant system has been put in place for development of infrastructure and processing (threshers, local grain mills, agricultural water supply for supplementary irrigation). To date three learning groups have taken advantage of these grants ***Matching grant funding provides some opportunities for development of agricultural infrastructure. Most smallholders still find the outlay of 50% too onerous.***

3 PRODUCTIVITY INDICATORS

3.1 Reduction in the labour requirements of smallholder farming systems is an important aspect and proxy-indicator of the sustainability of the system. Increasingly, smallholders are limited by labour constraints as family labour is systematically decreasing and farmers have to pay for extra labour. Seventy-eight percent of the CA participants have indicated a reduction in the need for labour throughout the season in their CA plots, compared to their normal farming system plots and this is an important reason for continuation with the CA approach. Weeding falls into a similar category as a large proportion of their labour requirement is for weeding. In cases where herbicides or mechanical weeding are employed, extra costs are incurred. Thirty-nine percent of the CA participants have indicated a reduction in weeding requirements in their CA plots. ***CA linked to close spacing and intercropping reduces labour and weeding requirements for smallholder farmers.***

3.2 Introduction and promotion of a range of CA planters (hand planters, animal-drawn planters and tractor-drawn planters) have been central to this innovation system. At the start of the process most of the smallholders involved (97%) were using hand hoes for planting. Around 3% of the farmers used animal traction. Use of CA hand planters has increased to 69% of participants, animal-drawn CA planters to 5%, and tractor-drawn CA planters to 0,5% for those few farmers with plot sizes that justify this form of traction. Around 26% of participants still use hand hoes for their CA planting. The latter has to do both with the reluctance of older participants to embrace new ideas and work with “fancy” equipment, and with soil conditions in some areas, where very high clay percentages make using the planters difficult.

3.3 Maize yields for both CA experimentation and control plots have been measured annually for around 70% of the participants. Average maize yields for the CA plots have increased from 2,3t/ha in 2013 to 3,3t/ha in 2018. These averages include all the participants, whether they are only starting to implement CA or have been implementing for several years. Maximum yields increased from 4,4t/ha to 8,5t/ha during this time. Maize yield averages for the control plots averaged 1,8t/ha for the entire period and did not increase, although there were annual fluctuations. The 2018 season, saw a 30% drop in yield averages, when compared to the 2017 season. This was due to the third consecutive year of extremely difficult weather conditions - late onset of rains, mid-season drought, extreme temperatures, and then above-average rainfall late in the season. ***CA implementation assists in maintaining or stabilizing crop yields for 2–3 seasons under extremely variable climatic conditions.***

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

security by providing access to a wider range of food crops as well as feed and fodder for poultry and livestock.

3.5 Ninety-two percent of participants have reported reduced run-off in their CA plots compared to their control plots. They have also reported improved moisture in their soils under CA, as well as improved friability and a reduction in compaction.

3.6 Increase in percentage soil organic carbon (SOC) has been measured for around 10% of the participants; comparing these values when they started CA implementation with values 2–5 years into the implementation process. For the Bergville area (2015–2018) there has been no significant increase in the percentage SOC in the soil (1%). Likely causes were significantly more extreme climatic conditions over the last 3–4 seasons (compared to Southern KZN) and heavy grazing of the CA plots in the dry winter seasons, which left little or no soil cover. The average percentage SOC for the control plots in Bergville, during this time was 30% lower than the CA plot values. For Southern KZN (2016–2018), the increase has been significant at 24%, and for Midlands (2017–2018) no increases have been noted yet. ***Increases in SOC are only possible in smallholder CA systems where the variability in climatic conditions is not extreme. It is possible to maintain reasonable levels of SOC in the more extreme situations.***

1.6 SOIL HEALTH INDICATORS

Biological changes in soil properties, such as population and diversity of soil organisms, soil aggregation, and the interplay between the carbon, nitrogen, and phosphate cycles are strongly linked to soil organic matter (SOM) (Swanepoel, et al., 2017).

Just considering average increases in SOC over time within a CA system can, however, obscure some interesting and significant trends in soil health at a local level.

In Bergville, over a period of four cropping seasons, soil health indicators have been monitored for different cropping options within the CA system. These were compared to undisturbed veld samples in the vicinity as a benchmark. Below the combined results for three participants from Ezibomvini village, who have all been implementing CA for a five-year period is presented as an example.

