APPENDIX 2:
MALUTI PROGRESS REPORT

Participatory systems research on conservation agriculture in the Maluti region

September 2021

ANNUAL PROGRESS REPORT:

PARTICIPATORY SYSTEMS RESEARCH ON CONSERVATION AGRICULTURE IN THE MALUTI REGION
YEAR 1

For the period:

October 2020 to September 2021

Compiled by:

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Asset Research

In collaboration with:

Maluti CA study group

Funded by and submitted to:

The Maize Trust

SEPTEMBER 2021

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EXECUTIVE SUMMARY

Maluti Annual Progress Report

Participatory systems research on Conservation Agriculture in the Maluti region.

Compiled by: J Knot, G Trytsman, HJ Smith and G du Preez
For the period October 2020 to September 2021

This study is done in collaboration with the Maluti CA study group.

The Maluti Conservation Agriculture (CA) project, which is funded by The Maize Trust and coordinated by Asset Research, has been successfully implemented for the first season (2020-2021). The Maluti CA project comprises of two statistical, collaboratively managed trials, or mother trials, which were successfully implemented by Theunis Pretorius (Ficksburg area) and Nant Yzel (Marquard). The trials are a comparative assessment between conventional tillage systems (CT), high input cash crop 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 research, 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 / quantity (production) of plants / grain.

Various indicators were selected to measure and monitor the impact of different trial treatments. Profitability of any crop is a function of the commodity price, yield and costs. Profitability changes when there is 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 costs. 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 in order to compile baseline data for additional research on food nutrition density. Production (crop quantity or productivity) of the different treatments is measured through grain and biomass (dry matter) yield measurements.

The CA production systems included a maize and soya bean crop rotation as compared to monoculture maize under CT. The RA system includes a maize-soya cash crops rotated with annual summer and winter cover crops and livestock integration.

The results are expressed in profitability, soil ecosystem health and quantity / quality of crops / grain.

The rainfall distribution was high in the November and December hampering early planting in the season. Maize yields were 6-6.3 t ha^{-1} at Ficksburg and 3.03-4.16 t ha^{-1} at Marquard. Soya yields were between 2.52-2.59 t ha^{-1} at Ficksburg and 2.14 t ha^{-1} at Marquard. The Ficksburg seasonal rainfall of 971mm yr^{-1} was 145% higher than the farm's long-term average. The water use efficiency was low for both trials; for maize the WUE was between 4.57 - 6.48 and for soya it was 2.52 - 3.16.

The profitability of the SCC + WCC treatment was highest at Ficksburg (with a net margin of R15,720 ha^{-1}) and with a margin of R161 ha^{-1}second highest at Marquard trials (i.e. net margins of R10,754 ha^{-1}). The lowest net margin per hectare at both trials was CT maize. In addition, both trial results showed that soya had higher net margins ha^{-1} than maize. The monthly rainfall distribution was high for November and December at both trials. This resulted in late plantings at Marquard. This report included a farm case study example based on backgrounding lambs on cover crops including supplementary feeding (SS200 from Voermol). This example of "groenlammers" (*green lambs*) is included in order to show that net margins can be around R20k ha^{-1} when SCC is prioritized, timely planted and grazed, and managed in an integrated manner. The farm case study from Yzel Boerdery, adjacent to the trial area, reflected highest net margins ha^{-1} of R20,124 ha^{-1}.

This research study investigates four cover crop strategies, namely: SCC, WCC with or after SCC (in the same growing season), relay- or intercrop maize and WCC after soya. Intercrop differs from relay CC in time where intercrop is planted at V6-V8 stage of maize and relay CC at the stage when maize starts drying off. All four CC strategies were applied at Marquard. The Ficksburg trial applied all except the WCC after soya. The financial analyses clearly show increased net margins when all cover crop strategies are successfully applied. Both trials reflected net margins in the following order (i.e. highest to lowest): RA maize + relay > CA maize > CT maize. The same results were found for soya at both sites: RA soya + WCC > CA soya.

Baseline and mid-season soil data was collected and analytical results reported. The Ficksburg trial with predominantly Avalon soil, 950-1150 cm deep, has 3% (veld) and 0.8% (crop land) SOC and a clay content of 15-16%. The Marquard trial site, in the contrary, has shallow (i.e. 57-61 cm) Avalon/ Westleigh soils, clay content of 7% and SOC levels of 0.35%.

Maize was planted at the following NPK rates (in kg ha^{-1}). At Fickburg 69-17-90 and Marquard 60-9-4. No fertilizer was applied on soya and SCC or WCC at Marquard. The following NPK rates were applied at Ficksburg for SCC (i.e. 69-17-60) and WCC (i.e. 40-7-13). The biological indicators, pH, volumetric aggregate stability, and C: N ratio were low at both trial sites. Most available N and P were from the inorganic pool. The Ca:Mg ratio is low for Marquard and well in range for Ficksburg trial sites.

The soil cover was between 68-69% on the trials prior to planting and the average water infiltration rate for 500 ml in a ring of 150 ml in diameter was between 246 – 279 seconds. There was no soil compaction in the A horizon of both trials except for veld at Marquard with a reading of 308 psi. Penetrometer readings between 200-300 psi were only found in the B horizon at Marquard. Veld had highest compaction (297 psi) followed by SCC (248 psi) and CT maize (231 psi). This makes us to reconsider veld sampling points at Marquard. There were no significant differences in Hectolitre mass and Brix readings between the treatments and this season.

1. BACKGROUND AND PROBLEM STATEMENT

1.1. Local problem statement

On 13th February 2020, a meeting was held at the Farmers hall (Boereplek) in Clocolan, with a group of CA farmers from the **Maluti region** (including areas of Ladybrand, Clocolan, Ficksburg, Marquard, Fouriesburg, Senekal, etc.). The meeting was a fact-finding mission (or brainstorm) to get a general idea about the groups' strength, activities, vision, problems, opportunities, solutions, needs and possible actors (capacity) and their interest in a regional CA project. The group unanimously expressed their need and willingness to participate in such a project, which is really the key criteria for any CA Farmer Innovation Programme (FIP) funding. This meeting was facilitated by Dr Hendrik Smith (CA Facilitator at Grain SA), assisted by Dr Jaap Knot (independent regenerative farming facilitator). The steering committee was formed namely: Christoff Botha, Johan Groenewald, Hennie and Henk Vermooten and Jaap Knot.

The following issues or problems were listed during this brainstorming session with the Maluti group that gave a good idea what the focus of the project will be:

- More research is needed on various cover crop strategies & ley crop (permanent pastures) and how that fits in into most prevalent local crop rotation systems.
- Farmers expressed the need for good economic gross margins comparative analysis of the different CA strategies applied already by farmers (i.e. summer cover crops, winter cover crops, high density grazing, NT and strip till maize, soya, sunflower and wheat) as well the figures under the combined research trials.
- Farmers also expressed the need for researching practical differences between farmers' production methods like coulter vs. tine planters, row width and plant population effect. Measurable indicators will be identified during the brainstorming activities later in the season.
- The Maluti CA group area consist out of divergent and variable ecotypes with differences in soil types, soil depth, rainfall, slope and management. This is important that these main ecotypes are identified, documented and treated as area-specific areas.

According to a recent CA adoption study in South Africa (FAO, 2021), the Free State Province has a very low adoption of 3.35% comprising 73 519 hectares under commercial farming.

