APPENDIX 3:
MPUMALANGA HIGHVELD ANNUAL PROGRESS REPORT

Participatory systems research on Conservation Agriculture in the Mpumalanga Highveld region

September 2021

ANNUAL PROGRESS REPORT

PARTICIPATORY SYSTEMS RESEARCH ON CONSERVATION AGRICULTURE IN THE MPUMALANGA HIGHVELD

For the period:

October 2020 to September 2021

Compiled by:

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ASSET Research

In collaboration with:

Mpumalanga CA Network

Funded by and submitted to:

The Maize Trust

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EXECUTIVE SUMMARY

Participatory systems research on Conservation Agriculture in the Mpumalanga Highveld region.

Annual Progress Report for the period October 2020 to September 2021
Compiled by:
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This study is done in collaboration with the Mpumalanga Highveld study group. The project is executed, administrated and monitored by ASSET Research.

The Mpumalanga Highveld Conservation Agriculture (CA) project, which is funded by The Maize Trust and coordinated by Asset Research, has been successfully implemented for the first year (2020-2021). The Mpumalanga Highveld CA project comprises of three statistical trials, or Mother Trials (MT's), where two are located in the Kinross/ Evander area (implemented by Nicol de Vos & sons) and the other one at Standerton (implemented by Hendrik Odendaal). The season's rainfall was 807 mm and 633mm at Kinross and Standerton respectively. The trial at Standerton was planted late as commercial crop planting prevailed after early spring rains. By the time the research plots were to be planted, it was too wet on the soils with a high clay content of 41%. The trials are a comparative assessment between conventional tillage systems (CT), high input cash crop CA (CA) and an ideal, best practice CA, or regenerative agricultural (RA) system. This RA is designed on lessons learned from previous MT-funded projects and other (inter)national crop production systems, which include management aspects like no-till planting, reducing levels of synthetic inputs, the inclusion of cover crops, and livestock integration. The comparative assessment between the systems is measured by profitability, soil ecosystem health and quality and quantity of production of the plants or grain.

Various indicators were selected to measure and monitor the impact of different trial treatments. The profitability of any crop is a function of the commodity price, yield and costs. Profitability changes when there is a variation of any of these three factors. Profitability assessments include various sources of income (cash crops, crop residue grazing, cover crop grazing), and levels of inputs and expenditure. The indicator of soil ecosystem health includes various soil health lab analyses from the Haney soil health test as analysed by Ward laboratory through the Soil Health Support Centre in the Western Cape and additional measurements by the North West University (NWU). The quality of the crops is measured by the Hectolitre mass of both maize- and soya bean grain at harvesting and the Brix plant readings during the active stages of the growing season (January-March). The quality of the crops is measured to compile baseline data for additional research on food nutrition density. Production (crop quantity or productivity) of the different treatments are measured through grain and biomass (dry matter) measurements.

The CA and CT production systems include a maize and soya bean crop rotation. The RA system includes maize-soya cash crops rotated with annual summer and winter cover crops and livestock integration.

The results are related to (1) profitability, (2) soil ecosystem health and (3) quality of plant or grain. These results with sub-categories are discussed in this report.

The profitability of maize and soya cash crops was highest at Onverwacht and New Farm due to maize and soya yields 141-167% above long-term farm average yields. The seasonal rainfall of 807 mm (measured from August to July) was 130% higher this season than long term average seasonal rainfall (620 mm). The rainfall distribution was good this season with good rains in spring resulting in early-in-the-season planting making optimal use of heat units through the season. Maize yields were 11-12.5 t ha^{-1} at Onverwacht and 9-10 t ha^{-1} at New Farm. Soya yields were between 3-3.5 t ha^{-1} at Onverwacht and New Farm. In addition, commodity farm gate prices were 128% higher for maize compared to the 2019-2020 season. Excellent dryland cash crop yields resulted in high income per ha.

The Standerton trial in contrast did not reflect so well. This season's rainfall of 633mm is more or less in line with the long-term average rainfall of 650 mm. Above-average spring rainfall resulted in wet and waterlogged soil conditions at the Sepane soils of 41% clay content. Priority was given to commercial cash- and cover crops resulting in late planting of the trials under the wet soil conditions. That affected the growth of all crops and appeared to be stunted for the beginning of the season and especially maize plants being off colour. Yield data got lost due to turnover of personnel but maize and soya yields of 2.5 t and 1.2 t ha^{-1} were used based on recall. These low yields resulted in unsustainable net margins. This season's real farm data was used in addition to reflecting net margins with maize and soya grain yields of 8.1 t ha^{-1} and 2.5 t ha^{-1} respectively. The Standerton farm implemented high-density grazing already for multiple years. Farm grazing and cover crop data were used for the abovementioned financial analysis. The yields of SCC, WCC after SCC and WCC after soya were 12 t ha^{-1}, 1.8 t $ha^{-1}$and 1.4 t ha^{-1} DM respectively, were used for net margins under SCC/ WCC.

The profitability of any crop is a function of the commodity price, yield and costs. Profitability changes when there is a variation of any of these three factors. Commodity farm gate prices and yields were discussed above. The expenditure of the cash crops was in all treatments the same due to similar levels of external inputs in year one, namely seed, fertilizer and herbicides. The difference in input costs between CT and CA & RA was diesel and repair & maintenance costs. The CT practice at Onverwacht and New Farm included deep rip (chisel plough) and offset. The Standerton trials had two offset passes. Net margins were also positively influenced when grazing cover crops under RA systems were incorporated.

The research team included two categories that are not a standard part of crop production financial analysis, namely the value of crop residues and the income & expenditure levels of cover crops. The financial analysis used in this report is in line with Grain SA templates with the difference of the abovementioned two aspects. These two aspects are included in this research to measure the profitability of cover crops and livestock integration in monetary terms. The research team tested various methods of determining the monetary value of grazing cover crops. This was partly done due to the challenge of grazing the trial strips (SCC treatments) with animals that were not used to the high-density grazing system and the risk of breaking out and grazing other strips negatively affecting trial outcomes. The Standerton farm implemented high-density grazing on SCC and WCC for multiple years reflecting competitive net margins for cover crops. In contrast to Standerton farm, Onverwacht or New Farm with exceptional high cash crop yields reflected much lower net grazing margins on cover crops.

The soil cover was between 30 - 75% on the trials before planting and the average water infiltration rate for 500 ml in a ring of 150 ml in diameter was between 23 – 192 seconds. Baseline soil data was taken and although it is discussed in this report not many differences are noticed between the treatments. The SOM of the veld is higher in the A and B horizons of all trials. The biological indicators are very low at all three trial sites although C:N ratios were most in the right ranges. Nitrogen and Phosphorous reflect high values mostly from the inorganic pool. The soil health scores at Standerton are *good to excellent* whilst Onverwacht and New Farm are *average to below*. The iron content was very high at all three trials.

There was no soil compaction in the A horizon of all trials. Penetrometer readings between 200-300 psi were only found in the B horizon. Veld had the lowest compaction. A small increase in resistance was found at the 10-11 cm soil depth mark indicating a possible plough layer from previous tillage practices.

Brix readings were used to assess plant quality and growth vigour. The Onverwacht and New Farm Brix first and second readings were good to excellent except for the first maize reading at Onverwacht that gave an average reading. These high readings correspond with high cash crop yields. Standerton trial gave good Brix reading for the first soya reading and excellent for the second soya reading, which may be contributed to a foliar leaf application on the soya. The maize Brix readings in contrast were poor for the first reading and average for the second reading. Once again, this time from the bottom end of the index shows a correlation with the low grain yields at this trial.

The hectolitre mass is used as an indicator of grain quality. This was measured at Onverwacht and New Farm. There was no real difference between the hectolitre mass between the treatments. All soya grain readings were around 0.7 and maize around 0.8.

1. BACKGROUND AND PROBLEM STATEMENT

1.1. Local problem statement

Harmful soil degradation processes are part of many environmental problems caused by conventional tillage (CT) and unsustainable agricultural practices. These practices are continuing unabated under many crop-livestock agricultural systems in the Mpumalanga Province and pose a major threat to the sustainability of agriculture, food production and national security (Borrelli et al., 2017). Impacts can be severe, not only through soil erosion and fertility loss (Le Roux et al., 2008) but through a conspicuous number of off-site effects (e.g., sedimentation, siltation and eutrophication of waterways or enhanced flooding). In addition, the impact of bare (fallow) soil on climate through the loss of soil carbon and erosion-induced changes in soil carbon cycling remains an increasing threat. Sustainable governance of soil has therefore become a topic of fundamental importance on the Mpumalanga Highveld.

Rising input and overhead costs and sliding real prices of commodities (e.g. maize) put the economic viability and profitability of maize-based cropping systems under severe pressure resulting in many farmers being affected by the cost squeeze and having financial difficulties, even on the Mpumalanga Highveld. A study done by De Wit et al. (2015) confirms this trend, but show a very large monetary benefit of adopting CA in maize-based systems of South Africa, inter alia in the Mpumalanga Highveld. The outcomes of this study demonstrate that the transition from CT to CA systems has the potential of not only reducing costs, increasing yields, increasing net farm income but also ecological benefits too. This is through lower greenhouse gas (GHG) emissions, lower input use and carbon sequestration. Maize farmers should therefore be encouraged to adopt CA systems to improve the profitability of their farms. It is therefore of utmost importance that maize production on the remaining high potential land is intensified sustainably.

1.2. Description of the targeted study area(s)

The Mpumalanga Highveld region can be divided into six uniform agro-ecological regions or sub-regions based on a combination of soil, climate and topographic features. These regions are:

1. **Central Region or Highveld Rift** (includes the area west of Ermelo in the Msukaligwa and Govan Mbeki Local Municipalities with Bethal in the centre)
2. **Mist belt Region** (in the eastern parts of the Msukaligwa, northern parts of the Mkhondo and central to eastern parts of the Albert Luthuli Local Municipalities including Ermelo, Amsterdam, Lothair and Chrissiesmeer)
3. **Black Clay Region** (mostly in the Lekwa Local Municipality with Standerton as the centre)
4. **South Western Region** (in the Dipaleseng and Govan Mbeki Local Municipalities with towns such as Delmas, Balfour and Greylingstad)
5. **South Eastern Region** (in the Mkhondo Local Municipality with Piet Retief in the centre)
6. **Northern Region** (in the Emalahleni, Steve Tshwete, Albert Luthuli and Emakhazeni Local Municipalities with towns such as Emalahleni, Middelburg, Belfast and Stoffberg)

In terms of agricultural production, summer cereals and legumes (maize, soybeans, dry beans, sunflower, sorghum and potatoes) dominate the Highveld region. For the most part, dryland farming is utilised in agricultural production in the Highveld, with intensive irrigation activities taking place in the Loskop area near Groblersdal and the Lowveld area adjacent to the Crocodile and Komati rivers. Considerable potential for increased agro-processing exists in the province, but this is constrained by access to water resources.

Up to 70% of rain-fed grain farming in the Mpumalanga Region involves some level of soil tillage. As already mentioned above, these practices lead to significant levels of soil degradation, especially loss of soil organic matter (SOM), erosion and sedimentation of rivers and dams. The loss of SOM from tilled soils is a significant contributor to greenhouse gasses and poor soil health.

In the Mpumalanga Region, 24% of the rain-fed cropping is practised under CA (FAO, 2021). According to this study, several magisterial districts show significant adoption levels such as Ermelo (37 250 ha, or 35%), Hoëveldrif (26 600 ha, or 79%), Belfast / Stoffberg (12 120 ha, or 50%), Standerton (23 810 ha, or 16%), Bethal (17 600 ha, or 22%), Balfour (18 480 ha, or 28%), Lydenburg (10 750 ha, or 76%) and Piet Retief (15 128 ha, or 91%).

CA farmers in the region mostly use no-till planters with tines (i.e. minimum tillage), however, there is a significant and increasing percentage of farmers using NT planters with discs, especially on higher clay soils (e.g. the Black clay and South Eastern Regions, as well as the Stoffberg area). Many of the CA farmers have started with cover crops and livestock integration, especially using winter cover crops. Some CA farmers still deemed it necessary to rip some of their soils (around 450 cm deep) every 5th year. Many commercial farmers in this region are using precision farming with detailed soils maps, grid sampling and variable rate fertiliser application.

The advancement of NT and CA under commercial farmers in the Mpumalanga Highveld was primarily a farmer-driven process with a few study groups that actively, but informally pursue this practice for a while. Several government initiatives in the past have tried to promote CA under black semi-commercial and smallholder farmers in the region. The Mlondozi LandCare project (Van Rensburg, 2002) might have been the most important or comprehensive of these initiatives, which had the overall goal to demonstrate and implement profitable farming systems, by involving local communities, to contribute to sustainable agricultural production in the Mlondozi district by the year 2003.

1.3. Participatory planning event

On 23 September 2020, after the project proposal was approved by The Maize Trust, a participatory planning event was held at the Janvos Estate near Ermelo involving 17 participants in the Mpumalanga Highveld area, of which most were farmers. Dr Hendrik Smith facilitated the meeting, assisted by Dr Jaap Knot. This event was of critical importance to set the scene or lay the foundation for the whole project process and to get the buy-in (ownership) of the farmers involved. The programme for the day is seen in Box 1, of which the key activity and outcome was the design of on-farm experiments and treatments (see below).

Box 1: Programme

- Opening and welcome
- Introduction of participants
- Background to CA FIP and ASSET Research
- CA principles
- Aim and purpose of planning meeting
- Key problems – review
- On-farm systems research methodology
- On-farm experiments – conceptualisation, localities, design, planning, actions, responsibilities
- Indicators
- Production costs – CA vs CT

The following steps were followed to design the on-farm experiments:

- Identify, define sub-regions x ecotope(s)
  - prominent soil type and climate of major agronomic importance in the Mpumalanga Highveld region (*soil type, depth, texture, slope, etc.*)
- Identify 3-7 localities or farmers to monitor
  - (selected ecotopes, implements, access, interest, etc.)
- Design treatments
  - <u>Stats matrix</u>:
  - Replicates x Treatments x samples, linked to budget
- Indicators
- Action plan (what, how, where, when, who)

Treatments designed

1) Conventional tillage systems
2) CA/NT with high inputs and simple rotations e.g. maize x soya
3) Regenerative low input CA (ideal, future CA system, including cover crops and livestock integration)
4) Veld (current, most representative way of grazing)

Research question(s)

- What is the correct or the best conversion strategy to CA?
- Access to appropriate equipment for small scale farmers?
- Can CA reduce input costs and increase profitability?
- Focus on the biggest problems especially on sandy soils

- Could we introduce cover crops and livestock sustainably, especially on specific ecotopes, e.g. sandy soils?
- How could we manage weeds better?

Hypothesis

- That the CA system will address the profitability and ecological problems over the long term.

2. Project aim

The project aims to research, develop and adopt appropriate CA systems for a range of diverse and unique contexts in the Mpumalanga Highveld region.

The following short-term objectives will assist the project in achieving its aim:

I. To establish and facilitate appropriate on-farm trials with the Mpumalanga Highveld CA study group

II. To monitor and analyse a series of appropriate indicators from on-farm trials on selected farmers' fields

III. To create wider awareness and innovation capacity in the Mpumalanga Highveld CA study group and the broader farming communities on the practices and benefits of locally adapted CA systems

IV. To support farmer facilitation, administration and reporting processes

To effectively implement the above short-term objectives, a couple of cross-cutting work packages were designed and implemented with each having a designated person or institution to implement and manage the specific activities and budget (see Table 1 for a detailed discussion of work packages). Table 1 shows the different work packages and responsible champions in each project:

Table 1: Work packages and lead partners in the Mpumalanga Highveld project

Work Package	Lead partner
1. Coordination and management	ASSET Research (Hendrik Smith), Mpumalanga Highveld group
2. Facilitating, monitoring and evaluation	Jaap Knot (ASSET research)
3. Assessment of soil health comparing different systems	Jaap Knot, Gerhard du Preez (NWU) and Soil Health Solutions;
4. Assessment of cover crop adaptability and suitability	Gerrie Trytsman (Independent researcher); Jaap Knot

3. SUMMARY OF PROGRESS FROM OCTOBER 2020 TO SEPTEMBER 2021

Several Work Packages (WPs) were designed and implemented at the start of the 2020-2021 season. The implementation of these WPs was collectively monitored and managed through the project team (see Table 2). The on-farm trials form the basis of all the other activities in the project and will run through several seasons. Emphasis is placed on data collection, interpretation, reporting and awareness.

Table 2: Progress on key activities

KEY ACTIVITY	TIMELINE	INDICATOR OF SUCCESS	PROGRESS TO DATE
Objective 1: To establish and facilitate appropriate on-farm trials with the Mpumalanga CA network			
a) Participatory planning workshop	Held in September 2020	Active participation of and inputs from CA network and key stakeholders in the workshop to plan various project implementation activities.	Held in Sept 2020
b) Discuss, facilitate, prepare, establish roles and responsibilities within the Mpumalanga committee and plan Mother and Baby trials on selected sites (farms)	July-August (Continuous)	(Clear) Roles and responsibilities documented CAT and FAT sites identified and discussed	Liaison and discussions are held between the project team and trial farmers
c) Establish and manage on-farm Mother and Baby trials on selected sites (farms)	September to June (Continuous)	Well-selected on-farm trials and ecotopes were established and managed on selected sites and/or farms	Three MT's were established. There are no baby trials.
Objective 2: To monitor and analyse a series of appropriate indicators from on-farm trials on selected farmers' fields			
a) Participatory monitoring and data collection	January to June	Collection of a range of selected indicators from	Selected indicators discussed in this report as well as reflected under table 4 in the proposal

KEY ACTIVITY	TIMELINE	INDICATOR OF SUCCESS	PROGRESS TO DATE
		trials, especially soil samples	
b) Participatory M&E and discovery learning	January to June	Completion of field monitoring form with farmers	The project team maintains database and trial farmers assisted the project team with data collection
c) Data Analysis and Evaluation	June to August	Analysis of data collected from on-farm trials and field forms	In progress and ongoing
Objective 3: To create wider awareness and innovation capacity in the Mpumalanga CA network and the broader farming communities on the practices and benefits of locally adapted CA systems.			
a) Annual farmers day or conference	February to May	A well organised and -attended awareness event	*Landbouweekblad* made video footage as an alternative for farmers days that were cancelled as a result of COVID-19 lockdown regulations.
b) Exposing on-farm trials to interested farmers and other	Continuous	Trial visits by interested people	*Landbouweekblad* intended to show video footage on national TV Hendrik Smith circulated footage on both Maluti and Mpumalanga CA WhatsApp groups
Objective 4: d) To support project facilitation, administration and reporting processes.			
a) Project meetings	Quarterly meetings	At least two project meetings per year	Two zoom meetings were held as well as on-site meetings when collecting data
b) Social learning facilitation of innovation platform(s)	Continuous	Effective facilitation to assist implementation, M&E and adaptation	Ongoing
c) Mpumalanga Highveld network innovation platform meeting	August	A well organised annual innovation platform & feedback meeting	Report results to be disseminated to Mpumalanga CA farmers
d) Reporting	March and September	Six-monthly and annual reports according to specifications	In progress

4. IMPLEMENTATION OF WORK PACKAGES

4.1. Project monitoring, evaluation and facilitation

4.1.1. Activities and deliverables

Table 3: Progress and results achieved under project monitoring, evaluation and facilitation

Activities	Deliverables	Progress and Results achieved
1. On-farm experimentation - Land preparation	Assist farmers in the layout of their trial plots Prepare (calibrate and train) farmers on the trial treatments Make sure land preparation (e.g. weeding) is done according to specifications Make sure the correct type and quantity of production inputs are ready and used Advise and liaise with farmer's optimal windows of opportunity for example interseeding cover crops Ensure the same data methods are used for data comparisons and statistical analysis for example standard soil sample depth Monitor planned activities against project plan, budget and expected outcomes	Three trial plots were laid out, with small changes between actual and planned layout to accommodate planter and harvester work-width. Weeding and planting was done and the correct type of inputs was applied High rainfall at the beginning of the season affected the Standerton trial negatively. Planting was therefore late. High January and February rains affected plant growth and – vigour with waterlogged soil conditions and long overcast periods. In-season monitoring is done frequently
2. On-farm experimentation - Planting	Assist and coordinate activities and implements, inputs for planting Move planter between farmers for timely planting, where necessary. Otherwise, document details of farmer equipment used Make sure farmers plant according to standard treatment specifications	Farmer co-workers (Hendrik Odendaal and Nicol de Vos) implemented the trials and planted the strips as per the planned layout.
3. On-farm experimentation - Seasonal management	Assist farmers to implement seasonal activities, such as weeding and pest/disease management	Farmers applied herbicide as in line with standard weed control practices

4. Data collection, monitoring and sampling	Collect field data/indicators with farmers Assist to collect soil samples Monitor the farmer-led actions Document all farmer mechanisation details, input costs, external input quantities, time of application, labour time used for certain activities, other relevant info related to weather for comparative financial analysis purposes	Soil cover- and water infiltration rate assessments were done before planting. Baseline soil sampling (block method per treatment) was done and sent to labs. February 2021 repeated soil samples taken per trial strip (1-27) Income & expenditure assessment done as seen under results
5. Data management and analyses	Ensure list of activities, and were necessary expected output and outcomes are timely distributed/ disseminated to selected research farmers Monitor planned activities Ensure different data sets from different selected work packages are coordinated, monitored and managed Ensure standardised research methods and equipment are implemented at all sites Write the internal monthly report. Compile quarterly progress reports and discuss with relevant stakeholders, which can include meetings or individual follow-up as what deems practical and time-efficient Ensure right data is collected, timely done and ensure data sets are complete including monitoring various people's data from various work packages and other (e.g. soil lab reports) are filed Ensure standardised data sets for future meta-analysis, follow-up research or other comparative analysis	List of activities monitored and frequent communication between trial farmers and Asset Research team members. Data is filed and per Trial recorded in a standardised template

6. Monthly social learning meetings (project team)	Organise learning meetings with smaller groups of farmers; Facilitate meetings, discussing problems and possible solutions to that.	Farmer meetings are on an individual level and there were no group meetings besides the farm level, mostly due to Covid regulations. There were group meetings at the farm level.
7. Annual social learning and project meeting (Mpumalanga Highveld CA network)	Report progress and findings to the advisory committee; Discussion and evaluation of data. Learning from each other.	Progress reports and results/outcomes will be ready for discussion.
8. Annual report and admin	Written report e.g. covering trials implementation, results and progress Draft reports and statistical analysis. Coordinate input from, and safeguard high standard reporting, by involving various appointed discipline experts (soil scientist, agronomist, statistician among others) to contribute to final high-quality transdisciplinary report(s) Record audio-visual material Ensure annual report findings, suggestions and improvements (lessons learned) are included and coordinated in following years' research proposals	Annual progress reports are drafted and each trial's data set is documented separately. *Landbouweekblad* made video shots at all trial sites.
9. Coordinate and participate in awareness events	Coordinate and participate in awareness events, such as information day and/or cross-visits Write/ assist with articles/ news snippets (standard info, core findings, key stats) if necessary (and if requested) for leading agricultural news forums (e.g. farmer weekly, coop quarterly report, stakeholder's internal news dissemination channels, social media platform etc) Ensure standardised report templates (Asset/ MT logo) are created for future presentations, -	*Landbouweekblad* assisted at the Kinross trials on the 16th of March 2021 after the planned farmer day was cancelled due to Covid-19 regulations. A farmer day was held at Standerton on the 7th of May 2021.

	comparative assessments, and - meta-data analysis Liaise and coordinate potential follow-up research with other Research agencies/ Universities	

4.1.1.1. Establishment and management of on-farm trials

Three collaboratively managed trials (CMT), or mother trials, were established on experimental sites on key sub-regions and ecotopes (uniform soil and terrain units) in the Mpumalanga Highveld region on three trial sites of participating farms, two in the Kinross/ Evander area (Onverwacht and New Farm sites implemented by Nicol de Vos & sons) and another one in the Standerton area (implemented by Hendrik Odendaal). These sites were selected during the participatory planning session on 23 September 2020, as described above. These trials will be used as 'benchmark ecotopes' that have relevant treatments to compare, e.g. RA, CA, CT, natural (pristine) veld and grazing for long term monitoring purposes. Long term monitoring data from these on-farm trials and/or treatments will provide a strong source of appropriate information for awareness and investigation of the project objectives assisted by the farmer's experiences, observations or problems.

