



APPENDIX 4:
CA SMALLHOLDERS RESEARCH
ANNUAL PROGRESS REPORT
Quantitative research support to the
Conservation Agriculture Smallholder
Farmer Innovation Programme,
KwaZulu-Natal



September 2021

PROGRESS REPORT

Quantitative research support to the Conservation Agriculture Smallholder Farmer Innovation Programme, KwaZulu-Natal

**For period:
October 2020 to September 2021**

Submitted to The Maize Trust

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ASSET Research

**In collaboration with:
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PHOTO CREDITS: Cover Page: Left: Strip crop planting by Mr Cosmos Xaba (Madzikane, SKZN) and Right: Strip crop planting of maize, beans and summer cover crops by Phumelele Hlongwane (Ezibomvini, Bergville).

1 Background and project description

Mahlathini Development Foundation (MDF) (2003–2021) is one of the few NGOs in South Africa focussing on promoting collaborative pro-poor agricultural innovation. As such MDF is a specialist NGO working in the fields of participatory research, training and implementation; focussing on agroecological approaches, including conservation agriculture (CA).

The Maize Trust-funded CA Smallholder Farmer Innovation Programme (SFIP) in South Africa, as conceptualised and implemented through 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 cognisance 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.

MDF has worked with smallholder farmers in CA learning groups, who implement CA as farmer-led trials and expand their implementation into their whole fields over time. Around 480 smallholders across 43 villages in KwaZulu-Natal (Bergville, SKZN and Midlands) have been implementing CA for a period of between one to eight years, because of The Maize Trust SFIP support. Over this period several different indicators were designed and used to track the progress of the participants. Table 1 outlines the progress, using a range of output and impact indicators that have been monitored between 2014 and 2020.

Table 1: Innovation system indicators for the CA SFIP (2013–2020)

CA innovation system indicators for smallholder farmers in KZN; 2014 and 2020			
Social agency indicators			
Indicator	2014	2020	Description/comments
Participants	53	482	Number of CA experimentation participants, from farmer registration lists across all three areas
Learning groups	7	43	Count of number 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	Number of platforms set up that include farmers and external stakeholders
Value chain indicators			
Months of food provisioning			Number of participants, shown as a percentage who can provide enough maize meal 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%	25%	Number 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%	Number 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	Number of farmer centres set up for sharing CA equipment, providing advice and sale of agricultural inputs and produce between 2014 and 2020
Cooperatives	0	4	Number of cooperatives registered for CA smallholders between 2014 and 2020
Co-financing of local infrastructure	0	4	Number of learning groups who took advantage of the matching grant funding to finance local mills, threshers and water infrastructure or supplementary irrigation
Mechanisation committees	0	4	Number of committees set up within learning groups to manage the group-owned CA equipment, for use, hire and maintenance
Productivity indicators			
Reduced labour in CA plots	0%	78%	Number 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%	Number 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			Number 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
<i>Hand hoes</i>	97%	26%	
<i>Hand planters</i>	0%	69%	
<i>Animal-drawn planters</i>	3%	5%	
<i>Tractor-drawn planters</i>	0%	10%	
Average maize yield for CA and conventional plots (t/ha)	1,8 (CA), 2,2 (Conv)	4,5 (CA), 2,5 (Conv)	Yield data measured and averaged for between 50 to 200 participants annually across all three areas
Crop rotation	0%	20%	Number 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%	Number 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%	Number 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%	Number of participants, shown as a percentage who undertook the 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%	Number of participants, shown as a percentage who undertook the 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%	Number 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%	15%	Number 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 runoff in CA plots	0%	92%	Number of participants, shown as a percentage who saw less runoff in their CA plots compared to their control plots; from planting and crop monitoring forms, completed for between 50–200 participants annually, across all three areas
% runoff for CA plots	13,5%	6,9%	Runoff pans were installed for 2–6 participants in each area and results averaged for the cropping season, for 2–4 years
Percentage organic matter (%OM) per annum			Percentage organic matter measured and calculated for -5–8 participants from each area, annually, after being averaged across all CA plots for each participant The average annual sequestration of carbon is 0,3 t/ha for CA plots (both trial and control)
<i>Midlands (2018–2020)</i>	5,1%	7,8%	
<i>SKZN (2018–2020)</i>	5,7%	6,7%	
<i>Bergville (2018–2020)</i>	4,13%	4,05	
Water productivity (kg/m ³)	0,88	1,66	Water productivity is calculated as kg of crop produced per m ³ of water. This has been calculated for between 3 and 5 participants in each of the three areas for maize grain and compared to conventionally tilled plots

For the present financial year, the intention is to focus on the adaptive research aspects of this process, setting up quantitative collaborative managed trials (CMT). In CMTs farmers and researchers work together on problem definition, design, management and implementation of trials as well as evaluation. These CMTs are considered the “mother”¹ trials and have been implemented for 45 selected participants across the Bergville, SKZN and Midlands sites. They are managed alongside the farmer-led experimentation or “baby” trials, of which there have been 161 in this season.

Experimentation protocols chosen by the participants (researchers and farmers) in participatory review and planning sessions are as follows:

1. **10x10 blocks (1 000 m²):** This denotes a 10-plot layout of 100 m² plots, for multiple cropping options (maize, legumes and cover crops), which is rotated on an annual basis.
2. **Strip cropping (1 000 m²):** Planting is done in 4 m wide strips on contour, to provide for soil and water conservation concerns and ease of implementation in larger fields, for multiple cropping options (maize, legumes and cover crops), which is rotated on an annual basis.
3. **Short season maize:** Planting of early maturing maize (white – PAN5A172 and yellow – PAN5A190) alongside the normal varieties to test adaptability to climate variation, either in block or strip cropping trials.
4. **Fodder production:** Planting of annual and perennial livestock fodder species (Teff, Tall fescue, Lespedeza), for both in situ grazing and baling, either in block or strip cropping trials.
5. **Cover crop seed production:** 250 m² fenced plots are planted to 4–5 cover crop species (sunflower, sun hemp, fodder sorghum, dolichos, turnips) with the specific intention of keeping seed, for sharing and sale of cover crop seed to local CA farmers.
6. **Poultry feed:** Planting of 400–1 000 m² experimentation plots to poultry fodder species (sunflower, sun hemp, fodder sorghum) for harvesting of grain and preparation of poultry rations.
7. **Two-row planter:** Introduction of two-row minimum-till planters for use by CA participants to plant their larger CA trials and their own CA fields.

2 Approach and methodology

Of the CA participants, 36–48 from the already established CA learning groups volunteered to take part in the collaboratively managed trials (CMTs), while other members of the groups also undertook experimentation according to the seven variations outlined above but are not supported that closely in terms of quantitative measurements.

The process involves a learning workshop and practical demonstration for each of the seven variations, followed by intensive mentoring and support as each farmer implements their experimentation in their own field.

¹ Sieglinde, S., Snapp, S., DeDecker, J. and Davis, A. 2019. Farmer Participatory Research Advances Sustainable Agriculture: Lessons from Michigan and Malawi. *Agronomy Journal*. 111(6):2681–91.

In addition, with support from the LandCare division of the KZNDA, a larger group of farmers undertake CA, but not the farmer experimentation process. Most of these farmer participants have been implementing CA for several years and they will be provided limited support and mentoring to continue. The intention is to gather crop growth and yield data also from this larger group but to focus on the smaller groups for the quantitative data.

This is to include the following:

1. YIELD DATA:

- Maize yields under CA vs conventional cropping systems (100 participants)
- Yield comparisons of different varieties of maize in the CA system (OPVs and Hybrids, including short-season varieties); linked to planting dates, climate variability and pest and disease resistance (36 participants)
- Maize yields in CA rotation and intercropping systems (36 participants)
- Biomass/dry matter yields for maize for water productivity assessments (9 participants)
- Bean and cowpea yield in CA vs conventional tillage systems (50 participants)
- Grain yields of cover crops planted (36 participants)
- Biomass/dry matter yields for livestock fodder (18 participants)

2. WATER-RELATED DATA:

- Local rainfall measurements in each village (x 8 villages)
- Weather station and SAEON seasonal data; ET_0 , temperature, rainfall per site x 3 sites
- Runoff (runoff pans installed in CA and conventional control plots and different CA cropping options e.g. monocropping, intercropping, cover crops); 3–4 runoff pans per participant (9 participants)
- Bulk density assessments (9 participants)
- Gravimetric water assessments; 3–4 treatments per participant (1 participant)
- Water productivity assessments; 3–4 treatments per participant (9 participants)

3. SOIL-RELATED DATA:

- Soil health analyses (Haney Soil Health Test (SHT))
- Nematode diagnostic indices (24 participants, x treatments each, including veld, control and one to two CA samples)

3 Key activities: October 2020–September 2021

CA farmer-level experiments (1 000 m² block and strip cropping trials) were implemented by 192 participants across 22 villages in KZN (Bergville, KZN and Midlands) in this season, with a further 189 participants implementing CA under the KZN Landcare Programme. The CMT plots have been set up with 9 participants in SKZN and Midlands, respectively, and with 27 participants in the Bergville site.

Participants have focussed on experimentation in strip cropping, cover crops, different maize varieties, use of 2-row tractor-drawn planters, production of cover crop seed, and annual and perennial livestock fodder species. Crop growth monitoring using an e-survey (Pendragon

platform) was conducted for 30 participants from Bergville, 23 from SKZN and 20 from the Midlands.

Rain gauges and runoff plots have been set up for 13 participants across as many villages and participant farmers have undertaken to keep ongoing records. The weather station in Ezibomvini (Bergville) has provided accurate weather data for the Bergville region and SAEON has assisted with further data for comparison with the farmer-level records.

Gravimetric soil sampling has been undertaken for 2 participants; one each from Bergville and SKZN. Thus far two sets of samples have been taken, dried and recorded.

Soil health samples have been taken for 24 participants across 14 villages and have been submitted to the Soil Health Support Centre (in the Western Cape) for Haney SHT analyses, as well as nematode indices (through North West University, Potchefstroom) for comparison of soil health results.

Stakeholder engagement and open days have been severely hampered by the continued COVID-19 pandemic and movement restrictions. However, within these limitations, a cross visit was conducted with 11 smallholder CA farmers from Ngongonini in Southern KwaZulu-Natal (SKZN) to Bergville, specifically to view the collaboratively managed experimentation and processes and a full-length article was written for the March 2021 edition of the African Farmer Magazine. A case study of our programme was submitted to the 8th World Congress on Conservation Agriculture (8WCCA), for a session on 23 June for experiences in Africa related to sustainability and mechanisation.

3.1 Budget

The budget for this programme (see Table 2) from October 2020–September 2021 is R778 664,00. To date, the end of June 2021 expenditure has totalled R636 460,00. This leaves a monthly amount of R47 401,00 x 3 for the finalisation of the project.

Table 2: Budget summary for expenditure between October 2020 and September 2021

CA Adaptive research: Farmer Centred Innovation in CA. October 2020 September 2021; Maize Trust				INVOICES												EXPENDITURE		
Milestones/ Outputs	Key activities	OUTCOMES/ DELIVERABLES	Budgets	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Actual exp	Pd by ASSET Research	TOTAL EXPENDITURE
Farmer experimentation Bergville	Administration and sundries	travel accommodation, admin, accounting	R12 120,00		R11 085,25											R11 085,25		
	Farmer centred innovation systems	farmer experimentation, researcher managed experimentation, savings groups, farmer centres	R608 144,00	R59 876,64	R63 030,20		R131 011,38	R67 182,45	R44 865,77	R37 674,22	R62 882,65	R63 437,98				R529 961,29		
	Analysis	laboratory costs, soil health samples	R158 400,00													R0,00	R95 413,50	
	Monthly expenditure		R778 664,00	R59 876,64	R74 115,45	R0,00	R131 011,38	R67 182,45	R44 865,77	R37 674,22	R62 882,65	R63 437,98	R0,00	R0,00	R0,00			
Overall expenditure																R636 460,04 (Actual end June 2021)		R778 664,00 (Budget)

3.2 Progress

Table 3 outlines activities related to objectives and key indicators from October 2020 to September 2021.

Table 3: Summary of progress (October 2020–September 2021) related to objectives and key activities

Objectives	Key activities	Summary of progress	% completion
Objective 1: To assess the impact of a range of CA practices on water, soil and productivity indicators, within a smallholder farmer-level experimentation process	<i>Key activity 1. Participatory planning, design and layout of experiments</i> 160 participants across 20 villages plant CA baby trials, and mother trials for 36 of these participants	161 participants across 32 villages have planted CA trials. 45 mother trials set up.	100%
	<i>Key activity 2. Collection and analysis of results</i> Quantitative measurements for a minimum of 18 participants (including runoff plots, soil health analysis, bulk density and water productivity calculations, and yield measurements (maize, cover crops and fodder)).	<ul style="list-style-type: none"> - Soil health samples and analysis for 24 participants across 14 villages - Rain gauges and runoff plots for 13 participants across 13 villages - Gravimetric water sampling; 2 participants across 2 villages - Crop growth monitoring for 73 participants across 14 villages - Water productivity samples (110) for 13 participants from all three areas for both grain and biomass analysis - Bulk density samples (27) from 13 participants across all three areas were taken and analysed - Mycotoxin samples (3–5 per participant for 9 participants across all three areas were taken and sent to the ARC for analysis - Yield measurements were done for 96 participants across all three areas, for maize, beans and cover crops 	100%

Objective 2: To use results from qualitative and quantitative results to outline best-bet options for the smallholder CA farming system and to provide recommendations for improvement of the system	<i>Key activity 1: Write up of results</i>	- Progress and annual reports submitted	100%
	- Interim and annual reports	- Short cases are presented in this report	100%
	- Case studies (1 to 2 per site x 3 sites)	- African Farmer Magazine, "Farmer Cheats" – January 2021 and full-length feature February–March 2021	100%
	- Popular magazine and peer-reviewed articles (minimum of 1 each)	- 8WCCA case study for 23 June Africa session	
	- Posting on appropriate websites and online newsletters and forums	- www.mahlathini.org website updated with latest documents.	
		Not done yet, planned for late August–September	
	<i>Key activity 2: Presentation of results</i>	- Farmers cross visit from SKZN to Bergville x 1	0%
	- Farmer review and planning sessions (minimum 3, maximum 6 sessions)	- Learner group presentations on fodder production in other villages and mycotoxin results x 3 in Bergville	100%
	- Results presented to broader farmer–stakeholder forums for networking and awareness-raising (1 to 3 events)		

A performance dashboard is indicated in Table 4 which provides a snapshot of performance according to suggested numbers and outputs in the proposal.

Table 4: Performance dashboard – Proposed March 2021 vs Actual August 2021

Outputs	Proposed (March 2021)	Actual (Aug 2021)
Number of areas of operation	3	3
Number of farmer-level experiments	160	192
Number of CMTs	36	45
Number of local facilitators		14
VSLAs		18
Participatory monitoring and evaluation process (farmer level)	60	73

4 Results achieved to date

Table 5 outlines the villages, numbers of participants and experimentation processes for the programme.

Table 5: Activities and number of farmers involved, per village for October 2020–August 2021

Area	No	Village name (no of CMTs or mother trials)	No of participants	1 000 m ² trials (10x10 , s)	400 m ² trials	Strips	Fodder species	Seed	Poultry	Two-row planter	Short season maize	Actual planted (hectares)
Bergville (12)	1	Eqeleni (3)	15	3	3	14	2				2	1,38
	2	Ezibomvini (9)	16	11	4	2	3	3	1		7	1,46
	3	Emafefetheni	8		2	8						0,88
	4	Ndunwane	9		6	9						0,64
	5	Stulwane (9)	38	26	12	10	5		4	6	10	4,08
	6	Vimbukhalo (6)	24	3	5	13	2	2		3	10	1,8
	7	Ngoba	2	2								0,2
	8	Mhlwazini	11	4	7							0,38
	9	Emabunzini	10	2	8							0,52
	10	Emadakaneni	11		6	11						1,34
	11	Emahlathini	9		1	9						0,94
	12	Thamela	6			6						0,6
Midlands: Ozwathini	13	Ozwathini (5)	38 (27)	12	15	8	5	1	6	4	3	2,72
Midlands: Swayimane (2)	14	Gobizembe (2)	25	3	15	7	4	1	6	2	8	1,6
	15	Emayizekanye (2)	35	7	28	7	8	1				2,32
SKZN (9)	16	Madzikane (3)	7		3	4				4	2	0,34
	17	Springvalley (2)	13		13							0,52
	18	Ofafa (1)	12		12							0,48
	19	Ngongonini (2)	11		11					2	2	0,44
	20	eMazabekweni			4							0,16
	21	St Elois			9							0,36
	22	Plainhill	9		9							0,36
	23	Nkoneni (1)	17			11				1		1,7
	24	Mission	11		11							0,44
			365	73	184	119	29	8	17	22	44	25,66

4.1 CA collaboratively managed trials (CMTs)

The seven experimentation protocols mentioned above (blocks, strips, short season maize, fodder species, cover crop seed, poultry feed and use of the two-row planter) were implemented within three different layouts of CMTs:

1. **1 000 m² (10x10 m) plot (34 replications)**, divided into 100 m² and 10 blocks planted to maize, beans, maize and bean intercrop, maize and cowpea intercrop, summer cover crop mix (sunflower, sun hemp and fodder sorghum), dolichos beans. The blocks are rotated for those participants active for longer than 2 years, on an annual basis.
2. **1 000 m² strip cropping plots (29 replications)**, with 2 m wide strips of 4 rows of maize alternated with a selection of legumes and cover crops, including for example beans, cowpeas, dolichos (lablab), summer cover crops, teff, turnips, lucerne and perennial fodder species such as Lespedeza, Pensacola and tall fescue. Short season maize was included in the strip cropping trials as well.
3. **250 m² poultry feed or cover crop seed plots (25 replications)**, which are fenced and planted to tramlines or strips of a selection of crops from which seed needs to be kept: including dolichos (lablab), sunflower, sun hemp, millet, and fodder sorghum.

Plot layouts (2018–2020) were compiled for a total of 148 participants in Bergville, 37 participants in SKZN and 50 participants in the Midlands.

Participants in the CMTs also undertook a controlled planting of at least 1 000 m². Two types of control were recorded:

1. CA-M control: For these plots, participants planted maize only in consecutive years, using CA, but their own fertiliser and row spacing regimes. The average inter-row spacing for these plots is between 75 cm and 90 cm, so wider than the CA trial plots and participants use fertiliser recommendations to determine fertiliser applications.
2. M-Conv control: For these plots, participants use conventional tillage and plant maize only in consecutive years. As farmers have moved across to using CA as their preferred farming practice, they have stopped ploughing, meaning that there are very few conventional tillage controls. This season, only 2 participants in the Midlands ploughed. All other control plots were CA-M controls.

5 Rainfall and runoff

This season runoff microplot pans have been installed for 13 participants from all three areas. The pans need to be installed after ploughing for the control plots, but before planting for both the control and CA plots. This provided some logistical difficulties and some of the pans could only be installed in December 2020 and January 2021. It means that the data did not start in October, as we had hoped.

Figure 1: Right and far-right: Installation of runoff pans in control and CA trial plots, respectively



Table 6 outlines the rain gauges and runoff pans installed.