The Free State Province has the biggest area under annual crop-livestock systems in South Africa (2 196 986 ha), dominated by maize-based systems. Although the Province has an overall exceptionally low adoption rate, a few magisterial districts show encouraging upward trends in adoption rates, such as Viljoenskroon (ha 12 270, or 12%), Clocolan (6 056 ha, or 19%), Ficksburg (5 995 ha, or 19%), Marquard (3 050 ha, or 8%), Harrismith (6 500 ha, or 12%), Reitz (4 940 ha, 5%), Vrede (3 960 ha, or 4.2%), Koppies (6 560 ha, 13%) and Kroonstad (4 000 ha, or 5%).

1.2. Participatory planning event

On the 17 September 2020, after the project proposal was approved by The Maize Trust, a participatory planning event was held at the Clocolan Country Club involving 20 participants in the Maluti 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).

Steps to design on-farm experiments

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

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 – conceptualization, localities, design, planning, actions, responsibilities
- Indicators
- Production costs – CA vs CT
- Other activities

Treatments

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)
5) Veld (regenerative, strip/ HD grazing)

2. Project aim

The aim of the project:
The aim of the project is to research, develop and adapt appropriate CA systems for a range of diverse and unique contexts in the Maluti region.

Main objectives:

Research, develop, adapt and communicate site and context specific CA systems for the Maluti 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 Maluti 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 Maluti 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 below for detailed discussion of work packages). Table 2 shows the different work packages and responsible champions in each project:

Table 1: Work packages and lead partners in the Maluti project

Work Package	Lead partner - Maluti
1. Coordination and management	Asset research (Hendrik Smith), Maluti group committee (names on p10)
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 Support Centre;
4. Assessment of cover crop adaptability and suitability	Gerrie Trytsman (Independent researcher); Jaap Knot

Note: the names of the responsible experts are mentioned first. Jaap Knot, because he is living in the area, will conduct certain activities liaising with the criteria coordinators. This is done to reduce travel and accommodation expenses.

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. 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 trial establishment and facilitation

KEY ACTIVITY	TIMELINE	INDICATOR OF SUCCESS	PROGRESS TO DATE
Objective 1: To establish and facilitate appropriate on-farm trials with the Maluti CA study group			
a) Participatory planning workshop	Done in September 2020	Active participation of and inputs from CA network and key stakeholders in workshop to plan various project implementation activities.	Done on September 17th

KEY ACTIVITY	TIMELINE	INDICATOR OF SUCCESS	PROGRESS TO DATE
b) Discuss, facilitate, prepare, establish roles and responsibilities within Maluti project and (re)plan Mother and Baby trial activities on selected sites (farms)	July-August (Continuous)	(Clear) Roles and responsibilities documented CAT and FAT sites identified and discussed	The work packages are managed by members of the project team. Two MT are implemented and one BT
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 established and managed on selected sites and/or farms	Two statistical trials, with three repetitions have been established. One trial is implemented at Yzel Boerdery (Nant Yzel) at Marquard and the second trial is implemented at Theunis Pretorius' farm, Ficksburg area.
Objective 2: To monitor and analyse a series of appropriate indicators from on-farm trials on selected farmers' fields			
a) Participatory monitoring / data collection	January to June	Collection of a range of selected indicators from trials, especially soil samples	Collection of a range of selected indicators from trials and monitoring points, especially soil and biodiversity parameters. The proposed outcomes are listed in the proposal, but the three main indicators are: 1. Profitability 2. Soil ecosystem health 3. Crop quantity and quality Each set has its own sub-indicators as seen in a table above.
b) Participatory M&E and discovery learning	January to June	Completion of Field monitoring form with farmers	The two trial farmers are part and parcel of the M&E and participated in data collection so far
c) Data Analysis and Evaluation	June to August	Analysis of data collected from on-farm trials and field forms	In progress Analysis of data collected from on-farm trials and monitoring points. Trial layouts discussed with farmers and monitored Soil baseline, soil cover, water infiltration rates data taken before planting Seed varieties, seeding rates, fertilizer rates discussed

Objective 3: To create wider awareness and innovation capacity in the Maluti CA study group and the broader farming communities on the practices and benefits of locally adapted CA systems.				
a)	Annual farmer's day or conference	February to May	A well organised and -attended awareness event	Annual farmers day held on 27th of April (Yzel Boerdery)
b)	Exposing on-farm trials to interested farmers and other	Continuous	Trial visits by interested people	Selected updates provided on Maluti WhatsApp CA group
Objective 4: To support project facilitation, administration and reporting processes.				
a)	Project meetings	Twice a year	At least two project meetings per year	The project committee has not been involved in meetings. A planning meeting is planned for Ocotber 2021 discussing the draft report and annual results so far. There is good communication and frequent phone calls between the Maluti facilitator and trial farmers. Selected data and info is communicated via the Maluti whatsapp group
b)	Social learning facilitation of innovation platform(s)	Continuous	Effective facilitation to assist implementation, M&E and adaptation	Sharing of knowledge is continuous. The program facilitator visited local CA farmers, baby trial implementers (those that planted one repetition of the full statically "mother" trial and farmers from the Maluti group re the perennial covers, veld improvement and alternative (high density) grazing
c)	Maluti region innovation platform meeting	August	A well organised annual innovation platform & feedback meeting	Good feedback between coordinator and trial farmers The larger CA committee or group participate a bit in the online group
d)	Reporting	March and September	Six-monthly and annual reports according to specifications	In progress Field data frequently updated for ease of 6 months reports

4. IMPLEMENTATION OF WORK PACKAGES

4.1. Project monitoring, evaluation and facilitation

4.1.1. Activities and deliverables

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

Activities	Deliverables	Progress and Results achieved
1.On-farm experimentation - Land preparation	The two mother trial plots/ strips are planted as per the randomized plot layout. The strip length varies between 200-400 meter and strips are the width of farmer's seed drill/ planter (i.e. 12 and or 16 row) The two mother trial plots/ strips are planted as per the randomized plot layout. The strip length varies between 200-400 meter and strips are the width of farmer's seed drill/ planter (i.e. 12 and or 16 row)	Two MTs planted
2.On-farm experimentation - Planting	Plot layout randomized. Three repetitions with seven treatments per treatment. The trials reflects a comparison between conventional farming, NT and regenerative or ideal CA systems. The production systems reflect a maize – soya rotation. The conventional system is maize mono crop and the ideal CA includes various different cover crop strategies	Farmers tend to give more emphasis on commercial planting than on research trials. Marquard trial is therefore planted slightly later than commercial maize, soya and CC
3.On-farm experimentation - Seasonal management	Two site visits are done per three months. Trial and grazing protocol has been written and communicated to the trial farmers. Quite some phone communication done to iron out trial maintenance issues	Two site visits per three months are conducted 7-9 Dec, 20-21 January, 2-3 March, 15-16 April and 22-23 June
4.Data collection, monitoring and sampling	Baseline soil samples taken on 14th & 15th Oct 2020	Randomized samples per strip (24 strips in total) on 2-3 March 2021. Brix data is taken and we started with grazing data at Ficksburg trial
5.Data management and analyses	Data sheets are maintained as data is collected. This is managed by the coordinator and distributed to team and trial farmers. Photographs were frequently taken.	Report template per MT maintained
6.Monthly social learning meetings (project team)	No monthly meetings were held. Other form of communication, perhaps more	Internal staff meetings done via zoom