The trial designs and layouts at the three sites are shown below.

Crop rotation systems: 1. Maize-soya for CA and CT

2. For the RA system the cropping sequence over 4 seasons looks as follows:

a) Maize + WCC (relay cropping)
b) SCC + WCC
c) Soya + WCC
d) SCC + WCC

The CT and CA systems have a maize-soya rotation (treatment 1 above). The RA treatment has four treatments under each repetition and the trial layout started with each of the crops mentioned under crop rotation (treatment 2 above). That implies that one treatment started with maize, one with soya and two with SCC. This is designed to find out at what stage of the crop rotation to start when converting to CA/ RA by analysing the various trial results.

Plant spacing – row-width and plant population:

- Maize: 0.50 - 0.76 m rows at 45,000 - 50 000 plants ha^{-1}
- Soya: 0.50 – 0.76 m rows at 300,000 - 330,000 plants ha^{-1}
- Cover crop: 17-24 cm spaced rows at 31 kg Summer CC and 67 kg Winter CC seed mixture ha^{-1} depending on the planter/seed drill on site

The three treatments CT, NT/ CA and RA or best CA are practically the same for the first year i.e., fertilizer rate, chemical composition and application, seed cultivar for both maize and soya.

The CT, CA and RA maize and soya treatments will be discussed below as it is the same for all three. The difference in treatments is the additional primary tillage under CT maize and soya.

Conventional tillage (CT): Primary tillage before planting includes chisel plough and disc actions.

Conservation Agriculture/No tillage and Best Conservation Agriculture (BCA) or regenerative agriculture (RA): chemical burn down before planting and a glyphosate-based cocktail (see description below) at planting applied.

The description of maize and soya of the three treatments below are the same hence it is documented only once.

Fertilizer

Table 4: Onverwacht and New Farm maize fertilizer application rates

Description	Kg ha^{-1} & type	Kg N ha^{-1}	Kg P ha^{-1}	Kg K ha^{-1}
OV, NF broadcasting prior to planting maize	120 kg 4.3.4 (33)	14.4	10.8	14.4
OV, NF at planting maize	400 kg 5.3.4 (22)	36.6	22	29.3
OV, NF top-dress maize	150 kg LAN	42	-	-
TOTAL OV, NF for maize (rounded)		**93**	**33**	**44**

Key: OV = Onverwacht, NF = New farm

100 kg KCL at 22 kg K ha^{-1} was broadcasted before planting soya at OV and NF.

Additional treatment info for Onverwacht/ New Farm:

Herbicide

- Maize
  - No chemical burn down under CT, but mechanically seedbed preparation
  - Chemical burn down under CA, RA - 3 kg glyphosate granules, 1 kg ammonium sulphate and two-litre paraquat ha^{-1}.
  - After emergence in season on maize: application 1: 250 ml Cantron (mesotrion), one-litre autochlor, 65 ml Lamda
  - Application 2: 250 ml Cantron, one-litre autochlor, 1 kg atrazine and two litres of glyphsate
- Soya
  - No chemical burn down under CT, but mechanically seedbed preparation
  - Chemical burn down under CA, RA - 3 kg glyphosate granules, 1 kg ammonium sulphate and two-litre paraquat ha^{-1}.
  - At planting Lamda (insecticide) 65 ml ha^{-1}, metalachlor 1.5 litre ha^{-1}
  - 2 x after emergence: glyphosate and ammonium sulphate at 2 litre ha^{-1}.

Seeds

  - Maize – yellow, Pioneer 2432R
  - Soya – Pannar 1555R
- Row width and plant population
  - Maize – 53 000, 0.76 cm
  - Soya – 330 000, 0.76 cm

At Standerton the following production inputs were applied on maize.

Table 5: Maize fertilizer rates at Standerton trial, 2020-2021

Description	Kg ha^{-1} & type	Kg N ha^{-1}	Kg P ha^{-1}	Kg K ha^{-1}
ST Broadcast before planting maize	30 kg ha^{-1} K_2SO_4	-	-	12
	100 kg ha^{-1} MAP	11	22	-
ST at planting maize	70 kg ha^{-1} urea	30	-	-
ST top-dress maize	78 kg ha^{-1} urea	36	-	-
TOTAL ST for maize (rounded)		**77**	**22**	**12**

Key: ST = Standerton trial

30 kg ha^{-1} potassium sulphate (K_2SO_4) was broadcasted before planting soya at ST at 12 kg K ha^{-1}. There was no other fertilizer applied to soya.

Additional treatment info:

Herbicide

- Maize
  - Chemical burns down under CT, CA, RA - 2 kg glyphosate granules, 0.8 kg ammonium sulphate and one litre 2-4D ha^{-1}.
  - After emergence in season on maize: 1 x application: 200ml Cantron (mesotrion), and two litres of glyphosate
- Soya
  - Chemical burns down under CT, CA, RA - 2 kg glyphosate granules, 0.8 kg ammonium sulphate and one litre 2-4D ha^{-1}.
  - After emergence in season on soya: 2 x application: 0.8 kg ammonium sulphate, 100ml wetting agent and 2 kg of glyphosate ha^{-1}

Seeds

  - Maize – yellow, DKC6454DR
  - Soya – DM4800
- Row width and plant population
  - Maize – 45 000, 0.50cm
  - Soya – 300 000, 0.50 cm

Best CA practice (BCA):

SCC and WCC

- Diverse crop rotation: 1 or 2 cash crops with various cover crops (summer and winter) strategies like SCC followed by WCC, maize intercrop or maize relay and WCC after soya
- No-till planter (tine or disc) or cover crop Piket planter
- Fertilizer SCC at OV and NF
  - 120 kg 4.3.4 (33) ha^{-1} @ 14.4 kg N; 10.8 kg P; 14.4 kg K\
  - 150 kg LAN ha^{-1} @ 42 kg N
  - Total NPK SCC: 56.4 kg N, 10.8 kg P and 14.4 kg K ha^{-1}

- The fertilizer applied on SCC at Standerton was:
  - 30 kg K_2SO_4 ha^{-1} broadcasted before planting @ 12 kg K
  - 70 kg ha^{-1} urea broadcasted as well @ 30 kg N
- Fertilizer WCC at all three trials
  - no fertilizer applied to WCC
- Herbicides
  - At Onverwacht and New Farm: burn downmix 3 kg glyphosate granules, 1 kg ammonium sulphate and two-litre paraquat ha^{-1}.
  - At Standerton the burndown mix was 2kg glyphosate, 800 gr ammonium sulphate and one litre ha^{-1} 2-4D

- Seeds – SCC mix followed by WCC mix

  - 10 kg babala
  - 2 kg hybrid Babala
  - 10 kg cowpeas
  - 8 kg sun hemp
  - 1 kg tillage radish

The following winter (temperate) cover crop (WCC) mixture is used in the CA trials:

- 25 kg rye
- 30 kg triticale
- 10 kg grazing vetch
- 1 kg canola
- 1 kg fodder turnips

- Row width: 17-24 cm
- Reduce external synthetic inputs gradually year by year

Grazing SCC/ WCC

- Livestock integration (farmers' own animals) – same animal / grazing intensity/density; can diversify animal herd/component; a combination of different species is recommended
- Grazing practice
  - Electric fences or other fencing options include cattle gates due to the relatively small width of treatment strips
  - SCC – in Jan and Feb, before seeding, high density, terminate or graze before WCC
  - WCC – graze before seeding, April till October as to be assessed per season
  - When – in a row with planting (not broadcasting); top-dress broadcast
- WCC – plant in February or March into SCC.
- Planting time - SCC – min temp, mid to end November; WCC – end March or April, after short growing soya; in Maize plant December to January (intercropping).

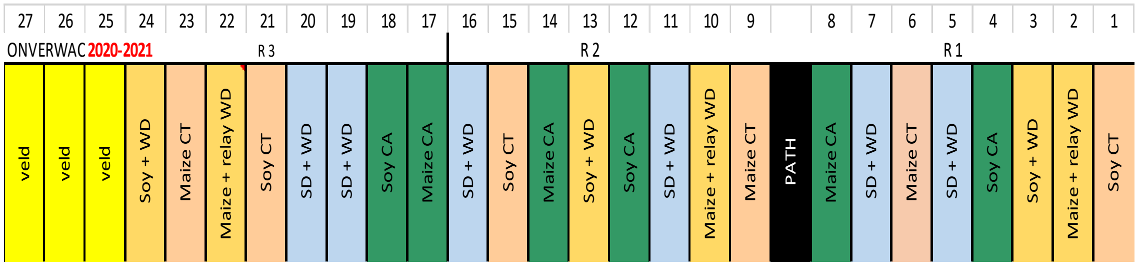


Figure 1: Onverwacht Trial layout

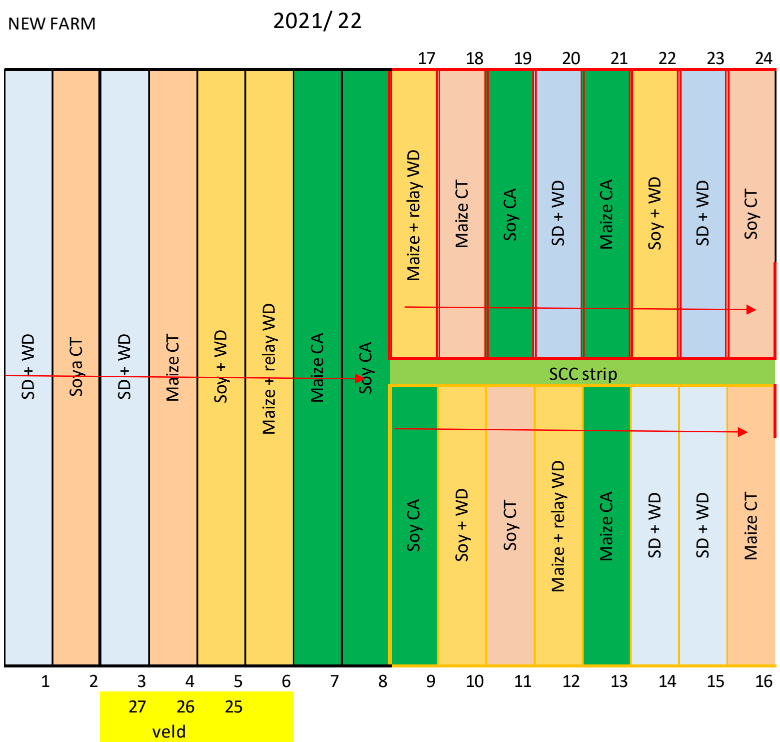


Figure 2: New Farm Trial layout

The planned trial layout had plots 17-24 adjacent to strip 16. The 3rd repetition block (strip 17-24) did not fit in completely hence the split of block 2 (strip 9-16) and block 3 (strip 17-24). The red arrows indicate the area where baseline soil data was taken. Strips 1-8 are approximately 400 m which makes blocks 2 and 3 close to 200m each.

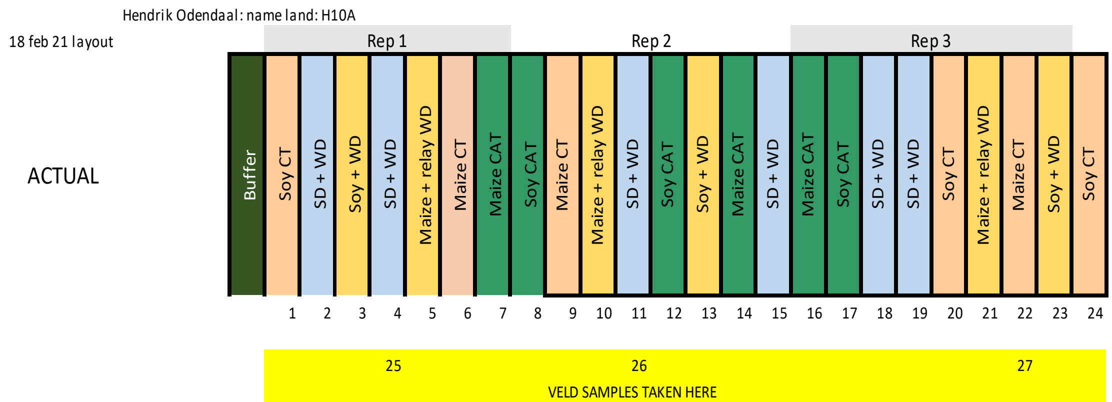


Figure 3: Standerton Trial layout

4.1.1.2. Monitoring of trial sites

The planning of this research kicked off on 23 September 2020 with an initial participatory farmer meeting.

Monitoring the budget, expenditure and project activities took place throughout the season.

Baseline soil sampling (5-9 October) was conducted at all three MTs and samples were sent for Haney soil health tests (SHT) at Ward laboratories and NWU lab. A discussion on the parameters analysed in the Haney SHT is done in detail in this report. The procedure for baseline soil sampling was to collect six to eight sub-samples at 0-10 cm and 11-30 cm depths mixed as a composite sample. Two composite samples were taken at each of the three repetitions resulting in an A and B soil layer result for both depths. Results are attached in appendixes reflecting the number 1-3 (repetitions) and soil horizon (A=1-10 and B=11-30). Veld samples were taken in addition to potentially reflecting more long-term undisturbed conditions ("pristine benchmark") at or nearby the cropland. Veld is either natural veld, long term undisturbed pasture or "under the fence" grass vegetation. The baseline soil results refer to <code MT>VA, VB, 1A,1B,2A,2B,3A,3B.

Baseline water infiltration rates were measured on crop fields and veld. Soil cover assessments were done before planting by using a line-transect method. Water infiltration rates were measured by measuring the period for 500 ml of water to infiltrate in a ring with a diameter of 150mm.

All activities were done in collaboration with the farmers and or some of their co-workers

Monitoring crop progress at the trials was done repeatedly throughout the season (3-5 November; 8-9 December; 14-18 January; 13-14 April; 16-17 June).

Brix assessments were done to measure crop quality. Measurements were done twice during the growing season at all three MTs. Leave samples were taken from a minimum of 15 plants at random in a specific maize or soya treatment strip. In as far as practically possible the Asset Research team conducted Brix readings in the afternoon. The time when Brix readings were conducted was documented.

The randomised trial layout reflects eight treatments with three repetitions which resulted in 24 strips. Three additional measuring points were identified on the veld. All three Mpumalanga mother trials have therefore 27 “strips”.

Soil samples were taken again in February per strip (i.e. 1-27), which will be used with the original soil sampling as an extensive baseline database. Five sub-samples made up a composite sample. Bulk density was measured separately at the sub-sample spots by making use of a 10 cm steel cup.

Soil compaction was additionally measured by using a penetrometer at depths of 0-10 cm and 11-20 cm.
Soil sampling (15-18 February) resulted in comprehensive info set per strip with Haney SHT results. NWU in addition measured soil texture (sand %, silt %, clay %), pH, EC and Active C and bulk density).

More details of each set of monitoring data are reflected under results and or appendixes.

The Kinross trials’ farmers day was cancelled due to Covid-19 regulations. Therefore, alternative interviews and video recordings by *Landbouweekblad* were done on the 16th of March 2021.

Monitoring summer cover crops and measuring the biomass of summer and winter cover crops (SCC and WCC) were done. This info is also used for reporting on livestock and grazing purposes.

Monitoring was done on-site and complimented by occasional telephone conversations throughout the season (13-14 April; 16-17 June).

A farmers day was organised at the Standerton trials on the 7th May 2021.

Monitoring WCC’s and measuring biomass dry quantity of summer and winter cover crops. This info is also used for reporting on livestock and grazing purposes

A data framework and template was developed and populated in Excel per trial for comprehensive analyses, including financial analyses. Maize and soya yields were measured by the harvester and converted to t ha^{-1}. The hectoliter mass of soya and maize was determined by special equipment from nearby cooperative’s staff that assisted on the harvesting days. Crop production financial analyses (including incomes, costs, gross margins, overheads and net margins) were done. First data was collected from each farmer to develop draft data sets. Then the draft data sets were discussed between researchers and the farm team (i.e. those on the farm responsible for the overall management, livestock and crops) to develop a more comprehensive data set and analysis.

Financial data collection included a list of the description of inputs, discussing types of inputs and costs and also included discussions on the income and expenditure of cover crops and grazing.

4.1.1.3. Awareness videos

Due to the Covid pandemic, the first CA farmers' day on the Mpumalanga Highveld (on Nicol de Vos farm in Kinross) scheduled for 18 February had to be cancelled. Instead of the farmers day, it was decided to shoot a range of short videos that were distributed in the Mpumalanga Highveld CA network (through a Whatsapp group). These videos illustrate the objectives, activities, treatments and indicators measured on the trials. Video material was also collected for a *Landbouweekliks* TV show and were also used for a CA webinar done in collaboration with *Landbouweekblad* on 27 and 28 July 2021. The photos below were taken during the fieldwork and video sessions on the Mpumalanga Highveld trials from 15 to 19 February 2021.

Photo 1a–d: Field video sessions at the Mpumalanga Highveld study areas (15-19 February 2021).

4.1.1.4. Annual farmers day

On 7 May 2021, the annual farmers' day was held at Standerton, on the farm Welgevonden of the H2 Agri-Business, where Hendrik Odendaal established a Mother trial (Photos 2a and 2b). About 80 people attended the event. The programme started with presentations of two CA farmers, namely Izak Dreyer from Vrede en Hannes Botha from Carolina. After them, Dr Gerhard du Preez (NWU) made a presentation on soil health and then Dr Hendrik Smith gave an overview of CA on the Mpumalanga Highveld. He showed that the adoption of CA in the province is quite good (24% in total), but in certain magistrate districts, it is much higher, such as Piet Retief (91%), Hoëveldrif (79%), Lydenburg (76%) and Belfast (50%). In the afternoon there was a tour of the farm where various points were visited, and discussions facilitated.

Photos 2 a-b: Participants have discussions on cover crops and livestock integration and a soil profile evaluation during the field day at H2 Agri-Business, Standerton on 7 May 2021.

4.1.2. Data and analysis

4.1.2.1. Rainfall

There were 46 rainfall events this season between August 2020 and July 2021 resulting in a total of 807 mm for the Kinross trials. There were 40 rainfall events for Standerton that received 633 mm this season. Figure 4 shows the distribution of rainfall during the growing season at the two trial site areas. Rainfall data is collected on-site by using closest farm rain gauges.

This season's rainfall of 807 mm yr^{-1} at Onverwacht and New Farm was above the long-term annual rainfall average of 620 mm yr^{-1}. The seasonal rainfall at Standerton of 633 mm yr^{-1} was more or less in line with the annual long-term average of 650 mm yr^{-1}. The distribution of rainfall, however, affected the planting of the Standerton trials namely that 14% of the annual rainfall fell on 4 November 2020 (91mm). This rainfall event and nine rainfall events in December at on average three days apart kept the Sepane soils with 41% clay content wet.