Table 6: Rain gauges and runoff pans installed for 13 participants across Bergville, SKZN and Midlands for 2020–2021

Village	Name and Surname	Rain gauge	Runoff	Plot	CA-control
Ezibomvini	Phumelele Hlongwane	Yes	Yes	Plot (2-SCC; 4-M+B; 6-M & 9-Lablab)	Yes
Stulwane	Nelisiwe Msele	Yes	Yes	Plot (3-M+CP; 5-M; 7-M+B & 10-SCC)	Yes
Vimbukhalo	Sibongile Mpulo	Yes	Yes	Plot 6	Yes
Eqeleni	Thulile Zikode	Yes	Yes	Plot (3-M+B; 5-Pumkin; 6-Lablab & 9-SCC)	Yes
Ndunwana	Boniwe Hlatshwayo	Yes	Yes	Plot 1 (M+B)	Yes
Emabunzini	Valindaba Khumalo	Yes	No	No	No
Ofafa	Velephi Hadebe	Yes	Yes	Strip	Yes
Ngongonini	Mandla Mkhize	Yes	Yes	Plot 1 (M+B)	Yes
Springvalley	Letha Ngubo	Yes	Yes	Plot 2 (M+B)	Yes
Madzikane	Cosmos Xaba	Yes	Yes	Strip	Yes
Madzikane	Vakashile Gambu	Yes	Yes	Plot 2 (M+B)	Yes
Ozwathini	Doris Chamane	Yes	Yes	Strip	Yes
Gobizembe	Rita Ngobese	Yes	Yes	Plot 5 (SCC)	Yes
Mayizekanye	Dumazile Nxusa	Yes	Yes	Plot 1 (M+SCC)	Yes

Participant farmers have been provided with monitoring sheets to record rainfall events and runoff for their CA trails and control plots. From previous experience, it was thought to be an acceptable strategy to obtain data. In addition, the participants who showed a lack of interest in previous seasons were replaced with other participants and a few new farmers were brought on board.

The onset of rain was again later than expected, being around the middle to end of November 2020. Subsequent rainfall has been above normal, with very high levels of rainfall in February 2021.

Weather station data (Bergville) are compared for the 2019/20 and 2020/21 growing seasons in Table 7.

Table 7: Bergville weather station data for 2019/20 and 2021/21 growing seasons

Month	Rainfall 2019/20 (mm); Weather station SAEON – Didima	Rainfall 2020/21 (mm); Weather station SAEON – Didima	Rainfall 2020/21 (mm); rain gauges average for Bergville
Oct	131,0	103,37	
Nov	172,6	207,03	107,3
Dec	143,5	204,73	265,0
Jan	99,1	409,16	323,7
Feb	86,1	197,09	340,8
March	49,2	101,61	178,9
April	17,7	48,01	61,0
Total	699,2	1 270,99	1276,7

From Table 7 it can be seen that the rainfall for the 2020/21 season has been much higher than the 2019/20 season. In addition, monthly averages have been consistently high between October and February, while rainfall in the 2019/20 season dropped substantially after December 2019.

The cumulative rainfall between October 2020 and October 2021 as recorded by the farmers from the rain gauges is very similar to the weather station data, even though the monthly averages vary somewhat. Weather station data for the Midlands region was taken from a weather station in Swayimane, managed by the Umgeni Resilience Project (UKZN) in the area.

Averages have been calculated for monthly rainfall and runoff for each area.

Table 8: Rainfall and runoff results for the 2020/21 cropping season for Bergville, SKZN and Midlands

Bergville (6 participants)			
Month	Avg monthly rainfall (mm)	Avg monthly runoff CA plot (L)	Avg monthly runoff control plot (L)
Nov 20	107,3	2,8	
Dec 20	265,0	15,1	16,6
Jan 21	323,7	30,2	62,0
Feb 21	162,7	15,9	22,7
Mar 21	178,9	4,5	5,1
Apr 21	61,0	3,9	4,0
Sum	1276,7	76,7	146,1
% rainfall conversion		6%	11%
SKZN (4 participants)			
Month	Avg monthly rainfall (mm)	Avg monthly runoff CA plot (L)	Avg monthly runoff control plot (L)
Nov 20	83		
Dec 20	148,3	10,2	14,0
Jan 21	141,8	0,5	1,2
Feb 21	132,8	1,6	3,3
Sum	505,8	12,3	18,4
% rainfall conversion		2%	4%
Midlands (3 participants)			
Month	Avg monthly rainfall (mm)	Avg monthly runoff CA plot (L)	Avg monthly runoff control plot (L)
Nov 20		8,1	6,2
Dec 20	131,1	8,3	21,9
Jan 21	447,4	4,0	8,0
Feb 21	234,0	10,0	23,5
Mar 21	86,6	4,9	3,4
Apr 21	40,0	2,1	1,1
Sum	939,1	37,3	64,1
% rainfall conversion		4%	7%

Overall runoff in Bergville was substantially higher than the other two regions. The high percentage of clay in the soil in addition to high rainfall experienced this season has caused water tables to rise, resulting in water saturation in the surface soil layers and thus higher levels of runoff.

Figure 2: Right: An example of a saturated soil profile in Ezibomvini, Bergville in mid-February 2021. The small hole made by a soil auger immediately fills up with water. Far-right: An example of a field where excessive rain caused runoff and waterlogging in a portion of the field.



For those participants where runoff between the CA trial microplots and cControl microplots were compared, the general trend noted in the last four seasons has remained the same. Runoff is lower in the CA plots than in conventionally tilled control plots or CA control plots where monocropping has been practised. The average runoff on CA trial plots is 4,3% of the rainfall and for the control plots is 7,7%. Thus, runoff is cut by around 50% when conservation tillage and mixed cropping is practised.

5.1 Bulk density

Soil bulk density (BD), also known as dry bulk density, is the weight of dry soil (mass of solids) divided by the total soil volume (V_{soil}). Total soil volume is the combined volume of solids and pores which may contain air (V_{air}) or water (V_{water}), or both.

On cropland, long-term solutions to bulk density and soil compaction problems revolve around decreasing soil disturbance and increasing soil organic matter. A system that uses cover crops, crop residues and/or reduced tillage results in increased soil organic matter, less disturbance and reduced bulk density. Additionally, the use of multi-crop systems involving plants with different rooting depths can help break up compacted soil layers.

Samples were collected from the top 5 cm of soil using sampling rings 7,2 cm in diameter using the following procedure:

- The ring was pushed (buried) into the ground using a piece of wood and a hammer (the piece of wood was used to protect the ring).
- A spade was used to dig the ring out of the soil.
- Excess soil sticking out of the ring was cut using a knife to ensure the soil fitted perfectly into the ring (making sure the volume was the same for all samples).
- The soil samples (in the ring) were wrapped with aluminium foil and transported to the lab for analysis.
- At the lab, samples were unwrapped, placed in aluminium dishes, weighed and assigned codes, and put in an oven to dry at 100°C for 48 hours.
- After 48 hours, samples were weighed and the masses were recorded for calculation of dry mass.

The equation used to calculate the total soil volume is as follows:

$$Volume_{(soil)} = \pi r^2 \times d$$

Where π is pi, r is radius and d is depth for the ring. Volume was calculated in cm^3 and the mass of the sample was measured in grams (g).

Average dry mass for all samples collected in the same plot was used to calculate the bulk density and the same volume (based on the dimensions of the ring) was used. The following equation was used to calculate the BD.

$$Bulk\ density\ (BD) = \frac{Mass\ of\ soil\ (g)}{Volume\ of\ soil\ (cm^3)}$$

Bulk density samples were taken for 13 participants across all three areas, taking a range of CA trial plot samples (M+B, M+CP, B, SCC, M) as well as samples from both conventional and CA control plots planted to maize.

Table 9 outlines samples taken and the bulk density results.

Table 9: Bulk density samples and results for 13 participants from Bergville, SKZN and Midlands, June 2021

Area	Farmer's name	Plot name/number	Bulk density (BD) (g/cm ³)
Bergville	Phumelele Hlongwane (PH)	Plot 1 (M+B)	1,182137
Bergville	Phumelele Hlongwane (PH)	Plot 4 (M+B)	1,173315
Bergville	Phumelele Hlongwane (PH)	Control CA	1,160083
Bergville	Nelisiwe Msele (NM)	Plot 3 (M+CP)	0,943946
Bergville	Nelisiwe Msele (NM)	Plot 7 (M+B)	1,182137
Bergville	Nelisiwe Msele (NM)	Plot 1 (M)	1,23948
Bergville	Nelisiwe Msele (NM)	Control CA	1,213014
Bergville	Sibongile Mpulo (SM)	Plot 1 (M+B)	1,305644
Bergville	Sibongile Mpulo (SM)	Plot 3 (M+B)	1,199781
Bergville	Sibongile Mpulo (SM)	Plot 6 (M+CP)	1,10274
Bergville	Sibongile Mpulo (SM)	Control Conv	1,257124
Bergville	Ntombakhe Zikode (NZ)	Strip 1 (M)	1,213014
Bergville	Ntombakhe Zikode (NZ)	Strip 7 (M)	1,323288
Bergville	Ntombakhe Zikode (NZ)	Strip 9 (M)	1,270357
Bergville	Ntombakhe Zikode (NZ)	Strip 3 (M+Pk)	1,14685
Bergville	Ntombakhe Zikode (NZ)	Control Conv	1,221836
Bergville	Boniwe Hlatswayo (BH)	Trial (M+B)	1,107151
Bergville	Boniwe Hlatswayo (BH)	Control CA	1,327699
SKZN	C Xaba (CX)	Plot 1 (M)	0,926302
SKZN	C Xaba (CX)	Plot 2 (B)	0,767507
SKZN	C Xaba (CX)	Plot 4 (SCC)	1,089507
SKZN	C Xaba (CX)	Control Conv	0,87337
SKZN	M Mkhize (MM)	M+B	1,093918
SKZN	M Mkhize (MM)	Control CA	0,966
SKZN	Thandiwe Hadebe (TH)	Trial (M+B)	1,182137
SKZN	Thandiwe Hadebe (TH)	Control CA	0,996877
SKZN	Letta Ngubo (LN)	Trial (M+B)	1,186548
SKZN	Letta Ngubo (LN)	Control CA	1,168904
Midlands	Mrs Xulu (MX)	Plot 2 (M)	1,138028
Midlands	Mrs Xulu (MX)	Control CA	1,076274
Midlands	Rita Ngobese(RN)	M (only)	1,032165
Midlands	Rita Ngobese(RN)	M+B	1,151261
Midlands	Babhekile Nene (BN)	Plot 1 (M)	1,05422
Midlands	Babhekile Nene (BN)	Control CA	1,085096
Midlands	Nomusa shandu (NS)	Plot 4 (Scc)	1,067452
Midlands	Nomusa shandu (NS)	Plot 1 (M)	1,279179
Midlands	Nomusa shandu (NS)	M+B	1,310055
Midlands	Nomusa shandu (NS)	Control Conv	1,279179
	OVERALL AVERAGE		1,139305

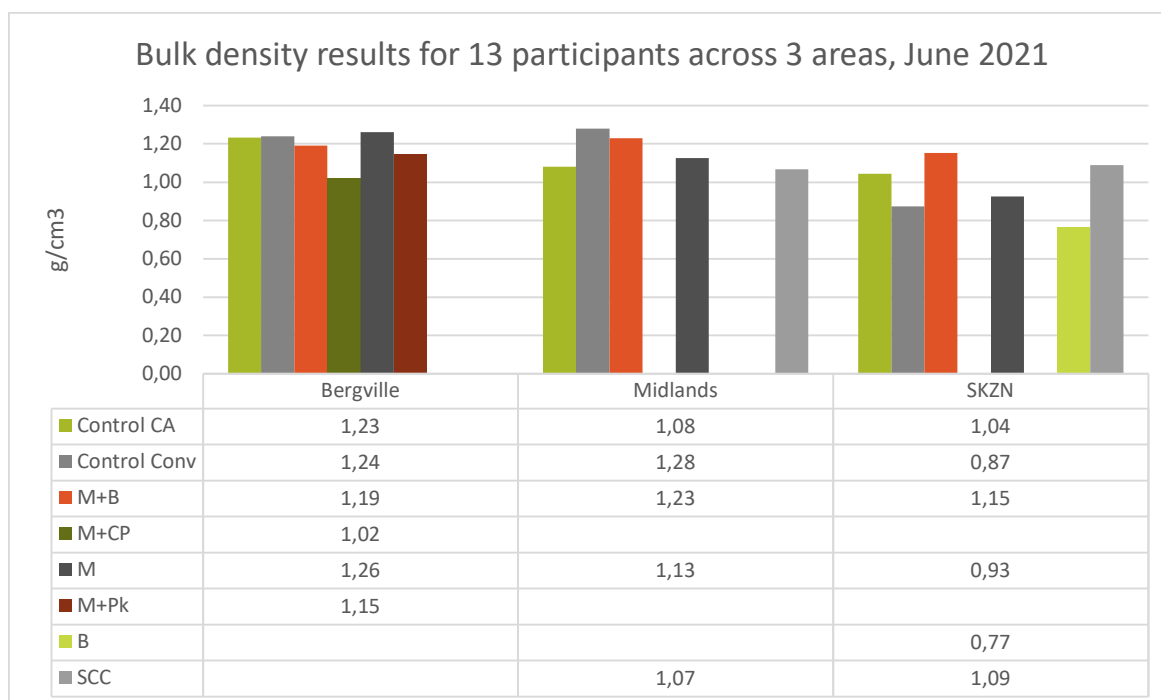


Figure 3: Bulk density results for CA trial and control plots across Bergville, Midlands and SKZN, 2020/21

In general, bulk densities greater than 1,6 g/cm³ tend to restrict root growth (McKenzie, Jacquier, Isbell & Brown, 2004). Sandy soils usually have higher bulk densities (1,3–1,7 g/cm³) than fine silts and clays (1,1–1,6 g/cm³) because they have larger, but fewer pore spaces. In clay soils with good soil structure, there is more pore space because the particles are very small, and many small pore spaces fit between them. It has also been shown that minimum tillage practices can increase bulk density without restricting aeration and water movement in the soil, compared to the same soils under tillage (Cavalieri, da Silva, Leão, Dexter & Håkansson, 2009). Soils rich in organic matter (e.g. peaty soils) can have densities of less than 0,5 g/cm³.

From Figure 3, the bulk density calculations for all cropping options in all three areas were within the low to average range. For both Bergville and the Midlands, the bulk density results for the conventionally tilled control maize plots were higher than the majority of the CA plots. The CA plots planted to mixed crops with legumes and cover crops had lower bulk densities than the CA maize only plots. For SKZN, most of the CA plot bulk densities were slightly higher than that for conventionally tilled maize.

Bulk density sampling has been done in Bergville for three consecutive seasons.

Table 10: Bergville bulk density for 2018/19, 2019/20 and 2020/21

Bergville BD (g/cm ³)	2018/19	2019/20	2020/21
CA multicropped plots combined	1,26	1,29	1,12
CA control (M)	1,36	1,40	1,23
Conventional control (M)	1,30	-	1,24

Bulk density for conventionally tilled, CA control plots (M) and CA multicropped plots do not vary significantly, even though the greatest reduction in bulk density has been for the multicropped CA plots. This could well be linked to the fact that increased soil organic matter in the fields in Bergville has been challenging due to extreme weather variability and that ploughing is rare enough that soil compaction is primarily due to the high-density clay soils in the area, rather than tillage. An average BD of 1,2 g/cm³, 1,1 g/cm³ and 1,0 g/cm³ is used for the water productivity calculations for Bergville, the Midlands and SKZN, respectively.

5.2 Water productivity

Crop water productivity (CWP) relates to the amount of yield per unit of water used. It is an important measure of the impact of different practices on productivity in rain-fed agricultural systems. Methods for improving CWP at the field level include crop selection, planting methods, minimum tillage, nutrient management and improved drainage, where appropriate. Average water productivity (WP) for maize is 1,2–2,3 kg/m³ (FAO, 2003). In this research process, WP has been compared for different crops and crop combinations under CA.

The main variables used in calculating WP are yields and the volume of water used to produce that yield. There are standard methods for working out the yield (e.g. putting the harvested grain or biomass on a scale and weighing it, weighing a sample of maize cobs and estimating yield using the plant population). The challenge is in determining the volume of water used to produce the yield. There are a couple of methods (from simple to more complicated) used in determining the volume of water used.

To determine WP, parameters (temperature, relative humidity, solar radiation, wind speed, wind direction to calculate ET_0) are required and these parameters are gathered from automatic weather stations. This information can be used to benchmark simpler methods used in the field that farmers can be involved in. These ET_0 values are then multiplied by the crop coefficient to find the actual evapotranspiration (Etc), which is the volume of water used to produce the yield.

To calculate the ET_0 , the following equation is used. The weather station calculates the reference evaporation ET_0 using the Penman Monteith equation:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

Where,

- ET_0 is reference evapotranspiration (mm/day)
- R_n is net radiation at the crop surface (MJ m⁻² day⁻¹)
- G is soil heat flux density (MJ m⁻² day⁻¹)
- T is air temperature at 2 m height (°C)
- u_2 is wind speed at 2 m height (m s⁻¹)
- e_s is saturation vapour pressure (kPa)
- D is slope vapour pressure curve (kPa °C⁻¹)
- γ is psychrometric constant (kPa °C⁻¹)

5.2.1 CWP for maize grain

Traditionally for intercropping, WP is calculated for the total grain in the plot, thus including maize and beans/cowpea grain to get an overall view of the WP in the plot. The same is done for the biomass. Maize grain yields are expected to be somewhat lower in intercropped plots than in single cropped plots.

In this research process, WP has been calculated for maize only, both in single and intercropped plots. The intention is to explore the WP of maize planted under different cropping options for farmer participants who have been implementing CA for between 3 and 8 years.

WP was calculated for nine participants KZN: 4 Bergville, 2 SKZN and 3 Midlands for the 2019/20 cropping season. WP for different CA cropping options was calculated using the maize grain weight only, for monocropped and intercropped plots.

The options were an M-CA control (consecutively monocropped maize); M-CA trial (single cropped maize in a rotation system); M+CP-CA trial (maize and cowpea intercropped plot in a rotation system), CA-M+B trial (maize and bean intercropped plot in a rotation system) and conventionally tilled maize as a control (Conv. Contr-M). The aim was to ascertain whether the different cropping options within the CA system provide for different WP outcomes. The results are shown in Figure 4.

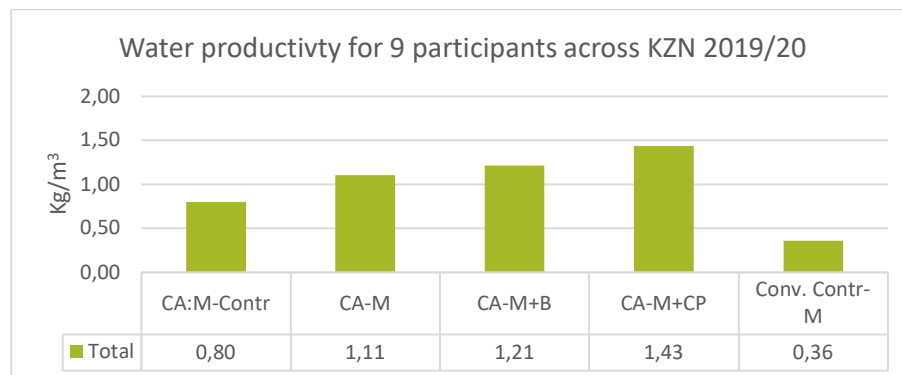


Figure 4: Water productivity for 9 participants across KZN 2019/20

NOTE: The WP results are for maize only within each different cropping option.