Activities	Deliverables	Progress and Results achieved
	individual meetings to be scheduled. Farmers are very busy.	
7.Annual social learning and project meeting (advisory committee, Maluti network)	To be scheduled after harvest were trial end-of year report draft can be discussed. Proposed end of August 2021 To be scheduled after harvest were trial end-of year report draft can be discussed. Proposed end of August 2021	
8.Annual report and admin	Mid-term report in progress	Ongoing
9.Coordinate and participate in awareness events	In progress	Team members participate in other Maize Trust funded projects like Ottosdal & Mpumalanga farmers day(s) Team participate in sharing CA FIP info (Hendrik Smith at *Landbouweekblad* webinar)
10.Documentation, reporting, build and monitor data sets	Annual report due in September, but facilitator maintains a general excel file per trial with all relevant technical data like soil data, brix readings, biomass production of cover crops, field passes and financial info, etc	Report template per Trial maintained

4.1.1.1. Establishment and management of on-farm trials

Two collaboratively managed trials (CMT's), or mother trials, were established on experimental sites on key sub-regions and ecotopes (uniform soil and terrain units) in the Maluti region on two (2) trial sites of participating farms, one in the Ficksburg area (implemented by Theunis Pretorius) and another one in the Marquard area (implemented by Yzel farming). These sites were selected during the participatory planning session on 17 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 – maize for CT

2. Maize - soya for CA

3. 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 and 2 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 3 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: 0.76 – 0.9 m rows at 20,000 - 33 000 plants ha^{-1}. CT Marquard is 20,000. RA/ CA Marquard is 30,000 and Ficksburg is 33,000
- Soya: 0.38 – 0.90 m rows at 250,000 (Marquard) - 280,000 (Ficksburg) plants ha^{-1}
- Cover crop: 0.38 m (Ficksburg) 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 best CA (or RA), are practically exactly 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.

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 prior to 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: Ficksburg maize fertilizer application rates

Description	Date	Kg ha^{-1} & type	Kg N ha^{-1}	Kg P ha^{-1}	Kg K ha^{-1}
broadcasting prior to planting maize	21-11-2020	120 kg ha^{-1} KCL	-	-	60
at planting maize	9-12-2020	60kg kg ha^{-1} KCL	-	-	30
		180kg ha^{-1} 1:1:0 (30)	27	27	-
top dress maize	21-01-2021	150kg LAN	42	-	-
TOTAL for maize			**69**	**17**	**90**

100kg MAP was applied at planting soya (i.e. 11N, 22P). In addition 120kg KCL at 60kg K ha^{-1} was broadcasted two days after plating soya.

Additional treatment information for Ficksburg trial:

Herbicide

- Maize
  - Pre-emergence herbicide mix under CT, CA, RA
    - 3.7 l/ha Touchdown,
    - 0.035 l/ha Max 357
    - 0.8 l/ha Gardomil Gold
    - 0.8l/ha Dual Gold
  - Post emergence in season on maize: application x 1:
    - 1.5 l/ha Touchdown
    - 0.035 l/ha Max 357
    - 1.2 l/ha Sorgomil Gold
    - 200ml Lamda EC
- Soya
  - Pre-emergence herbicide mix under CT CA, RA
    - 2 l/ha Touchdown
    - 0.035 l/ha Max 357 and
    - 100ml/ha Lambda.
  - At planting herbicide mix under CT CA, RA
    - 2 l/ha Touchdown
    - 0.035 l/ha Max 357 and
    - 100ml/ha Lambda.
  - Post emergence (at end of season) herbicide mix under CT CA, RA
    - 2 l/ha Touchdown
    - 0.035 l/ha Max 357 and
    - 100ml/ha Lambda.

Seeds

  - Maize – yellow, DKC 72-76 BR
  - Soya – Pannar 1521R
- Row width and plant population
  - Maize – 33 000, 0.76 m
  - Soya – 280 000, 0.38 m

At Marquard the following production inputs were applied on maize.

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

Description	Kg ha^{-1} & type	Kg N ha^{-1}	Kg P ha^{-1}	Kg K ha^{-1}
at planting maize	200 kg ha^{-1} 8:2:1 (26)	37.81	9.45	4.3
top dress maize	80 kg ha^{-1} LAN	22.4	-	-
TOTAL ST for maize (rounded)		**60**	**9**	**4**

There was no other fertilizer applied to soya.

Additional treatment information:

Herbicide

- Maize
  - Burn down herbicide mix under CA, RA
    - 2 l/ha Kalach
    - Additives/ wetting agent
  - At planting herbicide mix under CT, CA, RA
    - 4 l/ha Titan boor,
    - 0.016 l/ha Armur
    - 0.035 l/ha Karate
    - 0.7 l/ha Dual Gold
  - Post emergence in season on maize: application x 1:
    - 2.5 l/ha Kalach
    - 0.05 l/ha Max 357
    - 0.2 l/ha Cellerate
    - 200ml Twister
- Soya
  - Burn down herbicide mix under CA, RA
    - 2 l/ha Kalach
    - Additives/ wetting agent
  - At planting herbicide mix under CT CA, RA
    - 4 l/ha Xtreemb
    - 0.9 l/ha Metagan
    - 0.03 l/ha Armour and
    - 50ml/ha Karate.
  - Post emergence herbicide mix under CT CA, RA
    - 2 l/ha Kalach
    - 0.25 l/ha Como and
    - 1 l/ha Bymid.

Seeds

  - Maize – yellow, DKC7276BR
  - Soya – DM5953
- Row width and plant population
  - Maize CT– 20 000, 0.91 m
  - Maize CA/RA– 30 000, 0.91 m
  - Soya – 250 000, 0.91 m

Best CA practice (BCA) or RA:

SCC and WCC

- Diverse crop rotation: 1 or 2 cash crops integrated with various cover crop (summer and winter) strategies, such as SCC followed by WCC (entire season), maize intercrop / maize relay and WCC after soya
- No-till planter (tine or disc) or cover crop planter
- Fertilizer practices on SCC
  Ficksburg
  - Broadcasted prior to planting 120 kg KCL ha^{-1} @ 60 kg K

- At plant 180 kg 1:1:0 (30) ha^{-1} @ 27 kg N; 17 kg P
- Broadcast six weeks after emergence 150 kg LAN ha^{-1} @ 42 kg N

Total NPK SCC: 69 kg N, 17 kg P and 60 kg K ha^{-1}

Marquard
- No fertilizer applied on SCC at Marquard

- Fertilizer WCC

  Ficksburg - 181 kg 6:1:2 (33) ha^{-1} @ 39.82kg N; 6.64 kg P and 13.27 kg K

  Marquard - No fertilizer applied to WCC

- Herbicides
  - At Ficksburg: burn down mix 2 kg Touchdown and 0.035 L Max ha^{-1}.
  - At Ficksburg: at planting the same mix was applied at 2 kg Touchdown and 0.035 L Max ha^{-1}.
  - At Marquard the burn down mix was 2l Kalach and wetting agent/ additives
  - At Marquard: at planting 2.5 l/ha Kalach, 0.05 l/ha Max 357, 0.2 l/ha Cellerate, 200ml Twister ha^{-1}
- Seeds – SCC mix followed by WCC mix
  SCC
  - 10 kg babala
  - 2 kg hybrid Babala
  - 10 kg cowpeas
  - 8 kg sunnhemp
  - 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

At Marquard: the SCC was planted 15 February and therefore the SCC-mix, but with the addition of WCC (oats and rye) added to the mix, was used.