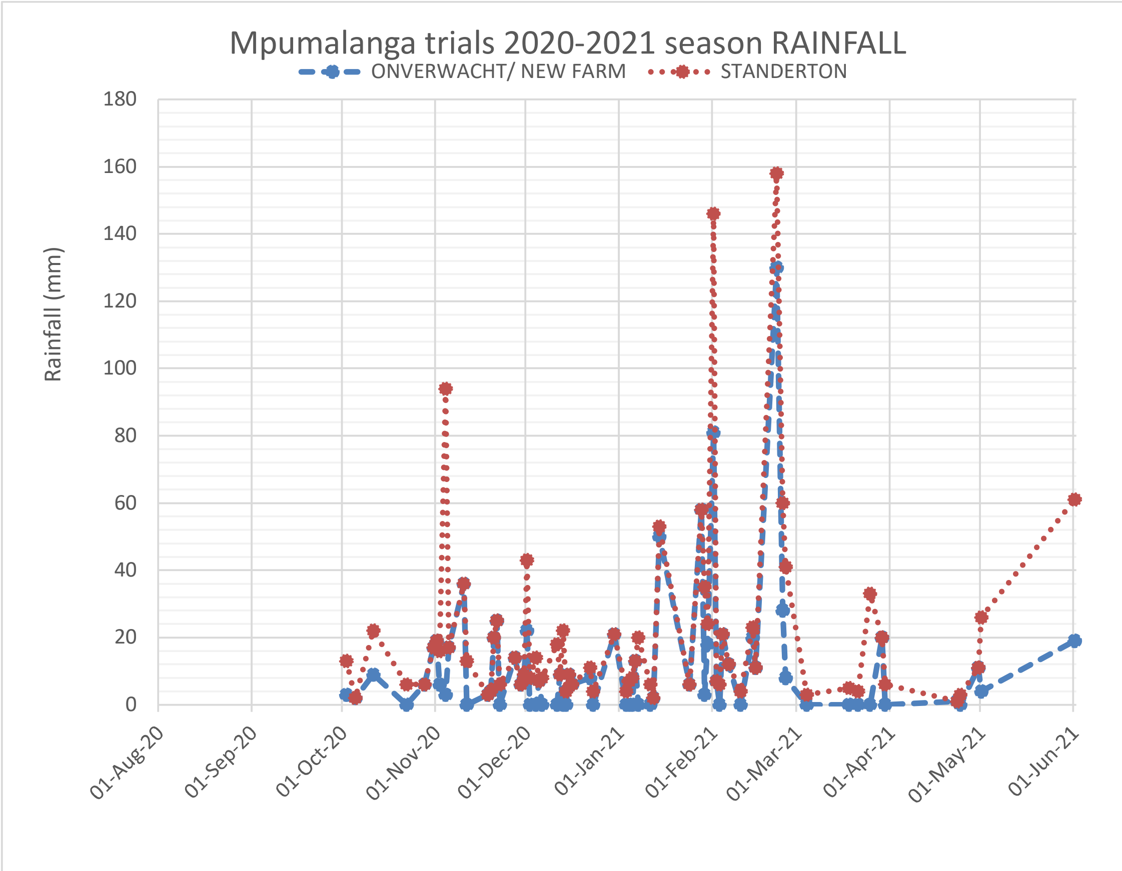


Figure 4: The 2020-2021 rainfall figures for Onverwacht, New Farm and Standerton trials

4.1.2.2. Crop quality, quantity and water cycle results

Table 5 below shows a range of crop and water cycle indicators collected at the three trial sites in the Mpumalanga Highveld trial sites.

The soil cover before planting was measured using the line-transect method. It is measured as a percentage of total soil cover. Soil cover builds up in CA is a challenge due to various reasons. The reasons being (excessive) grazing, microbial activity leading to high decomposition rate, the wind blowing crop residue away, hot dry weather and low autumn/ winter rainfall making it difficult for winter covers to establish, just to mention a few. Soil cover build-up is crucial for the success of CA (i.e. increased water use efficiency and build-up of soil ecosystem functions) that it is regarded as one of the CA core principles. It is therefore important to measure the soil cover before planting the summer cash (cover-) crop.

The water infiltration rate before planting was assessed by measuring the time (in seconds) for how long it takes for 500 ml to infiltrate in a ring firmly pushed in the soil. The ring's diameter is 150 mm. Occasionally the soil was too hard and a rubber hammer was used to hit in the ring. The water was poured on a plastic layer that was pulled gently away to avoid splashing ensuring that the total 500 ml was infiltrating at once.

Maize and soya yields were measured by using the harvester's GPS data system. A flexible distance on the strips was converted into t ha^{-1}

The water use efficiency (WUE) of any crop in South Africa is of paramount importance due to the limited availability of rainwater against the high evaporation rates. The WUE was expressed as the total grain produced (kg ha^{-1}) per unit of water used by the crop (mm). The WUE is calculated by using a simple formula

$$X = \frac{Cash\ crop\ grain\ yield\ (kg)}{Annual\ rainfall\ total\ (mm)}$$

This was done for both maize and soya. The WUE is expressed as X kg ha $^{-1}$ mm^{-1}.

The hectolitre mass was determined by using a special measuring tool that is used at grain silos for determining the hectolitre mass. The local cooperative (AFGRI) site manager assisted with their equipment at Onverwacht and New Farm as grain, after being measured, is delivered to the local AFGRI silos.

Unfortunately, this data got lost at Standerton due to the changeover of personnel co-responsible for managing the trials.

Table 6: A range of crop production and water cycle indicators collected at the Mpumalanga Highveld trial sites, 2020-2021 season

Description	ONVERWACHT			NEW FARM			STANDERTON		
	RA	NT	CT	RA	NT	CT	RA	NT	CT
Soil cover % at start of trial	30%	30%	30%	69%	69%	69%	75%	75%	75%
Water infiltration rate at start of trial (500 ml/ seconds)	192	192	192	117	117	117	23	23	23
Maize yield (t ha^{-1})	11.62	11.87	12.5	9.05	9.87	9.56	2.5	2.5	2.5
WUE Maize (kg ha^{-1} mm^{-1})	14.4	14.71	15.49	11.21	12.23	11.84	3.95	3.95	3.95
Hectolitre mass Maize	0.808	0.809	0.802	0.805	0.809	0.805			
Soya yield (t ha^{-1})	3.03	3.05	3.21	3.35	3.38	3.42	1.2	1.2	1.2
WUE Soya (kg ha^{-1} mm^{-1})	3.75	3.77	3.98	4.16	4.19	4.24	1.9	1.9	1.9
Hectolitre mass Soya	0.714	0.721	0.716	0.704	0.699	0.716			

4.1.2.3. Profitability analysis

ONVERWACHT TRIAL SITE, KINROSS

Table 7: Comparative financial analysis of Onverwacht trial treatments

Production system:	**RA**	**RA**	**CA**	**CA**	**CT**	**CT**	**RA**
Description of treatments (All figures in ZAR)	**Maize_ relay**	**Soya_ WCC**	**Maize**	**Soya**	**Maize**	**Soya**	**SCC_ WCC**
INCOME							
Cash crop	34,859	21,184	35,606	21,315	37,497	22,475	-
Crop residue graze value	1,903	272	1,944	274	2,047	289	-
Cover crop graze 1 value	-	-	-	-	-	-	8,880
Cover crop graze 2 value	-	-	-	-	-	-	1,480
GROSS INCOME	36,762	21,457	37,550	21,589	39,544	22,764	10,360
VARIABLE COSTS							
Cash crop related	11,481	7,300	11,481	7,300	12,305	8,135	-
Cover crop related	-	-	-	-	-	-	3,924
Livestock related	-	-	-	-	-	-	900
TOTAL COSTS	11,481	7,300	11,481	7,300	12,305	8,135	4,824
GROSS MARGINS	**25,281**	**14,157**	**26,069**	**14,289**	**27,239**	**14,628**	**5,536**
Overhead costs	2,550	2,550	2,550	2,550	4,000	4,000	2,550
NET MARGINS	**22,731**	**11,607**	**23,519**	**11,739**	**23,239**	**10,628**	**2,986**

For a detailed overview of the financial analyses see Appendices 4 to 6.

Table 7 above is a summary of financial analysis for the dryland crops under the Onverwacht trials. The complete financial analysis is in Appendix 4. This financial analysis used farm-based values derived from consulting the farmer co-worker (Nicol de Vos and sons) implementing the trials. The analysis and values are in line with Grain SA's crop production budgeting template.

The net margins on both maize and soya cash crops are high as grain yields this season are 141-167% above the farm's average long-term soya and maize average long term yields. The long-term farm average for soya is 2.2 t ha^{-1} and for maize, it is 7.2 t ha^{-1}. The rainfall distribution this season was favourable resulting in maize yields of 11-12 t ha^{-1} and soya yields between3-3.5 t ha^{-1} (See details in table 6 above). The commodity price of maize was also slightly higher this year as compared to the previous season. The maize farm gate price was 128% higher this season as compared to 2019/20. Soya, in addition, was only 105% higher this season as compared to last year's season, which not even offsets inflation costs. Maize traded at R3,000 (2019/20 season at R2,350) and soya at R7,000 (2019/20 season R6,675) all at farm gate price. The high(er) grain yields per hectare in combination with favourable maize commodity prices resulted in high cash crop income for all Onverwacht cash crop treatments.

Costs (Expenditure)

Most of the cost items or expenditure is the same when referred to maize or soya as the same amount of fertilizer and herbicides were used. The same maize seed cultivars were used for maize treatments as well as the same soya cultivars for the soya treatments at the same planting rates. This gave similar expenditure levels. The difference, however, in expenditure is attributed to diesel and repair & maintenance costs. The RA and CA treatments started with a chemical burn down followed by NT planting (see details herbicides under trial treatments discussion). The CT started with a disc and deep rip (chisel plough) action followed by an NT planting action. The diesel price used was R13,50 per litre. The table below reflects the litres ha^{-1} used under the different treatments and quantity of passes.

Table 8: Mechanisation and fuel details at Onverwacht

Description of action/ mechanization pass	Figures used		RA				NT/ CA		CT	
	L/ha	Maintenance	SCC	M RELAY	WCC	SOYA +WD	MAIZE	SOYA	MAIZE	SOYA
Discing	6	340							1	1
Chisel Plough	24.15	380							1	1
shallow tine	5.21	250							1	1
Plant Piket (fine seed cover crop drill)	3.00	173.08	1		1					
Plant (notill)	7.8	450		1		1	1	1	1	1
Spread fertilizer	1.86	70	1	1	1	1	1	1	1	1
Boom spray	1.75	130	1	3	1	3	3	3	2	2
Transport grain	8	80		3		1	3	1	3	1
harvest maize/ soya	15	700		1		1	1	1	1	1
grain wagon (tapkar)	4.6	40		2		1	2	1	2	1
Transport water and fertilizer (support)	2.63	50	1	1	1	1	1	1	1	1
Total liters ha^{-1}			**9.2**	**65.7**	**9.2**	**45.1**	**65.7**	**45.1**	**99.4**	**78.8**
13.5 **Fuel (ZAR) ha^{-1}**			**124.7**	**887.5**	**124.7**	**609.4**	**887.5**	**609.4**	**1341.2**	**1063.1**
Maintenance and repair costs (ZAR) ha^{-1}			**250**	**1980**	**250**	**1780**	**1980**	**1780**	**2570**	**2370**

The interest rate on production input credit was calculated at 8%.

Grazing income

The grazing income and crop residue grazing value has been included. This is not standard for crop production budgets / financial analysis, but since the ideal CA (RA) systems have no cash crop income when the SCC/ WCC are planted, it is therefore important to document the income from grazing. The cash crop residue value is determined by using the following assumptions:

- Maize: Grain yield ha^{-1} multiply with the harvesting index of 0.91. The research team assumed only 30% of crop residue to be consumed. The value of 1 t maize residue is estimated to be R600. See details in financial analysis framework in Appendix 4
- Soya: Grain yield ha^{-1} multiply with the harvesting index of 0.75. The research team assumed only 30% of crop residue to be consumed. The value of 1 t soya residue is estimated to be R400. Once again for more details see the financial analysis framework in Appendix 4.

The purpose of Table 7 is to show how net margins are derived. In addition, it was deemed important to show the extra income derived from the relay cover crop in maize and the WCC after soya. Both of these two cover crop strategies have not been applied at Onverwacht, but the table format allows, once again, to see additional costs and income from cover crops under the various cover crop strategies (i.e. SCC, WCC after SCC, maize relay or intercrop and WCC after soya).

The first grazing is SCC and the income of R8,880 is derived from the figures in the table below (Table 9). The second grazing, which is the WCC's income of R1480 is derived from the following calculations in the same table

Table 9: Onverwacht trial SCC and WCC grazing income calculations

ONVERWACHT GRAZING INCOME	SCC	WCC
# animals/ ha	6	1
start weight	210	210
end weight	260	260
weight gain per animal, kg	**50**	**50**
TOTAL weight gain (all animals, kg ha⁻¹)	**300**	**50**
Price premium R/kg	0	0
Kg value @ start weight (R/kg)	40	40
Kg value @ end weight (R/kg)	38	38
Kg value @ end weight (R/kg)_ Premium + price	**38**	**38**
Begin value	**8 400**	**8 400**
End value	**9 880**	**9 880**
Difference per animal	**1 480**	**1 480**
Total INCOME (RAND)	**8 880**	**1 480**

Overhead costs

Overhead costs are included to calculate the net margins per hectare. All overhead costs are the same per hectare at R2,550 except for hectares attributed under the conventional production practices. The mechanisation costs are higher under CT as well as the replacement period for tractors and equipment shorter than the RA and CA treatments. The CT fleet also requires more staff. The replacement of tractors is budgeted at 5 years under CT and 8 years for CA (63% of CT costs). This is the main reason for the higher overhead costs of R4,000 as compared to R2,550 for CA/ RA

Table 10: Overhead cost calculations for the three production systems at Onverwacht

Overheads	weight	RA	NT	RA	NT	CT
Tractor & equipment replacement cost	50%	63%	63%	31%	31%	50%
Administrative, insurance costs etc	15%	65%	65%	10%	10%	15%
Fixed labour costs	35%	65%	65%	23%	23%	35%
TOTAL	100%	-	-	64%	64%	100%
Overhead costs	**4000**			**2550**	**2550**	**4000**

Net margins

The net margins display very high values per hectare under the cash crops this season as discussed above due to a combination of higher-than-average cash crop grain yields and farmer favourable commodity prices. The SCC and WCC income could have been higher when SCC was planted at the same time as maize and soya and when SCC and WCC were grazed once or twice more. The research team will closely monitor net margins of treatments in seasons to come under variable grain yields and changing costs and commodity prices.

NEW FARM SITE, KINROSS

Table 11: Comparative financial analysis of New Farm trial treatments

Production system:	**RA**	**RA**	**CA**	**CA**	**CT**	**CT**	**RA**
Description of treatments (All figures in ZAR)	**Maize_ relay**	**Soya_ WCC**	**Maize**	**Soya**	**Maize**	**Soya**	**SCC_ WCC**
INCOME							
Cash crop	27,136	23,473	29,608	23,674	28,673	23,935	-
Crop residue graze value	1,480	302	1,615	304	1,564	308	-
Cover crop graze 1 value	-	-	-	-	-	-	8,880
Cover crop graze 2 value	-	-	-	-	-	-	1,480
GROSS INCOME	28,616	23,775	31,223	23,978	30,237	24,243	10,360
VARIABLE COSTS							
Cash crops related	11,481	7,300	11,481	7,300	12,305	8,135	-
Cover crop-related	-	-	-	-	-	-	3,924
Livestock related	-	-	-	-	-	-	900
TOTAL COSTS	11,481	7,300	11,481	7,300	12,305	8,135	4,824
GROSS MARGINS	**17,135**	**16,475**	**19,742**	**16,678**	**17,932**	**16,108**	**5,536**
Overhead costs	2,550	2,550	2,550	2,550	4,000	4,000	2,550
NET MARGINS	**14,585**	**13,925**	**17,192**	**14,128**	**13,932**	**12,108**	**2,986**

The cash crop income derived from maize yields between 9-10 t ha^{-1} and soya grain yields between 3 and 3.5 t ha^{-1}. For more details see the discussion points under Table 10 which in most, if not all, cases is the same for New Farm as Onverwacht.

Table 12: Comparative financial analysis of Standerton trial treatments

Production system:	**RA**	**RA**	**CA**	**CA**	**CT**	**CT**	**RA**
Description of treatments (All figures in ZAR)	**Maize_ relay**	**Soya_ WCC**	**Maize**	**Soya**	**Maize**	**Soya**	**SCC_ WCC**
INCOME							
Cash crop	7,750	8,640	7,750	8,640	7,750	8,640	-
Crop residue graze value	410	0	409	0	409	0	-
SCC; graze 1 value	-	-	-	-	-	-	3,420
WCC; graze 2 value	-	-	-	-	-	-	2,285
WCC after soya graze value	-	2,046	-	-	-	-	-
GROSS INCOME	8,160	10,686	8,159	8,640	8,159	8,640	5,705
VARIABLE COSTS							
Cash crops related	9,691	5,454	9,691	4,853	10,600	5,763	-
Cover crop cost-related	-	1,139	-	-	-	-	3,592
Livestock related	-	250	-	-	-	-	500
TOTAL COSTS	9,691	6,843	9,691	4,853	10,600	5,763	4,092
GROSS MARGINS	**-1,513**	**3,843**	**-1,531**	**3,787**	**-2,440**	**2,877**	**1,613**
Overhead costs	1,785	1,785	1,785	1,785	2,800	2,800	1,785
NET MARGINS	**-3,316**	**2,058**	**-3,316**	**2,002**	**-5,240**	**77**	**-172**

Table 12 above is a summary of the financial analysis for the dryland crops under the Standerton trials. The complete analysis is under Appendix 5. This analysis used on farm-based values derived from consulting the farmer co-worker (Odendaal family and personnel) implementing the trials. The financial analysis is in line with the Grain SA crop production budgeting template.

Maize traded at R3,100 (2019/20 season at R2,350) and soya at R7,200 (2019/20 season R6,675) all at farm gate price.

The income is based upon 2.5 t ha^{-1} maize and 1.2 t ha^{-1} soya. The farmer co-worker (Hendrik Odendaal) struggled to be able to plant the trials timely due to the wet soils in December 2020. Understandably the commercial cash- and cover crops were prioritised and planted first. The Standerton trial has a Sepane soil type with 41% clay. With a monthly rainfall of 120mm and 102mm for November 2020 and December 2020 respectively the soil remained wet. Waterlogging occurred at the downslope side of the field. This caused delayed planting of all crops on the trials. In addition, the yield data got lost due to a change of personnel responsible for the trials. The yields were estimated on recall at the 2.5 t ha^{-1} maize and 1.2 t ha^{-1} soya as explained above. The earlier planted maize and soya on the farm gave on average 8.1 t ha^{-1} and 2.5 t ha^{-1} for maize and soya respectively. Consequently, the financial analysis using these figures would have appeared much more optimistic and real.

The costs under the treatments are in most cases the same as discussed under the Onverwacht trial above. Diesel and repair & maintenance costs are once again higher under CT as the CT plots were offset twice before planting.

For a detailed overview of the financial analyses see Appendix 5.

Costs (Expenditure)

Most of the cost items or expenditure is the same when referred to maize or soya as the same amount of fertilizer and herbicides were used. The same maize seed cultivar (DKC6454DR) was used for maize treatments as well as the same soya cultivar (DM4800) for the soya treatments at the same planting rates. This gave similar expenditure levels. The difference, however, in expenditure is attributed to diesel and repair & maintenance costs. All treatments started with a chemical burn down followed by NT planting (see details herbicides under trial treatments discussion). The CT started with two-disc passes followed by an NT planting action. The diesel price used was R13,50 per litre. The table below reflects the litres ha^{-1} used under the different treatments and quantity of passes.

Three different data sets under Table 14 reflect mechanisation costs for the trials (1st data set under Table 14). Some of the passes (sprayer and harvester) are recorded in the economic analysis as done by a contractor. This is done as the farm consist of two entities and one entity rents the sprayer and harvester to the other (3rd data set under Table 14). The real farm mechanisation costs are recorded as well based on higher grain yields (2nd data set under Table 14) and imply higher costs for a grain cart (*tap kar*) and transporting grain. It is rated higher for maize than for soya due to higher grain yields (8.1 t ha^{-1} for maize as compared to 2.5 t ha^{-1} for soya). Litre ha^{-1} is included to give an impression of fuel use between the production methods.

The boom sprayer, as seen in table 13 below, has two passes for SCC, 3 x maize and 4 x soya. It includes a herbicide burn down for all, one foliar spray application for all, one herbicide application after emergence for maize and two herbicide applications for soya after emergence.