For the 2020/21 season, the WP was calculated again for the different CA cropping options, but this time for 11 participants across KZN, as shown in Table 11.

Table 11: WP calculated for 11 participants in KZN for different CA cropping options 2021/21

WP 2020/21 (kg/m ³)	Farmer's name	M	M+B	M+CP	M-CA Control	M-Conv Control
Bergville	Boniwe Hlatshwayo (strip)	2,74			0,96	
	Nelisiwe Msele	2,57	2,32	2,10	1,01	
	Ntombakhe Zikode (Strip)	1,91			0,72	
	Phumelele Hlongwane	4,65	4,45	4,31	1,16	
	Sibongile Mpulo	3,27	3,04	2,12	1,44	
SKZN	Cosmos Xaba (strip)	1,87			1,19	
	Letta Ngubo		3,52		2,08	
	Mandla Mkhize		2,15		1,00	
	Thandiwe Hadebe		2,55		0,92	
Midlands	Mrs Xulu		1,92		0,20	0,98
	Nomusa Shandu	0,44	1,01			0,53
	Babhekile Nene (Jan'21)	1,87	0,85		0,63	
	Rita Ngobese		3,14		0,85	
Overall averages		2,28	2,50	2,84	1,01	0,75

The results are summarised per cropping option in Figure 5.

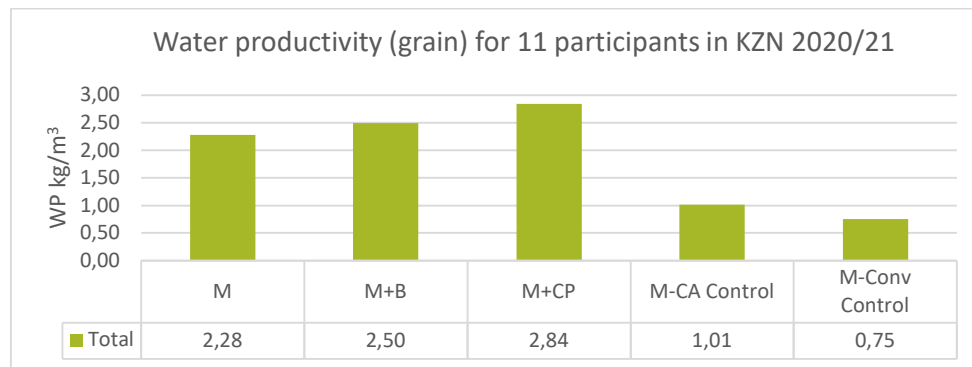


Figure 5: Water productivity for different CA cropping options in KZN 2021/21

What can be seen for the two figures for 2019/20 and 2020/21 is shown in Table 12.

Table 12: Water productivity for 2019/20 and 2020/21

Cropping options	WP (kg/m ³) 2020/21 (n = 11)	WP (kg/m ³) 2019/20 (n = 9)	Avg WP (2 seasons)
CA - Maize (M)	2,28	1,11	1,7
CA - Maize, bean intercrop (M+B)	2,50	1,21	1,9
CA - Maize cowpea intercrop (M+CP)	2,84	1,43	2,1
CA - Maize control (M-CA control)	1,1	0,8	1,0
Conventionally tilled maize (M-Conv Control)	0,75	0,36	0,6

- Overall CWP results were higher for all cropping options in 2020/21 than in 2019/20, indicating the different evapotranspiration effects of the two seasons.
- For both seasons the WP for the conventionally tilled monocropped plots is substantially lower than for all the CA cropping options.
- The WP for the CA control maize plots (which is planted to monocropped maize in every season) is lower than the WP for the CA maize only rotation plots for both seasons. This indicates a positive effect on WP due to the rotation of maize with intercrops, legumes and cover crops.
- The WP for maize in the legume (bean and cowpea) intercropped plots is substantially higher than the maize only CA plots for both seasons. This indicates a positive effect on WP for intercropping and closer spacing, which improves soil structure, organic matter and reduces overall evaporation as a result of the soil cover.
- The WP for maize in the M+CP intercropped CA plots is higher in both seasons than the M+B intercropped CA plots, indicating a more positive effect for cowpeas than beans on WP. This is likely to be directly linked to the improved soil cover offered by cowpeas, which grow with much higher biomass than sugar beans as well as the nitrogen fixation from cowpeas, also much higher than that of beans.

A small exploration of the effect of inter-row spacing of maize is provided below. One of the practices in the CA experimentation process is the use of closer spacing 50 cm within and between rows, than is the norm in these areas (75 cm–1 m between rows) and 50–75 cm within rows.

If the M CA-control samples for the Bergville participants, for example, are analysed for a 50 cm and 80 cm row spacing the results are as indicated in Table 13.

Table 13: Bergville water productivity for 50 cm and 80 cm spacing

Plot type	Spacing 50 cm	Spacing 80 cm
	WP (kg/m ³)	
M CA-control	2,00	1,72
M	2,61	
M+B	2,63	
M+CP	2,84	

This indicates a definite effect of row spacing on WP, indicating a positive effect on WP for closer spacing options in Bergville.

WP for CA maize grown as an intercrop with beans or cowpeas is higher than single cropped CA maize and WP for CA plots is higher than conventionally tilled plots. Despite annual differences in WP, these trends remained the same across two seasons for all three areas within KZN. The close spacing used in the CA trial plots provides extra WP benefits when compared to the 'normal' spacing used in these villages.

5.2.2 WP for biomass

The CWP was also calculated for the above-ground maize plant material (stalks and leaves).

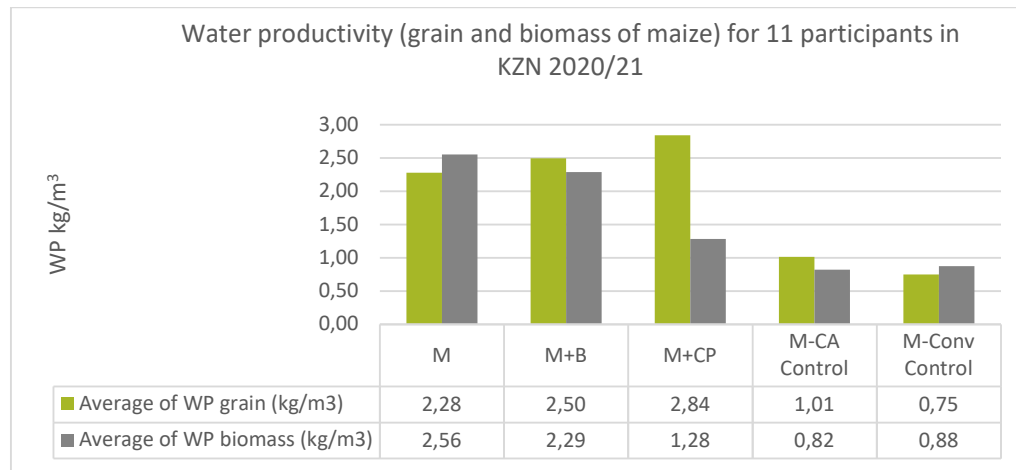


Figure 6: WP for grain and biomass for maize, for 11 participants in Bergville 2020/21

Again, there is a very clear trend of much improved WP for maize in the CA trial system when compared to the CA maize control and conventionally tilled maize. The expected effect of lower maize biomass yields in intercropped plots, compared to single cropped plots is also evident. The significance of this result lies in the improved maize biomass WP for the rotation and multicropped plots under CA, providing a clear indication of the benefit of this system in improving crop water use over time.

5.3 Nematode indices

Nematode indices were reported on in detail in the 6-monthly report, submitted in March 2021. In summary, the Nematode indices indicated that fields where CA has been implemented for 5–6 years, showed a trend of greater nutrient availability, greater ecosystem structure and stability (with the nematodes populations as the proxy for this) and a move from bacteria to fungal dominated energy pathways.

What the analysis showed, is that nematode populations or indices, as an indication for the soil ecosystem or soil biology, changed (as a trend) slowly over time, with the first ‘visible’ signs of change being a shift to a more fungal-dominated ecosystem followed in subsequent years by a greater structure and maturity of the nematode populations.

The analysis also showed that there were no significant differences in nematode indices between the different CA treatments, such as M, M+B and SCC plots. In summary, all the CA treatments, including the CA Maize control need to be considered important for the improvement of soil ecosystem health and each has a slightly different effect and impact on the soil ecosystem. SCC plots, for example, provide for the presence of the highest number of population types and numbers of nematodes as well as linkages between soil food webs but pushes the system temporarily into more bacterially-dominated pathways, due to higher enrichment values. M+B

intercropped plots have the highest channel index figures and the lowest enrichment values of the treatments, thus favouring fungal dominated soil ecosystem development.

5.4 Soil health

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

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

5.4.1 Method

SAMPLING

Sampling is done at the same time every year, during September, after harvest and before the start of seasonal rain, according to international conventions (Stolbovoy et al., 2007).

- CA plots: 10 m x 10 m plots are marked, and 10 cm depth cores are taken (with a soil auger), taking 20 samples along a zigzag pattern across the plot. These are combined, thoroughly mixed and then 500 g is placed in a plastic bag and sealed. These bags are kept in a cool, dark place until delivery to the soil health analysis laboratory – usually within four to six weeks of taking the sample.
- Control plots: 20 samples are taken in a zigzag pattern across the dimension of the control plot; these vary from one participant to the next and are otherwise treated in the same manner as the CA plot samples above.
- Veld samples: This changed after the first two seasons to reduce the potential variability in the samples. A patch of undisturbed veld, as close as possible to the participant's cropping field was chosen, to also have the same basic visual characteristics as the field in question. Four subsamples were taken at 10 cm depth at the four compass positions adjacent to the cropping field.
- Samples were air-dried and stored for a period of two to four weeks at room temperature (20–24°C), before analysis.

LABORATORY ANALYSIS

Laboratory analysis was undertaken by Soil Health Support Centre (<https://www.soilhealthlab.co.za/>), linked to WARD Laboratories (<https://www.wardlab.com/>) in the USA. Each soil sample received in the lab is dried at 50°C for 24 hours and ground to pass a 4,75 mm sieve. The dried and ground samples are scooped, with the weight recorded using a Sartorius Practum 2102-1S, into two 50 ml centrifuge tubes (4 g each) and one 50 ml plastic beaker (40 g) that is perforated and has a Whatman GF/D glass microfibre filter to allow water infiltration. The two 4 g samples are extracted with 40 ml of DI water and 40 ml of H3A respectively, for a 10:1 dilution factor. The samples are shaken for ten minutes, centrifuged for five minutes, and filtered through Whatman 2V filter paper. The water and H3A extracts are

analysed on a Seal Analytical rapid flow analyser for $\text{NO}_3\text{-N}$, $\text{NH}_4\text{-N}$, and $\text{PO}_4\text{-P}$. The water extract is also analysed on an Elementar TOC select C:N analyser for water-extractable organic C and total N. The H3A extract is also analysed on an Agilent MP-4200 microwave plasma for Al, Fe, P, Ca, and K.

The 40 g soil sample is analysed for $\text{CO}_2\text{-C}$ ppm after a 24-hour incubation at 25°C . Initially, the sample is wetted through capillary action by adding 18 ml of DI water to an 8 oz. glass jar (ball jar with a convex bottom), placed in the jar and then capped. Solvita paddles can be placed in the jar at this time and analysed after 24 hours with a Solvita digital reader. Alternatively, we use a system that we call HT-1, where, at the end of 24-hour incubation, the CO_2 in the jar can be pulled through a LiCor 840A IRGA, which is a non-dispersive infrared (NDIR) gas analyser based upon a single-path, dual-wavelength infrared detection system.

SOM% is a gravimetric expression of the organic material fraction lost from combustion at 360°C for three hours and is also termed the loss in ignition calculation method (LOI%).

5.4.2 Soil health test parameters²

The method uses nature's biology and chemistry by using (1) a soil microbial activity indicator; (2) a soil water extract (nature's solvent); and (3) the H3A extractant, which mimics the production of organic acids by living plant roots to temporarily change the soil pH, thereby increasing nutrient availability.

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

Soil respiration one-day $\text{CO}_2\text{-C}$: This result is one of the most important numbers in this soil test procedure. This number (in ppm) is the amount of $\text{CO}_2\text{-C}$ released in 24 hours from soil microbes after the soil has been dried and rewetted (as occurs naturally in the field). This is a measure of the microbial biomass in the soil and is related to soil fertility and the potential for microbial activity. In most cases, the higher the number the more fertile the soil.

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

Water extractable organic C (WEOC): Consists of sugars from root exudates, plus organic matter degradation. This number (in ppm) is the amount of organic C extracted from the soil with water. This C pool is roughly 80 times smaller than the total soil organic C pool (% organic matter)

² Haney/Soil Health Test Information Rev. 1.0 (2019). Lance Gunderson, Ward Laboratories Inc.

and reflects the energy source that feeds soil microbes. A soil with 3% soil organic matter, when measured with the same method (combustion) at a 0–10 cm sampling depth, produces a 20 000 ppm C concentration. When the water extract from the same soil is analysed, the number typically ranges from 100–300 ppm C. The water-extractable organic C reflects the quality of the C in the soil and is highly related to microbial activity. On the other hand, the percentage SOM is about the quantity of organic C. In other words, soil organic matter is the house that microbes live in, but what is being measured is the food they eat (WEOC and WEON).

If this value is low, it will reflect in the CO₂ evolution, which will also be low. So, less organic carbon means less respiration from microorganisms, but again this relationship is unlikely to be linear. The microbially active carbon (MAC = WEOC/ppm CO₂) content is an expression of this relationship. If the percentage MAC is low, it means that nutrient cycling will also be low. One needs a %MAC of at least 20% for efficient nutrient cycling.

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

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

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

SAMPLING

Sampling has been done for each of the three areas for between 3 and 5 seasons. As the SH results are not comparable across areas, they will be tackled per area in the discussions below.

Table 14: Sampling in Bergville, SKZN and Midlands during 2020/21, 2019/20 and 2018/19

Area	Village	2020/21	2019/20	2018/19
Bergville (5–8 years)	Stulwane	4	3	2
	Ezibomvini	3	3	2
	Ndunwana	1	2	2
	Egeleni	2	-	2
	Vimbukhalo	2	-	-
SKZN (3–5 years)	Mhlwazini	-	-	2
	Madzikane	2	2	2
	Ngongonini	1	1	1
	Spring Valley	1	1	1
Midlands (1–3 years)	Ofafa	1	1	1
	Gobizembe	1	1	1
	Mayizekanye	2	3	3
	Ozwathini	3	-	-

For the 2020/21 season, soil health samples have been collected from 24 participants across 12 villages. Ozwathini (Midlands) has now been included as the participants there have been practising CA for a period of between 1 and 3 years. Table 15 outlines samples taken across the three areas.

Table 15: Soil samples were taken for 24 participants across all three areas in September 2020

Name	Surname	Trial plot	Control plot	Veld	No. of soil samples
Ezibomvini					
Phumelele	Hlongwane	M, M+B, SCC, Dolichos (Plots 2,4,6,9)	Maize (hand hoe)	Yes	6
Zodwa	Zikode	M, M+B, SCC,	Maize (hand hoe)	Yes	5
Nombono	Dladla	M, M+B, SCC	Maize (hand hoe)	Yes	5
Ndunwana					
Boniwe	Hlatshwayo	M+B	Maize (hand hoe)	Yes	3
Stulwane					
Dlezakhe	Hlongwane	M, M+B, SCC	Maize (hand hoe)	Yes	5
Khulekani	Dladla	M, M+B, SCC	Maize (hand hoe)		4
Nelisiwe	Msele	B, M, SCC	Maize (hand hoe)	Yes	5
Cuphile	Buthlezi	M, M+B, SCC	Maize (hand hoe)	Yes	4
Matolozana	Gumbi	M, M+B, SCC	Maize (hand hoe)		4
Egeleni					
Ntombakhe	Zikode	M, M+B, SCC	Maize (hand hoe)	Yes	5
Thulile	Zikode	M, M+B, SCC	Maize (hand hoe)		4
Vimbukhalo/Emazimbeni					
Sibongile	Pulo	M, M+B	Maize (hand hoe)	Yes	3
Zweni	Ndaba	M, M+B	Maize (hand hoe)		4
Springvalley					
Letta	Ngubo	M+B	Maize (hand hoe)	Yes	3
Ofafa					
Velephi	Hadebe	M+B	Maize (hand hoe)	Yes	3
Madzikane					
Vakashile	Gambu	M+B	Maize (hand hoe)	Yes	3
Cosmos	Xaba	M, M+B	Maize (hand hoe)	Yes	4

Ngongonini					
Mandla Mkhize	Mkhize	M+B	Maize (hand hoe)	Yes	3
Mayizekanye					
Babhekile	Nene	M+B	Maize (hand hoe)	Yes	3
Manene	Mkhize	M+B	Maize (hand hoe)	Yes	3
Gobizembe					
Rita	Ngobese	M+B + SCC	Maize (hand hoe)	Yes	4
Ozwathini					
Doris	Chamane	M+B	Maize (hand hoe)	Yes	3
Martina	Xulu	M+B	Maize (hand hoe)	Yes	3
Aron	Nkomo	M+B	Maize (hand hoe)	Yes	3

5.4.3 Soil health scores

The following three assumptions are made regarding SH scores:

- SH scores for the CA trial plots will be higher than for the conventionally tilled control plots.
- SH scores will increase over time for CA trial plots.
- SH scores for different cropping combinations, such as monocropped plots, intercropped plots and multicropped plots will be different.

Soil health assessments over time

BERGVILLE

As this area is the most well-established with on-farm trials, soil health assessments have been conducted for several participants over four seasons. To determine trends in soil health over time, the results from all CA trial plots (M, M+B, M+C, Dolichos, SCC) for each soil health parameter were averaged for three participants across the Bergville study area.

The figures for the veld benchmark samples have not been included. The results for these samples mirrored the same trends as the CA trial plots although to a lesser extreme.

The participants are:

- Dlezakhe Hlongwane (Stulwane): 2015–2020
- Ntombakhe Zikode (Eqeleni): 2018–2020
- Phumelele Hlongwane (Ezibomvini): 2016–2020

Figure 7 shows the result of this analysis.