- Row width : 7.5 cm at Marquard (Starra) and 38 cm at Ficksburg (equalizer drill)
- 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; 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 row with planting (not broadcasting); top dress broadcast
- WCC – plant in February/ March into SCC
- Planting time - SCC – min temp, mid to end Nov; WCC – end Mar / Apr, after short growing soya; in Maize plant Dec/Jan (intercropping)

MARQUARD

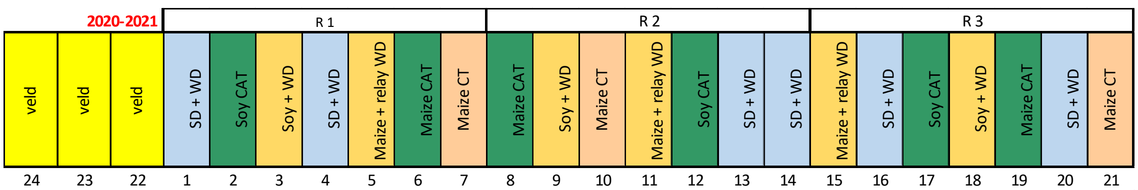


Figure 1: Trial layout for Marquard 2020/21 season

FICKSBURG

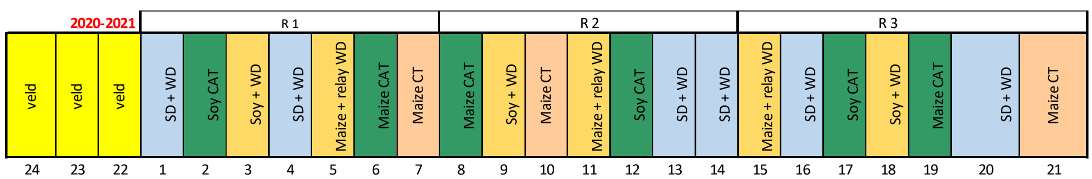


Figure 2: Trial layout for Ficksburg 2020/21 season

4.1.1.2. Monitoring of trial sites

The planning of this research kicked off on 17 September 2020 with an initial participatory farmer meeting.

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

Baseline soil sampling (14-15 Oct) was conducted at both MTs and samples were sent for Haney soil health tests (SHT) at Ward laboratories and North West University (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 and 11-30cm 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 as to potentially reflect more long-term undisturbed conditions ("pristine benchmark") at or nearby the crop land. 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 prior to planting by using a line-transect method. Water infiltration rates were measured by measuring the time span 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 (7-9 Dec; 20-21 January; 15-16 April; 22-23 June).

Brix assessments were done to measure crop quality. Measurements were done twice during the growing season at both 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 randomized trial layout reflects eight treatments with three repetitions which resulted in 21 strips. Three additional measuring points were identified on the veld. Both Maluti mother trials therefore have 24 “strips”.

Soil samples were taken again in February per strip (i.e. 1-24), which will primarily be used with the original soil sampling as an extensive baseline data base. 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 and 11-20cm.

Soil sampling (2-3 March) resulted in a 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.

Monitoring summer cover crops and measuring 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 (15-16 April; 22-23 June).

A farmers’ day was organized at the Marquard trial on 27 April 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. 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 (i.e., income, costs, gross margins, overheads and net margins) were done. First data was collected from each farmer to develop draft data sheets. Then the draft data sheets were discussed between researchers and the farm team (i.e. those on the farm responsible for overall management, livestock and crops) to develop a more comprehensive data set and assessment.

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. Annual farmers day

The Maluti farmers day was held at Yzel farming on 27 April 2021 in the Marquard study area. Yzel farming implements one of the mother trials of the Maluti CA project. Around 100 people attended the day that started at the trial site, whereafter they divided up into groups that rotated between three different field points. After that there was a demonstration of various different CA implements.

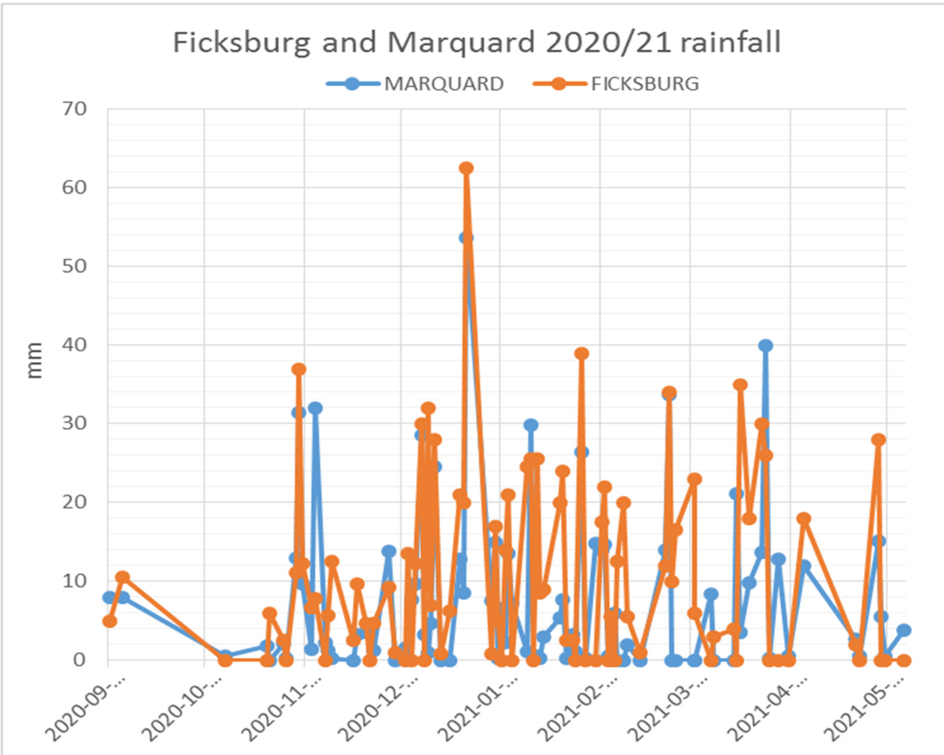
The three field points dealt with the following themes: i) Cover crops and their role in grain production (presented by Gerrie Trytsman (ASSET Research and Pieter Taljaard (Agricol) (Photo 4 a), ii) the Mother trial treatments and soil profiles (presented by Nant Yzel, Simon Hodgson (AGT) and Dr Jaap Knot (ASSET Research) (Photo 4 b), and iii) a farmers discussion lead by two pioneer CA farmers in the region, namely Hans van Rooyen (Clocolan) and Henry du Preez (Ficksburg). Du Preez started with CA in 1993, and both farmers could share valuable lessons in their long journeys in CA.

Photo 1 a and b: Participants have discussions on cover crops and livestock integration and a soil profile evaluation during the field day at Yzel farming, Marquard on 27 April 2021.

4.1.2. Data and analysis

4.1.2.1. Rainfall

There were 75 rainfall events during this season between August 2020 and July 2021 resulting in a total of 971 mm for Ficksburg trials. There were 65 rainfall events for Marquard that received 633 mm this season. Graph 1 shows the distribution of rainfall during the growing season at the two Maluti trial site areas. Rainfall data is collected on site by using closest farm rain gauges complemented by on-farm weather stations.