Table 13: Mechanisation and fuel details at Standerton

Description of action/ mechanization pass TRIALS	Figures used		RA				NT/ CA		CT	
	L/ha	Maintenance	SCC	M RELAY	WCC	SOYA +WD	MAIZE	SOYA	MAIZE	SOYA
Discing	6	340							2	2
Plant (notill)	7.8	450	1	1	1	2	1	1	1	1
Spread fertilizer	1.86	70	1	3	0	1	3	1	3	1
Boom spray **	1.5	130	2*	3*	0	4*	3*	4*	3*	4*
Transport grain	8	80		0.5***		0.5	0.5	0.5	0.5	0.5
harvest maize/ soya **	15	700		1		1	1	1	1	1
grain wagon (tapkar)	4.6	40		0.5***		0.5	0.5	0.5	0.5	0.5
Transport water and fertilizer (support)	2.63	50		1		1	1	1	1	1
Total liters ha^{-1}			**12.8**	**42.2**	**7.8**	**47.5**	**42.2**	**39.7**	**54.2**	**51.7**
13.5		**Fuel (ZAR) ha^{-1}**	**172.8**	**570.1**	**105.3**	**641.7**	**570.1**	**536.4**	**732.1**	**698.4**
Maintenance and repair costs (ZAR) ha^{-1}			**720.56**	**1681.68**	**450**	**2240.56**	**1681.68**	**1790.56**	**2361.68**	**2470.56**

Key: * Boom sprayer pass includes 1 pass for foliar application for all. Herbicide: 1x burn down all, maize 1x after emergence and soya 2 x after emergence
** harvesting (R600) and boom spray (R120 per spray) is reflected as contractor cost in the price framework.
*** transport grain & grain wagon (tap kar) was marked as 0.5 due to the low maize and soya yields

Description of action/ mechanization pass FARM CASE STUDY****	Figures used		RA				NT/ CA		CT	
	L/ha	Maintenance	SCC	M RELAY	WCC	SOYA +WD	MAIZE	SOYA	MAIZE	SOYA
Discing	6	340							2	2
Plant (notill)	7.8	450	1	1	1	2	1	1	1	1
Spread fertilizer	1.86	70	1	3	0	1	3	1	3	1
Boom spray **	1.5	130	2*	3*	0	4*	3*	4*	3*	4*
Transport grain	8	80		2		1	2	1	2	1
harvest maize/ soya **	15	700		1		1	1	1	1	1
grain wagon (tapkar)	4.6	40		2		1	2	1	2	1
Transport water and fertilizer (support)	2.63	50		1		1	1	1	1	1
Total liters ha^{-1}			**12.8**	**61.1**	**7.8**	**53.8**	**61.1**	**46.0**	**73.1**	**58.0**
13.5		**Fuel (ZAR) ha^{-1}**	**172.8**	**825.3**	**105.3**	**726.7**	**825.3**	**621.4**	**987.3**	**783.4**
Maintenance and repair costs (ZAR) ha^{-1}			**720.56**	**1861.68**	**450**	**2420.56**	**1861.68**	**1850.56**	**2541.68**	**2530.56**

Key: ****refers to farm case study mechanization costs based on 8.1 t ha-1 maize and 2.5 t ha-1 soya.

Description of action/ mechanization pass minus passes by CONTRACTOR *****	Figures used		RA				NT/ CA		CT	
	L/ha	Maintenance	SCC	M RELAY	WCC	SOYA +WD	MAIZE	SOYA	MAIZE	SOYA
Discing	6	340							2	2
Plant (notill)	7.8	450	1	1	1	2	1	1	1	1
Spread fertilizer	1.86	70	1	3	1	1	3	1	3	1
Boom spray	CONTRACTOR									
Transport grain	8	80		0.5		0.5	0.5	0.5	0.5	0.5
harvest maize/ soya	CONTRACTOR									
grain wagon (tapkar)	4.6	40		0.5		0.5	0.5	0.5	0.5	0.5
Transport water and fertilizer (support)	2.63	50		1		1	1	1	1	1
Total liters ha^{-1}			**9.8**	**22.7**	**7.8**	**26.5**	**22.7**	**18.7**	**34.7**	**30.7**
13.5		**Fuel (ZAR) ha^{-1}**	**132.3**	**306.9**	**105.3**	**358.2**	**306.9**	**252.9**	**468.9**	**414.9**
Maintenance and repair costs (ZAR) ha^{-1}			**460.56**	**591.68**	**450**	**1020.56**	**591.68**	**570.56**	**1271.68**	**1250.56**

Key: ***** Net margin analysis in report based on this table's mechanizations figures.

The interest rate on production input credit was calculated at 8%.

Grazing income

The grazing income and crop residue graze value has been included. This is not standard for crop budgets/ financial analysis, but since the ideal CA (RA) systems have no cash crop income when the SCC/ WCC are planted; it is, therefore, important to calculate graze income. The cash crop residue value is determined by using the following assumptions:

- Maize: Grain yield ha^{-1} multiply with the harvesting index of 0.91. The Asset team assumed only 30% of crop residue to be consumed. The value of 1 t maize residue is estimated to be R600. See details in financial analysis in Appendix 6.

- Soya: Grain yield ha^{-1} multiply with the harvesting index of 0.75. The Asset team assumed only 30% of crop residue to be consumed. The value of 1 t soya residue is estimated to be R400. Once again for more details see financial analysis in Appendix 6.

The SCC struggled under the wet conditions in the first 6 weeks after establishment. The SCC was estimated at 3 t ha^{-1} DM.

The following calculations were done at the Standerton trial to derive the SCC grazing income of R3,420. The two WCC grazing calculations are reflected below as well.

Table 14: Grazing quantities and related graze gain values at Standerton trial

Cover crop strategy >>	SCC	SCC	WCC	WCC after SCC	WCC	WCC after soya
t ha^{-1} DM		3		0.56		0.50
Feed use efficiency (FUE)	30%		70%		70%	
t ha^{-1} DM x FUE =		0.9 t ha^{-1}		0.39 t ha^{-1}		0.35 t ha^{-1}
Feed conversion rate (ratio kg DM feed used for 1 kg weight gain)	1: 10		1: 6.5		1: 6.5	
KG meat produced ha^{-1}		90 kg		60.1 kg		53.8 kg
Rand value live weight beef (R kg)	38		38		38	
Income R ha^{-1}		3,420		2,284.87		2,046.15

The SCC t ha^{-1} DM was estimated as well as the WCC after soya. The WCC after SCC was measured by using a 1 m^2 randomly thrown hoop. The plant material in the hoop was cut and dried in a special oven determining the DM values. The DM value measured of the WCC after SCC was measured at 0.56 t ha^{-1}.

The relay (intercrop) cover crop was not planted into maize as the focus was on getting the maize crop that was planted late, established in January/ February which then closed the window of opportunity for intercropping maize at stage V6-V8 for maize.

Overhead costs

Overhead costs are included to accurately derive the net margins per hectare. All overhead costs are the same per hectare at R1,785 except for hectares attributed under the conventional production practices. The mechanisation costs are higher under CT as well as the replacement period for tractors and equipment shorter than the RA and CA treatments. The CT fleet also requires more staff. The replacement of tractors is budgeted at 5 years under CT and 8 years for CA (63% of CT costs). This is the main reason for the higher overhead costs of R2,800 as compared to R1,785 for CA/ RA

Table 15: Overhead cost calculations for the three production systems at Onverwacht

Overheads	weight	RA	NT	CT	RA	NT	CT
Tractor & equipment replacement cost	50%	63%	63%	100%	31%	31%	50%
Administrative, insurance costs etc	15%	65%	65%	100%	10%	10%	15%
Fixed labour costs	35%	65%	65%	100%	23%	23%	35%
TOTAL	**100%**				**64%**	**64%**	**100%**
	2800				**1785**	**1785**	**2800**

Net margins

The net margins of cash crops are very low this season as discussed above, due to the late planting of the trials. The SCC and WCC income could have been higher when SCC was planted early as can be seen under the farm case study under the "results" discussion of net margin. The research team will closely monitor net margins of treatments in seasons to come under variable grain yields and changing costs and commodity prices.

4.1.2.4. Brix readings

Brix readings are included to start building a data set related to the quality of the maize- and soya plants. The better the soil quality or the more balanced the soil ecosystem health is with a healthy plant the higher the Brix reading (http://zylemsa.co.za/2019/11/11/high-brix/). The Brix meter measures the sucrose level of plants, which is used to infer the quality of the plant. The higher the Brix the better the plant (and future) grain quality. A high Brix value indicates a good taste (sweetness) and quality of your crop. Grain with a high Brix value can be preserved longer and are more resistant to insect attacks (http://zylemsa.co.za/2019/11/11/high-brix/).

A Brix index, as seen below in table 16, is used. The index differs from plant to plant, but these indices were used to compare the trial Brix values with (http://ag-usa.net/brix_test_meaning.htm).

Table 16: Brix index figures for comparison of trial Brix readings

0-2	Very low
3-7	Mid Level
8-11	Higher Brix
12-20	High

Source: http://zylemsa.co.za/2019/11/11/high-brix/

The above-mentioned index is generic for all crops. Another source at http://ag-usa.net/brix_test_meaning.htm gave the following index with specific reference to maize (young, stalks), soya and grains (Table 17). Only maize and soya plants were measured on the trials (by collecting samples from leaves of >15 plants per strip). The grain Brix index is included as a reference if cover crop grains are measured.

Table 17: Brix index figures for maize and soya

Maize (young)				Maize (stalks)				Soya				Grains			
Poor	Average	Good	Excellent	Poor	Average	Good	Excellent	Poor	Average	Good	Excellent	Poor	Average	Good	Excellent
6	10	18	24	4	8	14	20	4	6	10	12	6	10	14	18

ONVERWACHT SITE, KINROSS

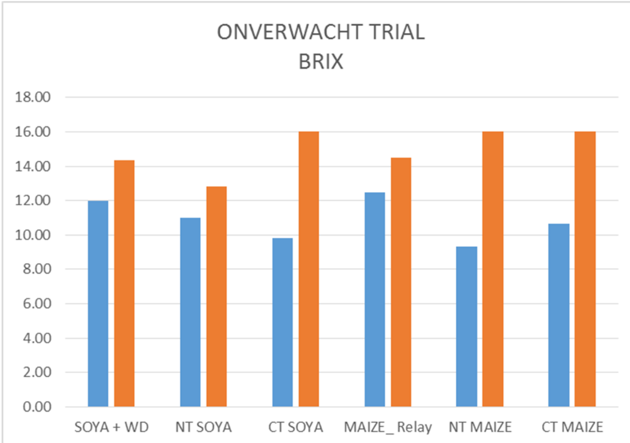


Figure 5: Brix readings (maize and soya) in 2020-2021 season at Onverwacht trial

Key: Blue bar Brix readings were taken on 13 January 2021 (10.00-11.30 am) and orange bar on 17 February 2021 (2.00-3.30 pm).

The index reference values as mentioned under http://ag-usa.net/brix_test_meaning.htm are used. The colour line represents one of the categories average (orange), good (yellow) or excellent (green). The rectangular block reflects a range between values of maize young and maize stalks.

NEW FARM SITE, KINROSS

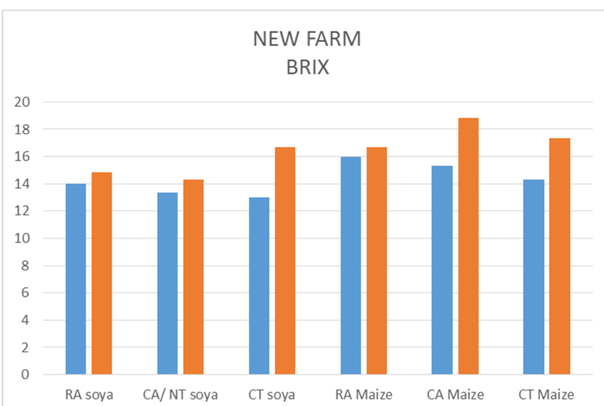


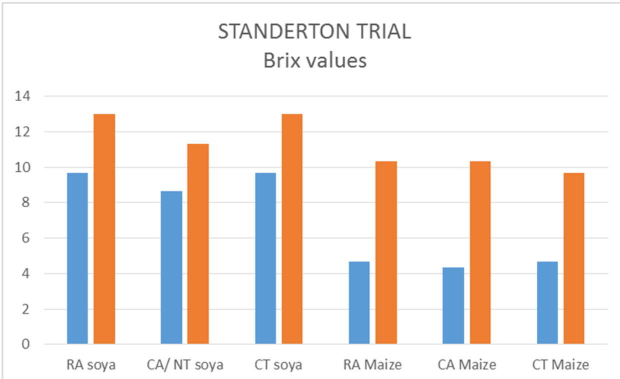
Figure 6: Brix readings (maize and soya) in 2020-2021 season at New Farm trial

Key: Blue bar Brix readings were taken on 13 January 2021 (13.10 pm-14.30 pm) and on 16 February 2021 (15.30 pm – 17.15 pm).

The index reference values as mentioned under http://ag-usa.net/brix_test_meaning.htm are used. The colour line represents one of the categories bad (red), average (orange), good (yellow) or excellent (green).

STANDERTON SITE

Figure 7: Brix readings (maize and soya) in 2020/21 season at Standerton trial



Key: Blue bar Brix readings were taken on 14 January 2021 (9.45-10.50 am) and on 18 February 2021 (10.00-11.20 am).

The index reference values as mentioned under http://ag-usa.net/brix_test_meaning.htm are used. The colour line represents one of the categories bad (red), average (orange), good (yellow) or excellent (green).

4.1.3. Results and discussion

4.1.3.1. Cover crops and livestock integration

Farmer co-workers' CA systems in perspective

Both Kinross and Standerton farmers have mixed farming practices. The Kinross farmer (Nicol de Vos, manager of Onverwacht and New Farm trials) is applying conventional grazing strategies on his farms. That implies grazing on the veld, pasture, green feed, and crop residues during the season as per the feed flow plan. Bales and silage are fed in addition. Backgrounding is done at the farm's own feedlot. The conventional managed cattle are not exposed to and not familiar with high-density grazing strategies. The farm infrastructure is not geared towards high-density strip grazing at this stage either.

This season a mixture of winter cover crops (WCC) was planted for the first time under supplementary irrigation after harvesting the dry beans in March on two centre pivots with a combined area of 42 ha. The 42 ha were divided into eight camps. The WCC was grazed by 300 weaners at a stocking rate of 7.1 weaners per hectare. Camps were grazed twice over 64 days. Live weight gain for every calf was in the order of 71 kg. A total amount of 21 229 kg of meat was produced. After deductions for input cost, a net margin of R 11 715.34 was realised per hectare. This case study allowed us to educate producers on how to measure pasture biomass. Intensification by double-cropping ensures that infrastructure such as centre pivots and soil resources can be used optimally.

The Standerton farming system is already geared towards high-density strip grazing and multiple cover crop strategies are implemented already with ease: summer cover crops and winter cover crops with livestock and in rotation with cash crops (maize and soya). The infrastructure has been adapted on the farm with high investments in water pipes and troughs. Cover crops and wheat have been planted after soya. Pollinator strips are planted. The cattle are divided into multiple herds across the farm and is used for high-density strip grazing.

From all the different cover crop strategies the one that is hardly practised on any farm in the Highveld is maize intercropping (inter-seeded at V6-8 stage of maize) or maize relay cropping (casting or drilling seed at the stage when maize starts drying off). This is primarily due to a lack of suitable planters or planting methods for this purpose. Maize relay- or intercropping was consequently not done at the trials.

Table 18 shows the potential of livestock income from best CA practices applied in the area. Grazing summer cover crops with an average yield of 15 t ha^{-1} DM the Standerton farm would gain R17,000/ha income. In most years they don't have more than 2 summer grazing events. If a winter cover crop is drilled into the grazed summer cover crops 1 or 2 additional grazing events should be feasible. Livestock grazing on cover crops that are planted early and managed well should based on the Standerton case study, provide the farmer with R25,000 or more income as seen in the table below.

Table 18: Potential of livestock income under best CA practices

Description	**DM t/ha**	**Feed use efficiency**	**Feed conversion (1 kg growth: DM kg required)**	**Monetary value from grazing /ha**
Early – middle Nov planting SCC, grazing 1	15	30%	1:10	R17,000
Regrowth, grazing 2	2	30%	1:10	R2,280
Winter cover crops drilled into SCC March	2	70%	1:6.5	R8,184
Grazing 2, WCC	0.5	70%	1:6.5	R2,046
Potential income			**TOTAL**	**R29,510**

If cover crops are planted very late after the ideal planting window, say for example at 20th of December, then one can not gain more than one grazing event out of the SCC, especially when the trial protocol anticipates a WCC to be planted into the SCC between middle February and middle March. This season can be seen as a learning curve on planting and managing cover crops. Income from livestock grazing on various cover crops can only be profitable and competitive when it is planted timely and grazing is well managed.

This season's cash crop income was very high for the Kinross area due to high commodity prices at farm gate prices of R7000 and R3000 for soya and maize, respectively. The production was also extraordinary high with maize yields between 9 and 12.5 t ha^{-1} and soya between 3-3.5 t ha^{-1} for Kinross. Standerton trials had low maize yields of 2.5 t ha^{-1}, but for the gross margins analysis, we also included this seasons' farm figures of 8.1 t ha^{-1} for maize and 2.5 t ha^{-1} for soya.

Cover crop grazing would have more competitive profit margins when cash crop yields are lower (in line with long term averages of 6-8 t ha^{-1} for maize), and when commodity prices are lower (R2200-R2500 t^{-1}) as seen in 2019-2020

4.1.3.2. Crop quality

There were no significant differences in Hectolitre mass between the treatments as neither were there significant differences between Brix readings of the different treatments this season. Brix readings correlate with crop growth and plant vigour. Brix readings above 12 are regarded as good, but the index ranges can go as high as 20-24. Onverwacht trial had most initial readings below 12 when there was a dry spell in January. Plants showed some drought stress in middle January. Standerton trial's Brix readings were initially low due to the late cash crop plantings under wet and waterlogged soil conditions. The initial yellowish colour of especially maize resulted in Brix readings between 4 and 9. All Brix readings improved at the 2nd readings of all three trials.

4.1.3.3. Profitability

The profitability (net margins) of the three trials are shown below.

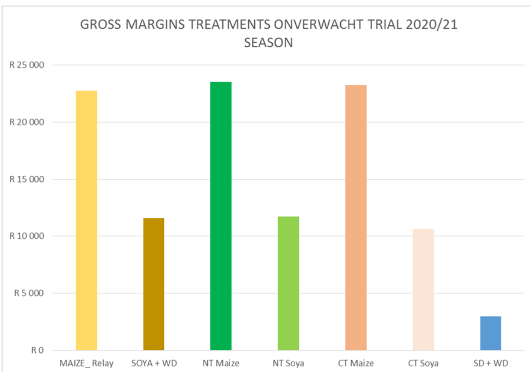


Figure 8: Net margins for different treatments at Onverwacht trial in 2020-2021 season

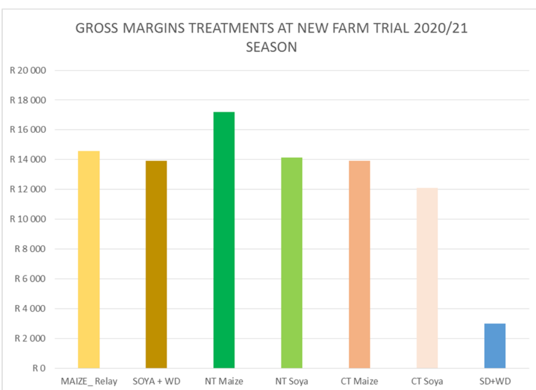


Figure 9: Net margins for different treatments at New Farm trial in 2020-2021 season

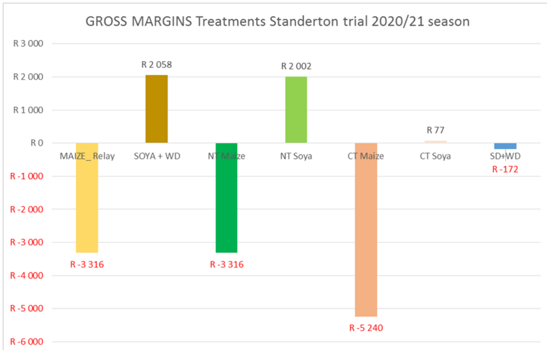


Figure 10: Net margins for different treatments at Standerton trial in 2020-2021 season

The trial at Standerton was planted late as a result of wet soil conditions. The farm's 2020-2021 average maize and soya yields was 8.1 t ha^{-1} and 2.t ha^{-1} respectively. We hereby include the farm's gross margins

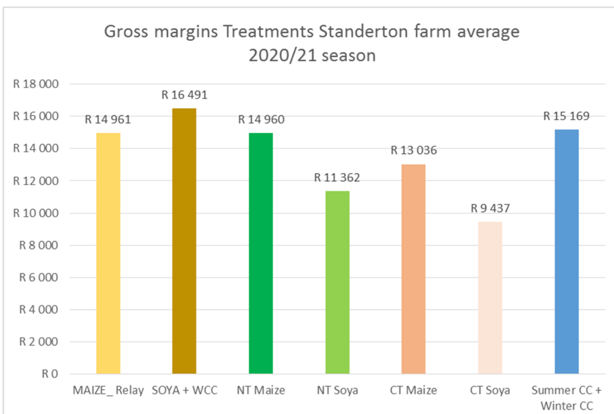


Figure 11: Net margins for different treatments at Standerton farm case study in 2020-2021 season

There were three grazing incomes reflected under the farm case study 2020-2021 namely:

- R13,680 under SCC (based on 12 t ha^{-1} DM),
- R7,366 for WCC after SCC (based on 1.8 t ha^{-1} DM) and lastly
- R5,729 for WCC after soya (based on 1.4 t ha^{-1} DM).

The difference in net margins can be seen when the added grazing value of WCC is reflected under RA soya (Soya + WCC). The Standerton trial data is far from this season real farm case study's data due to late planting. The research team will focus on aligning real farm practices at the trials in the seasons to follow.

4.1.4. Conclusions

The RA SCC followed by WCC grazing reflected the lowest net margins as compared to the maize and soya cash cropping. The reason why is because maize and soya were planted before SCC; maize and soya grain yields were 141-167% above the long term farm average at Onverwacht and New Farm. Grain yields being higher than long term farm averages can be contributed to good rainfall distribution and seasonal rainfall being 130% higher than long term rainfall average (807 mm 2020-2021 season vs. 620 mm LTA).