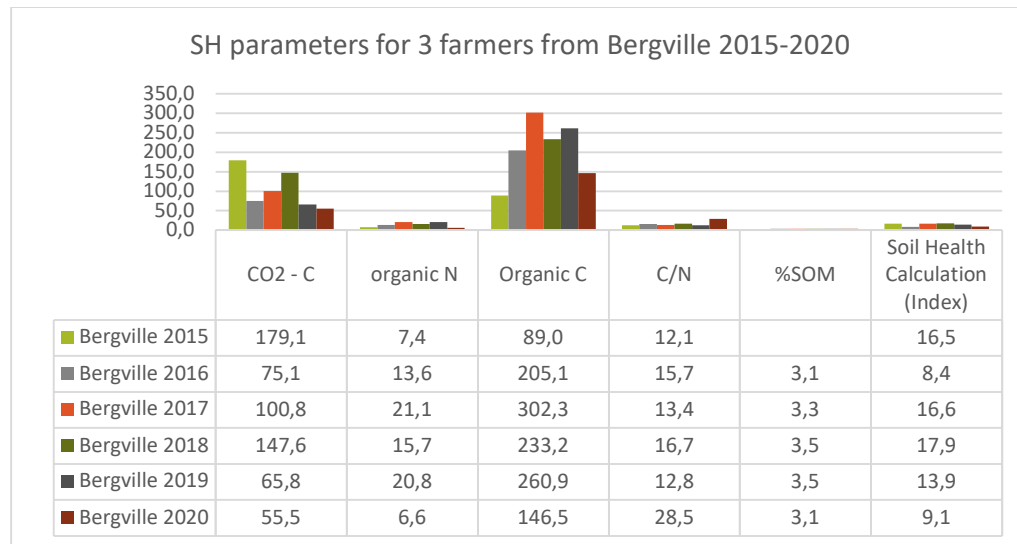


Figure 7: SH scores between 2015/16 and 2020/21 for 3 participants in Bergville

From Figure 7, the following trends are visible:

- The soil health index scores vary considerably between 2015 and 2020. The first reduction is from 2015–2016 – the latter following an extreme, short-term drought year. After that for 2017–2018 the SH scores increased substantially (16,6 and 17,9, respectively) to a similar level as the starting point in 2015 (16,5), just to plummet again for 2019 and 2020. The latter two years showed a very late onset of rains, with increased heat and midseason dry spells.
- Organic N increased at variable levels from 2015 to 2019 and then decreased dramatically for the 2020 season.
- Organic C increased although at variable levels between 2015 and 2019 and then also reduced substantially for 2020.
- CO2-C respiration has shown the same periodicity as the overall SH scores, decreasing dramatically after a drought, late-onset rains and mid-season dry spells.
- % soil organic matter (SOM) has remained reasonably stable as expected but has shown no overall increase in the 6 years of CA implementation.

If one now looks at the SH scores over time for a selection of individual farmers in Bergville, from three different villages (Ezibomvini, Stulwane and Eqeleni), one can see the same trends as indicated above mirrored for each individual, despite the individual differences and variations.

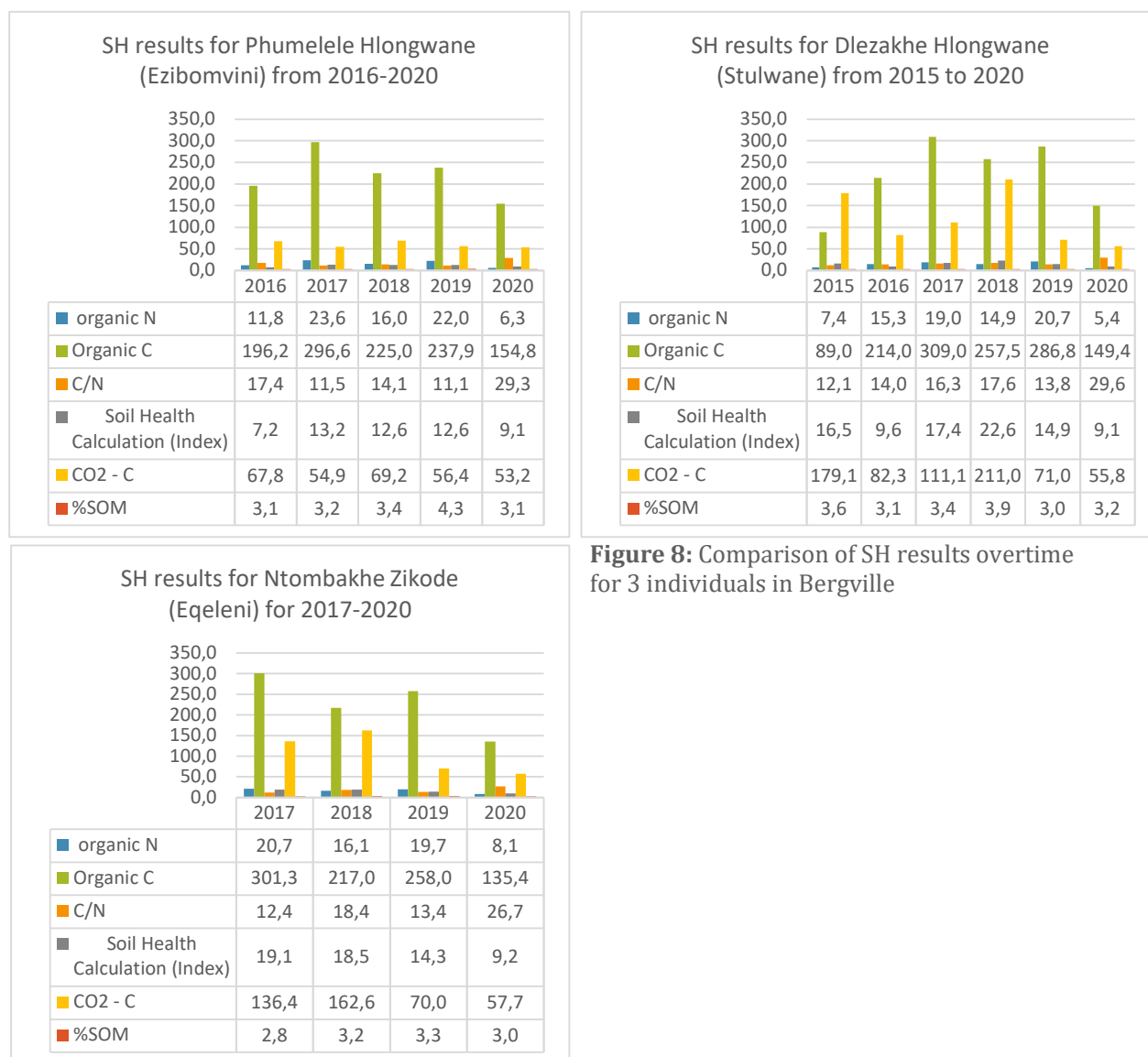


Figure 8: Comparison of SH results overtime for 3 individuals in Bergville

The extreme climatic conditions in the area, including heat and dry soil profiles, reduce the soil health impact of the CA practices and increase variability in the results for different seasons. The analysis in effect becomes an analysis of the effect of climate change on the soil health indicators in the area.

Looking more closely at one of the participants, Phumelele Hlongwane from Ezibomvini, and comparing the SH results for different plots within her 10 block CA trial, one can see that even within one field there can be quite a lot of variability in the SH results.

Table 16 indicates crops and crop combinations planted in each plot between 2017 and 2020 and indicates the rotations Phumelele has used.

Table 16: Crop rotations in the 10 plots of Phumelele Hlongwane's 10 block (1 000 m²) CA trial plot over time (2015–2020)

Plot no	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	Run-off plots
1	M+B	M	M+WCC	SCC	M	M+B	Rotations have been done attempting to ensure a different crop/crop mix on each plot in each consecutive year.
2	SCC	M	M+B	M+CP	M+B	SCC	
3	M+SCC+WCC	M+B	M	M+CP	M+B	M	
4	M+B	LL	M	M+B	M+CP	M+B	
5	LL	M	LL	M	LL	M	
6	M+LL	SCC	M+CP	M+B	SCC	M	
7	M+CP	M	M+CP	M+B	M+B	M+CP	
8	M+B	M+CP	B	M+B	M+B	M+PK	
9	M+CP	M+B	SCC	M	M+B	LL	
10	M+B	M+B	M	LL	M	M+B	
	Control: M (CA)	CA Control: M	CA Control: M	CA Control M	CA Control M	CA control M	
			CA Control: M+B (CA)	Conventional control: SP		CV control M	

SH samples were taken from the plots marked in orange in Table 16 between 2016 and 2020. The results for 2017–2020 for each plot number is shown in Table 17.

Table 17: SH parameter results for Phumelele Hlongwane 2017–2020, according to CA trial plot numbers

numbers	CA trial plot numbers								
SH parameters/per year (2017-2020)	2	4	5	6	9	10	CA Contrl	Veld	Overall average
Average of soil organic matter									
2017	3,2	3,2		3,2	3,4		4,2	3,3	3,4
2018	3,5	3,6	3,6			3,2			3,5
2019	3,7	3,6	3,9	3,5	4,0		2,9	4,1	3,7
2020	3,1	3,2		3,1	3,4		2,9	3,0	3,1
Average of CO2 - C									
2017	42,6	68,7		62,3	68,8		61,2	97,3	66,8
2018	82,4	48,0	25,0			68,5			56,0
2019	61,1	48,0	40,5	52,8	62,0		53,7	76,4	56,4
2020	53,2	27,2		50,2	62,1		76,3	50,1	53,2
Average of Organic N									
2017	19,5	6,5		17,8	19,9		17,8	16,1	16,3
2018	17,0	16,0	14,0			14,7			15,4
2019	28,6	23,6	16,8	23,0	28,9		16,0	17,1	22,0
2020	2,5	8,9		6,9	5,7		5,8	8,1	6,3
Average of Organic C									
2017	232,0	157,0		235,5	256,5		227,5	260,5	228,2
2018	197,0	211,0	187,0			237,0			208,0
2019	280,0	219,0	191,0	199,0	328,0		227,0	221,0	237,9
2020	147,0	113,0		198,0	163,0		185,0	123,0	154,8
Average of C/N									
2017	12,7	24,2		13,2	14,5		13,5	15,9	15,7
2018	12,0	13,0	14,0			16,1			13,8
2019	9,8	9,3	11,4	8,7	11,3		14,2	12,9	11,1
2020	58,8	12,7		28,7	28,6		31,9	15,2	29,3
Average of soil health calculation (index)									
2017	10,9	10,7		12,7	14,0		12,5	16,5	12,9
2018	13,8	11,0	7,6			13,1			11,4
2019	14,6	11,5	9,6	11,6	15,7		11,5	13,8	12,6
2020	8,5	5,9		9,7	10,0		11,9	8,3	9,1

Originally the intention was to see whether different crops and crop combinations positively affect soil health in any given season (between different plots) and over a period of time on the same sampling point or plot. It was, however, found that the inherent abiotic soil characteristics, especially soil texture, has a much larger impact on the soil health results than the crop combinations in a given season when different plots are compared. In other words, the variation in soil characteristics between plots has a much bigger effect on soil health than different treatments.

We hypothesised that over time given the multicropping rotations, that the soil health test results on each plot would improve and also that the SH test results for the different plots would slowly become more even, or more closely resemble each other – thus less variation between plots.

Figure 9 shows that there is a large variation in the active soil health parameters over time and space (between the different plots), i.e. average of CO₂ (respiration), Organic N and C, C:N ratio and even the soil health index. The only stable soil health parameter, i.e. SOM, shows steady increases per plot for three years (2017–2019). However, all plots had a fairly sharp drop in 2020, which is unexplainable. Even the veld plot had a sharp drop in SOM from 4,1 to 3, which can't be explained unless there was either a different spot sampled with higher clay% or an error in the laboratory procedure. Similar sharp increases in 2020 are also seen with organic C:N ratios in all the plots.

The variability in plot-level SH parameter results, especially the active parameters, have shown the same trends as the SH results averaged across the whole CA trial plot and participants in and between villages in Bergville. This then provides more evidence for the argument that the variability is a result of climate variability, rather than any specific farming practice or intervention.

From the above figure the overall trends in increase and decrease for the different SH parameters, mirrors that of Figure 7. The rather dramatic decrease in Organic N and to a lesser extent, Organic C in the 2020 season is evident. Overall SOM values show a steady increase over three years (2017–2019) and then a slight drop in 2020; the reason behind this change in SOM is still being investigated.

The high loss of Organic N and Organic C from the soil between 2019 and 2020 can be considered a combined effect of high temperatures early in the season, leaching, due to extreme rainfall events mid to late season (January–March 2021) and reduced stover or soil cover, due to increased grazing pressure from livestock because of dwindling grazing in the area.

This effect, combined with the significantly lower CO₂-C respiration values for 2020, indicate the need for new applications of stable organic matter into the system and Nitrogen supplementation.

Despite gains made in soil health and structure through the implementation of CA principles these results indicate that:

1. Smallholders need to ensure increased permanent soil cover through reduced removal of stover during the winter season.
2. They need to increase and consolidate their multicropping processes – specifically with legumes, the latter inter alia aiming to reduce the C:N ratio.

Without these interventions, the effects of climate variability can easily outweigh the gains made in their CA implementation.

MIDLANDS

To determine trends in soil health scores over time, the results from all CA trial plots for 4 participants were averaged across villages for the study area. The figures for the veld benchmark samples have not been included. The results for the veld samples mirrored the same trends as the CA trial plots although to a lesser extreme.

Figure 9 shows the result of this analysis.

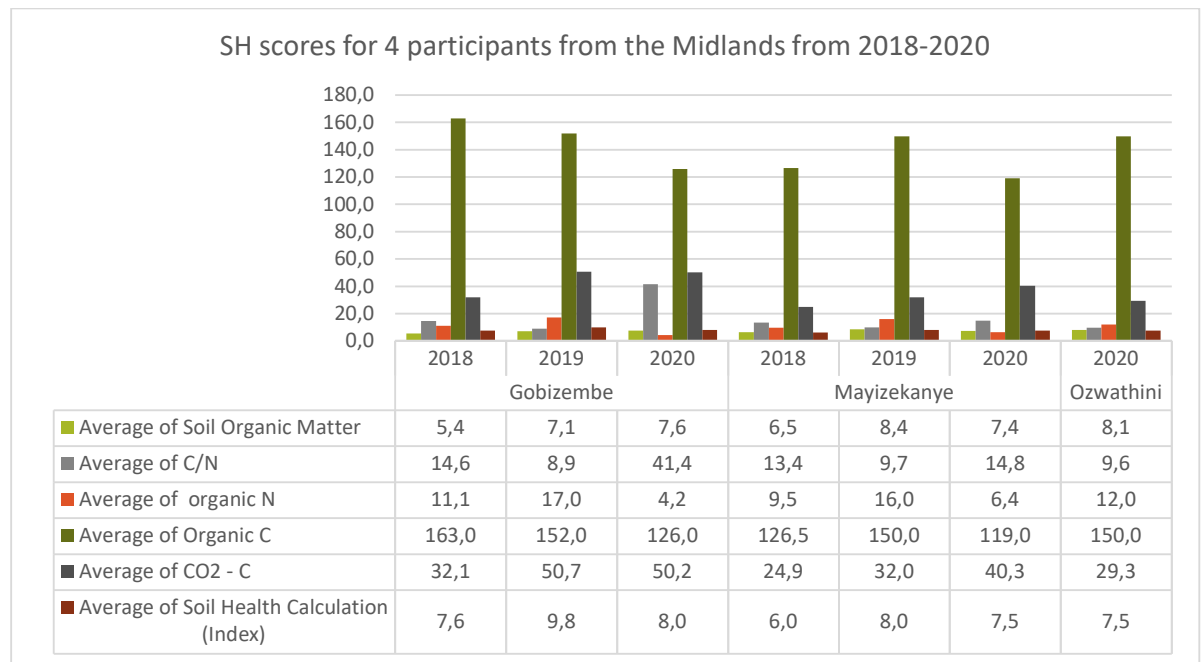


Figure 9: SH scores between 2018/19 and 2020/21 for 4 participants in the Midlands region

From Figure 9, the following trends are visible:

- The soil health index scores have remained reasonably similar, and overall values are fairly high (above 7 in most cases). These are also reflected in the low microbial respiration, and organic N values. Organic C values are moderately high.
- A similar dramatic reduction in organic N, as was seen for Bergville above, also occurred in Gobizembe for the 2020 samples. This is related to the sharp increase in C:N ratio in the same region.
- SOM values are generally very high in the Midlands area. There is a fairly sharp increase in % SOM under CA in Gobizembe (2018–2020) and Mayizekanye, but a slight drop in 2020 in the latter region, although still very high at 7,4%.

The low microbial respiration is indicative of soils with very little microbial activity. The soils in this area are naturally high in organic matter, more so than for Bergville for example, and these low respiration values are indicative of long-term 'biological mining' or suppression of the soils – frequent disturbance through tillage with too little diversity through cropping systems and living

roots and good soil organic cover. The fairly high Organic C values are encouraging and show a fresh stream of food that could reactivate the soil microbes.

Recommendations for increased permanent soil cover and much increased inclusion of legumes and cover crops are important here as well.

SOUTHERN KWAZULU-NATAL (SKZN)

This area consists of reasonably spread-out villages from Ixopo to Creighton in SKZN.

To determine trends in soil health scores over time, the results from 5 participants on all CA trial plots were averaged across villages into one average for each of the soil health parameters in the study area. The values for the veld benchmark samples have not been included. The results for the veld samples mirrored the same trends as the CA trial plots although to a lesser extreme.

Figure 10 shows the result of this analysis.

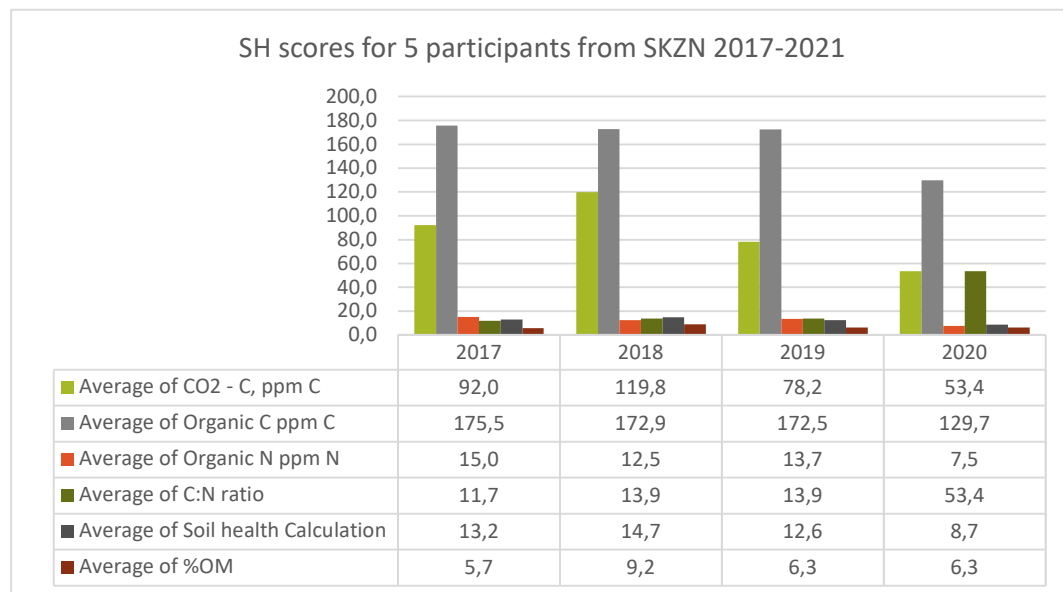


Figure 10: SH scores between 2017/18 and 2020/21 for 5 participants in SKZN

From Figure 10, the following trends are visible:

- The soil health index scores here follow a similar trend as those in Bergville increasing for 2017–2018, decreasing in 2019 and with a dramatic decrease for 2020.
- This dramatic decrease for 2020 is related primarily to a significant drop in the Organic N in the soil, as well as Organic C, again a trend reflected in both Bergville and the Midlands.
- SOM% values show a steady increase under CA over time, although the high value in 2018 (9,2) is an outlier due to possible errors in the laboratory or during the soil sampling.