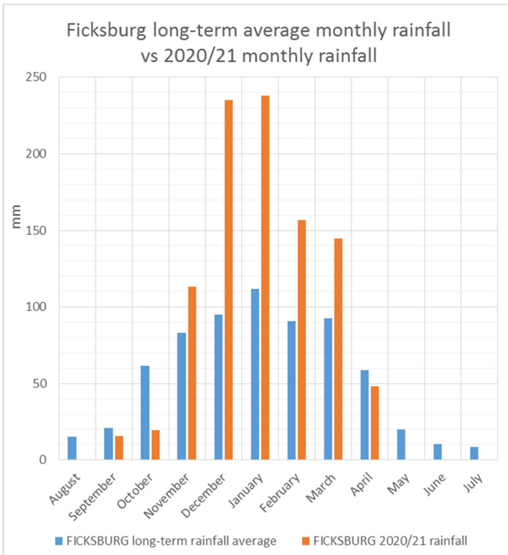
Graph 1: Rainfall graph for Ficksburg and Marquard trials 2020/21 season

This season's rainfall of 971 mm yr^{-1} at Ficksburg was 145% above the long-term annual rainfall average of 668 mm yr^{-1}. The trial crops actually performed well with the excess rainfall water as compared to other parts of Ficksburg and Maluti area where farmers experienced waterlogging to a large extend. The maize yield was between 6 – 6.3 t ha^{-1} which is slightly lower than the farm's long-term average of 7.2 t ha^{-1}. The soya yield was between 2.45 – 2.52 t ha^{-1} which is slightly higher than the farm's long-term average of 2.2 t ha^{-1}. The maize and soya crops were planted on 8 December and 19 November respectively. The fact that the soya crops were planted relatively early as well as deep drained soils of 750-1150 mm on 80% of the trials helped as well to cope with this season's amount of rainfall.

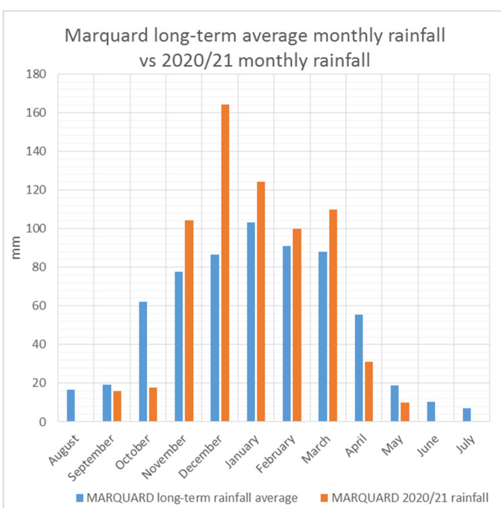
The seasonal rainfall at Marquard of 677 mm yr^{-1} was more or less in line with the annual long-term average of 636 mm yr^{-1}. The distribution of rainfall was different than long term averages as can be seen in graph 3 below. It was high in November and December. The latter being the 2nd highest recording for December for the farm in 40 years. The trial was planted slightly late (i.e.

maize at January 1) due to prevailing commercial planting priorities. By the time the trials could be planted the operations were hampered by wet conditions as a result of 29 rainfall events in November and December totalling 104 and 164 mm for these months respectively.

The two graphs below reflect the long-term seasonal rainfall per month as compared to the 2020/21 season's rainfall at Ficksburg and Marquard trials.



Graph 2: Ficksburg long-term average monthly rainfall vs. 2020/21 monthly rainfall



Graph 3: Marquard long-term average monthly rainfall vs. 2020/21 monthly rainfall

4.1.2.2. Crop quantity / quality and water cycle results

Table 6 below shows a range of crop and water cycle indicators collected at both trial sites in the Maluti area.

The soil cover prior to planting was measured using the line-transect method. It is measured as a percentage of total soil cover. Soil cover build up in CA is a challenge due to various reasons. The reasons being (excessive) grazing, microbial activity leading to high decomposition rate, 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 prior to planting the summer cash (cover-) crop.

The water infiltration rate prior to 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. This was not done at Marquard due a communication error.

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

Description	Ficksburg			Marquard		
	RA	**NT**	**CT**	**RA**	**NT**	**CT**
Soil cover % at start of trial	68%	68%	68%	69%	69%	69%
Water infiltration rate at start of trial (500 ml/ seconds)	279	279	279	246	246	246
Maize yield (t ha^{-1})	6.00	6.30	6.04	3.79	4.16	3.09
WUE Maize (kg ha^{-1} mm^{-1})	6.18	6.48	6.22	5.60	6.14	4.57
Hectolitre mass Maize	0.743	0.745	0.734	*	*	*
Soya yield (t ha^{-1})	2.52	2.45	**	2.14	2.14	**
WUE Soya (kg ha^{-1} mm^{-1})	2.59	2.52	**	3.16	3.16	**
Hectolitre mass Soya	0.722	0.730	**	*	*	**

Note: *Not measured **No soya in CT crop rotation

4.1.2.3. Profitability analysis

Table 7: Comparative financial analysis of Ficksburg trial treatments

FICKSBURG

Production system:	RA	RA	CA	CA	CT	RA
Description of treatments (All figures in ZAR)	**Maize_ relay**	**Soya_ WCC**	**Maize**	**Soya**	**Maize**	**SCC_ WCC**
INCOME (R ha^{-1})						
Cash crop	17,710	17,617	18,575	17,127	17,818	-
Crop residue graze value	982	227	1030	220	988	-
CC graze 1 SCC value (12.48 t ha^{-1})	-	-	-	-	-	17,971
CC graze 2 WCC value (1.5 t ha^{-1})	-	-	-	-	-	7,736
Graze 3 relay CC in maize (0.5 t ha^{-1})	2,585	-	-	-	-	-
Graze 4 WCC after soya (*)	-	0	-	-	-	-
GROSS INCOME	21,277	17,843	19,606	17,347	18,806	25,707
VARIABLE COSTS (R ha^{-1})						
Cash crops related	9,444	5,260	9,444	5,260	10,677	-
Cover crop related	-	-	-	-	-	6,791
Livestock related	-	-	-	-	-	200
TOTAL COSTS	9,936	5,260	9,444	5,260	10,677	6,991
GROSS MARGINS (R ha^{-1})	**11,341**	**12,583**	**10,162**	**12,087**	**8,129**	**18,717**
Overhead costs	2,438	2,438	2,438	2,438	3,000	2,438
NET MARGINS (R ha^{-1})	**8,904**	**10,146**	**7,724**	**9,649**	**5,129**	**16,279**

Note: * WCC after soya not planted

Table 7 above is a summary of a financial analysis for the dryland crops under the Ficksburg trials. The complete financial analysis is under appendix 3. This financial analysis used farm-based values derived from consulting Theunis Pretorius implementing the trials. The analysis and values are in line with Grain SA's crop production budgeting template.

The long term farm average for soya is 2.2 t ha^{-1} and for maize it is 7.2 t ha^{-1}. The excess rainfall distribution this season did affect maize yields slightly as maize yields were between 6 and 6.3 t ha^{-1} Soya yields on the other hand were slightly higher than long term average between 2.45-2.52 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 125% 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 R2,950 (2019/20 season at R2,350) and soya at R7,000 (2019/20 season R6,675) all at farm gate price.