The financial analysis data for the Standerton trial was not representative and no conclusions can be drawn from that. The research team included this season's Standerton farm data solely for the reason to complement the trial data this season. The Standerton farm's standard grazing practice is high-density grazing on SCC and WCC and the farm net margins shown that SCC+WCC are competitive as compared with cash cropping. Therefore, the profitability of high grain yields in favourable conditions appear to be higher than SCC+WCC grazing figures, but the latter, if well managed (i.e. timely planted, timely and repeatedly grazed) show the potential of competitive net margins ha^{-1}.

The emphasis in the 2021-2022 season will be on timely planting and improved grazing management.

4.2. Assessment of soil health

4.2.1. Activities, Methods and Deliverables

Table 19: Progress and Results achieved under Soil Health work package

Activities	Deliverables	Progress and Results achieved
1. Monitoring and Sampling	Ecotope classification and/or selection (e.g. soil types) Site assessment of each trial site to identify suitable treatments Sampling or monitoring of selected treatments on ecotope Evaluations of soil profiles for compaction, etc.	Soil assessment and sampling of selected treatments were done in October 2020 and February 2021.
2. Lab Analyses	Haney Soil Health Test Nematode soil health index analysis Other, e.g. texture, chemical analyses, etc.	Haney soil health test results were done in October 2020 (baseline data) at 0-10 cm and 11-30 cm and in February 2021 per strip at 0-10 cm. Nematode soil health index analysis was conducted by the North West University (NWU); analyses were still in progress when this report was submitted. Detailed soil lab reports attached under results/ appendixes
3. Monthly meetings (project team)	Participate in monthly forum meetings, discussing problems and possible solutions to them.	The Asset Research team members frequently interacted with the trial farmer co-workers during the season.

4. Annual project feedback meeting to innovation platform or network	Report progress and findings to broad CA network; Discussion and evaluation of data. Learning from each other.	Report progress feedback planned for October 2021. Selected info and audio-visuals circulated via CA-WhatsApp groups
5. Annual report and admin (technical data analyses)	Written technical report covering trial procedures, results and progress.	Done. See this report for details.
6. Participate in Awareness events	Trial visits with stakeholders; participate in awareness events, such as information day and/or cross-visits	The facilitator reached out to ARC and government agencies regarding the CA promotion among black commercial and emerging farmers. AGT donated seed was distributed at a limited scale, but collaboration is viewed as one-sided and inefficient so the Asset Research team stopped interaction. The farmers day at Standerton served as a good platform for sharing CA-related info. The audio-visual material from *Landbouweekblad* was also widely circulated

4.2.2. Soil Health Analyses

4.2.2.1. Haney Soil Health Test

The Haney Soil Health Test offers a more comprehensive look at the nutrient needs and overall health of your soil system. However, it is not a complete evaluation of your soil's health due to its lack in the direct measuring of some of the other soil health indicators such as bulk density, water infiltration rates or water holding capacity. Some of the items measured by the Haney Soil Health Test are similar to traditional tests. Soil pH and organic matter, for example, are evaluated in the same way as the more traditional soil tests many of you have used in the past. In addition, plant-available nutrients such as NPK are evaluated with the same instrumentation. The Haney Test, however, uses different soil extracts, namely H3A and H_2O, to determine what quantity of these nutrients are available to the crop and accessible to the microbes. Nitrate, for example, is soluble and there is little difference between various extracts. Other nutrient levels, however, will vary from traditional tests that use different extracts due to the unique ability of each extract to effectively pull nutrients out of the soil. The Haney Test differs from traditional soil tests in that it also evaluates some soil health indicators such as soil respiration, the water-soluble fractions of organic carbon and organic nitrogen and the ratio between them. Finally, a soil health score is calculated based on a combination of these different soil health indicators. Below is a guideline for understanding and interpreting some of these different values.

4.2.2.2. Haney SHT key parameters explained

Soil organic matter (SOM) and soil organic carbon (SOC)

SOM, expressed as a percentage, is determined by the Loss on ignition (LOI) method. As a rule of thumb, the soil organic carbon (SOC) content can be derived by dividing this value by 1.72. SOM includes all living organisms, dead non-decomposed and completely decomposed organic matter and all substances between these two distinct points which incorporates the water-insoluble and water-soluble organic carbon compounds. SOM is a very important indicator of soil health or quality. Higher SOM values are associated with higher productivity and resilience. Increasing the SOM content through CA is the primary goal, although it is a relatively slow process.

Water extractable organic carbon content (WEOC)

The WEOC expressed in mg kg^{-1} soil, is usually a minute fraction of the total carbon pool. This active or labile pool of carbon is roughly 80 times smaller than the total soil organic carbon pool (which is 0.58% of SOM) and is the energy source for soil microbes. The most common of these compounds are sugars and sugar-like substances, also called liquid C. The WEOC typically ranges from 100 - 400 mg kg^{-1} soil. Readings as high as 800 are common in completely regenerative soils where Ultra High-Density Grazing on very diverse plant covers have been done for several years and is a function of the feeding demand from the extremely high microbial biomass and their activity. This pool is replenished from the microbial degradation of the non-water-soluble portion of the resident organic material (larger cellulose, starches, pectin's, and polysaccharides) to sugars as well as the root exudate sugars.

For example, a soil with 3 % soil organic matter (SOM) when measured with the combustion method at a 0-3 inch sampling depth produces a 20,000 ppm C concentration. When we analyse the water extract from the same soil, that number typically ranges from 100-300 ppm C. The organic C in the soil water extract reflects the quantity of the C in your soil that is readily available to the microbial population; whereas % SOM is reflective of the entire organic C pool that may become available over the lifetime of the soil. The amount of WEOC reflects the quality of the soil. In other words, % SOM is the house that microbes live in, but what we are measuring is the food they eat (WEOC and WEON).

Water Extractable Organic Nitrogen content (WEON)

WEON consists of amino acids or amino acid-like compounds and is measured as the water-extractable nitrogen of the organic fraction. It is the total nitrogen minus the inorganic nitrogen (NO_3 and NH_4) in mg kg^{-1} soil. The organic nitrogen pool is replenished by the protein in plant residues, manure, composts, and dying soil microbes. Microbial action breaks down large protein molecules into peptides and ultimately into amino acids that replenish this pool. This pool is also replenished through plant-associated Rhizobia bacterial action as well by free-living nitrogen binding organisms. The WEON 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 readily plant-available inorganic N.

Total Water Extractable Nitrogen content (WEN)

WEN is the total water-extractable nitrogen expressed in mg kg^{-1} soil.

Nitrogen Mineralisation

The amount of nitrogen being released through mineralisation is expressed in mg kg^{-1} soil. This is an estimate of the amount of nitrogen that will be available to the crop based on microbial activity and the organic C:N ratio. When the organic C:N ratio is above 20, some nitrogen remains tied up in the bacterial biomass with a certain portion being released into the soil as plant-available organic nitrogen.

Organic Nitrogen Release

The total amount of nitrogen being released through microbial activity from the organic nitrogen pool is expressed in mg kg^{-1} soil. It is the sum of microbially active carbon, WEON which is the fraction of the organic nitrogen pool acted upon by the microbes over 24 hours, and nitrogen mineralisation. This nitrogen is immediately available and never reflected in conventional chemical analysis. The nitrogen released here is counted as a credit to the next crop by the Haney test and is subtracted from the conventional recommendation. The amount of nitrogen being released is thus dependent on the water-extractable organic nitrogen content, the soil respiration rate and the organic C:N ratio. Overall, the organic nitrogen release value typically increases as the soil system or soil food web gets healthier.

Organic N reserve

This is the amount of organic N that is not credited as plant available usually due to lower microbial activity relative to the WEOC and WEON pools. If this number is 0 then the entire WEON pool is considered plant available.

Organic C:N ratio

It is very important to note that there is a lot of different C:N ratios discussed in agriculture. This particular C:N ratio is that of the water extract performed as part of the Haney Test. This ratio is not the same as the total C:N ratio of your soil or the manure or cover crop you are using or even the C:N ratio of the organic matter in your soil.

This is the ratio of WEOC:WEON in the soil based on the water extraction. The organic C:N ratio is a very sensitive indicator of the health of the soil and has a significant impact on the activity of soil microbes. Preferably, the ratio should be below 20. Above 20 a higher inclusion of legumes in the cropping system will increase the organic nitrogen and lower the ratio over time. Ratios between 8 and 15 are considered good with an ideal between 10 and 12 (see Table 20).

Table 20: Organic C:N Ratio Ranking:

Ratio Result	Ranking	N Implications	Management Needs
>20:1	Poor; Too much organic C and/or not enough organic N	N tie up by microbes: No N credit given from WEON pool	Increase legumes in rotation or covers; reduce high carbon inputs; graze longer to reduce carbon
Between 15:1 – 20:1	Marginal	Some N tie up; Slower mineralization; Lower N credit from WEON	Increase legumes in rotation or covers; reduce high carbon inputs; graze longer to reduce carbon
Between 8:1 – 15:1	Good	Less N tie up; greater potential for N mineralization; higher credit from WEON	Make slight adjustments if near the boundaries to keep within this range
Between 10:1 – 12:1	Ideal	Greatest potential for N mineralization from WEON pool; good balance of available energy and N for microbes	Increase intensity to drive both WEOC and WEON up together to help increase biological processes
<8:1	Poor; Too little organic C and/or too much organic N	Limited energy for microbial activity; N credit may still be high if soil respiration and WEON are also high	Increase carbon inputs; graze shorter to retain carbon

Carbon respiration burst test - 24 hours CO_2

This is the amount of CO_2 - carbon released in 24 hours by soil microbes after a soil sample has been dried and rewetted. This is a measure of microbial biomass and is related to a soil's potential microbial activity during ideal conditions. Furthermore, it is influenced by SOM, aggregation, texture and overall fertility of the soil. Higher values indicate higher microbial activity and thus healthier soil. This value can range from zero to nearly 1000 mg kg^{-1} soil. Typically, values are below 400 mg kg^{-1} for most soil types and management scenarios. Rankings are shown in Table 21.

Table 21: Ranking of 24 h CO_2 – Carbon respiration burst test

Value (mg CO^2 kg^{-1} soil)	Ranking
0 – 10	Very low
11 – 20	Low
21 – 30	Below average
31 – 50	Slightly below average
51 – 70	Slightly above average
71 – 100	Above Average
101 - 200	High
201+	Very High

True averages are not listed because these rankings are on a sliding scale, which is also dependent on soil types and climate. Sandier soils or dryer climates tend to score lower. Relative differences between crop soils and pastures per locality are of importance and to track change over time of microbial activity.

Inorganic Phosphorus

The amount of inorganic phosphorus in the soil is determined by using the H3A extractant which mimics the root exudate organic acids produced by living plant roots that temporarily change the soil pH thereby increasing nutrient availability. It is expressed in mg phosphorus kg^{-1} soil and is an indication of fertilizer applied phosphorus levels in the soil.

Organic Phosphorus (release)

This is the total phosphorus using water as an extractant minus the inorganic phosphorus. This represents phosphorus that is not currently available for the plant but may become available through microbial activity.

Table 22: Soil Fertility Ratings for Haney H3A Extraction:

Nutrient	Very Low ppm	Low ppm	Medium ppm	High ppm	Very High ppm
P04-P	0-4	5-11	12-22	23-45	45+
P04-PICAP Phosphorus	0-5	6-12	13-25	26-50	51+
Potassium, K	0-18	19-36	37-53	54-89	90+
Sulfate, S	0-3	4-6	7-10	11-14	15+
Magnesium, Mg	0-6	7-11	12-20	21-29	30+
Zinc, Zn	0-0.12	0.13-0.25	0.26-0.38	0.39-0.50	0.51+
Iron, Fe	0-2.0	2.1-4.0	4.1-9.0	9.0-20.0	20.1+
Manganese, Mn	0-0.5	0.6-1.0	1.1-2.0	2.1-3.0	3.1+
Copper, Cu	0-0.03	0.04-0.07	0.08-0.10	0.11-0.20	0.2+

Haney Soil Health Score

This number for soil respiration from 0-100 ppm is calculated as 1-day CO2-C / 10 + WEOC/50 + WEON/10 to include a weighted contribution of microbial activity, water-extractable organic C and N. Since the SHC is heavily weighted for soil respiration, we use a sliding scale system to stabilise the score as respiration rises above 100 ppm CO2-C. This score represents the overall health of your soil system. It combines five independent measurements of your soil's biological and chemical 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. We would like to see this number be more than 7 but this is simply a starting point and should increase over time. This number indicates the current soil health and helps us identify what the soil needs to reach its highest sustainable state. Keeping track of this Soil Health Calculation will allow you to gauge the effects of your management practices over the years.

Volumetric Aggregate stability percentage (VAS)

VAS is a measure of resistance that soil particles exhibit to dispersing when subjected to water immersion and expressed as the percentage volume loss during the immersion process. It serves as a valuable proxy indicator of general soil health.

Microbially Active Carbon (%MAC)

Microbially active carbon or %MAC is how much of the WEOC pool was acted upon by the microbes measured as soil respiration. If this value is below 25% this tells you that WEOC is probably not the factor limiting your soil respiration. Perhaps it is the soil's overall fertility, prolonged cold temps or drought that is limiting microbial biomass. On the other hand, if the %MAC value is above 80% this might tell you that WEOC could become limiting to microbial respiration soon and your management focus should be on introducing more carbon into the system. Ideally, we like to see a %MAC value between 50 and 75% for most production systems. This generally tells you that the soil has a good balance of fertility and WEOC to support microbial biomass, but you are not limited by your WEOC pool. This value, however, should be taken into context and we still need to look at the respiration and WEOC individually to gain a better understanding of the overall status of your soil.

4.2.3. Data and analysis

4.2.3.1. Salient soil features of the different trial sites

Table 23: Soil classification info – soil types, depth and texture

Trial	Geo-reference	Soil type	Soil depth	Soil texture
Onverwacht	**26°20'37"S29°7'54"E**	Avalon	120 cm	Sandy to sandy loam
New Farm	**26°21'28" S29°11'45" E**	Bainsvlei and to a lesser extend Oackly, Valsrivier and Bloemdal	120 cm	Sandy
Standerton	**26°57'21.3"S28°57'30.2"E**	Sepane	80-90 cm	Clay

All three trial areas are on the eastern Highveld falling within a summer rainfall area of on average 620-650 mm yr^{-1}. These areas are characterised by warm summers and cold winters. Minimum temperatures just below -3^0 C, with exceptions up to -9^0 C.

The soil texture, pH, EC, Active C and bulk density values of the different trials and treatments are shown in Tables 24-26 below. The active C value of the veld samples is much higher than the other treatments at the New Farm and Standerton trials, but not so at the Onverwacht trial. The % clay of the Standerton trial is much higher than the other two trials due to the black clay soil types found in that area.

Table 24: Soil texture, pH, EC, Active C and bulk density values of the Onverwacht trial and treatments

Name:		ONVERWACHT	Depth						
Date		Feb-21	0-10 cm						
	A	25-27	19,16,5	22,10,2	20,11,7	24,13,3	17,14,8	18,12,4	23,9,6	21,15,1
NWU LAB		VELD	REGENERATIVE				NT/CA		CONVENTIONAL	
Description		Veld	SD+WD	MAIZE_ Relay	SD+WD	SOYA + WD	MAIZE	SOYA	MAIZE	SOYA
Soil Texture (Sand %)		47.04	67.63	71.24	68.38	70.75	69.03	70.94	70.94	68.33
Soil Texture (Silt %)		26.74	17.83	15.38	17.17	17.04	17.19	16.58	16.50	17.34
Soil Texture (Clay %)		26.22	14.54	13.38	14.46	12.21	13.77	12.48	12.56	14.32
pH		5.37	6.93	7.03	6.80	7.13	6.80	7.13	7.03	6.90
EC (uS/cm)		80.0	130.0	103.3	100.0	93.3	450.0	96.7	103.3	86.7
Active C (mg/kg)		477.3	427.1	408.2	400.3	391.4	374.7	322.3	346.3	351.3
Bulk Density (g/cm3)		0.87	1.46	1.34	1.49	1.37	1.33	1.38	1.37	1.30

Table 25: Soil texture, pH, EC, Active C and bulk density values of the New Farm trial and treatments

Name:		NEW FARM	Depth						
Date		Feb-21	0-10 cm						
		25-27	5,17,10	3,23,15	6,22,12	1,20,14	8,19,9	7,21,13	2,24,11	4,18,16
NWU LAB		VELD	REGENERATIVE				NT/CA		CONVENTIONAL	
Description	A	Veld	SD+WD	MAIZE_ Relay	SD+WD	SOYA + WD	MAIZE	SOYA	MAIZE	SOYA
Soil Texture (Sand %)		52.45	73.80	74.17	73.94	53.65	75.25	74.92	74.20	76.74
Soil Texture (Silt %)		20.71	13.06	11.25	12.23	34.73	11.50	11.72	11.29	11.63
Soil Texture (Clay %)		26.83	13.14	14.58	13.83	11.62	13.26	13.36	14.51	11.63
pH		6.10	6.53	6.63	6.50	6.73	6.70	6.50	6.83	6.77
EC (uS/cm)		116.67	170.00	210.00	93.33	166.67	83.33	83.33	80.00	90.00
Active C (mg/kg)		690.32	273.21	257.42	273.21	167.81	240.86	258.71	258.71	264.28
Bulk Density (g/cm3)		1.12	1.41	1.35	1.44	1.46	1.38	1.35	1.35	1.37

Table 26: Soil texture, pH, EC, Active C and bulk density values of the Standerton trial and treatments

Name:		HO Standerton	Depth						
Date		Feb-21	0-10 cm						
		25-27	2,11,18	5,10,21	4,15,19	3,13,23	7,14,16	8,12,17	6,9,22	1,20,24
NWU LAB		VELD	REGENERATIVE				NT/CA		CONVENTIONAL	
Description		Veld	SD+WD	MAIZE_ Relay	SD+WD	SOYA + WD	MAIZE	SOYA	MAIZE	SOYA
Soil Texture (Sand %)		16.27	20.50	20.75	19.86	22.15	20.66	19.91	26.76	21.13
Soil Texture (Silt %)		36.73	38.46	38.03	38.78	37.22	37.31	37.00	32.31	38.12
Soil Texture (Clay %)		47.00	41.04	41.22	41.36	40.64	42.03	43.09	40.92	40.75
pH		6.27	5.50	5.67	5.53	5.67	5.60	5.60	5.60	5.60
EC (uS/cm)		156.7	163.3	110.0	103.3	93.3	96.7	90.0	106.7	103.3
Active C (mg/kg)		737.2	352.9	366.9	320.6	347.9	415.4	389.2	366.3	328.4
Bulk Density (g/cm3)		1.15	1.19	1.20	1.28	1.25	1.27	1.17	1.13	1.16

4.2.3.2. Soil health

The baseline Haney SHT results (samples taken in February 2021 after the implementation of all the treatments) of all the trials are shown in Appendices 1 to 3. The Haney SHT analyses were done by the Ward lab (https://www.wardlab.com/) in the USA, through the Soil Health Support Centre (https://www.soilhealthlab.co.za/) in the Western Cape. Analytical data of all the parameters are displayed per treatment at 0-10cm (A) and 11-30 cm (B) at Onverwacht, New Farm and Standerton trials. The analytical data were also grouped in the following categories: Soil health (Haney soil health score, VAS, pH), Biological (SOM, SOC, WEOC, soil respiration, MAC, C:N ratio), Nitrogen (all the N values and ratios), Phosphorous (all the P values and ratios), other mineral nutrients, mineral ratios and Plant effective saturation analyses.

4.2.3.3. Soil compaction

Soil compaction was measured with a penetrometer at A (0-10) and B (11-20) horizons.

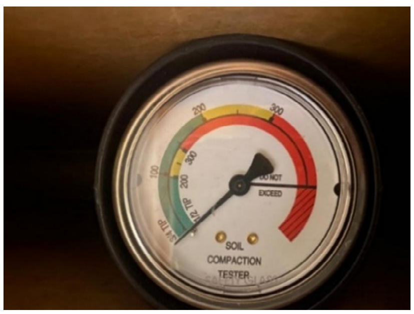


Photo 3: Example of penetrometer used for measuring soil compaction at Mpumalanga trials

Photo 3 reflect:

LOW (No compaction)	0-200	(green)
MEDIUM (Increased resistance)	201-300	(yellow)
HIGH (Compaction)	301-400	(red)

The field team took five penetrometer readings per treatment around the soil sample area.

Onverwacht:

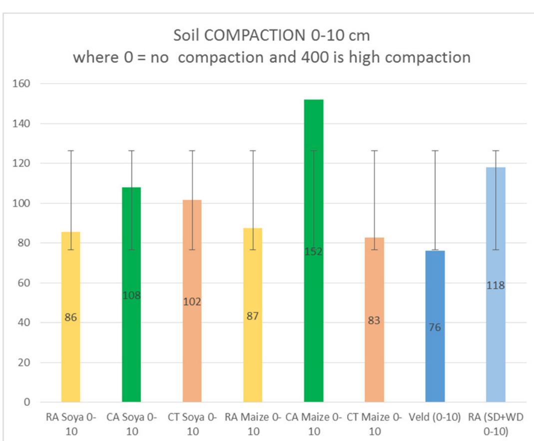


Figure 12: Soil compaction measured with a penetrometer at Onverwacht trial at 0-10 cm

The penetrometer values are below 160 and are categorised as LOW (0-200psi)

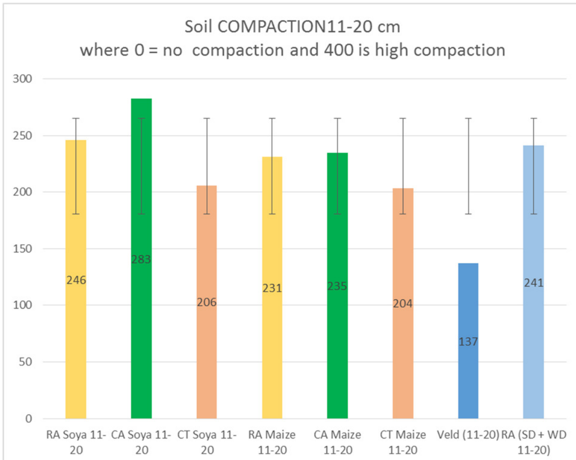


Figure 13: Soil compaction measured with a penetrometer at Onverwacht trial at 11-20 cm

The penetrometer values between 0-200 psi (green line) are regarded as no to low compaction. Most of the results in figure 14 fall within the category medium compaction (200-300 psi) except veld as a point of reference.