The drastic changes of sensitive indicators, such as Organic N (related to a drop in Organic C and CO₂ respiration) from the soil between 2019 and 2020 can be considered a combined effect of increased temperatures especially early in the season (September–November), extreme rainfall

events mid to late season (January–March 2021) and reduced stover or soil cover, due to increased grazing pressure from livestock because of dwindling grazing in the area.

In SKZN, however, the microbial respiration figures are above average and high from 2017 to 2019 (92, 119, 72) when compared to the Midlands study area and are comparable to values in the Bergville study area. The 2020 result of 53,4 ppm, which is slightly above average, however, indicates the need for food for the soil food web (SFW), which is best derived from healthy diverse cropping systems and living roots in the soil, as well as soil organic cover. The practices or factors were probably negatively influenced by environmental factors, such as drought and high temperatures.

Overall, the results for all three areas indicate that climate variability (short-term droughts late onset of summer rains, mid-season dry spells and high early season temperatures) had a significant effect on soil health status and that unless CA participants can substantially improve their soil cover and crop diversification with leguminous cover crops, gains made by the present level of reduction in soil tillage, increase in diversity and small increases in soil cover, are not likely to be able to sustain the higher yields that participants are looking for.

Different CA cropping options

The CA experimentation process has been designed to maximise crop diversity.

The following progression has been used:

- Years 1 and 2: Single cropped plots of maize (M) and beans (B) and intercropped plots of M+B and M+C (cowpea).
- Year 3: Inclusion of cover crops; a 3-species mix of summer cover crops (SCC) including sunflower, millet and sun hemp and a 3-species mix of winter cover crops (WCC), saia/black oats, fodder rye and fodder radish.
- Year 3+: Inclusion of legume cover crop – lablab beans (LL).
- Year 3+: Rotation of the above-mentioned plots within the CA trial (ten plots).
- Year 3+: Inclusion of permanent fodder strips and strip-cropping as a crop rotation strategy.

The assumption is that the combination of multicropping and crop rotation would provide for the fastest build-up of organic matter and improvement of SH for this smallholder CA system. The assumption was also made that if crop rotation is included as a practice in such a multicropping system, then the SH for all the plots would increase over time and that variability between the plots would decrease, as each plot undergoes a rotation of multiple crops.

SH samples were taken for 13 participants in their 5th to 8th year of CA implementation who have used both multiple cropping and crop rotation in their CA plots to ascertain whether these assumptions could be proven. Samples have been taken from the sample plots every season, even though the crop on each plot differs in each season. Figure 11 is indicative.

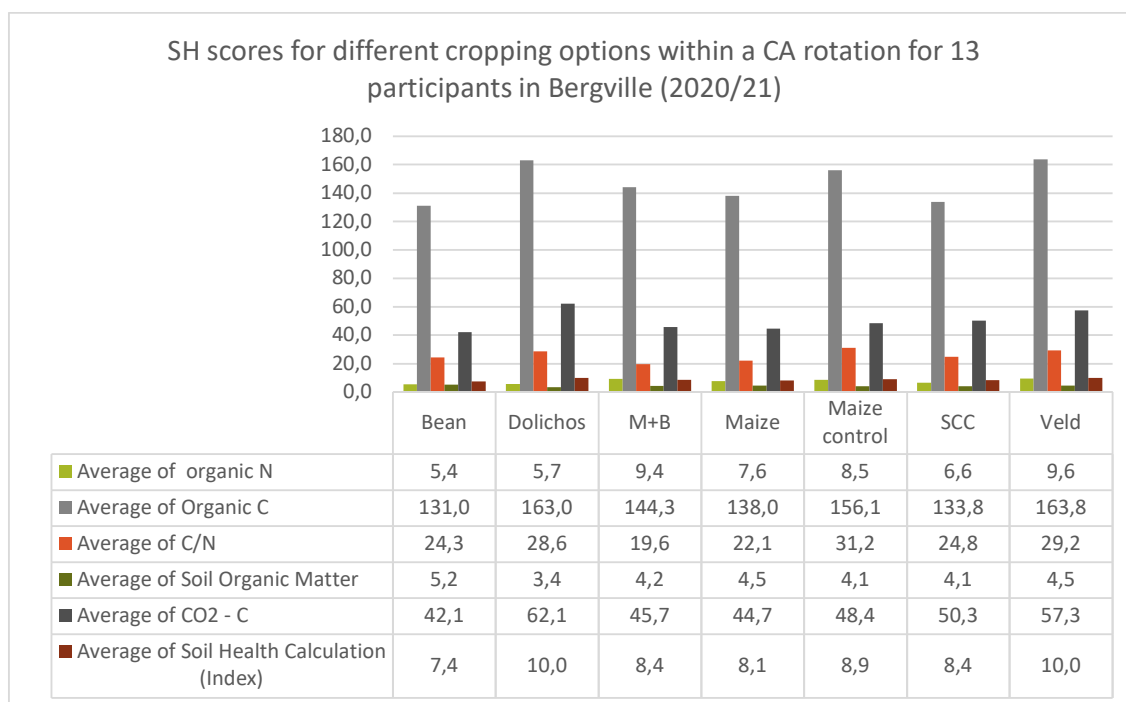


Figure 11: SH scores for different cropping options for 13 participants in Bergville for 2020/21

From Figure 11, the following trends can be seen:

- The SH scores, although low for this season as explained in the previous section are all similar and additionally are also similar to the SH index scores of the veld samples. If these average values are used, the assumption that SH scores in multicrop rotations will become similar over time can be verified as can the assumption that SH scores will improve and more closely resemble the veld benchmark scores.
- However, variability for SH scores between different plots in individuals' CA trials is high due to variation in inherent soil characteristics, especially texture, climate and the implementation of CA practices by the participants. From the approach taken here, the major factor in the change (reduction) of soil health scores seems to be climate variability.
- Furthermore, it is at this stage not possible to separate the effect of cropping systems on soil health, compared to climate variability and the inherent soil characteristics. Another more comprehensive methodological approach, such as a multivariate analysis of all the factors and parameters per participant, might be necessary to improve the analyses.

Soil organic matter (SOM)

Soil organic matter (SOM) is where soil carbon is stored and is directly derived from biomass of microbial communities in the soil (bacterial, fungal and protozoan), as well as from plant roots and detritus and biomass-containing amendments like manure, green manures, mulches, composts and crop residues (Motaung, 2020). Soil organic carbon (SOC) refers to the carbon component of SOM that is measured in mineral soil which passes through a 2 mm sieve. It is the largest component of SOM (approximately 45%) and the easiest and cheapest to measure. The SOC content of agricultural soils is generally between 0,5% and 4%.

There is general agreement among researchers that CA improves soil health by increasing SOM. Increased SOC also sequesters atmospheric carbon and thereby contributes to climate change mitigation targets (Swanepoel et al., 2017).

Despite this understanding, some studies in Africa and southern Africa have reported only small increases, or very slow build-up of SOC and even negligible increases in some cases, compared to conventional systems. It is being argued that the build-up of SOM in CA systems is related more to increased biomass and organic mulch than a reduction in tillage (Giller et al., 2009). It has also been suggested that in drier climates with sandier soils it may take up to ten years to detect a noticeable difference in SOC accumulation (GRDC, 2014).

In addition, it has been suggested that to get reliable data on changes in SOC related to land use patterns, large numbers of samples need to be taken – between 80 and 500 on average for croplands and undisturbed soils such as forests, respectively (Stolbovoy et al., 2007). This is not financially feasible for small, multifaceted programmes such as the CA SFIP.

5.4.4 Methods

Sampling for laboratory analysis of soil health is, as described above in section 1, with 20 subsamples making up one composite sample within a 100 m² plot, taken during the fallow season (August–September each year) and air-dried and stored at room temperature before analysis. Soil sampling depth was 0–10 cm, as this is the depth of soil where the most change in SOC is likely to occur.

Percentage SOC (kg C/kg soil x 100) has been provided for these samples (Soil Health Solutions Laboratory, WC). A constant factor of 1,72 is used in South Africa, to convert %SOC to %SOM (GRDC, 2014).

BERGVILLE

Percentage SOM has been calculated for participant samples between 2018–2020 to ascertain whether there is a build-up of carbon as an outcome of the CA implementation for participants. The average results for all the CA multicropped plots (both intercropping and crop rotation) of the 7–13 participants for whom samples were taken in this period, is presented in Table 18, along with the average of the Control plots (both CA and conventional controls monocropped over time with maize) and an average of the veld samples.

Table 18: %SOM and tons of Carbon/ha for Bergville CA and Control plots: 2018/19 to 2020/21

	%SOM			tC/ha		
	2020	2019	2018	2020	2019	2018
CA multicropping	4,05	4,75	4,13	3,1	3,6	3,1
Control M*	3,79	4,79	4,46	2,9	3,6	3,4
Veld	4,75	4,62	5,66	3,6	3,5	4,3

**This value is a combination of control plots, which included CA control plots as well as conventionally tilled plots planted to maize only in consecutive years. This combination of controls was done for this analysis only, to get an averaged OM value for maize only plots as control compared to multicropped CA plots.*

As with the soil health samples for 2020, there has been a reduction in SOM measured in the soil for 2020 for the CA plots and the control plots, when compared to the 2019 results. This is very unusual since SOM doesn't easily change over a few years, especially if the land use or management stays constant. %SOM in the veld samples increased slightly for 2020 when compared to 2019.

This result provides further urgency to the need for improving soil cover and crop diversification by the smallholder participants, to offset the effects of climate variability in the system.

MIDLANDS

Percentage SOM has been calculated for participant samples between 2018–2020 to ascertain whether there is a build-up of carbon as an outcome of the CA implementation for participants. The average results for all the CA plots of the 4 participants for whom samples were taken in this period, is presented in Table 19, along with the average of the CA Control plots and an average of the veld samples.

Table 19: %SOM and tons of Carbon/ha for Midlands CA and Control plots: 2018/19 to 2020/21

	%SOM			tC/ha		
	2020	2019	2018	2020	2019	2018
CA multicropping	7,8	7,5	5,1	5,9	5,7	3,9
CA Control M	8,4	8,3	6	6,3	6,3	4,5
Veld	8,2	10,2	8,1	6,2	7,7	6,1

For both the CA trial plots (M, M+B, M+CP and SCC) and the CA control plots (maize monoculture), the % SOM has increased in both 2019 and 2020 when compared to the 2018 result. This indicates the build-up of SOM through the CA process in the Midlands, at a rate of 0,2t/ha/annum on average higher for the CA plots (both trial and control) when compared to the veld samples over the period tested.

SKZN

Percentage SOM has been calculated for participant samples between 2018–2020 to ascertain whether there is a build-up of carbon as an outcome of the CA implementation for participants. The average results for all the CA plots of the 5 participants for whom samples were taken in this period, is presented in Table 20, along with the average of the Control (both CA and conventionally tilled plots planted to monocropped maize) plots and an average of the veld samples.

Table 20: %SOM and tons of Carbon/ha for SKZN CA and Control plots: 2018/19 to 2020/21

	%SOM			tC/ha		
	2020	2019	2018	2020	2019	2018
CA multicropping	6,7	6	5,7	5,1	4,5	4,2
CA Control M	7,1	5,7	5,9	5,4	4,2	4,5
Veld	7,4	8,3	8,0	5,6	6,3	6,0

Note: the sharp increase in %SOM for the control M plots in 2020 is physically almost impossible to obtain in one season for one parcel of land. This value is an average of the %SOM for 5 participants and although extremely unusual needs to be considered as a valid result. As discussed in the section above it is suspected that the high levels of change of Organic N and Organic C in the soil, due to the most part too extreme weather conditions are at the root of these unusual outcomes.

For both the CA trial plots (M+B and M+C) and the control maize plots, the %SOM has increased quite sharply for both 2019 and 2020 when compared to 2018. The %SOM for the veld samples have however been variable, first increasing and then decreasing in the two consecutive seasons since 2018. This indicates the build-up of OM through the CA process in SKZN, at a rate of 0,6t/ha/annum on average higher for the CA plots (both trial and control) when compared to the veld samples over the period tested.

Overall, the %OM results indicate that the practice of CA is important in providing for the build-up of organic matter in the soil, at average rates of -0,1t/ha/annum (Bergville), 0,45t/ha/annum (SKZN) and 0,7t/ha/annum (Midlands). The impacts of climate variability, specifically in Bergville, but also in the other areas have negated much of the potential positive impact of organic matter build-up necessitating a far stronger emphasis on crop residues and crop diversification than is presently the case to mitigate for this effect.

5.5 Mycotoxin analysis

Mahlathini is collaborating with another project funded by The Maize Trust and managed by Dr Belinda Janse van Rensburg from the ARC Grain Crops Institute in Potchefstroom to analyse the presence of mycotoxins on smallholder CA participants' maize.

Mycotoxins are secondary metabolites produced by filamentous fungi which contaminate a large fraction of the world's food, mainly staple foods such as maize and beans in our case. This worldwide contamination of foods is an enormous problem to human populations, principally in less industrialised countries and the rural areas of some developed countries. The adverse effects of mycotoxins on human health can be both acute and chronic, provoking problems such as liver cancer, reduction of immunity, alterations in the protein metabolism, gangrene, convulsions, and respiratory problems, among others. Mould growth can occur either before harvest or after harvest, during storage and on/in the food itself often under warm, damp and humid conditions. Most mycotoxins are chemically stable and survive food processing.

Several hundred different mycotoxins have been identified, but the most commonly observed mycotoxins that present a concern to human health and livestock include aflatoxins, ochratoxin A, patulin, fumonisins, zearalenone and nivalenol/deoxynivalenol.

Some factors which influence the presence of mycotoxins in foods are related to environmental conditions, such as storage, that can be controlled without too much expense.

Good practices for reducing the presence of mycotoxins are summarised in the following list.

- Host resistant or tolerant varieties are the most cost-effective and practical means of combating the disease.
- Avoid planting maize at unacceptably high densities as this increases stress.
- Rotate with non-hosts of the *Fusarium graminearum species complex* such as legumes, cotton and sunflower.
- Harvest early to avoid lodging. Get rid of infected debris to avoid the build-up of inoculum.
- Control insects such as stalk borers which may serve as possible vectors, observing the threshold value of 10% infested plants for chemical control.
- To prevent ear rot after harvest, store grain under low moisture conditions.
- Maize that is harvested can be further decayed and contaminated by the already present *Fusarium* spp. Maize harvested must contain a low moisture content and the area in which the maize is stored must be kept dry and clean.

Table 21 summarises the mycotoxins tested for and some of their characteristics.

Table 21: Mycotoxins tested for and health effects in humans and animals

Mycotoxin type	Fungal origin	Health effects in humans	Health effects in animals
Aflatoxins (B ₁ , B ₂ , G ₁ , G ₂)	<i>Aspergillus flavus</i> and <i>parasiticus</i>	Liver damage, liver cancer, immunosuppressive, damage to DNA - genotoxic (10 µg/kg)	Liver cancer, immunosuppressive (50 µg/kg)
Fumonisin	<i>Fusarium spp</i> , <i>Fusarium verticillioides</i>	Oesophageal cancer in humans, liver toxicity, immunosuppressive (2000 µg/kg)	Carcinogenic, liver and kidney toxicity, immunosuppressive (5 000 µg/kg for horses and pets, 10 000 µg/kg for pigs and 50 000 µg/kg for cattle and poultry)
Trichothecenes (T-2 HT-2)	<i>Fusarium spp</i>	Liver damage, liver cancer, immunosuppressive	Liver damage, liver cancer, immunosuppressive
Deoxynivalenol (DON)	<i>Fusarium spp</i>	Anaemia, skin lesions, vomiting, diarrhoea, and damage to liver damage (2000 µg/kg)	Anaemia, skin lesions, vomiting, diarrhoea, and damage to liver damage (1000 µg/kg for pigs, pets and calves, up to 5000 µg/kg cattle)
Zearalenone (ZEN)	<i>Fusarium spp</i>	Hormonal imbalance and reproductive effects	Carcinogenic, hormonal imbalance and reproductive effects (500 µg/kg for cattle, 3000 µg/kg for pigs)
Ochratoxin A	<i>Aspergillus</i> and <i>Penicillium spp</i>	Upper urinary tract disease, carcinogenic, liver and cell toxicity	Upper urinary tract disease, carcinogenic, liver and cell toxicity (50 µg/kg pigs, 200 µg/kg poultry)

NOTE 1: References: National mycotoxin regulations for foodstuffs to be consumed by humans (Government Gazette, No 987) and National mycotoxin regulations for maximum allowable levels of mycotoxins in animal feeds (Act 36 of 1947; Government notices No.R.70; SAGL, 2019,)

NOTE 2: Neither aflatoxins nor Ochratoxin was found in samples analysed.

Fusarium ear rot is especially common in fields with bird or insect damage to the ears. Affected ears usually have individual diseased kernels scattered over the ear or in small clusters (associated with insect damage) among healthy-looking kernels. The fungus appears as a whitish mould and infected kernels sometimes develop a brownish discolouration with light-coloured streaks (called starbursts).

Gibberella ear rot is similar but presents more like a white- pinkish mould. The main difference is that it is favoured by cool, wet conditions whereas the fusarium ear rot is favoured by hot and dry conditions. Gibberella and Fusarium ear rot pathogens overwinter on corn residue and in the soil (www.pioneer.com/us/agronomy/common_corn_ear_rots_crofocus.html).



Table 22 outlines the participants and samples where high levels of mycotoxins were found.

Table 22: Mycotoxin presence for samples taken in Bergville, Midlands and SKZN, 2019/2020

Area	Village	Name and Surname	Plot description	% Ear rot	Fumonisin $\mu\text{g}/\text{kg}$			DON $\mu\text{g}/\text{kg}$	15-Acetyl-DON $\mu\text{g}/\text{kg}$	ZEN $\mu\text{g}/\text{kg}$	T2 $\mu\text{g}/\text{kg}$	HT-2 $\mu\text{g}/\text{kg}$
					B ₁	B ₂	B ₃					
Midlands	Mayizekanye	Fikile Maphumolo	Conv Maize	30	1826	127	313					
		Fikile Maphumolo	CA Maize	3						976		
		Nomusa Shandu	CA Maize	12	4719	1233	944					
		Nomusa Shandu	M+Cp	14						587	1409	1446
		Babhekile Nene	M+Cp	25	539	174	88			4294		
SKZN	Madzikane	Cosmos Xabane	M+B, M+Cp	0				2050				
Bergville	Ezibomvini	Phumelele Hlongwane	CA Maize	1	157	77		1950				
		Phumelele Hlongwane	M+SCC	0	183	57		1418				
	Stulwane	Neliswe Msele	CA Maize	0	466	92	57	1665				

Red cells indicate toxic levels of the mycotoxin concerned and pink cells indicate high levels, although slightly below the maximum level allowable.