Costs (Expenditure)

Most of the cost or expenditure items for maize and soya were the same as the same amount of fertilizer and herbicides were used. The same maize seed cultivars were used for maize treatments as well as 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 plow) action followed by a 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: Mechanization and fuel details at Ficksburg

Description of action/ mechanization pass	Figures used		RA				NT/ CA		CT
	L/ha	Mainte-nance	SCC	MAIZE RELAY	WCC	SOYA + WCC	MAIZE	SOYA	MAIZE
Discing	6	340							1
Chisel Plough	24.15	380							1
Plant (notill)	7.8	450	1	1	1	1	1	1	1
Spread fertilizer	0.93	40	1	1		1	1	1	1
Boom spray	1.75	130	1	3	1	2	3	3	2
Transport grain	8	80		3		1	3	1	3
harvest maize/ soya	15	700		1		1	1	1	1
grain wagon (tapkar)	4.6	40		1		0.5	1	0.5	1
Transport water and fertilizer (support)	2.63	50	1	1		1	1	1	1
		Total liters ha-¹	**13.1**	**52.2**	**9.6**	**40.2**	**52.2**	**41.9**	**80.6**
	13.5	**Fuel (ZAR) ha-¹**	**176.9**	**704.7**	**129.6**	**542.7**	**704.7**	**565.7**	**1088.1**
		Maintenance and repair costs (ZAR) ha-¹	**670**	**1830**	**580**	**1600**	**1830**	**1730**	**2420**

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 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 being R600. See details in financial analysis framework on in Appendix 3.
- 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 being R400. Once again for more details see financial analysis framework in Appendix 3.

The purpose of table 9 below is to show how net margins are derived. In addition, it was deemed important to show the extra income derived from the SCC, relay cover crop in maize and the WCC after SCC.

The first grazing is SCC and the income of R17,971 ha^{-1} is derived from the figures in the table below (table 9). The second grazing, which is the WCC after SCC's income of R7,736 ha^{-1} is derived from the following calculations in the same table. Lastly the relay CC as seen below had a grazing income of R2,584 ha^{-1}.

Table 9: Ficksburg trial SCC and WCC grazing income calculations

FICKSBURG GRAZING INCOME	QTY			
Cover crop strategy		SCC	WCC	M RELAY
DM t ha-^{1} measured		12.48	1.5	
dm t ha-^{1} estimated				0.5
Feed use efficiency SCC	30%	3.744		
Feed use efficiency WCC	70%		1.05	0.35
Feed conversion SCC	1:10	374.4		
Feed conversion WCC	1:6.5		161.17	53.84
Kg meat produced per ha-^{1}		**374.4**	**161.17**	**53.84**
R/ kg live weight Beef	38			
R/ kg live weight Lambs	48	48	48	48
Total INCOME (RAND)		**17 971**	**7 736**	**2 584**

Overhead costs

Overhead costs are included to calculate the net margins per hectare. All overhead costs are the same per hectare at R2,438 ha^{-1} except for hectares attributed under the conventional production practises. The mechanization costs are higher under CT as well as the replacement time 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 R3,000 ha^{-1} as compared to R2,438 ha^{-1} for CA/ RA

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

Overheads	weight	RA	NT	CT	RA	NT	CT
Tractor & equipment replacement cost	50%	63%	63%	100%	31%	31%	50%
Administrative, insurance costs etc	15%	100%	100%	100%	15%	15%	15%
Fixed labour costs	35%	100%	100%	100%	35%	35%	35%
TOTAL	**100%**				**81%**	**81%**	**100%**
	3000				**2438**	**2438**	**3000**

Net margins

The net margins reflect highest under the SCC + WCC of R15,720 ha^{-1}. The CT maize treatment has lowest net margins at R5,129 ha^{-1}

Table 11: Comparative financial analysis of Marquard trial treatments

MARQUARD

Production system:	**RA**	**RA**	**CA**	**CA**	**CT**	**RA**
Description of treatments (All figures in ZAR ha^{-1})	**Maize_ relay**	**Soya_ WCC**	**Maize**	**Soya**	**Maize**	**SCC_ WCC**
INCOME						
Cash crop	11,376	15,836	12,470	15,836	9,281	-
Crop residue graze value	621	193	680	193	506	-
CC graze 1 SCC value (7.1 t ha^{-1})	-	-	-	-	-	10,195
CC graze 2 WCC value (1.49 t ha^{-1})	-	-	-	-	-	7,676
Graze 3 relay CC in maize (1.84 t ha^{-1})	9,531	-	-	-	-	-
Graze 4 WCC after soya (0.5 t ha^{-1})	-	2,585	-	-	-	-
GROSS INCOME	21,528	18,613	13,150	16,029	9,787	17,871

Production system:	RA	RA	CA	CA	CT	RA
Description of treatments (All figures in ZAR ha^{-1})	**Maize_ relay**	**Soya_ WCC**	**Maize**	**Soya**	**Maize**	**SCC_ WCC**
VARIABLE COSTS						
Cash crops related	8,649	5,371	8,415	4,783	7,983	-
Cover crop related	653	245	-	-	-	4,190
Livestock related	-	-	-	-	-	864
TOTAL COSTS	9,354	5,636	8,415	4,783	7,983	5,054
GROSS MARGINS	**12,174**	**12,978**	**4,735**	**11,246**	**1,804**	**12,817**
Overhead costs	2,063	2,063	2,063	2,063	3,000	2,063
NET MARGINS	**10,112**	**10,915**	**2,672**	**9,183**	**-1,196**	**10,754**

Table 11 above is a summary of a financial analysis for the dryland crops under the Marquard trials. The complete financial analysis is in Appendix 4. This financial analysis used farm-based values derived from consulting Tom and Nant Yzel implementing the trials. The analysis and values are in line with Grain SA's crop production budgeting template.

The long term farm average for soya is 2 t ha^{-1} and for maize it is 4 t ha^{-1}. The maize and soya yields were in line with the farm's long term average. The CT maize plant population was 20,000 ha^{-1} according to conventional standard practices. The CA and RA maize was planted at 30,000 ha^{-1}. Soya was planted on 5 December 2020 and maize at 1 January 2021 respectively. The relatively late plantings may have influenced grain yields.

The commodity price of maize at R3000 t was also slightly higher this year as compared to the previous season. The commodity price for soya was R7,400 t soya. Maize traded at R3000 (2019/20 season at R2,350) and soya at R7,400 (2019/20 season R6,675) all at farm gate price.

Costs (Expenditure)

Most of the cost items or expenditure was the same for 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 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 deep rip (chisel plow) and vibraflex action followed by a NT planting action. The diesel price used was R13,50 lit^{-1}. The table below reflects the litres ha^{-1} used under the different treatments and quantity of passes.

Table 12: Mechanization and fuel details at Marquard

Description of action/ mechanization pass	Figures used		RA				NT/ CA		CT
	L/ha	Maintenance	SCC	MAIZE RELAY	WCC	SOYA + WCC	MAIZE	SOYA	MAIZE
Chisel Plough	24.15	340							1
Vibroflex	5.21	40.81							1
Plant CC	5.61	140.52		1					
Plant (notill)	7	450	1	1	1	2	1	1	1
Boom spray	1.75	130	2	3		3	3	3	2
Harvest maize/ soya	12	450		1		1	1	1	1
Transport water and fertilizer (support)	2.63	50		1		1	1	1	1
grain wagon (tapkar)	4.6	40		1		1	1	1	1
Transport grain	8	80		1		1	1	1	1
Total liters ha^{-1}			**10.5**	**45.1**	**7.0**	**46.5**	**39.5**	**39.5**	**67.1**
13.5 **Fuel (ZAR) ha^{-1}**			**141.8**	**608.9**	**94.5**	**627.8**	**533.3**	**533.3**	**905.9**
Maintenance and repair costs (ZAR) ha^{-1}			**710**	**1601**	**450**	**1910**	**1460**	**1460**	**1711**

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 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 being 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 being R400. Once again for more details see financial analysis framework in Appendix 4.