NEW FARM

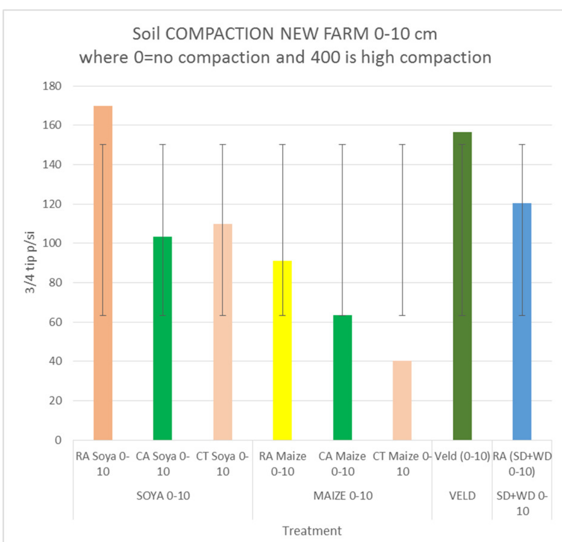


Figure 14: Soil compaction measured with a penetrometer at New Farm trial at 0-10cm

The penetrometer values are below 170 and are categorised as LOW (0-200psi)

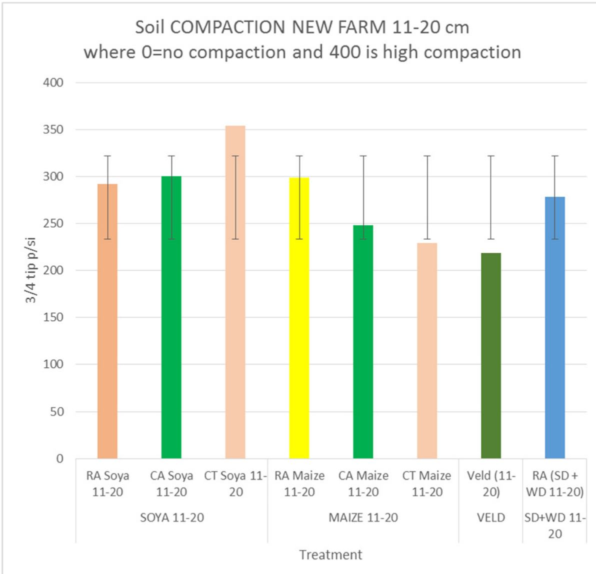


Figure 15 Soil compaction measured with a penetrometer at New Farm trial at 11-20cm

The penetrometer values between 0-200 psi (green line) are regarded as no to low compaction. Most of the results in Figure 16 fall within the category of medium compaction (200-300 psi) except CT soya around 350 psi with HIGH compaction.

STANDERTON

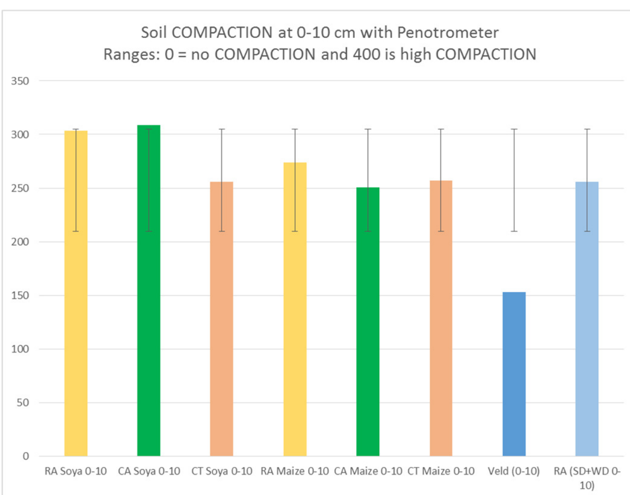


Figure 16: Soil compaction measured with a penetrometer at Standerton trial at 0-10cm

The penetrometer values like veld between 0-200 psi (green line) are regarded as no to low compaction. Most of the results in Figure 17 fall within the category medium compaction (200-300 psi) except RA soya and CA soya that is just above the MEDIUM compaction mark.

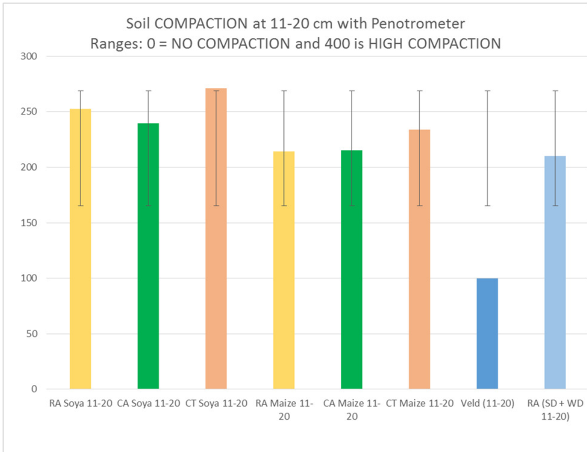


Figure 17: Soil compaction measured with a penetrometer at Standerton trial at 11-20cm

The penetrometer values between 0-200 psi (green line) are regarded as no to low compaction. Most of the results in Figure 18 fall within the category medium compaction (200-300 psi) except veld as a point of reference.

4.2.4. Results and discussion

4.2.4.1. Soil health

A short discussion of the two sets of data taken in the 2020-2021 season (essentially all baseline data) in each of the main categories follows below.

Biological (SOM / SOC, WEOC, soil respiration, MAC, C:N ratio)

- SOM/SOC values of Veld were much higher at both A and B horizons, which reflects a very high "*pristine*" benchmark and reflects the potential SOM/SOC levels in the area possible under best CA practices. SOM/SOC values under cultivated treatments were much higher at the Standerton trial site (between 3 and 4% SOM, compared to 1,5 to 2,5% at the other trial sites) mainly due to the high clay content.
- Values of WEOC, soil respiration, MAC were all very low at all the trial sites, except at the veld sampling points, which were much higher. C:N ratios were mostly in the right ranges.

Nitrogen (all the N values and ratios)

- WEON (Organic N) levels were between 10 and 20 in all the trial sites. Inorganic N values were between 10 and 105 with an average of 25; this shows the presence of large amounts of residue N from synthetic fertiliser at some sampling points.

Phosphorous (all the P values and ratios)

- The Total P values in soils of the Standerton trial range from Medium (12-22 ppm) to High (23-45 ppm) in the topsoil, to Low (5-11 ppm) in the subsoil, while the neighbouring CT farmer has High total soil P values of 41 ppm and 30 ppm in the top-and subsoil respectively.

Almost all the soil P are from the inorganic source (i.e. fertilisers). The topsoil of the Veld is 12 ppm and the subsoil is 6 ppm, also mostly from the inorganic pool.

- The Total P values in soils of the New Farm trial are all High (27-32 ppm) in the topsoil, to Low (5-14 ppm) in the subsoil. All the soil P are from the inorganic source (i.e. fertilisers). The topsoil of the Veld is 35 ppm and the subsoil 12 ppm, also mostly from the inorganic pool.
- The Total P values in soils of the Onverwacht trial are all High to Very High (34-49 ppm) in the topsoil, to High (20-31 ppm) in the subsoil. All the soil P are from the inorganic source (i.e. fertilisers). The topsoil of the Veld is Low (7 ppm) and the subsoil Low (2 ppm), also mostly from the inorganic pool.

Soil health (Haney soil health score (SHS), VAS, pH)

- The Haney SHS's on the Standerton trial are *Good* to *Excellent* and ranges between 8 and 26.
- The Haney SHS's on the New Farm are all *Average* and *Below Average* and are all below 7. However, the SHS of the topsoil under Veld is 18.
- The Haney SHS's on the Onverwacht are all *Average* and *Below Average* and are all below 7, primarily due to the sandy nature and poor structure of these soils. However, the SHS of the topsoil under Veld is 9.
- The VAS values on the Standerton trial are much higher than the two Kinross trials due to the high clay content and strong subangular blocky structure of those black soils. The VAS values of the Standerton trial are all very high (48 to 59). The top-soils (0-10 cm) are slightly lower than the sub-soils (11-30 cm). SHS's of the CT system of the neighbouring farm are still high at 41 (top-soil) and 43 (sub-soil).
- The VAS values on the two Kinross trials are all low (below 10), except for the two sampling points under Veld at New Farm with a score of 41.

Other Haney parameters standing out

- The Fe values on all the trials are Very High (above 20).
- The Mn values of many sampling spots in the topsoil at the New Farm and Onverwacht trials are above the expected range of 4-6 ppm.
- Although Ca and Mg levels at all the trial seem to be adequate (>300 and >30 ppm respectively), the %Ca are below 68% in the Standerton trial site ranging from 36 to 43%, the New Farm trial site (54-68%), as well as the Onverwacht trial site (43-63%).

Soil compaction

There is no soil compaction measured with the penetrometer on any of the three trials in the A horizon. Readings between 200-300 psi were found in the B horizon. Veld had the lowest penetrometer readings in general. At New Farm, the A horizon penetrometer readings were lowest under the three maize treatments. We observed a small increase in resistance/ compaction past the 10-11cm soil depth mark, which may be explained as a compacted plough layer, possibly as a result of previous tillage practices.

4.2.5. Conclusions

The Haney Soil Health Test offers a more comprehensive look at the nutrient needs and overall health of the soils under different treatments at all three trial sites. The fact that the Haney Test includes alternative 'biological' parameters, compared to traditional soil tests, such as soil respiration, the water-soluble fractions of organic carbon and organic nitrogen and the ratio between them, added great value to these studies.

The % clay of the Standerton trial is much higher than the other two trials due to the black clay soil types found in that area, which had a big effect on the Haney Test results. For example, SOM/SOC values under cultivated treatments were much higher at the Standerton trial site (between 3 and 4% SOM, compared to 1,5 to 2,5% at the other trial sites) mainly due to the high clay content. SOM/SOC values of Veld were much higher at both A and B horizons, which reflects a very high "pristine" benchmark and reflects the potential SOM/SOC levels in the area possible under best CA practices.

Values of WEOC, soil respiration, MAC were all very low at all the trial sites, except at the veld sampling points, which were much higher. C:N ratios were mostly in the right ranges.

Inorganic N values were dominant and shows the presence of large amounts of residue N from synthetic fertiliser at most sampling points. The Total P values in all trials were Medium to Very High with almost all the soil P from the inorganic source (i.e. fertilisers). The topsoil total P values of the Veld soils are Low, and mostly from the inorganic pool.

The Haney SHS's on the Standerton trial are *Good* to *Excellent* and on the New Farm and Onverwacht trial all *Average* and *Below Average*, primarily due to the sandy nature and poor structure of these soils.

The Fe values on all the trials are Very High. Although Ca and Mg levels at all the trials seem to be adequate, the %Ca are below 68% in the Standerton trial site ranging from 36 to 43%, the New Farm trial site (54-68%), as well as the Onverwacht trial site (43-63%).

There is no soil compaction measured with the penetrometer and bulk density assessments in the A horizon on any of the three trials.

4.3. Assessment of cover crop adaptability, suitability and livestock integration

4.3.1. Activities, Methods and Deliverables

Table 27: Progress and results of the work package: assessment of cover crop adaptability, suitability and livestock integration

Activities	Deliverables	Progress and Results achieved
1. Land preparation	Weeding and management of cover crops before planting.	Done
2. Purchase Materials and Equipment	Acquisition of seed, inoculum, stickers, implements, chemical inputs.	Done. Farmers supplied cash crop seeds and AGT sponsored cover crop seeds. Farmers purchased winter CC seeds themselves.

3. Establishing and Planting of trials	Established trial according to the selection of trial sites and decisions made.	Done
4. Seasonal management and maintenance of trials	Regular visits to the trial site for inspection of weeds and insect damage and control if needed. Treatment of cover crop at the appropriate time (usually before seed set) using appropriate equipment. Submission of technical feedback after each visit. Photos from the trial during visits	Regular visits are done throughout the season. Photos made and biomass assessment done throughout the season
5. Monitoring and Sampling	Completed data sheets for 1. Input cost 2. Germination 3. Cover % 4. Height of cover of each addition 5. Biological productivity t/ha^{-1}	Biomass reports are made per cover crop treatment. On-site assessments were made evaluation crop stand, cover%, cover crop performance. Grazing strategies and timing was discussed
6. Lab Analyses	C:N content of plant material Protein content	Detail lab results on soil data are available for all strips within this case special emphasis on the RA cover crop strips
7. Monthly meetings	Participate in project meetings, discussing problems and possible solutions to them.	Monthly and bi-monthly farmer meetings held
8. Annual innovation platform meeting	Report progress and findings; Discussion, reflection and evaluation of trial results. Learning and adjustment from results.	Reports made and livestock integration is part of the economic analysis
9. Annual report and admin (production and technical data)	Written technical report covering trial procedures, results and progress.	A cover crop-livestock integration document was sent to farmers as an advisory guide and protocol doc (see below). Grazing management on trials posed some challenges due to plots size, untrained animals to electric fence systems, unpracticality of fencing off six strips of between 100-400 m, and risk of animals breaking out into

		soya and maize strips affecting the trial outcomes. Discussions with farmers frequently
10. Participate in Awareness events	Trial visits with stakeholders; participate in awareness events, such as information day and/or cross-visits	High-density grazing was displayed and discussed at Standerton farmer day

4.3.1.1. Cover crop mixtures used in CA trials

In many ecosystems, there is high biodiversity in vegetation that contributes to the stability of the ecosystem. Agro-ecosystems have much less biodiversity. Planting a mixture of cover crops increases the biodiversity of farming systems, which may increase soil health.

Cover crop mixtures can provide a variety of benefits. In regenerative systems, grasses in the mixture provide a longer-lasting residue that helps with reducing erosion, reducing soil temperature, preventing crusting, adding carbon, and weed suppression. Cover crop residues left after being grazed or rolled can form a mat at the soil surface also moderate soil temperatures, which reduces crop stress. Legumes fix nitrogen that may be available to the following cash crop. Brassicas can scavenge nitrogen, may alleviate compaction, and provide early pollen as well as nectar for pollinator and beneficial insects. A cover crop mixture will provide some of all these benefits. Whether or not a mixture is right for your operation will depend on the benefits you want the cover crop to provide.

There are several things to consider when designing a mixture. The first is functional groups. Cover crop species can be grouped by when they grow and plant family. These groups roughly correspond to the function of the cover crops.

The six functional groups are fall/winter planted small grains, legumes and brassicas, and spring/summer planted annual grasses, legumes, and broadleaf plants.

By selecting species with complementary growth forms, you reduce competition between species. For example, tall and open-canopied species, such as pearl millet, are complimentary to vining species, such as cowpeas.

For the trial plant species that are known to perform and complement each other in the agro-ecotopes were put together as a summer and winter mixture for treatments that included SCC, WCC, delayed intercropping in maize and double cropping of soya.

The following summer cover crop (SCC) mixture is used in the CA trials:

- 10 kg babala
- 2 kg hybrid Babala
- 10 kg cowpeas
- 8 kg sun hemp
- 1 kg tillage radish

The following winter (temperate) cover crop (WCC) mixture is used in the CA trials:

- 25 kg rye
- 30 kg triticale
- 10 kg grazing vetch
- 1 kg canola
- 1 kg fodder turnips

4.3.1.2. Management protocol for cover crop and livestock integration treatments

Introduction

The objective of this protocol was to supply farmers with information on establishing and managing cover crop trial plots during the 20/21 period. The protocol focuses on grazing animals and diversity of cover crop establishment as positive drivers for changes in agro-ecosystems. The advantage of grazing cover crops in rotation with cash crops on the yield of cash crops and the physical, biological and chemical soil parameters will be investigated. It is envisaged that the coupling and decoupling of nutrients in nature are being simulated by grazing of cover crops, where diversity, intensification and integration plays a role. Management of stocking density (intensity of grazing) and spatial orientation of animals (continuous vs rotational) is of utmost importance. Overgrazing leads to soil degradation, while light to moderate grazing leads to system functionality that results in emerging properties. Through management, by taking into account the local environment and socio-economic environment, we try to benefit the environment through a holistic approach, compared to the current system that focuses on short term financial gain, already responsible for the 50% loss in soil carbon.

Cover crops in the context

In the summer rainfall areas, temperate cover crops are mostly used after a crop such as soybeans with a relatively short growth period. *"Establish immediate after soybeans (planter follows the harvester), in other words, grazing of soybean residues are sacrificed" (Izak Dreyer, CA farmer, Vrede).* A single crop or a mixture of different functional groups can be used. The main purpose of cover crops is to protect the soil by creating a mulch. The mulch will lessen the kinetic energy of raindrops as well as increase the residential time of water on the soil surface, reduce temperature, improve the nutrient cycle and provide food for microbes. The biomass produced by temperate cover crops under these conditions is usually low and is closely correlated with soil moisture that is a function of late rain.

Through intensification and the establishment of summer cover crops during the wet season (spring planting), it is proposed to use in particular C4 grasses because they use natural resources (light and water) more efficiently than C3 crops, thereby increasing the sequestration of soil carbon more effectively. Research by the CA FIP indicated that crops such as babala, hybrid babala, sorghums, sweet sorghums and sudan grass in a vegetative stage contain up to 21% crude protein. On farms where these mixtures were planted, good average daily gains of productive animals were measured. A simple mixture of 10 kg babala, 2 kg hybrid Babala, 10 kg cowpeas, 8 kg sunn hemp and 1 kg tillage radish is recommended. The summer grasses do not cause prussic acid poisoning and cowpeas and sunn hemp fixes atmospheric nitrogen that reduces nitrogen fertilizer costs. Tillage radish breaks soil compaction layers and is a good scavenger to absorb available nitrogen in the soil solution and thus reduce possible nitrate pollution. The cover crop also ensures that habitat is created for useful insects and the colonisation of arbuscular mycorrhizal fungi (AMF).

An increase in both the cover crop biomass and C:N ratio was shown to lead to a negative effect on the availability of inorganic nitrogen in the follow-up crop, *"especially where maize is planted after fodder sorghum and more so when fodder sorghum regrows during early spring. Volunteer fodder sorghum is also problematic where non-Roundup maize is planted" (Izak Dreyer, CA farmer, Vrede)*. This further lead to greater management skills expected from the farmer. Of utmost importance for the cover crop to add positively to the available nutrient pool, its growth must be terminated when in a vegetative growth stage, or it should be grazed. *"Rather too early than too late" (Izak Dreyer, CA farmer, Vrede).*

For intensification as well as to increase biodiversity it is recommended that as soon as cooler weather in mid-February to mid-March occurs, summer cover crops have to be grazed and winter cover crops are established with a no-till planter. The winter mixture consists of temperate grasses (25 kg rye and 30 kg triticale), temperate legumes (10 kg grazing vetch) and brassica crops (1 kg canola and 1 kg fodder turnips). The temperate grasses' growth potential is significantly improved when it is combined with short growing soya cultivars during the summer months. *"Winter cover crops grow better when summer cover crops regrowth is terminated using Roundup" (Izak Dreyer, CA farmer, Vrede).*

Cover crop grazing

Grazing of cover crops allows farmers to produce additional products such as milk and meat from traditional bare fallow arable lands. This can be described as a form of ecological intensification that brings about functional and biological synergism through the interaction of plant and animal in the system. This result is a more resilient system that can manage unfavourable climatic conditions better whilst production and ecosystem services are maintained. The inclusion of animals in a simple crop rotation or monoculture system reduces risks and enhances farm stability.

Photo 4: Ideal growth stage for first grazing

The intensification of grazing (animal density LSU ha^{-1}) is the management tool that determines productivity and sustainability. The grazing period is also important since it determines the dry matter intake of animals. If the available biomass is low, animal production will decrease due to limitation in bite sizes. Optimal grazing intensity will ensure optimal animal production and biomass utilisation, without limiting intake. In a no-tillage system, the grazing intensity also determines the quantity and quality of the mulch. This mulch serves as a physical barrier against compaction through hoof action and limits water erosion. Earlier utilisation for instance in a late vegetative stage will adhere to the rule of thumb of "take half, leave half". This will allow the regeneration of the cover crop faster because sufficient leaves will be left on the plants to continue with photosynthesis (see Photo 4).