A total of 36 samples were taken from 10 participants across all three areas. Of these, 9 samples contained high levels of mycotoxin and 10 samples contained no mycotoxins. Fifteen samples contained low levels of a range of mycotoxins. *All mycotoxins were produced by Fusarium spp.* See appendix 1 for the full analysis. In several cases, participants had both high levels of mycotoxins in some of their plots and no mycotoxins in others.

In general mycotoxin levels in maize for CA plots intercropped with beans were low and much lower than some of the maize only plots. The results indicate an urgent need to work with smallholder farmers on strategies to reduce mycotoxin levels in their maize, both in their fields and in subsequent storage methods and processes.

6 Progress summary

Monitoring results were summarised in the six-monthly report. In this section, we provide a summary of monitoring for trials planted in late-January 2021 and for the experimentation in cover crops, and livestock and poultry fodder production.

6.1 Collaboratively managed trials (CMTs)

BERGVILLE

Compiled by Lungelo Buthelezi, Nkanyiso Mzobe and Michael Malinga

For this adaptive research process, we have focussed mainly on four villages: Stulwane, Ezibomvini, Vimbukhalo and Eqeleni with a total of 64 participants.

Strip cropping (2 m wide strips w 4 lines of crop per strip) on either 400 m² or 1 000 m² plots was introduced as an alternative to the 100 m² blocks used to date. Participants have found this layout a lot easier to handle and implement and many of the participants thus opted for strips.

Bergville additional fodder, poultry feed and seed plots

Ten (10) participants across 3 villages (Stulwane, Ezibomvini and Eqeleni) undertook the experimentation in fodder and cover crop seed plots, over and above planting their 1 000 m² block and strip trials. Three participants in Vimbukhalo who undertook to do this experimentation (Zweni Ndaba, Sphelele Zondo, Nomusa Zikode) found the additional load of work too onerous. In addition, 5 participants in Stulwane volunteered but never planted (Nikeziwe Ndlovu, Thembi Nsele, Mpithi Mabaso, Mrobeth Miya and Khethabahle Miya).

Of the participants who planted the fodder strip cropping plots, the trials for Sabelo Mbhele and Dombolo Dlamini (Stulwane), Ntombenhle Hlongwane (Ezibomvini) and Thulile Zikode (Eqeleni) were destroyed due to livestock invasions.

For the seed production plots, participants were supplied with fencing material to fence a 250 m² area within which to produce the cover crop seed. The idea was to plant the cover crops and dolichos in these areas. Four participants received the fencing: Phumelele Hlongwane, Landiwe Dlamini and Ntombenhle Hlongwane (Ezibomvini) and Zweni Nadaba (Vimbukhalo). Ntombenhle has been ill with COVID-19 and did not plant. Zweni Ndaba's fencing was returned to MDF as she was also ill and did not plant.

This lack of implementation has been a direct result of COVID-19, where 3–4 of the participants were very ill and others were unfocussed due to increased pressure on their household incomes and livelihoods. Livestock which is usually herded or moved to the mountains in summer, have remained in the villages and have caused substantial crop damage. Below a summary is provided for some of the participants.

Stulwane

Thulani Dlamini

He planted the following trials:

Year	Date of planting	Size of trial	Trial type	Plot 1	2	3	4	5	6	7	8	9	10
2018/2019	17/11/2018	1000	blocks	SCC	M+B	M+C	B	M+C	M	CP	M	B	M
2019/2020	18/12/2019	1000	blocks	LL	SCC	M+B	B	B	M	B	SCC	M+C	LL
2020/2021	17/11/2020	1000	blocks	M+PK	CP	M+C	LL	SCC	B	M+B	M	M+B)	M+B
	16/12/2020	1000	CA Strip	M	B	M	CP	M	SCC	M + SCC	M	C	M
	26/02/2021	371	Poultry feed-strips	SCC	M	SCC	M						

Note: Maize varieties; (blocks) PAN53 and (strips) PAN5A190. Bean varieties: PAN9292. Pumpkin varieties: Queensland Blue. SCC varieties: Sun hemp, sunflower, fodder sorghum.



Figure 12: The maize and SCC trips planted in late February 2021 as poultry feed

Comments: Mr Dlamini planted both the SCC and PAN5A 190 short season yellow maize, to be able to make a mixed feed for his small broiler business. The trial was growing well, but there was some danger of livestock invasions as he planted late in the season. He has however undertaken to look after this plot and ensure harvesting of the seed.

Khulekani Dladla

He planted the following trials:

Year	Date of planting	Size of trial	Trial type	Plot 1	2	3	4	5	6	7	8	9	10
2018/2019	20/11/2018	1000	block	SCC	M+B	M+C	M+B	B	M	LL	M	B	M
2019/2020	14/12/2018	1000	block	M	SCC	M+B	M+C	M+B	B	M	LL	M	B
2020/2021	18/11/2020	1000	strip	SCC	LL	M)	B	M+	C	M+	M+Pk	M+C	M+C
	17/12/2020	1000	Strip	M	B	M	CP	M	SC	M	LL	M	B

	End Feb 2021	182	Poultry feed strip	C	SCC	C	SCC	C	SCC	C	SCC		
	Dec 2020		Fodder strip	M	Luc	M	Pens	M	Lsp	M	Pens	M	Lsp

Note: Maize varieties; (blocks) PAN53 and (strips) PAN5A190. Bean varieties: PAN146. Pumpkin varieties: Queensland Blue. SCC varieties: sun hemp, sunflower, fodder sorghum. Fodder lucerne (Luc), Lespedeza (Lsp) and Pensacola (Pens).



Figure 13: Left and centre: Lespedeza harvested and dried for baling as livestock fodder and Lespedeza seed collected; Right: Khulekani Dladla standing in one of his late-season SCC strip plots, planted as poultry feed

Comments: For the fodder strip cropping, the lucerne took a very long time to germinate and grow and germination was not very good. Pensacola did not germinate at all. The lespedeza germinated and grew well and Khulekani has managed to harvest a reasonably substantial quantity of seed.

Nelisiwe Msele

She planted the following trials:

Year	Date of planting	Size of trial	Trial type	Plot 1	2	3	4	5	6	7	8	9	10
2018/2019	17/11/2018	1000	block	M+CP	M+B	M	CP	M	B	M	M	SCC	M
2019/2020	2019/12/12	1000	block	LL	M+CP	B	M	CP	M	B	B	M	LL
2020/2021	23/11/2020	1000	block	M	C	M+C	B	M	LL	M+B	M+PK	M+B	SCC
	Jan 2021	100	Poultry feed block	SCC									

Note: Maize varieties; (blocks) PAN6479. Bean varieties: Gadra. Pumpkin varieties: Queensland Blue. SCC varieties: sun hemp, sunflower, fodder sorghum.

Figure 14: Right: Nelisiwe's SCC plot planted as poultry feed in January 2021; Far right: Sunflower seed harvested from this plot

Comments: She has already harvested the sunflower seeds and is now waiting for the sun hemp and sorghum to mature.



Nothile Zondi

She planted the following trials:

Year	Date of planting	Size of trial	Trial type	Plot 1	2	3	4	5	6	7	8	9	10
2018/2019	2018/12/11	1000	block	SCC	M+B	M+C	B	M	LL	M	C	B	M
2019/2020	19/12/2019	1000	block	M	C	SCC	M	B	M	LL	M	M+C	B
2020/2021	17/11/2020	1000	block	C	SCC	M	B	M+PK	LL	M	M+B	B	M
	30/12/2020	1000	Strip	M	B	M	C	M	SCC	M	LL	M	B
	10/12/2020	300	Poultry feed block	SCC									
	January 2021		Fodder strip	M	Lsp	M	TF	M	TF	M	Lsp		

Note: Maize varieties; (blocks) PAN53 and (strips) PAN5A190. Bean varieties: PAN9292. Pumpkin varieties: Queensland Blue. SCC varieties: sun hemp, sunflower, fodder sorghum. Fodder: Tall fescue (TF), lespedeza (Lsp).

Figure 15:

Right: The short season maize and perennial fodder strip trial showing tall fescue; Far Right: Nothile's poultry feed block of SCC



Comment: Nothile has already harvested the sunflower from her poultry feed plot and is still waiting for the sun hemp and sorghum to mature. For her fodder strip trial, she has one strip of Lespedeza that was planted in 2019/20 continuing this season and has planted further strips of Lespedeza and Tall Fescue. She also planted Pensacola, but this did not germinate well. In future, the focus will be on lespedeza and Tall Fescue grass.

Figure 16: Lespedeza strips at different stages of maturity

Note: She kept one strip to go to seed, to keep for future planting and used the other strip to cut and store some fodder for her livestock. The rest will be grazed directly by livestock in the winter season.



Eqeleni

Ntombakhe Zikode

She planted the following trials:

Year	Date of planting	Size of trial	Trial type	Plot 1	2	3	4	5	6	7	8	9	10
2018/2019	06/12/2018	1000m ²	block	M	SCC	M	B	M	LL	M+B	M+B	M+B	M+LL
2019/2020	05/12/2020	1000m ²	Block	M + B	M	M + B	M	M + B	M	B	SCC	M + C	LAB LAB
2020/2021	17/11/2020	1000m ²	Strip	M	B	M+Pk	SCC	M	C	M	B	M	Pk
		100m ²	Fodder block	Lsp+M									

Note: Maize varieties; (blocks) PAN6479. Bean varieties: PAN9292. Pumpkin varieties: Queensland Blue. Fodder: Lespedeza (Lsp) Pensicola (Pens), Maize PAN5a190

Comments: This season Ntombakhe did not maintain her fodder plot well. Lespedeza however still managed to germinate and grow despite high weed pressure.

Figure 17: Lespedeza growing among weeds in Ntombakhe's fodder plot



Ezibomvini

Zodwa Zikode

She planted the following trial plots:

Year	Date of planting	Size of trial	Trial type	Plot 1	2	3	4	5	6	7	8	9	10
2018/2019	21/11/2018	400m ²	block	M+C	M+C	M	B	M+B	M	SCC	LL	M+B	M+B
2019/2020	2019/11/12	1000m ²	block	LL	M+B	M+B	M+P	M+C	SCC	M	M	B	M
2020/2021	25/11/2020	1000m ²	block	M	M	B)	M	M+C	M)	M+B	M	M	LL
	Dec 2020	250m ²	block	M	Teff	M	Lsp						

Note: Maize varieties; (blocks) PAN53. Bean varieties: Gadra. Cover cops: sunflower, sun hemp, fodder sorghum. Fodder: Lespedeza (Lsp) Teff, Maize PAN5a190.

Comments: Zodwa harvested all the teff in her fodder plot and provided the fodder to her neighbour Phumelele Hlongwane for her cattle.

Mantombi Mabizela

She planted the following trials:

Year	Date of planting	Size of trial	Trial type	Plot 1	2	3	4	5	6	7	8	9	10
2018/2019	21/11/2018	400m ²	block	M	M+B	M	M+C						
2020/2021	19/11/2020	1000m ²	block	B	M	M	M+C	M	B	M+Pk	M	M	M+Pk
		250m ²	Seed block	Lsp	M	T	M						

Note: Maize varieties; (blocks) PAN53. Bean varieties: Gadra. Pumpkin varieties: Queensland Blue. Cover cops: sunflower, sun hemp, fodder sorghum. Fodder: Lespedeza (Lsp) turnip (T), Maize PAN5a190.

Comments: Mantombi's turnips did very well and was cut in April 2021 to feed her goats. Lespedeza has grown very slowly and will be kept for direct winter grazing as it had not developed enough biomass for cutting.

Figure 18: Right: Turnips in Mantombi's fodder plot which was harvested for goats; Far Right: Lespedeza growing, but suffering a bit from weed pressure



Landiwe Dlamini

She planted the following trial plots:

Year	Date of planting	Size of trial	Trial type	Plot 1	2	3	4	5	6	7	8	9	10
2018/2019	20/11/2018	400m2	block	M+B	M+C	M	LL						
2019/2020	21/11/2019	500m2	block	M+B	M	M+C	M	B					
2020/2021	24/11/2020	1000m2	block	M	M	M	M+Pk	M	LL	M	B	M	M+B
	Dec 2020	420m ² fenced	block	sunflower	sorghum	Sun hemp	Sunflower	Sorghum					

Note: Maize varieties; (blocks) PAN53. Bean varieties: Gadra. Pumpkin varieties: Queensland Blue. Cover cops: sunflower, sun hemp, fodder sorghum.

Comments: She has harvested her sunflower seeds (0,428 kg) and is still waiting for the sun hemp and sorghum to mature.

Figure 19: Landiwe's fenced plot with summer cover crops planted for seed production



Phumelele Hlongwane

She planted the following trial plots:

Year	Date of planting	Size of trial	Trial type	Plot 1	2	3	4	5	6	7	8	9	10
2018/2019	2018/07/11	1000m ²	block	SCC	M+C	M+C	M+B	M	LL	M	M+B	M+B	M+B
2019/2018	21/11/2019	1000m ²	block	M	M+B	M+B	M+C	LL	SCC	M+B	M+B	M+B	M
2020/2021	16/11/2020	1000 m ²	block	M+B	SCC	M	M+B	M	M	M+C	M+Pk	LL	M+B
	16/11/2020	1000m ²	Strip	M	B	M	SCC	M	Pk				
		100m ²	block	M PAN5A 190									
		250m ²	Seed block	M PAN5A 190	T, Luc	M PAN 6479	SCC						

Note: Maize varieties; blocks and strips PAN53. Bean varieties: Gadra. Pumpkin varieties: Queensland Blue. Cover cops (SCC): sunflower, sun hemp, fodder sorghum. Fodder turnips (T) and lucerne (Luc).

Comments: For Phumelele's 250 m² fenced plot for seed production she planted in 4 small blocks: PAN 5A190 (short season yellow maize), fodder turnips and lucerne, PAN6479 (left of hybrid maize seed from last year) and SCC mix. She was not aware that one should plant the hybrid maize for keeping the seed. This seed will be used for poultry fodder as an alternative. The fodder species, turnips and lucerne did not germinate or grow well. As with other participants, she has already harvested the sunflower seed but is still waiting for the sun hemp and sorghum to mature.



Figure 20: Right: Phumelele's strip cropping trial showing maize, cowpeas and SCC; Far Right: Her 250 m² fenced plot for cover crops seed production with sun hemp visible in the picture

Bergville bean yield summary and photos.

Compiled by Nkanyiso Mzobe

Bean yields were measured for 59 participants across 7 villages (Ezibomvini, Eqeleni, Stulwane, Ndunwana, Vimbukhalo, Emafefeteni and Thamela), for both the 10x10 CA intercropped plots and the strip cropping plots. Figure 21 provide a summary of the yield results.

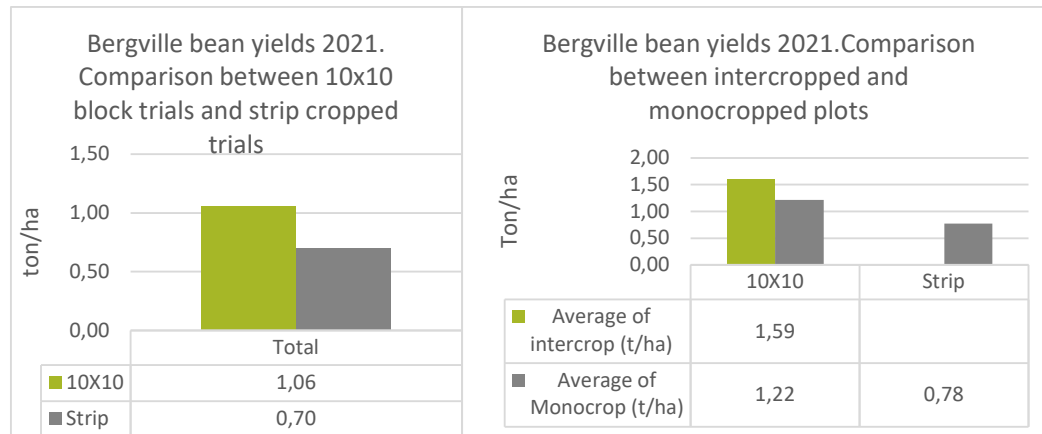


Figure 21: Left: Comparison of block and strip planting bean yields; Right: Comparison of intercropped and monocropped bean yields

The average yield for beans in Bergville was 0,88t/ha, which is low. Yield reduction was primarily due to heavy rains late in the season (March and April 2021), which led to a lot of water damage in the drying beans and a reduction in yields. Participants were sure that the intercropping had exacerbated this problem due to close spacing and shading from the maize intercrops. From Figure 21 (right), it can however be seen that the average yield of intercropped beans was 1,59t/ha compared to 1,22t/ha for the single cropped blocks and 0,78t/ha for the single cropped strip planting. Reasons for this difference are likely to be higher weed pressure in the strip plantings and also differences in inter-row spacing.

From Figure 21 (left) it can be seen also that the average yield for beans planted in the 10x10 blocks was higher than that of beans planted in the 4x25 m strips.

In summary, beans intercropped with maize in the CA trials produce higher yields than the monocropped beans, despite participants continued belief that this is not the case. Participants are also still reluctant to follow the close spacing regimes, insisting that it is easier to weed when crops are more widely spaced, but not considering that this concurrently increases the weed pressure.

Figure 22 shows a few indicative photographs of bean weighing and yields for participants.



Figure 22: Left to Right: Phumelele Hlongwane (Ezibomvini), Bhukisile Mpulo (Vimbukhalo) and Lindiwe Bhengu (Thamela) with their bean harvests for 2021

MIDLANDS

Compiled by Temakholo Mathebula

For the Maiyekanye villages (x4) in Swaiymane, participants generally plant a lot later than in most of the other areas, opting to plant in mid- to end-January, rather than November, necessitating a later monitoring date in March 2021.

Background on Mayizekanye Farmers

The community of Mayizekanye derives a significant part of their income from various farming activities, over and above small government social and pension grants, as well as to a much lesser degree, remittances from young adults employed in the city. Their farming activities include but are not limited to maize, beans, sugar cane, amadumbe, sweet potatoes, avocados, poultry (mainly traditional chickens) and livestock farming. Most grow both for market and to supplement household income and the majority of the participants working with MDF are between the ages of 40 and 70 years old and are mostly unemployed women. Many households in the village are female-headed mainly due to husbands passing away, migrating to the city to work, men spending the majority of their time in local taverns and other undisclosed reasons.

Overview of the 2020/21 growing season

This season the team introduced larger CA trials, in the form of 1 000 m² 10x10 plots and 1 000 m² CA strips as well, which is more than double the standard 400 m² CA trial size introduced in the area in the past. Thirty-five (35) participants were involved, with a substantial group of new participants. The focus, however, has been on the CMTs for the longer-term participants. Crop growth monitoring was carried out during March 2021 and all participants were monitored. The nine longer-term participants (Mrs Nxusa, Babhekile Nene, Nakeni Ngubane, Fikile

Maphumulo, Fikelephi Maphumulo, Florence Cebekhulu, Thembi Mkhize, Lungile Madlala, Ntombi Shandu and Mavis Shezi) planted in line with CA principles. Below are a few snapshots of the CA experimentation.