The purpose of table 9 below is to show how net margins are derived. In addition, it was deemed important to show the extra income derived from the cover crop.

The first grazing is SCC and the income of R10,195 ha^{-1} is derived from the figures in the table below (table 9). The other three WCC's income is derived from the following calculations in the same table. WCC after SCC R7,676 ha^{-1}; relay CC R9,531 ha^{-1} and WCC after soya at R2,584 ha^{-1}.

Table 13: Marquard trial SCC and WCC grazing income calculations

FICKSBURG GRAZING INCOME QTY

Cover crop strategy		SCC	WCC	M RELAY	WCC after soya
DM t ha-¹ measured		7.08	1.49	1.84	
dm t ha-¹ estimated					0.5
Feed use efficiency SCC	30%	2.124			
Feed use efficiency WCC	70%		1.043	1.29	0.35
Feed conversion SCC	1:10	212.4			
Feed conversion WCC	1:6.5		159.92	198.57	53.84
Kg meat produced per ha-¹		**212.4**	**159.92**	**198.57**	**53.84**
R/ kg live weight Beef	38				
R/ kg live weight Lambs	48	48	48	48	48
Total INCOME (RAND)		**10 195**	**7 676**	**9 531**	**2 584**

Overhead costs

Overhead costs are included to calculate the net margins per hectare. All overhead costs are the same per hectare at R2,063 except for hectares attributed under the conventional production practises. The mechanization costs are higher under CT as well as the replacement time 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 R3,000 ha^{-1} as compared to R2,063 ha^{-1} for CA/ RA

Table 14: Overhead cost calculations for the three production systems at Marquard

Overheads	weight	RA	NT	CT	RA	NT	CT
Tractor & equipment replacement cost	50%	63%	63%	100%	31%	31%	50%
Administrative, insurance costs etc	15%	75%	75%	100%	11%	11%	15%
Fixed labour costs	35%	75%	75%	100%	26%	26%	35%
TOTAL	**100%**				**69%**	**69%**	**100%**
	3000				**2063**	**2063**	**3000**

Net margins

The net margins for CA/NT maize and CT maize are the lowest at R2,672 ha^{-1} and –R1,196 ha^{-1} respectively. The CT maize with negative net margins state that it is unsustainable. This scenario will worsen when diesel prices are at R16 lit^{-1} as compared to R13,50 used in the analyses. The RA maize in comparison to the other two maize treatments reflects net margins at R10,112 ha^{-1}. The difference is the added grazing value of the relay cover crop into the standing maize. The intercrop, comprising a mix of summer and winter cover crops, was planted on 2 February 2021 (i.e. 31 day after planting maize). It had ample time to grow. This result shows the importance of the inclusion of cover crops.

The SCC followed by WCC reflected the highest net margin of all treatments at R10,754 ha^{-1}.

The soya margins reflect significant higher net margins than maize. The soya was planted on 5 December 2020 before maize which was planted on 1 January 2021. The soya at 2.14 t ha^{-1} is in line with long term farm soya yield average. This reflects that soya is a promising cash crop to be included in crop rotations in the Maluti region.

Marquard case study: Yzel farm

This financial analysis includes grazing on summer cover crops (SCC) that was only planted on 2 February 2021. The authors included this farm case study from Yzel boerdery to illustrate that net margins of SCC + WCC (plus livestock integration) can even be higher than R10,754 ha^{-1}. A more detailed description follows below as well as in Section 4.1.3.3. and Appendix 5.

The farm case study includes the following: 351 lambs grazed on a 14ha block of SCC, which resulted in a net margin of R17,002 ha^{-1}.

The following is a description of the case study income per hectare from Yzel Boerdery. 351 lambs were put into a 14ha block with summer cover crop mixture. Lambs were on average 37kg (at R40/kg; 37 kg x R40 = R1480) when going in and out at 56.7 kg. Slaughter weight was on average 26.6 kg at R93/kg resulted in R2473 per lamb. The difference is R993 per lamb. Total meat produced on that 14 ha block is equivalent to R348,543 (R993 income per lambs x 351 lambs). The costs of establishing the SCC (seed, planting, chemicals and rent for land) added up to R44,170. Additional feed supplements (SS200-mixture) was R66,339. The total sum reflects an income of R348,543 minus cover crop costs + SS200 (i.e. supplementary feeding from Voermol) of R110,509, which resulted in a profit of R238,034 for 14 ha, or R17,002 ha^{-1}. This figure is used in the abovementioned Marquard financial trial analysis for SCC.

The SCC as described above in this case was planted as early and conveniently possible in the commercial context of the Yzel farming enterprise. In order to achieve this kind of meat production per ha one needs to plant early in the season. The economic analysis as mentioned in this report included the grazing of SCC of on average 7.1 t ha-1. It speaks for itself what SCC + WCC contribute to net margins if the DM is between 12-18 t ha^{-1} as compared to 7.1 t ha^{-1}. The different CC strategies are all important and is a risk reduction strategy as the CC strategies can be applied and adapted per season (i.e. to mitigate and adapt to climate and rainfall variations).

4.1.2.4. Brix readings

Brix readings were 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 the these indices were used to compare the trial brix values with (http://ag-usa.net/brix_test_meaning.htm).

Table 15: 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/

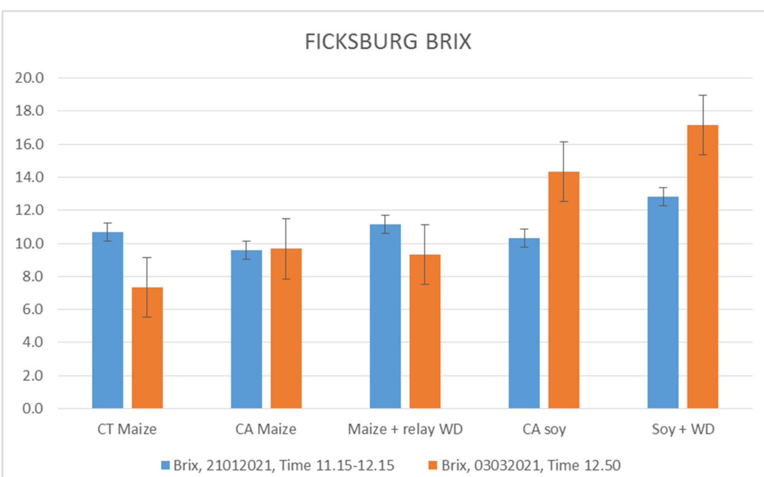
The above mentioned index is generic for all crops. Another source at http://ag-usa.net/brix_test_meaning.htm gave the following index with specific reference to maize (young, stalks), soya and grains (Table 17). Only maize and soya plants were measured on the trials (by collecting samples from leaves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