In cases where annual fodder crops are grazed too intense, the leaf area index will decrease, and biomass accumulation will be below. Leaves absorb sunlight energy and produce sugars. The survival strategy of annual crops is to produce energy for seed production and to produce a seed head, energy has to be used to produce stems. It will therefore be advantageous to graze grasses only once in a late vegetative state, i.e. just before the flag leave stage (50%). Young leaves produced after grazing will have a greater photosynthetic capacity than mature leaves. Residual material will also break down faster because of lower lignin content. A more intensive grazing system is proposed for follow-up grazing, i.e. close to planting the winter cover crop. This will ensure that a dense mulch will form and that regrowth will serve as a nurse crop for winter established cover crops. *"We struggled to get more than one grazing from summer cover crops. "Furthermore, sorghum regrowth only from its base. To establish winter cover crops as early as possible ads more value." (Izak Dreyer, CA farmer, Vrede)*

The establishment of winter cover crops must be at a time when follow-up rain is still, expected. Winter cover crops react well to rain after establishment while it establishes more difficulty with only accumulated soil moisture. Utilisation will depend on biomass. One of the main aims of using winter cover crops is to keep growing roots as long as possible in the soil. When early spring rains fall, these crops will again start growing actively. Roundup can be used to chemically kill WCC two weeks before cash crops are planted. The planting process will be positively influenced if the plant residues are still green, through the prevention of hair-pinning (see Photo 5). The establishment of WCC is ideal from middle February to middle March after final grazing of an SCC mixture.*"Oats (Overberg and Kompasberg) two out of three years had frost damage. It is recommended that rye and triticale are added" (Izak Dreyer, CA farmer, Vrede).*

Photo 5: Winter cover crop planted after summer cover crop

Data collection:

For the monitoring of the cover crops, the following data must be collected and analysed.

- Dry matter intake requirements of animal
- Dry matter yield of cover crops (t ha^{-1})
- Dry matter yield of residues (t ha^{-1})
- Estimation of losses due to trampling
- Grazing days

Animal production

The size of the plots differs between trial localities. It is therefore impractical to determine animal production in terms of growth (g day^{-1}). The total number of animals and mass must be determined. Farmers have good observation skills and can estimate animal weight based on their conformation. The dry matter need can then be established daily. *"If you can weigh before and after grazing, it will be first prize" (Izak Dreyer, CA farmer, Vrede).*

Plant production

To monitor the cover crop the available dry matter must be determined before the plots are grazed. For this, a 1 m^2 plot is harvested and the wet mass determined. A subsample is taken, weighted, and dried at 60 ^{o}C for 48 hours if nitrogen will be determined. From this, the dry matter percentage is determined as well as the dry matter production per ha. Since there are great distances between trials it is impossible to visit plots weekly. It is suggested that the participating farmer should use exclusion gates to determine the utilisation amount of the plots. Photos 6 and 7 is an example of such an exclusion gate. This gate should be big and high enough so that animals cannot reach the forage inside.

Photo 6: Using exclusion gates on grazing plots to determine biomass

Photo 7: Determine DM after grazing the plot

To determine what is utilised, it is important to measure the plant material left after grazing. The same procedure should be applied to determine this. Subtracting the two figures will give an estimation of the plant material that was wasted due to trampling.

4.3.2. Data and analysis

The following figures and assumptions were used to calculate the production potential of SCC and WCC:

For SCC a general mistake made by farmers is grazing the cover crops too late (at a reproductive stage). Summer annual grasses develop stems that are trampled by animals and it was calculated that only 30% of available forage was utilised during a grazing trial at Ottosdal, in the North West Province. Earlier utilisation for instance in a late vegetative stage will adhere to the rule of thumb of "take half, leave half". This will allow the regeneration of the cover crop faster because sufficient leaves will be left on the plants to continue with photosynthesis. This mistake was also observed during the grazing of the SCC by participating farmers in Mpumalanga. Hence the assumptions to use the value of 30% utilisation to calculate the margins for SCC. The feed conversion ratio that is used for calculating monetary values for SCC, was the actual value that was obtained during the trial period.

For WCC the situation changes somewhat. Being C3 crops means that they are utilized much more efficiently than the C4 grasses in SCC. The WCC forage is shorter and cattle can top-graze them. This situation brings the added advantage of less wastage due to trampling. For regrowth to occur farmers must move the animals frequently, while enough leaves are still present. Overgrazing of WCC occurs regularly. At a grazing trial of WCC at Jaco De Vos in the Kinross area, Mpumalanga, it was observed that 70% of available cover crop material was used during the trial period, which included two grazing events. Hence the assumption to use the value of 70% utilisation to calculate the margins for WCC. The feed conversion ratio that is used for calculating monetary values for WCC, was the actual value that was obtained during the trial period. Calculating available biomass for SCC and WCC respectively (DM t ha^{-1})

The fodder availability as a %, with feed conversion rate (FCR) of respective cover crops used in the trial for calculating monetary values:

For SCC 30% (DM t/ha * 30%) 1: 10 (10kg fodder results in 1 kg meat/ha produced)
For WCC 70% (DM t/ha * 70%) 1: 6.5

Dividing the available fodder per hectare by the FCR gave us a value that resembles the amount of meat that can be produced from one hectare. Multiply kg meat ha^{-1} produced with the actual live weight prices of lambs (R48) and beef (R38) helped to calculate margins for WCC and SCC.

Livestock income is based on cover crop assessments, which is reflected under the financial analyses in this report. Dry matter content of SCC treatments was measured on 16 February and for die double-crop WCC on 17 June 2021 with a 1 m^2 square quadrant. The contribution in terms of dry matter production at Onverwacht and New farm for the SCC from the functional groups was 70%, 13.5% and 16.5% for grasses legumes and brassicas, respectively. In Table 28 the plot numbers (Nr.) and the DM t ha^{-1} (DM) for the different locations for the SCC and WCC planted as double crops are displayed. Values for SCC at Standerton were estimated by the farmer after grazing the CC.

Table 28: Dry Matter yield t ha^{-1} at trials in Mpumalanga for the CC treatments

Onverwacht			New Farm			Standerton		
Nr.	*DM	**DM	Nr.	*DM	**DM	Nr.	*DM	**DM
5	18.1	0.5	5	16.8	1.0	2	3.0	0.3
7	19.3	0.5	6	18.5	1.0	4	3.0	0.3
11	17.1	0.5	10	20.6	0.5	11	3.0	0.7
16	16.0	0.9	12	16.5	0.9	15	3.0	0.7
19	9.4	0.5	17	25.5	1.9	18	3.0	0.8
20	12.0	0.5	22	21.3	1.2	19	3.0	0.5
AVG	15.3	0.6		18.6	1.1		3.0	0.6
* SCC harvested 16/02/2021 * * WCC harvested 17/06/2021								

At Standerton WCC was planted very late after soya harvest and no harvesting took place also no attempted was made to plant the delayed intercrop treatment between maize. At Onverwacht and New farm these two practises were left out altogether.

4.3.3. Results and discussion

The ASSET Research team is busy developing a financial analysis system to measure the monetary value of the various cover crops in the RA systems. The aim is to develop and encourage farmers to conduct their own farm case studies and capture data such as LSU grazing days, FCR and average daily gain (ADG) gain, just to mention a few.

It has been a challenge to apply high-density strip grazing on the various RA strips due to the size of the strips, animals not used to or exposed to HDSG and the risks of having animals grazing next to maize and soya plots. Onverwacht and Standerton SCC were grazed by beef cattle but not with enough success. At Onverwacht livestock trampled most of the available grazing material, while at Standerton clay soils and wet weather hampered the livestock integration treatment. At New Farm, SCC was sprayed with a 2% Roundup whereafter it was slashed two days later. This action was deemed necessary to counterbalance the threat of nitrogen immobilisation. Letting the CC grow to full maturity would have impacted the C:N ratio negatively.

As can be seen in Table 28 dry matter production for the two locations (Onverwacht and New Farm) were satisfactory at 15.3 and 18.6 t ha^{-1}, respectively. At Standerton the low yield of 3 t ha^{-1} can be attributed to the fact that the CC was planted too late. The financial implications (profits) are discussed under the gross margin analysis.

4.3.4. Conclusions

Grazing the SCC and WCC on the treatment strips in all the three trial sites posed challenges in terms of fencing, water supply and livestock was not staying overnight on the strips. That resulted in part-time hit-and-run grazing where more feed was trampled than consumed. The livestock was not familiar with strip grazing and therefore it did expose risks of breaking out of the cover crops potentially damaging the maize and soya strips.

Attention will be given to timely planting of the CC in this forthcoming season as well as improved grazing management. Treating the CC like a cash crop, getting seed and all other inputs before planting is a recipe of success. Special skills and knowledge are of importance when changing from a conventional to an integrated approach. As a team we expect farmers to gain skills and that farmer-to-farmer knowledge transfer will improve the implementation of certain practices in the subsequent year.

It is envisaged that practises that include integration, intensification and diversity will contribute to a system that will not only sustain the resource but will lead to a systems approach that will enhance ecosystem functions and processes. This scenario will stabilize yields and will reduce the risk associated with farming in the semi-arid regions of South Africa.

5. References

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Appendix 1: Baseline Haney soil health test data for Onverwacht trial, February 2021

Name:	ONVERWACHT	Depth										
Date	Feb-21	0-10 cm										
			A	25-27	19,16,5	22,10,2	20,11,7	24,13,3	17,14,8	18,12,4	23,9,6	21,15,1
Sample ID				VELD	REGENERATIVE				NT/CA		CONVENTIONAL	
Lab ID			A 0-10 cm	Veld	SD+WD	MAIZE_ Relay	SD+WD	SOYA + WD	MAIZE	SOYA	MAIZE	SOYA
SOIL HEALTH	Score	Ideal > 7		18.15	6.08	5.56	7.34	5.10	5.75	5.78	5.59	6.14
	Comment											
Volumetric Aggregate Stability %		Ideal > 45		12.85	7.48	4.26	7.48	8.06	8.48	5.19	9.57	6.19
Soil pH (1:1 H2O)		Ideal 5,5 - 6,5		4.64	6.41	6.54	6.23	6.84	6.53	6.67	6.61	6.47
BIOLOGICAL ANALYSES	Organic Matter %	Ideal > 2,5		5.00	2.00	1.70	1.87	1.80	1.80	1.63	1.83	1.77
	Soil respiration CO2-C (ppm C)	Ideal > 50		144.13	25.75	25.94	36.28	21.35	21.80	23.58	24.57	24.36
	H2O Total Organic C			133.33	120.00	115.00	120.67	113.67	128.00	123.33	118.33	130.00
	Soil Organic Carbon %			2.91	1.16	0.99	1.09	1.05	1.05	0.95	1.07	1.03
	Water Extractable Organic C %			0.55	1.13	1.28	1.16	1.21	1.16	1.35	1.16	1.37
	% Microbially Active Carbon	Ideal > 20		106.66	21.39	22.85	29.72	18.69	18.40	18.99	20.74	18.68
	Organic C:N			13.30	13.65	21.77	18.62	21.06	16.75	14.25	26.34	12.65
NITROGEN	H2O Total N			42.23	38.07	29.17	41.23	27.93	26.33	28.77	27.03	31.30
	H2O Organic N			10.70	11.07	6.70	13.03	6.97	10.13	9.53	7.63	11.00
	H3A Nitrate			24.43	20.60	14.37	20.80	13.17	9.63	11.73	12.20	13.13
	H3A Ammonium			7.93	3.63	3.63	3.77	3.43	3.23	4.07	3.10	3.97
	H3A Inorganic Nitrogen			32.37	24.23	18.00	24.57	16.60	12.87	15.80	15.30	17.10
	Total N (Organic + Inorganic)			43.07	35.30	24.70	37.60	23.57	23.00	25.33	22.93	28.10
	Organic N: Inorganic N ratio			0.37	0.45	0.36	0.46	0.40	0.74	0.59	0.47	0.64
	Organic N Release			10.70	9.71	6.21	13.03	5.33	6.76	7.51	6.35	8.40
	Organic N Reserve			0.00	1.35	0.49	0.00	1.64	3.37	2.03	1.29	2.60
	Total available N			43.07	33.95	24.21	37.60	21.93	19.63	23.31	21.65	25.50
	N kg/ha			96.47	76.04	54.23	84.22	49.12	43.96	52.21	48.49	57.12
PHOSPHOROUS	H3A Total Phosphorus			8.67	49.00	56.67	43.67	56.33	28.33	53.00	40.00	52.67
	H3A Inorganic Phosphorus			5.43	43.00	50.47	38.03	49.63	24.33	46.97	33.90	45.83
	H3A Organic Phosphorus			3.23	6.00	6.20	5.63	6.70	4.00	6.03	6.10	6.83
	Total available Phosphorous			8.67	46.84	54.44	43.04	53.41	26.49	50.31	37.68	49.53
	P kg/ha			9.82	53.09	61.71	48.78	60.53	30.02	57.03	42.71	56.14
	P Organic: Inorganic			0.68	0.15	0.14	0.15	0.14	0.17	0.13	0.18	0.17
	Organic P Release			3.23	3.84	3.98	5.00	3.77	2.15	3.35	3.78	3.69
	Organic P Reserve			0.00	2.16	2.22	0.63	2.93	1.85	2.69	2.32	3.14
POTASSI	H3A Potassium (ppm)	Ideal 120 - 200		120.00	84.00	76.00	67.67	97.00	75.33	90.67	67.33	82.67
	K kg/ha			133.86	93.70	84.78	75.48	108.21	84.04	101.14	75.11	92.22
OTHER NUTRIENT FACTORS	H3A Calcium			226.00	582.33	573.33	552.00	614.00	1654.33	528.00	565.33	568.67
	H3A Aluminum			251.33	226.00	233.33	232.00	213.67	190.67	226.33	233.00	237.00
	H3A Iron (ppm)	20 - 80		89.33	101.00	110.67	108.00	99.67	78.33	108.33	112.67	105.00
	H3A Sulfur (ppm)	< 12		9.37	15.07	10.60	10.83	6.50	286.70	6.77	12.13	6.40
	H3A Zinc (ppm)	1 - 3		4.96	2.87	3.18	3.10	2.70	1.87	3.85	3.17	2.93
	H3A Manganese (ppm)	4 - 6		10.10	25.47	22.73	23.03	23.43	15.50	23.97	21.77	21.63
	H3A Copper (ppm)	0,5 - 1,0		0.14	0.39	0.45	0.48	0.43	0.27	0.45	0.47	0.41
	H3A Magnesium			88.00	152.67	132.67	133.67	139.00	193.33	131.33	135.33	139.00
	H3A Sodium			5.67	6.67	6.00	6.33	5.67	6.67	5.67	5.67	6.67
	% P Saturation (Al/Fe)			2.66	15.60	16.31	13.05	17.96	15.58	15.91	11.83	15.07
	% P Saturation (Ca)			3.88	8.58	9.97	8.14	9.72	4.08	10.18	7.11	9.14
KEY CHEMICAL RATIOS	Calcium: Magnesium	> 5		1.57	2.40	2.70	2.67	2.75	4.36	2.52	2.60	2.65
	Calcium: Magnesium/ Aluminium	> 1,7		2.08	5.12	4.74	4.56	5.32	37.49	4.43	4.58	4.56
	Magnesium: Potassium	1 - 2		2.31	5.75	6.09	6.83	4.63	8.89	4.60	6.49	5.54
	Potassium: Sodium	> 1		12.62	7.32	7.35	6.54	10.29	6.54	9.71	6.97	7.88
PLANT EFFECTIVE CEC SATURATION ANALYSES	Calcium Ca %	> 68		35.42	55.17	56.99	55.95	57.84	64.29	55.03	56.72	55.84
	Magnesium Mg %	10 - 20		22.58	23.34	21.52	21.58	21.28	18.67	22.17	22.08	22.20
	Potassium K %	> 5		9.86	4.04	3.87	3.36	4.89	2.99	4.80	3.43	4.14
	Sodium Na %	< 2		0.82	0.57	0.52	0.59	0.50	0.44	0.52	0.49	0.57

Appendix 2: Baseline Haney soil health test data for New Farm trial, February 2021

Name:	NEW FARM	Depth										
Date	Feb-21	0-10 cm										
			A	25-27	5,17,10	3,23,15	6,22,12	1,20,14	8,19,9	7,21,13	2,24,11	4,18,16
Sample ID				VELD	REGENERATIVE				NT/CA		CONVENTIONAL	
Lab ID			A 0-10 cm	Veld	SD+WD	MAIZE_ Relay	SD+WD	SOYA + WD	MAIZE	SOYA	MAIZE	SOYA
SOIL HEALTH	Score	Ideal > 7		11.79	4.53	4.12	4.39	4.24	4.28	4.42	3.84	4.09
	Comment											
Volumetric Aggregate Stability %		Ideal > 45		10.45	3.44	4.38	4.55	3.14	2.62	3.90	4.08	3.79
Soil pH (1:1 H_2O)		Ideal 5,5 - 6,5		5.73	5.96	5.91	5.95	6.12	6.12	5.97	6.23	6.04
BIOLOGICAL ANALYSES	Organic Matter %	Ideal > 2,5		5.10	1.40	1.40	1.43	1.33	1.40	1.43	1.33	1.30
	Soil respiration CO2-C (ppm C)	Ideal > 50		84.54	25.80	23.65	24.20	21.28	24.86	24.11	19.45	21.12
	H2O Total Organic C			124.00	70.33	67.00	74.00	74.67	73.67	71.00	69.33	71.67
	Soil Organic Carbon %			2.97	0.81	0.81	0.83	0.78	0.81	0.83	0.78	0.76
	Water Extractable Organic C %			0.42	0.86	0.84	0.88	0.97	0.90	0.87	0.89	0.95
	% Microbially Active Carbon	Ideal > 20		71.23	36.92	35.66	33.32	28.36	34.58	33.95	27.88	29.55
	Organic C:N			15.36	12.99	16.16	15.57	12.57	23.11	12.15	13.78	13.13
NITROGEN	H2O Total N			21.20	17.97	14.37	17.90	20.17	13.87	19.47	15.60	18.63
	H2O Organic N			8.60	5.43	4.13	4.93	6.20	3.20	5.90	5.10	5.47
	H3A Nitrate			7.70	8.10	7.00	8.77	10.77	6.57	10.23	7.50	9.03
	H3A Ammonium			5.77	3.30	3.43	4.27	3.77	3.27	2.93	2.83	2.87
	H3A Inorganic Nitrogen			13.47	11.40	10.43	13.03	14.53	9.83	13.17	10.33	11.90
	Total N (Organic + Inorganic)			22.07	16.83	14.57	17.97	20.73	13.03	19.07	15.43	17.37
	Organic N: Inorganic N ratio			0.76	0.48	0.40	0.38	0.42	0.33	0.45	0.52	0.46
	Organic N Release			8.60	5.43	4.13	4.93	6.00	3.20	5.90	4.90	5.47
	Organic N Reserve			0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.20	0.00
	Total available N			22.07	16.83	14.57	17.97	20.53	13.03	19.07	15.23	17.37
	N kg/ha			49.43	37.71	32.63	40.25	46.00	29.19	42.71	34.12	38.90
PHOSPHOROUS	H3A Total Phosphorus			12.00	32.67	28.67	28.33	31.33	31.67	26.00	32.67	29.33
	H3A Inorganic Phosphorus			6.60	28.23	24.03	24.03	26.90	27.20	20.90	28.43	24.57
	H3A Organic Phosphorus			5.40	4.43	4.63	4.30	4.43	4.47	5.10	4.23	4.77
	Total available Phosphorous			12.00	32.66	28.52	28.11	30.61	31.40	25.82	31.98	28.73
	P kg/ha			13.60	37.02	32.33	31.86	34.70	35.59	29.26	36.24	32.56
	P Organic: Inorganic			1.43	0.16	0.20	0.18	0.21	0.17	0.26	0.17	0.20
	Organic P Release			5.40	4.42	4.49	4.08	3.71	4.20	4.92	3.54	4.16
	Organic P Reserve			0.00	0.01	0.14	0.22	0.72	0.27	0.18	0.69	0.60
POTASSIU	H3A Potassium (ppm)	Ideal 120 - 200		55.67	52.33	100.67	80.67	113.33	98.67	110.00	87.00	86.33
	K kg/ha			62.10	58.38	112.30	89.99	126.43	110.06	122.71	97.05	96.31
OTHER NUTRIENT FACTORS	H3A Calcium			163.00	390.67	320.00	362.33	362.33	377.67	335.33	435.00	339.67
	H3A Aluminum			86.00	139.00	175.00	153.00	208.67	147.33	213.00	137.67	198.67
	H3A Iron (ppm)	20 - 80		40.33	66.67	86.67	74.33	107.33	69.67	115.67	59.33	107.67
	H3A Sulfur (ppm)	< 12		8.17	6.33	4.73	6.03	5.33	4.60	4.57	5.23	4.33
	H3A Zinc (ppm)	1 - 3		1.53	2.38	2.15	2.41	2.36	2.56	2.24	2.49	2.53
	H3A Manganese (ppm)	4 - 6		1.90	40.87	33.00	38.90	36.23	34.00	32.37	39.20	39.30
	H3A Copper (ppm)	0,5 - 1,0		0.45	1.06	0.98	1.00	1.00	1.00	1.11	0.93	1.13
	H3A Magnesium			80.00	69.33	58.67	70.00	67.33	64.67	60.67	71.00	64.33
	H3A Sodium			14.00	8.33	7.33	6.67	7.00	6.33	7.33	6.33	6.67
	% P Saturation (Al/Fe)			9.75	19.05	11.85	14.08	16.33	16.32	12.10	18.19	13.18
	% P Saturation (Ca)			7.52	12.18	11.00	10.50	10.35	10.56	9.84	9.89	10.73
KEY CHEMICAL RATIOS	Calcium: Magnesium	> 5		1.74	3.35	3.15	3.03	3.09	3.37	3.14	3.56	3.18
	Calcium: Magnesium/ Aluminium	> 1,7		4.72	4.64	3.04	3.94	3.97	4.23	3.34	5.08	3.31
	Magnesium: Potassium	1 - 2		4.70	4.34	1.91	3.37	2.15	2.50	2.08	2.52	2.46
	Potassium: Sodium	> 1		3.27	3.79	8.10	6.72	9.13	8.44	8.47	9.82	7.38
PLANT EFFECTIVE CEC SATURATION ANALYSES	Calcium Ca %	> 68		41.92	59.62	51.07	55.19	51.34	56.79	50.16	59.65	52.74
	Magnesium Mg %	10 - 20		29.82	17.82	16.39	18.40	16.59	17.22	16.22	16.85	16.58
	Potassium K %	> 5		7.79	4.11	8.57	5.87	8.47	7.28	8.35	6.90	6.93
	Sodium Na %	< 2		2.90	1.11	1.06	0.87	0.94	0.88	0.98	0.74	0.95