CA strips

This season a new CA design was introduced which is planting in strips as an alternative to or in conjunction with 10x10 plots, depending on the farmer. It was explained that the strips would be 1 000 m² in size and would include both monocrop and intercrop plots. The following farmers planted CA strips:

Dumazile and Thembani Nxusa

Dumazile and Thembani Nxusa planted a 2 000 m² strip in November 2020 using the two-row tractor-drawn planter, which included maize, maize and summer cover crops as well as a maize and bean intercrop. They also planted a control plot next to the trial, which was ploughed and planted under a maize monocrop. In terms of growth and cob sizes, there wasn't a significant difference between the two fields, except that the trial plots seemed to have a higher percentage of weeds. This was in part due to the farmers accidentally killing off their beans by using a broadleaf herbicide during the season – a practice not promoted by the MDF team. This also meant the sunflowers did not grow in their SCC plot.

There were also gaps in the maize plantings, due to damage by crows. Normally maize seed is treated with Lavine to prevent crows from eating it, but this was not undertaken this season.



M
M+ SCC
M
M+B

Figure 23: A view of the strip cropped CA trial with sun hemp, sorghum visible on the left and maize (SC701) on the right; the layout of their strip cropping trial

Fikelephi Maphumulo

She planted a 1 000 m² strip cropping trial of maize, beans and summer cover crops, with no intercropped plot. She decided not to plough her field this season and thus her control plot is a CA monocrop plot.

Her reason for not ploughing was that since she started to incorporate CA principles, she noticed over time that the erosion was much less on her CA plot than on the conventional plot. Also, the crop yields from the conventional plots seemed to be declining with each season, and there were often large patches in between the maize. Her other challenge is that her field is on a steep slope and thus erosion and runoff have been a major challenge over the years. Lungile Madlala and Nomusa Shandu, also have fields situated on a steep slope and thus have significant challenges with soil erosion.



Figure 24: Fikile's Maize control plot and her SCC strip showing the fodder sorghum in the seed

Lungile Madlala

She planted a 400 m² strip cropping CA trial (SCC, M+B and M). In general, growth was good, except for weed competition in the SCC plot. Growth was somewhat patchy, again due to damage by crows.



Figure 25: Lungile's Strip cropping trial, planted on contour across the steep slope of her field and growing well

Mavis Shezi

Mavis Shezi is a 67-year-old pensioner and very active farmer who resides with her husband. She started planting CA trials in 2019 but had been attending meetings and farmers days prior out of interest. Last season she planted a 400 m² plot of maize and beans and cowpeas and planted short season maize. This season she planted a long strip of 10 (10x5 m) plots of M+B and M+SCC. She has had challenges with stalk borer for which she sprayed with Decis forte (Cypermethrin), which worked well. Stalk borer infestation of her adjacent control plot, however, remained high. Overall germination was very good and her crops were growing vigorously, despite patchy germination in portions of the strips



Figure 26: Above Left: A strip of M+B where germination was patchy, here looking to be due to localised soil quality issues, Above Centre: A strip of SCC growing very well and Above right: A view of Mrs Shezi's top half of her field which is very steep

CA block trials (10x10 m plots)

Babhekile Nene

Mrs Nene used the following layout:

Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10
M+B	M	B	SCC	M	M+B	M	B	M	SCC

The growth in different plots was quite dissimilar with some being patchy, some growing well and one of the SCC plots and one of the bean monocropped plots showing almost 0% germination. This is in part due to expanding to a 1 000 m² from her smaller plots and now incorporating plots that had previously been unused or planted with potatoes. Improved planting and crop management would solve these issues.



Figure 27: In the foreground is a highly weed-infested plot, where SCC did not germinate or was outcompeted; and in the background, maize and bean intercropped plot, showing reasonable growth

Ntombi Shandu

Ntombi Shandu has been one of our most consistent and enthusiastic farmers and has been part of the programme since 2018. She also planted a block CA trial with the following layout:

Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10
M+B	M	B	SCC	M	B	M+B	M	M+B	M

She also had the issue that in the expansion of her plot, she used the higher patches in her field, which had been left fallow due to lack of productivity in the last few years. The germination in this section was patchy and growth was moderate only. She planted winter cover crops in the spaces where the maize did not germinate.



Figure 28: Above Left: Winter cover crops maturing in a section of the field where the maize and beans did not germinate well; Above Centre: Poor germination higher up in Mrs Shandu's field; Above Right: A close-up view of the winter cover crops growing in between maize in a plot with patchy germination

Nakeni Ngubane

She is also one of the most consistent farmers who is in her third season of planting under CA. She decided to stick to the normal 400 m² plot, possibly due to the limited area around her household, as she uses the bottom section to plant other crops such as amadumbe, beans and vegetables. She planted two maize and bean intercrop plots and a separate plot of the summer cover crop mix and winter cover crops.



Figure 29: Above Left: A block of SCC with sunflowers dominating the mix; Above Centre: A M+B intercropped plot – maize is a bit patchy and yellowing; Above Right: A plot of winter cover crops growing well

Yield measurements: Introduction

This season was impacted quite heavily by COVID-19 for the Midlands, which is closer to larger cities and centres and saw much higher levels of infection than the other areas of implementation. Three participating farmers passed away and several others became ill. Despite the emotional and economic burden, most farmers participated well and the area saw a significant increase in the planting of cover crops.

Good rains in September and October meant that farmers could plant much earlier in the season than in past years and also impacted bean production positively. Following is a case study for Gobizembe which indicates CA production this season.

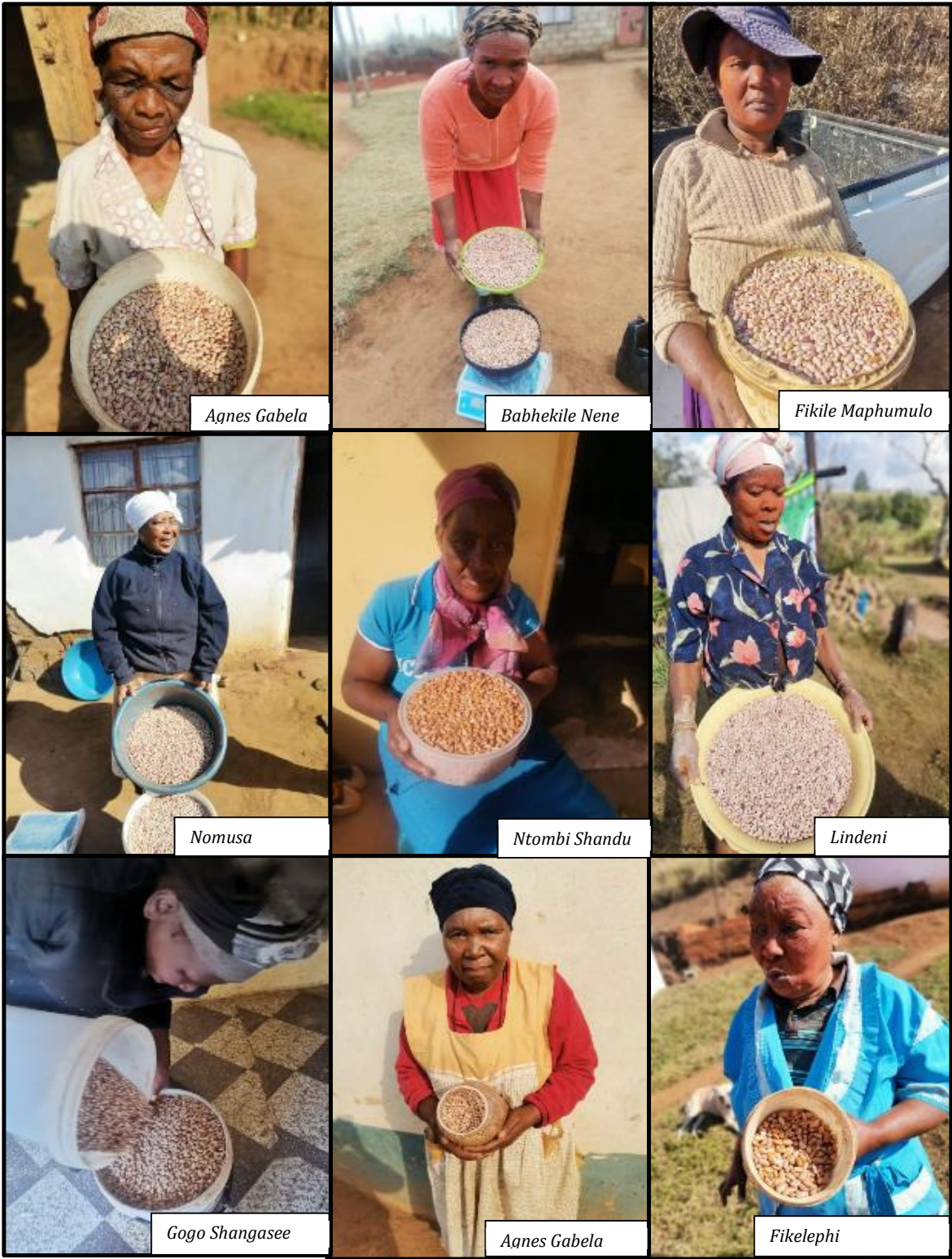
Bean and CC yields

Higher humidity caused some difficulties for farmers in harvesting and caused substantial rotting, both in intercropped and monocropped bean plots. One farmer attempted trellising the beans, but this had no significant impact on the yields. Bean yields were quite low, as can be seen in Table 23. Very few participants managed to harvest seed from cover crops, these being highly predated by both birds and buck in the area.

Table 23: Bean and CC yields for participants in Gobizembe 2021/21

GOBIZEMBE BEAN YIELDS (2020/21)			CA Trial Bean Yield (from all plots)				SCC		
Name	Surname	Experiment	Area (m2)	weight (kg)	t	t/ha	Crop name	weight (kg)	t/ha
Ntombiyomuntu	Ngobese	10x10	240	10,235	0,010	0,426			
Janet Ntombencane	Gasa	10x10	200	9	0,009	0,450	Sorghum , mung beans	9 and 1,2	0,9 and 0,1
Elijah	Ntuli	600m2	160	0	0,000	0,000	Sorghum	22,9	1,43
Khanyisile	Xasibe	400m2	160	2,5	0,003	0,156			
Zwelinjani	Zuma	400m2	200	5	0,005	0,250	Sunflower	1,3	0,13
Khombisile	Mncanya	strips	200	14,15	0,014	0,708			
		400m2	160	15,523	0,016	0,970			
Nelie	Ngcobo	100m2	50	5	0,005	1,000			
Simephi	Choncho		200	5	0,005	0,250			
TOTAL						0,468			

The following pictures provide a snapshot of weighing for several participants in the Midlands.



Maize weighing

One interesting case, for Rita Ngobese (Gobizembe) where maize yields were separated by CA plots for M only, M+B and M+SCC showed visible differences in the maize cob size and maize yields for those plots.



Figure 30: Above Left to Right: Rita Ngobese's 10x10 trial maize separated for different plot types, shows bigger and better filled cobs for M+B intercrops, than maize only and M+SCC, respectively. For the latter, the cobs were much smaller and incompletely filled, indicating some competition between maize and the SCC later in the season. This effect has been noted previously in Bergville as well.

In Gobizembe, the overall performance of maize in this season's CA trials was very poor, as most farmers either got stunted and deformed cobs or cobs went rotten while in storage. The maize this year seemingly had a very high percentage of mycotoxins, as most of the maize in storage had fungal growths barely a month after it was harvested and left to dry. The following photos are indicative. Mycotoxin samples have again been sent to the ARC for analysis.



Zwelinjani Zuma



Rita Ngobese



Ntombencane Gasa



Elijah Ntuli



Southern KZN

SKZN bean yield summary and photographs

Beans are produced in both the block and strip cropping trial options either as single crops or as intercroops with maize. Bean yields are generally not separated per plot by participants and thus the bean yields recorded are the overall values for their CA experiments. In general, bean yields have remained low for the entire experimentation period. Yield calculations take into account whether beans were monocropped or intercropped.

Bean yields have been collected in Ngongonini, Springvalley, Madzikane, Plainhill, Nkoneni and Ofafa. Figure 31 provides a summary of yields in each area. The average yield for SKZN was 1,16 ton/ha.

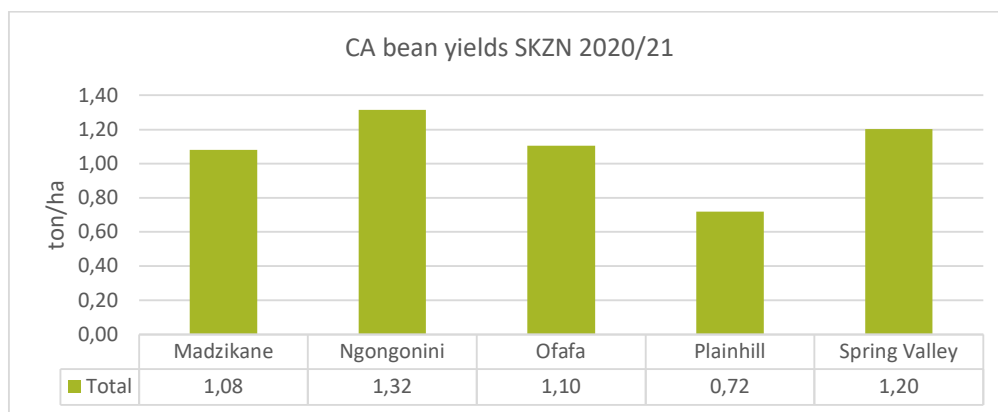


Figure 31: CA trial bean yields for 30 participants in SKZN

Bean yields this season were average to low, following a similar trend to previous years, but for different reasons. This season heavy rains towards the end of the season damaged bean harvests due to water damage and rotting of the pods and seeds.



Figure 32: Above Left: Leonard Gamede (Ngongonini), with his bean harvest, and Above Right: Bonginhlanhla Dlamini from Spring Valley planted a late plot of beans, photographed here in May 2021, which showed promise of providing a good yield

Cover crops in SKZN

Very few farmers this season opted to plant cover crops. In SKZN grazing is not as limited as in the other two areas and farmers are determined to focus solely on food crops in their farming.

Mthandeni Phungula (Spring Valley)

He was the only participant in SKZN to plant SCC. He intercropped the SCC with maize in one of his plots. He planted millet and sunflower but lost his sunflower seed harvest to bird damage. His millet yielded 18,2 kg for the 100 m² intercrop.

He will be using the millet with fermented maize for the brewing of traditional beer.



Figure 33: Phungula's millet harvest, maize seed kept for next season, pumpkins from the intercrop and maize soaked for imithombo (traditional beer)

6.2 Maize yield considerations

Yield measurements were undertaken for both the CA trial options where maize was either planted as a single crop or as an intercrop with beans and cowpeas (M, M+B and M+C) and CA control (maize only in consecutive years) plots. These trial options are the CMTs planted either in the 10x10 m block designs of 1 000 m² or in the 1 000 m² strip cropping trials.

For maize, the cob and grain weight for each participant was averaged before a count of the number of cobs per 50 kg bag and then a count of the number of bags per plot, to estimate the yields.

Bergville maize yields

In Bergville, yields for maize in the CA trial and control plots were calculated for a selection of participants ($n = 28$) who had CMTs. Yields were measured for 11 participants in Ezibomvini, 7 participants in Stulwane and 5 participants in Eqeleni and Vimbukhalo, respectively.

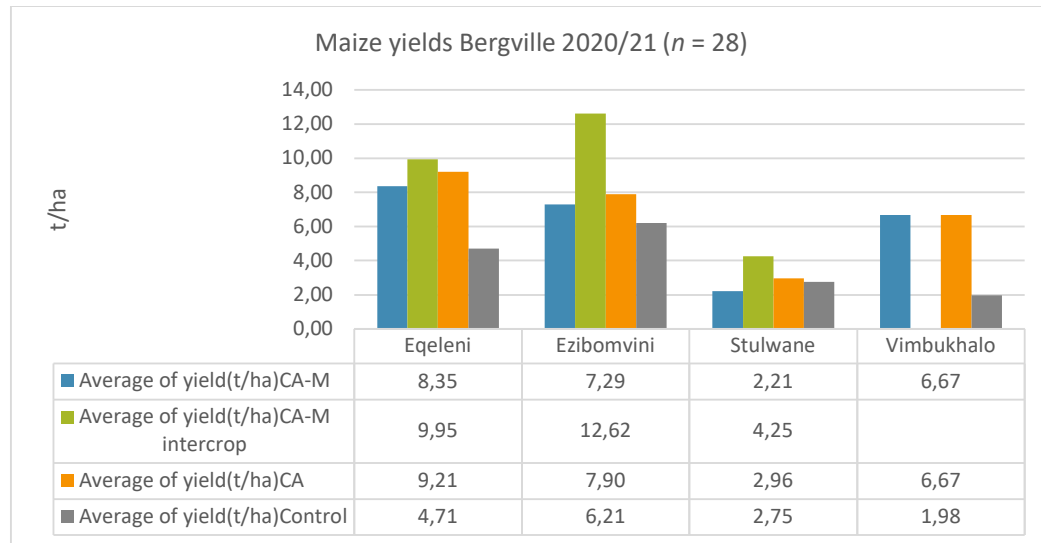


Figure 34: Maize yields for CA trial and control plots for Bergville, 2020/21

From Figure 34, the maize yields from the CA trial plots are all higher and, in some cases, (Eqeleni and Vimbukhalo), substantially higher than the maize yields for the CA control plots. The difference in treatments between CA trial plots and CA control plots is that the latter have been planted to maize only throughout.

It is interesting to also note that the maize yields in the CA intercropped plots (here a combination of M+B, M+C and M+Pk (Pumpkin) plots) are significantly higher than the maize yields in CA monocropped plots.

Here the results indicate the potential for incremental improvement in maize yields using the multicropping CA system, as opposed to a CA monocropping system where the yields remained similar across six years of CA implementation.

Yields for the generic hybrid maize varieties PAN 6479 and PAN53 were comparable to the short season variety (PAN5A190) planted later in the season in both Stulwane and Ezibomvini at 2,2 t/ha and 6,3 t/ha, respectively. As in previous years, the favourable yield comparisons indicate the planting of short-season maize later in the season (January vs November) in years with late-onset rains and higher late-season rainfall values as a good adaptive strategy to compensate for changing weather patterns.