(insert Figure 2) *Figure 2: %SOM for different CA cropping options in Bergville (2018) for three participants from Ezibomvini in their 5th year of implementation*

Abbreviations for the cropping options shown in Figure 2 are explained in the small table below.

Conv C SP	Conventionally tilled control plot planted to sweet potato
Lablab	CA plot planted to Dolichos beans
M	Ca plot planted to maize only
M+B	CA plot planted to a maize and bean intercrop
M+CP	CA plot planted to a maize and cowpea intercrop
SCC	CA plot planted to a summer cover crop mix of sunflower, millet and Sun hemp
Veld	Undisturbed veld plot within the homestead boundaries. This is used as a benchmark for an “ideal soil” in the locality.

The results indicate:

- Percentage SOM is highest for SCC plots, followed by M+CP, M+B, single-cropped maize and Dolichos,

- Carbon sequestration in the CA mixed crop plots is between 0,75-1,5t/ha more than the single crop plots and
- Overall carbon sequestration is on average around 2-3t/ha for CA plots and 1,8t/ha for the conventionally tilled plot.

This provides an indication of the advantages of multiple cropping options within the CA system in the build-up of SOM and SOC over time, despite the fact that the average %SOM for the area has not increased across seasons. It indicates the advantages of using multi-crop cover crop options and intercrops with cowpea in building carbon in the soil.

1.7 CLIMATE RESILIENCE INDICATORS

Resilience is the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change. (IPCC definition in Bizikova, et al., 2019) Various frameworks have been suggested for developing indicators to assess agricultural system resilience to climate change (Bizikova, et al., 2019). Indicator sets are divided into five broad thematic areas; social, environmental services, economic, physical and institutional. Specific indicators within these categories are flexible and dependent on the local and policy context, as well as measurability (Engle, et al., 2014) (Bizikova, et al., 2019) (Ellis, 2014). Frameworks used to develop the set of indicators used in this process are based on vulnerability and adaptive capacity (OXFAM, 2012) (Ziervogel, et al., 2014), typically used to assess the impacts of projects and processes (FAO, 2013) (Bizikova, et al., 2019). Individual questionnaires have been developed that incorporate scales to provide weighted answers for some of the indicators (Kruger, et al., 2019). Participatory impact assessments (Catley, et al., 2014) have been designed for focus group discussions to augment the information from interviews (Kruger, et al., 2019).

A combination of resilience snapshots and participatory impact assessments (PIAs) have been used to build a picture in these villages of factors to assess for resilience and assessment of improved resilience status for the programme participants, comparing their situations at the start of their involvement with their situations 1–3 years later.

1.7.1 Resilience snapshots

Resilience indicators appropriate to smallholder farmers have been developed in dialogue with farmers over a period of 2–3 years. These are used to create snapshots of resilience, understanding that building resilience is an ongoing process of adaptation and improvement. Individual interviews with smallholders are conducted seasonally and then compiled in a dashboard format of averaged and aggregated indicators. All aspects of their farming systems are considered. An example for Bergville participants is shown below (April 2019).

Table 3: Resilience snapshots for 7 individuals in Bergville who are actively implementing climate resilient agriculture strategies (April 2019)

Resilience indicators	Rating for increase	Comment
Increase in size of farming activities (% increase in land area and no of livestock)	Gardening - 18% Field cropping - 63% Livestock - 31%	Cropping areas measured, no. of livestock assessed
Increased farming activities (no of activity types_	No	Most participants involved in gardening, field cropping, and livestock management

Increased season (increase no of months in the year where cropping is undertaken)	Yes	For field cropping and gardening - autumn and winter options
Increased crop diversity (Now of new crops and agricultural practices)	Crops - 12 new crops Practices - 8 new practices	Management options include: drip irrigation, tunnels, no-till planters, water storage tanks, rainwater harvesting drums
Increased productivity (% increase in yield)	Gardening - 72% Field cropping - 79% Livestock - 25%	Based on increase in yields
Increased water use efficiency *Water access* *Rainwater harvesting* *Water holding capacity* *Irrigation efficiency*	 1 1 2 1	Scale: 0= same or worse than before; 1= somewhat better than before, 2= much better than before
Increased income	13%	Based on average monthly incomes
Increased household food provisioning (Weight of all crops produced, averaged across the no of weeks/ year)	Maize - 15kg/week Vegetables - 7kg/week	Food produced and consumed in the household NOTE: This indicator was not related to a baseline amount. Vegetable production was not undertaken prior to programme initiation. Maize production was only enough to feed households for 1-3 months of the year
Increased savings	R150/month	Average of savings now undertaken
Increased social agency (No of new group activities)	2	Villages savings and loan associations and learning groups. No of group activities before programme initiation average 1
Increased informed decision making (no of sources of information used to make decisions)	5	Own experience, local facilitators, other farmers, facilitators, extension officers. No of sources of information used before programme initiation were 2.
Positive mindsets	2,2	More to much more positive about the future; much improved household food security and food availability. . SCALE:0=less positive about the future; 1=the same; 2=more positive about the future; 3=much more positive