Appendix 3: Baseline Haney soil health test data for Standerton trial, February 2021

Name:	HO Standerton	Depth									
Date	Feb-21	0-10 cm									
		A	25-27	2,11,18	5,10,21	4,15,19	3,13,23	7,14,16	8,12,17	6,9,22	1,20,24
Sample ID			VELD	REGENERATIVE				NT/CA		CONVENTIONAL	
Lab ID		A 0-10 cm	Veld	SD+WD	MAIZE_ Relay	SD+WD	SOYA + WD	MAIZE	SOYA	MAIZE	SOYA
SOIL HEALTH	Score	Ideal > 7	37.96	10.00	12.27	12.09	10.67	10.13	9.76	12.94	11.29
	Comment										
Volumetric Aggregate Stability %		Ideal > 45	27.74	23.31	25.70	20.85	26.57	26.35	23.06	18.80	22.43
Soil pH (1:1 H_2O)		Ideal 5,5 - 6,5	5.90	4.90	4.95	4.96	5.04	4.92	5.01	5.03	5.11
BIOLOGICAL ANALYSES	Organic Matter %	Ideal > 2,5	6.63	3.40	3.63	3.63	3.53	3.63	3.57	3.60	3.57
	Soil respiration CO2-C (ppm C)	Ideal > 50	291.85	65.87	84.47	84.50	67.15	63.20	61.85	92.90	72.95
	H2O Total Organic C		323.00	128.67	135.67	135.67	137.67	141.00	132.67	133.33	144.67
	Soil Organic Carbon %		3.86	1.98	2.11	2.11	2.05	2.11	2.07	2.09	2.07
	Water Extractable Organic C %		0.89	0.65	0.64	0.64	0.67	0.67	0.64	0.64	0.70
	% Microbially Active Carbon	Ideal > 20	95.78	51.06	61.96	62.51	47.32	44.97	46.40	70.03	51.55
	Organic C:N		14.32	15.41	13.71	14.67	11.90	14.22	14.36	13.87	14.51
NITROGEN	H2O Total N		27.87	18.40	28.60	21.00	25.83	23.80	21.60	25.17	24.70
	H2O Organic N		23.17	8.43	11.07	9.30	12.00	9.93	9.27	9.83	11.00
	H3A Nitrate		1.40	7.07	14.97	8.87	12.03	11.30	9.43	12.07	11.03
	H3A Ammonium		3.33	3.80	2.80	3.20	3.67	3.40	2.67	2.93	2.33
	H3A Inorganic Nitrogen		4.73	10.87	17.77	12.07	15.70	14.70	12.10	15.00	13.37
	Total N (Organic + Inorganic)		27.90	19.30	28.83	21.37	27.70	24.63	21.37	24.83	24.37
	Organic N: Inorganic N ratio		6.85	0.83	0.64	0.80	0.75	0.72	0.77	0.66	0.80
	Organic N Release		23.17	8.43	11.07	9.30	12.00	9.93	9.27	9.83	11.00
	Organic N Reserve		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total available N		27.90	19.30	28.83	21.37	27.70	24.63	21.37	24.83	24.37
	N kg/ha		62.50	43.23	64.59	47.86	62.05	55.18	47.86	55.63	54.58
PHOSPHOROUS	H3A Total Phosphorus		11.00	18.00	24.33	18.67	24.67	20.00	30.00	27.67	25.00
	H3A Inorganic Phosphorus		6.50	13.93	19.23	14.30	19.50	15.07	24.10	22.33	19.83
	H3A Organic Phosphorus		4.50	4.07	5.10	4.37	5.17	4.93	5.90	5.33	5.17
	Total available Phosphorous		11.00	18.00	24.33	18.67	24.65	19.99	30.00	27.67	25.00
	P kg/ha		12.47	20.40	27.58	21.16	27.94	22.66	34.00	31.36	28.34
	P Organic: Inorganic		0.72	0.30	0.26	0.31	0.28	0.33	0.26	0.26	0.26
	Organic P Release		4.50	4.07	5.10	4.37	5.15	4.93	5.90	5.33	5.17
	Organic P Reserve		0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00
POTASSI	H3A Potassium (ppm)	Ideal 120 - 200	125.00	117.67	168.67	129.67	141.67	139.67	167.67	140.00	145.33
	K kg/ha		139.44	131.26	188.15	144.65	158.03	155.80	187.04	156.17	162.12
OTHER NUTRIENT FACTORS	H3A Calcium		553.00	364.33	455.33	363.00	423.67	394.00	416.33	408.67	434.67
	H3A Aluminum		183.00	199.67	193.33	204.00	186.33	202.33	206.67	194.67	188.33
	H3A Iron (ppm)	20 - 80	64.33	81.67	70.33	83.67	69.33	82.00	77.33	75.67	66.67
	H3A Sulfur (ppm)	< 12	15.50	12.50	14.97	12.27	13.53	14.70	11.37	15.97	18.43
	H3A Zinc (ppm)	1 - 3	0.20	0.42	0.62	0.48	0.62	0.42	0.52	0.72	0.68
	H3A Manganese (ppm)	4 - 6	10.57	4.53	5.93	4.90	4.13	6.53	5.33	4.97	4.87
	H3A Copper (ppm)	0,5 - 1,0	0.20	0.37	0.35	0.38	0.33	0.37	0.32	0.37	0.30
	H3A Magnesium		231.33	166.00	184.00	162.67	176.67	172.00	181.67	173.67	182.33
	H3A Sodium		224.00	22.67	23.33	22.00	20.33	23.67	22.33	22.67	21.33
	% P Saturation (Al/Fe)		4.35	6.45	9.24	6.48	9.65	7.03	10.53	10.15	9.81
	% P Saturation (Ca)		1.98	4.93	5.38	5.20	5.73	5.07	7.29	6.79	5.76
KEY CHEMICAL RATIOS	Calcium: Magnesium	> 5	1.46	1.34	1.50	1.36	1.46	1.40	1.40	1.44	1.45
	Calcium: Magnesium/ Aluminium	> 1,7	6.88	4.32	5.29	4.20	5.16	4.51	4.69	4.81	5.29
	Magnesium: Potassium	1 - 2	5.99	4.57	3.51	4.02	4.08	4.00	3.52	3.97	4.04
	Potassium: Sodium	> 1	0.61	3.11	4.34	3.55	4.29	3.53	4.44	3.64	4.09
PLANT EFFECTIVE CEC SATURATION ANALYSES	Calcium Ca %	> 68	41.98	42.13	45.08	41.77	44.89	42.91	42.78	43.98	45.00
	Magnesium Mg %	10 - 20	28.73	31.48	29.98	30.81	30.78	30.73	30.61	30.65	30.94
	Potassium K %	> 5	4.89	6.94	8.61	7.67	7.68	7.79	8.82	7.71	7.69
	Sodium Na %	< 2	14.13	2.28	2.02	2.19	1.92	2.24	2.00	2.12	1.92

Appendix 4: Financial analyses for Onverwacht trial

	MIXED FARMING SYSTEM	ONVERWACHT, 2020/21 SEASON						
	CASH CROP & LIVESTOCK	MAIZE_ Relay	SOYA + WD	MAIZE	SOYA	MAIZE	SOYA	SD +WD
	NET MARGINS >>	**R 22 731**	**R 11 607**	**R 23 519**	**R 11 739**	**R 23 239**	**R 10 628**	**R 2 986**
PROD SYST	Production system	**RA (relay)**	**RA (relay)**	**CA**	**CA**	**CT**	**CT**	**RA**
	type of Cover crop	WD_intercrop	EW					SD
INCOME	**1a CASH CROPS**	**R 34 859**	**R 21 184**	**R 35 606**	**R 21 315**	**R 37 497**	**R 22 475**	**R 0**
	Yield	11.62	3.03	11.87	3.05	12.50	3.21	
	SAFEX PRICE	3300	R 7 300	3300	R 7 300	3300	R 7 300	
	Total deductions	**R 300**	**R 300**	**R 300**	**R 300**	**R 300**	**R 300**	
	Transport differential	*R 300*	*R 300*	*R 300*	*R 300*	*R 300*	*R 300*	
	Net Farm Gate Price	R 3 000	R 7 000	R 3 000	R 7 000	R 3 000	R 7 000	
	1b GRAZING CROP RESIDUE	**R 1 903**	**R 272**	**R 1 944**	**R 274**	**R 2 047**	**R 289**	**R 0**
	Harvesting index (HI)	**0.91**	**0.75**	**0.91**	**0.75**	**0.91**	**0.75**	
	Available t of crop residue based on HI	10.57	2.27	10.80	2.28	11.37	2.41	
	% residue consumed (remainder left as % soil cover)	0.30	0.30	0.30	0.30	0.30	0.30	
	Quantity used (t/ha)	3.17	0.68	3.24	0.69	3.41	0.72	
	Value of 1 ton of crop residue	R 600	R 400	R 600	R 400	R 600	R 400	
	1c GRAZING INCOME (VELD/ CC)	**R 0**	**R 0**	**R 0**	**R 0**	**R 0**	**R 0**	**R 10 360**
	GRAZING 1, SD							R 8 880
	GRAZING 2, WD after SD							R 1 480
	GROSS INCOME (1a+1b+1c)	**R 36 762**	**R 21 457**	**R 37 550**	**R 21 589**	**R 39 544**	**R 22 764**	**R 10 360**
	2) VARIABLE EXPENDITURES							
	2a CASH CROPS	**R 11 481**	**R 7 300**	**R 11 481**	**R 7 300**	**R 12 305**	**R 8 135**	**R 0**
	Contracting	R 0	R 0	R 0	R 0	R 0	R 0	
	Crop insurance	R 650	R 0	R 650	R 0	R 650	R 0	
	Fertilizer	R 3 290	R 950	R 3 290	R 950	R 3 290	R 950	
	Lime	R 500	R 500	R 500	R 500	R 500	R 500	
	Foliar application: leaf nutrition		R 420		R 420		R 420	
	Seed	R 1 833	R 1 200	R 1 833	R 1 200	R 1 833	R 1 200	
	Inoculent	R 80	R 250	R 80	R 250	R 80	R 250	
	Fuel	R 887	R 609	R 887	R 609	R 1 271	R 993	
	Herbicide	R 1 110	R 750	R 1 110	R 750	R 900	R 550	
	Insecticide/ Fungicide	R 300	R 300	R 300	R 300	R 300	R 300	
	Marketing costs							
	Repairs and maintenance	R 1 980	R 1 780	R 1 980	R 1 780	R 2 570	R 2 370	
	Interest on production credit	R 850	R 541	R 850	R 541	R 912	R 603	R 0
	2b COVER CROPS/ VELD	**R 0**	**R 0**	**R 0**	**R 0**	**R 0**	**R 0**	**R 3 924**
	Seed							R 1 705
	Herbicide							R 610
	diesel							R 168
	Repairs and Maintenance							R 500
	Fertilizer							R 650
	Interest on production credit	R 0	R 0	R 0	R 0	R 0	R 0	R 291
	2c LIVESTOCK RELATED	**R 0**	**R 0**	**R 0**	**R 0**	**R 0**	**R 0**	**R 900**
	Vetenarian costs							R 300
	licks							R 100
	Other expenditure							R 500
	TOTAL VARIABLE EXPENDITURE	**R 11 481**	**R 7 300**	**R 11 481**	**R 7 300**	**R 12 305**	**R 8 135**	**R 4 824**
	3.1) GROSS MARGIN	**R 25 281**	**R 14 157**	**R 26 069**	**R 14 289**	**R 27 239**	**R 14 628**	**R 5 536**
	OVERHEAD COSTS	R 2 550	R 2 550	R 2 550	R 2 550	R 4 000	R 4 000	R 2 550
8%	NET MARGIN	R 22 731	R 11 607	R 23 519	R 11 739	R 23 239	R 10 628	R 2 986

Appendix 5: Financial analyses for New Farm trial

	MIXED FARMING SYSTEM CASH CROP & LIVESTOCK	NEW FARM, 2020/21 SEASON						
		MAIZE_ Relay	SOYA + WD	MAIZE	SOYA	MAIZE	SOYA	SD (Winter CC)
	NET MARGIN	R 14 585	R 13 925	R 17 192	R 14 128	R 13 932	R 12 108	R 2 986
PROD SYST	Production system	RA (relay)	RA (relay)	CA	CA	CT	CT	RA
	type of Cover crop	WD_intercrop	EW					WD
INCOME	1a CASH CROPS	R 27 136	R 23 473	R 29 608	R 23 674	R 28 673	R 23 935	R 0
	Yield	9.05	3.35	9.87	3.38	9.56	3.42	
	SAFEX PRICE	3300	R 7 300	3300	R 7 300	3300	R 7 300	
	Total deductions	**R 300**	**R 300**	**R 300**	**R 300**	**R 300**	**R 300**	
	Transport differential	*R 300*	*R 300*	*R 300*	*R 300*	*R 300*	*R 300*	
	Net Farm Gate Price	R 3 000	R 7 000	R 3 000	R 7 000	R 3 000	R 7 000	
	1b GRAZING CROP RESIDUE	R 1 480	R 302	R 1 615	R 304	R 1 564	R 308	R 0
	Harvesting index (HI)	**0.91**	**0.75**	**0.91**	**0.75**	**0.91**	**0.75**	
	Available t of crop residue based on HI	8.22	2.52	8.97	2.54	8.69	2.56	
	% residue consumed (remainder left as % soil cover)	0.30	0.30	0.30	0.30	0.30	0.30	
	Quantity used (t/ha)	2.47	0.75	2.69	0.76	2.61	0.77	
	Value of 1 ton of crop residue	R 600	R 400	R 600	R 400	R 600	R 400	
	1c GRAZING INCOME (VELD/ CC)	R 0	R 0	R 0	R 0	R 0	R 0	R 10 360
	GRAZING 1, SD							R 8 880
	GRAZING 2, WD							R 1 480
	GROSS INCOME (1a+1b+1c)	R 28 616	R 23 775	R 31 223	R 23 978	R 30 237	R 24 243	R 10 360
8%	2) VARIABLE EXPENDITURES							
	2a CASH CROPS	R 11 481	R 7 300	R 11 481	R 7 300	R 12 305	R 8 135	R 0
	Contracting	R 0	R 0	R 0	R 0	R 0	R 0	
	Crop insurance	R 650	R 0	R 650	R 0	R 650	R 0	
	Fertilizer	R 3 290	R 950	R 3 290	R 950	R 3 290	R 950	
	Lime	R 500	R 500	R 500	R 500	R 500	R 500	
	Foliar application: leaf nutrition		R 420		R 420		R 420	
	Seed	R 1 833	R 1 200	R 1 833	R 1 200	R 1 833	R 1 200	
	Inoculent	R 80	R 250	R 80	R 250	R 80	R 250	
	Fuel	R 887	R 609	R 887	R 609	R 1 271	R 993	
	Herbicide	R 1 110	R 750	R 1 110	R 750	R 900	R 550	
	Insecticide/ Fungicide	R 300	R 300	R 300	R 300	R 300	R 300	
	Repairs and maintenance	R 1 980	R 1 780	R 1 980	R 1 780	R 2 570	R 2 370	
	Interest on production credit	R 850	R 541	R 850	R 541	R 912	R 603	
	2b COVER CROPS/ VELD	R 0	R 0	R 0	R 0	R 0	R 0	R 3 924
	Seed							R 1 705
	Herbicide							R 610
	diesel							R 168
	Repairs and Maintenance							R 500
	Fertilizer							R 650
8%	Interest on production credit	R 0	R 0	R 0	R 0	R 0	R 0	R 291
	2c LIVESTOCK RELATED	R 0	R 0	R 0	R 0	R 0	R 0	R 900
	Vetenarian costs							R 300
	licks							R 100
	Other expenditure							R 500
	TOTAL VARIABLE EXPENDITURE	R 11 481	R 7 300	R 11 481	R 7 300	R 12 305	R 8 135	R 4 824
	3.1) GROSS MARGIN	R 17 135	R 16 475	R 19 742	R 16 678	R 17 932	R 16 108	R 5 536
	OVERHEAD COSTS	R 2 550	R 2 550	R 2 550	R 2 550	R 4 000	R 4 000	R 2 550
	Final GROSS MARGIN	R 14 585	R 13 925	R 17 192	R 14 128	R 13 932	R 12 108	R 2 986

Appendix 6: Financial analyses for Standerton trial

	MIXED FARMING SYSTEM CASH CROP & LIVESTOCK	STANDERTON, 2020/21 SEASON						
		MAIZE_ Relay	SOYA + WD	MAIZE	SOYA	MAIZE	SOYA	Summ er CC + Winter CC
	NET MARGINS	R -3 316	R 2 058	R -3 316	R 2 002	R -5 240	R 77	R -172
PROD SYST		Maize	Soya					
	Production system	RA (relay)	RA (relay)	CA	CA	CT	CT	
	type of Cover crop	WD_intercrop	EW					
INCOME	**1a CASH CROPS**	R 7 750	R 8 640	R 7 750	R 8 640	R 7 750	R 8 640	R 0
	Yield	2.50	1.20	2.50	1.20	2.50	1.20	
	SAFEX PRICE	3400	R 7 500	3400	R 7 500	3400	R 7 500	
	Total deductions	R 300	R 300	R 300	R 300	R 300	R 300	
	Transport differential	*R 300*	*R 300*	*R 300*	*R 300*	*R 300*	*R 300*	
	Net Farm Gate Price	R 3 100	R 7 200	R 3 100	R 7 200	R 3 100	R 7 200	
	1b GRAZING CROP RESIDUE	R 410	R 0	R 409	R 0	R 409	R 0	R 0
	Harvesting index (HI)	0.91	0.75	0.91	0.75	0.91	0.75	
	Available t of crop residue based on HI	2.28	0.90	2.27	0.90	2.27	0.90	
	% residue consumed (remainder left as % soil cover)	0.30	0.00	0.30	0.00	0.30	0.00	
	Quantity used (t/ha)	0.68	0.00	0.68	0.00	0.68	0.00	
	Value of 1 ton of crop residue	R 600	R 400	R 600	R 400	R 600	R 400	
	1c GRAZING INCOME (VELD/ CC)	R 0	R 2 046	R 0	R 0	R 0	R 0	R 5 705
	GRAZING 1, SD							R 3 420
	GRAZING 2, WD after SD							R 2 285
	GRAZING 3, WD after soya		2 046					
	GRAZING 4, relay into maize	R 0						
	GROSS INCOME (1a+1b+1c)	R 8 160	R 10 686	R 8 159	R 8 640	R 8 159	R 8 640	R 5 705
	2) VARIABLE EXPENDITURES							
	2a CASH CROPS	R 9 691	R 5 454	R 9 691	R 4 853	R 10 600	R 5 763	R 0
	Contracting (harvester R600, spreayer R120)	R 960	R 1 080	R 960	R 1 080	R 960	R 1 080	
	Crop insurance	R 0	R 0	R 0	R 0	R 0	R 0	
	Fertilizer	R 3 125	R 250	R 3 125	R 250	R 3 125	R 250	
	Lime							
	Foliar application: leaf nutrition	R 500	R 500	R 500	R 500	R 500	R 500	
	Seed	R 2 611	R 550	R 2 611	R 550	R 2 611	R 550	
	Inoculent	R 0	R 150	R 0	R 150	R 0	R 150	
	Fuel	R 307	R 358	R 307	R 253	R 469	R 415	
	Herbicide	R 645	R 645	R 645	R 645	R 645	R 645	
	Insecticide/ Fungicide	R 0	R 270	R 0	R 270	R 0	R 270	
	Marketing costs/ hedging	R 50	R 30	R 50	R 30	R 50	R 30	
	Repairs and maintenance	R 592	R 1 021	R 592	R 571	R 1 272	R 1 251	
	Transport	R 200	R 100	R 200	R 100	R 200	R 100	
8%	Interest on production credit	R 701	R 500	R 701	R 455	R 768	R 523	
	2b COVER CROPS	R 0	R 1 139	R 0	R 0	R 0	R 0	R 3 592
	Contracting							R 240
	Crop insurance							R 0
	Fertilizer							R 0
	Lime							R 0
	Foliar application: leaf nutrition							R 250
	Seed		R 500					R 1 455
	Fuel		R 105					R 238
	Herbicide							R 245
	Repairs and maintenance		R 450					R 911
8%	Interest on production credit		R 84	R 0	R 0	R 0	R 0	R 254
	2c LIVESTOCK RELATED	R 0	R 250	R 0	R 0	R 0	R 0	R 500
	Vetenarian costs		R 250					R 500
	licks							
	TOTAL VARIABLE EXPENDITURE	R 9 691	R 6 843	R 9 691	R 4 853	R 10 600	R 5 763	R 4 092
	3.1) GROSS MARGIN	R -1 531	R 3 843	R -1 531	R 3 787	R -2 440	R 2 877	R 1 613
	OVERHEAD COSTS	R 1 785	R 1 785	R 1 785	R 1 785	R 2 800	R 2 800	R 1 785
	Final GROSS MARGIN	R -3 316	R 2 058	R -3 316	R 2 002	R -5 240	R 77	R -172