Table 24: Average yields for maize and beans in CA trial plots; Bergville (2014–2020)

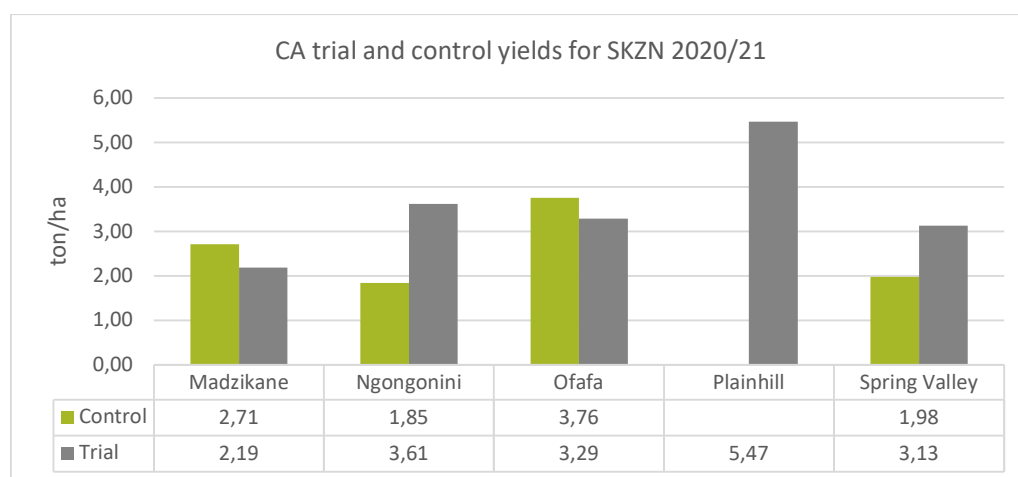
Maize and bean yields (CA trial plots)	Bergville						
Season	2014	2015	2016	2017	2018	2019	2020
No. of villages	9	11	17	18	19	18	4
No. of trial participants	83	73	212	259	207	225	28
Area planted (trials) (ha)	7,2	5,9	13,5	17,4	15,2	13,9	3,5
Average yield maize (t/ha)	3,63	4,12	5,03	5,7	3,4	3,6	6,3
Min. and max. maize yield (t/ha)	1-6,7	0,6-7,4	0,3-11,7	0,5-12,2	0,1-8,5	0,5-12,8	1,6-14,8
Average trial quantity of maize (kg)	576	654	487	206	113	261	390
Rand replacement value of maizemeal	R3 312	R4 120	R4 900	R2 350	R994	R1 850	R3 120
WP for CA multicropping maize (kg/m³)					2,4	1,25	2,94
WP for CA mono-culture maize (kg/m³)					1,6	0,8	1,06
Average yield of beans (t/ha)	0,26	0,79	1,05	1,22	0,56	1	0,88

Owing to climate variability (late-onset rains and rainfall variability in season), the initial gains in average maize yields under CA implementation from 3,6 t/ha to 5,7 t/ha on average between 2014 and 2017 could not be maintained into 2018 and 2019, but good average yields were again attained in the 2020 season, which had high rainfall later in the season, despite the late onset of rains. Maximum yields obtained by individual smallholders have, however, increased from 6,7 t/ha to 14,8 t/ha in that time, indicating that for high-performing smallholder farmers a yield gain of around 1 t/ha per annum is possible under CA cropping systems despite difficult climatic conditions. During this period, average maize control plot yields did not increase but remained stable at between 2,5 t/ha to 3,9 t/ha.

SKZN maize yields

Maize was weighed for 37 participants across five villages in SKZN, weighing CA trial maize and CA control maize for each participant.

Figure 35 indicates the average yields of maize per village.

**Figure 35: Maize yields for CA trial and control plots in SKZN 2020/21**

In this region, the large majority of control plots were also CA plots but planted to monocropped maize only in consecutive years. Maize yields for the CA trial plots were higher than the CA control plots in Ngongonini and Spring Valley, but not in the other three villages where yields were measured. For Madzikane and Ofafa the yields between the trial and control were very similar. Overall, the CA trial maize yield was higher at 3,4 t/ha than the CA control plot yield at 3,0 t/ha.

In SKZN participants have been slow to take up the multicropping options and also slow to rotate their intercropped plots. The yields of the CA trial plots are thus comparable to CA monocropped plots in this region.

A comparison of yields has been made for the period between 2014–2020/21.

Table 25: Average yields for maize and beans in CA trial plots: SKZN 2014–2020/21

Maize and bean yields (CA trial plots)	SKZN						
Season	2014	2015	2016	2017	2018	2019	2020
No. of villages	10	8	8	13	13	11	5
No. of trial participants	16	43	54	93	75	93	37
Area planted (trials) (ha)	0,3	0,37	1,18	3,58	4	3,72	1,25
Average yield maize (t/ha)	0,7	1,37	2,52	2,17	2,6	3,4	3,4
Min. and max. maize yield (t/ha)	0,3-1,8	0,5-4,4	1,1-5,2	0,2-6,7	0,2-6,9	0,3-9,6	0,5-10,2
Average trial quantity of maize (kg)	64	125	161	66	97	78	110,5
Rand replacement value of maizemeal	R500	R1 000	R1 700	R752	R854	R553	R884
WP for CA multi-cropping maize (kg/m³)						1,73	2,3
WP for CA mono-culture maize (kg/m³)						0,9	1,3
Average yield of beans (t/ha)	1,26	0,34	0,69	1,28	0,35	0,6	1,16

From Table 25, it can be seen that the average maize yield for 2020/21 is the same as the yield in the previous season. As with Bergville, the trend in the increase in maximum yields for each season is similar in SKZN where these have increased from 1,8 t/ha to 10,2 t/ha in the observation period, indicating that for high-performing smallholder farmers an average yield gain of around 1 t/ha per annum is possible under CA cropping systems despite difficult climatic conditions.

Midlands maize yields

Here yields were compiled for different CA experimental protocols (10x10 blocks, strips and control plots) for 50 participants from the 9 villages participating in the research process.

Figure 36 indicates the average yields.

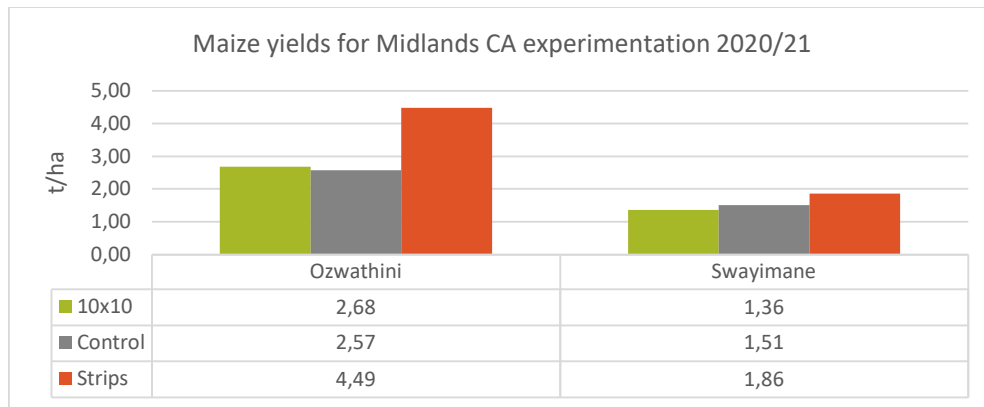


Figure 36: Average yields for CA experimentation in the Midlands

In this region, the large majority of control plots were also CA plots but planted to monocropped maize only in consecutive years, with different interrow spacing and fertilisation regimes to the CA trial plots. Here yields for the strip cropping CA multicropping trials are higher than the CA monocropped maize control plots and the 10x10 block trial plots. Average yields overall in Midlands for the CA trials is 2,6 t/ha and for the CA controls is 2,0 t/ha.

In the Midlands, there is a slight yield advantage shown for strip cropping in CA versus the 10x10 blocks trials that have been used to date. Yields for the CA multicropped and rotated plots are higher than the CA monocropped plots (controls).

Farmers in this area sell green maize to traders from the larger city centres in the vicinity and then keep some maize for drying and milling.

Incomes made from sales for green maize are shown in Table 26.

Table 26: Incomes from green maize for the Midlands villages for 2020/21

Village name	Income from Green Maize	Total income/area	Average income/area	Average Income/m ²
Ozwathini				
Gobinsimbi	R1 890,00			
Hlathikhulu	R1 200,00			
Mbalenhle	R1 650,00			
Mkhakhasini	R2 700,00			
Swidi	R7 620,00	R15 060,00	R 1 225,00	R3,84
Swayimane				
Gobizembe	R1 800,00			
Mayizekanye 1	R17 965,00			
Mayizekanye 2	R5 237,00			
Mayizekanye 3	R59 807,00	R84 809,00	R 2 827,00	R7,40
Grand Total	R99 869,00			

The maize yields for Ozwathini villages were almost double those in Swayimane, explaining the average income/m² for these two areas at R7,40 and R3,84, respectively. The average income per

participant is around R2 000 from an average area of around 300 m² of maize. This would equate to an income of around R66 600/ha. 80% of participants have sold some of their maize and actual incomes ranged from as little as R120 (400 m²) to a maximum of R39 550 (2 700 m²).

This is a significantly higher income potential than selling dry maize per ton, which would equate to around R10 400 for the 2,6 t/ha average for these farmers.

Yields have been compared for the 2017–2020 planting season in the Midlands in Table 27.

Table 27: CA trial yield comparisons for the Midlands for 2017–2020

Maize and bean yield for CA trial plots	Midlands			
Season	2017	2018	2019	2020
No of villages	4	9	14	9
No of trial participants	42	70	164	87
Area planted (trials) - ha	1,36	3,1	4,2	4,3
Average yield CA maize (t/ha)	2,04	1,43	1,35	2,6
Min and max yield maize (t/ha)	0,4-7,1	0,3-4,6	0,5-6,3	0,3-5,8
Average trial quantity of maize (kg)	87	65	118	160
Rand value (maizemeal)	R992	R572	R836	R1 280
Average yield beans (t/ha)	0,62	0,87	0,78	1,1

From Table 27, it can be seen that the average maize yield for 2020/21 is slightly higher than the yields in previous seasons. In this region, there have been no yield gains, but only a yield stabilisation for the CA plots. CA yields for the multicropping options (intercropping and crop rotation) are around 23% higher than consecutively monocropped maize.

7 Issues and recommendations

1. Despite the difficulties and inefficiencies resultant from the COVID-10 pandemic, most smallholder farmers in the programme continued with their farmer-led trials and worked well with MDF staff to plan and monitor the CMTs.
2. For the SKZN and Midlands areas, it will be important to be somewhat more directive in terms of implementation of the trials, to be able to increase the multicropping and cover crop planting in these areas, so that the experimentation can be comparable to that in the Bergville region.
3. Smallholder farmers in SKZN have not shown immediate interest in fodder production and winter supplementation for livestock as a way of integrating livestock into their CA systems. MDF will consider finding at least one farmer in each area to undertake this process and demonstrate the impacts to the rest of the CA learning groups in the coming season.
4. MDF is in the process of scouting for funding to ensure fencing of the CA plots, as unfenced fields are a major drawback restricting participants from meaningful contributions, both in terms of cropping and soil cover. The Okhahlamba LM have agreed to assist in the Bergville area for 30 participants.
5. Collaboration with NWU and the ARC have provided valuable insights into soil health, nematode population balances and mycotoxins and will be continued into the future.

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APPENDIX 1: SAGL TEST REPORT NO (20/21) 27

SEASON: 2020/2021

DATE OF RECEIPT: 2020/10/07

ORIGIN: ARC - Agricultural Research Council - Grain Crops

SENDER: Belinda Janse van Rensburg

ORDER NUMBER: PSO-021485-1

PRODUCT: Maize

LAB. NO.:	SENDE R'S CODE:	Multi-Mycotoxin (In-House Method 26 (UPLC-MS/MS))																							
											Aflatoxin ppb (µg/kg)			Fumonisin ppb (µg/kg)			Deoxyniv a- lenol (DON) ppb (µg/kg)	15- Acetyl -DON ppb (µg/k g)	Ochra- toxin A ppb (µg/kg)	Zearale- none ppb (µg/kg)	T2 ppb (µg/kg)	HT-2 ppb (µg/k g)	Diplodi a- toxin ppb (µg/kg)		
											B ₁	B ₂	G ₁	G ₂	Tot al	B ₁								B ₂	B ₃
Limit of quantitation (µg/kg)											5	5	5	5	-	20	20	20	100	100	5	20	20	20	50
ARC code		Farmer information			Production system / rotation 2020/21			Ear rot rating (%)																	
(20/21) / 27 / 112	30	Babhekele Nene (Mayizekane)			Monoculture maize			1			ND	ND	ND	ND	-	ND	ND	ND	ND	ND	354	ND	ND	80	
(20/21) / 27 / 114	31	Fikile Maphumolo (Mayizekane)						3			ND	ND	ND	ND	-	ND	ND	ND	ND	ND	976	ND	ND	ND	

(20/21) / 27 / 115	32	Simephi Hlatswhayo (Stulwane)	Monoculture maize (plot 6)	0	N D	N D	N D	N D	-	ND	ND	ND	798	208	ND	144	ND	ND	ND
(20/21) / 27 / 116	33	Neliswe Msele (Stulwane)	Maize-cowpea (plot 2)	0	N D	N D	N D	N D	-	ND	ND	ND	ND	ND	ND	29	ND	ND	ND
(20/21) / 27 / 117	34	Simephi Hlatswhayo (Eqeleni)	Maize (plot 4)	0	N D	N D	N D	N D	-	ND	ND	ND	240	<LOQ	ND	ND	ND	ND	ND
(20/21) / 27 / 118	35	Neliswe Msele (Stulwane)	Maize (plot 10)	0	N D	N D	N D	N D	-	ND	ND	ND	400	<LOQ	ND	134	ND	ND	ND
(20/21) / 27 / 119	36	Neliswe Msele (Stulwane)	Maize (plot 4)	0	N D	N D	N D	N D	-	ND	ND	ND	444	180	ND	78	ND	ND	ND
(20/21) / 27 / 120	37	Nomusa Shandu (Mayizekane)	Maize-cowpea	14	N D	N D	N D	N D	-	ND	ND	ND	ND	ND	ND	587	1409	1446	ND
(20/21) / 27 / 121	38	Neliswe Msele (Stulwane)	Maize (plot 8)	0	N D	N D	N D	N D	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
(20/21) / 27 / 122	39	Neliswe Msele (Stulwane)	Maize (plot 6)	0	N D	N D	N D	N D	-	466	92	57	1665	223	ND	49	ND	ND	ND
(20/21) / 27 / 123	40	Simephi Hlatswhayo (Eqeleni)	Maize (plot 8)	0	N D	N D	N D	N D	-	ND	ND	ND	530	168	ND	<LOQ	ND	ND	ND
(20/21) / 27 / 124	41	Fikile Maphumolo (Mayizekane)	Monoculture maize (ploughed) (plot 3)	30	N D	N D	N D	N D	-	1826	127	313	ND	ND	ND	21	ND	ND	ND
(20/21) / 27 / 125	42	Simephi Hlatswhayo (Eqeleni)	Maize monoculture (plot 2)	1	N D	N D	N D	N D	-	ND	ND	ND	613	144	ND	105	ND	ND	ND

(20/21) / 27 / 126	43	Phumelele Hlongwane (Ezibomvini)	Maize (plot 10)	0	N D	N D	N D	N D	-	104	53	ND	420	114	ND	<LOQ	ND	ND	ND
(20/21) / 27 / 127	44	Phumelele Hlongwane (Ezibomvini)	Maize-Beans (plot 3)	0	N D	N D	N D	N D	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
(20/21) / 27 / 128	45	SKZN Madzikane	Pooled maize from different plots	0	N D	N D	N D	N D	-	ND	ND	ND	2050	316	ND	53	ND	ND	ND
(20/21) / 27 / 129	46	Babhekele Nene (Mayizekane)	Maize-Beans	5	N D	N D	N D	N D	-	556	111	85	ND	ND	ND	85	ND	ND	ND
(20/21) / 27 / 130	47	Nomusa Shandu (Mayizekane)	Monoculture maize	12	N D	N D	N D	N D	-	4719	1233	944	ND	ND	ND	63	ND	ND	ND
(20/21) / 27 / 131	48	SKZN Madzikane	Monoculture maize	4	N D	N D	N D	N D	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
(20/21) / 27 / 132	49	Phumelele Hlongwane (Ezibomvini)	Maize-Beans (plot 2)	0	N D	N D	N D	N D	-	424	106	65	373	127	ND	ND	ND	ND	ND
(20/21) / 27 / 133	50	Sibongile Mpulo (Vimbukhalo)	Maize (plot 4)	0	N D	N D	N D	N D	-	ND	ND	ND	ND	ND	ND	27	ND	ND	ND
(20/21) / 27 / 134	51	Letta Ngubo (SKZN Springvalley)	Maize-beans	0	N D	N D	N D	N D	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
(20/21) / 27 / 135	52	Sibongile Mpulo (Vimbukhalo)	Maize (plot 1)	0	N D	N D	N D	N D	-	23	ND	ND	ND	ND	ND	ND	ND	ND	ND
(20/21) / 27 / 136	53	Phumelele Hlongwane (Ezibomvini)	Maize-Beans (plot 8)	0	N D	N D	N D	N D	-	116	27	ND	<LOQ	ND	ND	ND	ND	ND	ND

(20/21) / 27 / 137	54	Zweni Ndaba (Emabunzini)	Maize-Beans (plot 1)	0	N D	N D	N D	N D	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
(20/21) / 27 / 138	55	Babhekele Nene (Mayizekane)	Maize-Cowpea	25	N D	N D	N D	N D	-	539	174	88	ND	ND	ND	4294	ND	ND	ND
(20/21) / 27 / 139	56	Nomusa Shandu (Mayizekane)	Maize-Beans	0	N D	N D	N D	N D	-	69	36	ND	849	105	ND	29	ND	ND	ND
(20/21) / 27 / 140	57	Phumelele Hlongwane (Ezibomvini)	Maize (plot 1)	1	N D	N D	N D	N D	-	157	77	ND	1950	177	ND	30	ND	ND	ND
(20/21) / 27 / 141	58	Phumelele Hlongwane (Ezibomvini)	Maize-Beans (plot 7)	0	N D	N D	N D	N D	-	ND	ND	ND	379	121	ND	ND	ND	ND	ND
(20/21) / 27 / 142	59	Lethiwe Zimba (Ndunwana)	Maize-cowpea	0	N D	N D	N D	N D	-	ND	ND	ND	ND	ND	ND	56	ND	ND	ND
(20/21) / 27 / 143	60	Sibongile Mpulo (Vimbukhalo)	Maize (plot 10)	0	N D	N D	N D	N D	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
(20/21) / 27 / 144	61	Sibongile Mpulo (Vimbukhalo)	Maize-Cowpea (plot 6)	0	N D	N D	N D	N D	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
(20/21) / 27 / 145	62	Phumelele Hlongwane (Ezibomvini)	Maize-CC (plot 4)	0	N D	N D	N D	N D	-	183	57	<LO Q	1418	518	ND	107	ND	ND	ND
(20/21) / 27 / 146	63	Sibongile Mpulo (Vimbukhalo)	Maize-Beans (plot 9)	0	N D	N D	N D	N D	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
(20/21) / 27 / 147	64	Letta Ngubo (SKZN Springvalley)	Monoculture maize	0	N D	N D	N D	N D	-	81	<LO Q	ND	ND	ND	ND	ND	ND	ND	ND

(20/21) / 27 / 148	65	Phumelele Hlongwane (Ezibomvini)	Maize-Beans	0	N D	N D	N D	N D	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
(20/21) / 27 / 149	66	Sibongile Mpulo (Vimbukhalo)	Maize-Beans	0	N D	N D	N D	N D	-	ND	ND	ND	399	<LOQ	ND	ND	ND	ND	ND