1.7.2 Participatory Impact Assessments (PIAs)

Through a PIA process, farmers developed their own set of resilience indicators which were used to assess the impact of their climate resilient agriculture (CRA) activities, comparing their situation before their involvement with their situation during the process (after between 1–3 years of implementation).

One of the exercises in this process consisted of doing a matrix ranking of practices farmers had 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 by asking participants to outline how they made decisions about which practices to use and what changes they would observe. 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 group decided how these would be placed proportionally for each practice.

Participants conflated practices in the following way:

- ***Conservation agriculture*** includes minimal tillage (0% to 15% soil disturbance), soil cover, and crop diversification.
- ***Savings*** includes VSLAs, rotational saving in small groups towards specific infrastructural needs, and personal savings.
- ***Livestock*** includes fodder production, vaccinations, dipping, and supplementation.
- ***Gardening*** includes 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*** includes rotations with three to four crops, in field cropping.

- ***Intercropping*** includes grain-legume and grain-cover crop intercropping options in field cropping.
- ***Small businesses*** include 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 to at least two different aspects for each indicator.

Table 4: PIA matrix for climate change resilience related to different interventions and activities for Bergville participants. N=35 (July 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 (CA)	22	21	26	28	18	23	18	156
Crop rotation	16	12	13	12	12	15	10	90
Intercropping	12	13	15	12	11	11	9	83
Gardening	14	15	12	13	15	17	21	107
Livestock	19	11	18	7	5	12	11	83
Savings	6	15	14	15	12	11	15	88
Small businesses	11	17	15	10	20	11	9	93

From the above table it can be seen that:

- The participants clearly consider the use of Conservation Agriculture (CA) in field cropping as the most significant practice, followed by gardening, small businesses, savings, and livestock; in decreasing order.
- Participants consider CA, compared to the other activities and processes, to have the greatest potential for improving soil condition, incomes, productivity, and social empowerment.
- Crop rotation is considered to be better at increasing soil health and soil fertility than intercropping - showing an internalization by the group of the positive effects of rotation of the main grain crops with legumes and cover crop combinations (winter and summer cover crop mixes), as well as an observation that this works better than intercropping by itself.
- Income, savings, and productivity are considered to be somewhat higher for intercropping compared to crop rotation; again, a very astute observation from the group. Generally, participants prefer crop rotation to intercropping, 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 significantly better for crop rotation than 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, in principle, this is not the case in well managed fields, it is quite likely in more infertile plots and in adverse weather conditions.

1.8 IN CONCLUSION

Introduction of CA and associated CRA practices within an innovation system approach and using farmer-level experimentation and learning groups as the primary learning and social empowerment processes has created a sustainable and expanding farming alternative for smallholders that is improving their resilience to climate change substantially.

Through a knowledge co-creation process, smallholder farmers in the programme have adapted and incorporated a wide range of practices into their farming system, including minimum tillage, close spacing, improved varieties, judicious use of fertilizer, pesticides and herbicides, crop diversification, intercropping and crop rotation as well as fodder production and livestock integration. They have organised themselves into learning groups, local savings and loan associations, water committees, farmer centres and cooperatives and in so doing have created innovation platforms for local value chain development. They have built ongoing relationships with other smallholders, NGO's, academic institutions, Government extension services, and agribusiness suppliers and have promoted CA tirelessly within their local communities and social networks.

To date, this is the most successful model for implementation of CA in smallholder farming in South Africa and through networking and upscaling activities, is being promoted nationally as a strategic approach to smallholder adaptation and mitigation programming.

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