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

Figure 3: Brix value index for maize and soya

FICKSBURG

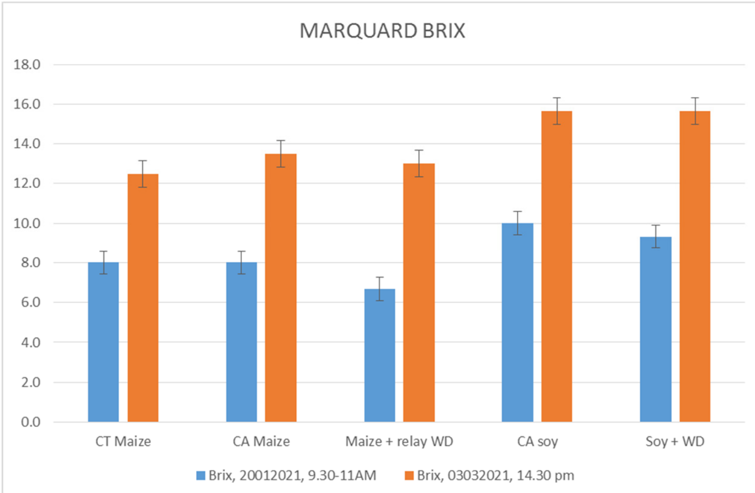
Brix readings were taken on 13 January 2021 (10am-11.30) and on 17 February 2021 (14-15.30 pm)



Graph 4: Brix readings for maize and soya at Ficksburg trial 2020/21 season

MARQUARD

The brix readings were taken on 13 January 2021 (13.10-14.30 pm) and on 16 February 2021 at 15.30 – 17.15pm)



Graph 5: Brix readings for maize and soya at Marquard trial 2020/21 season

Key: Blue bar Brix readings were taken on 13 January 2021 (10am-11.30) and orange bar on 17 February 2021 (14-15.30 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

4.1.3. Results and discussion

4.1.3.1. Cover crops and livestock integration

Farmer co-workers' CA systems in perspective

Both Marquard and Ficksburg farmers have mixed farming practises. Yzel Farm at Marquard has started with grazing lambs and to a lesser extend beef on cover crops already. Ultra High- or high density strip grazing is a CA practice they explore. This report partially highlights the income gained from cover crop grazing. The high density strip grazing was a new concept tried at the Ficksburg trial. It had challenges re fencing, water supply and lambs adapting to this grazing system.

From all the different cover crop strategies the one that is hardly practised on any farm in the Highveld is maize intercrop (inter-seeded at V6-8 stage of maize). This was successfully applied by Nant Yzel at the Marquard trial resulting in 1.84 t of DM only from the cover crops, planted as intercrops. It is anticipated that the feed utilisation rate of maize residue will improve whilst livestock has both access to an inter-cover crop mixture of radishes, oats and grazing vetch whilst grazing maize stover. Maize relay (casting or drilling seed at stage when maize starts drying of) was applied by Theunis Pretorius at Ficksburg. The seed was casted and lightly hand weeded thereafter to ensure good soil to seed contact

If cover crops are planted very late after the ideal planting window, for example at 20th of December, then one can realistically 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.

Cover crop grazing would have had more competitive profit margins when cash crop yields are lower (in line with long term averages of 4-6 t ha^{-1} for maize), and when commodity prices are lower (R2200-R2500/ t) as seen in 2019/20.

4.1.3.2. Crop quality

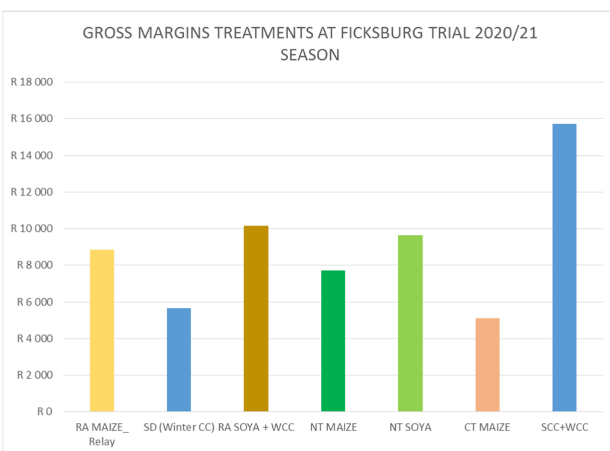
There were no significant differences in Hectolitre mass between the treatments and neither were there significant differences between Brix readings of the different treatments this season. Brix readings correlate with crop growth and plant vigour. Brix readings above 12 are regarded as good, but the index ranges can go as high as 20-24.

The Ficksburg trial reflected good to excellent readings on both soya treatments. The second reading (February 17) reflected higher readings than the first reading on 13 January. The time of the day is recorded when readings were taken for reference. The readings on maize reflected a different pattern where the second reading was the same or lower than the first reading. All maize readings were below 11 which according to the index is regarded as average. This can be a reflection of the excess rainfall during the season.

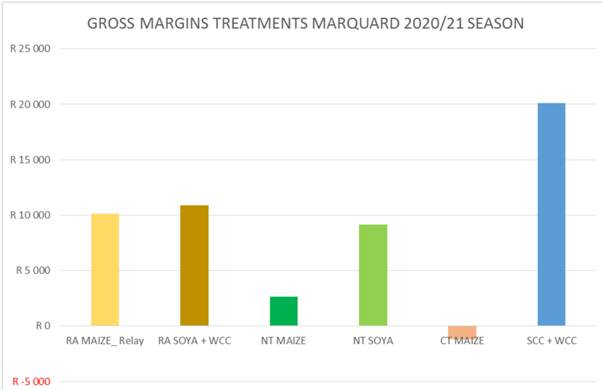
At Marquard both maize and soya reflected higher Brix readings in February as compared to January readings. All maize treatments reflected poor readings in January. That corresponds with late planting and rainfall effect. December 2020 monthly rainfall was the 2nd highest recording in 40 years. Maize was planted late under sub-optimal conditions as reflected in the low maize Brix readings. Soya was planted on 5 December 2020 and reflected good Brix readings (i.e. 10) in January. Both maize and soya had increased readings in February. All maize's readings were between 12-14 (i.e. average – good) and soya around 16 (i.e. excellent) for both soya treatments.

4.1.3.3. Profitability

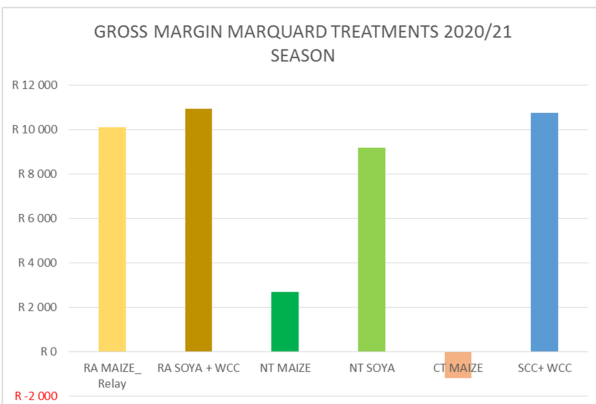
The net margins of the two trials are shown below.



Graph 6: Net margins for the different production systems at Ficksburg trial treatments 2020/21 season



Graph 7: Net margins for the different production systems at Marquard trial treatments 2020/21 season - based on 17 t ha^{-1} summer cover crop



Graph 8: Net margins for the different production systems at Marquard trial treatments 2020/21 season - based on 7.1 t ha^{-1} summer cover crop

The SCC + WCC reflected highest profit levels per ha^{-1} at both trials. CT maize reflected the lowest net margins at both trials. Even to the extent of negative net margins at Marquard based on maize grain yield of 3 t ha^{-1} which was 1 t below the CA/NT and RA maize as well as below the farm's long term maize average of 4 t ha^{-1}. Soya net margins are higher than maize margins at both trials.

The comparative financial analyses show the profitability of all four cover crop strategies applied at Marquard trial. WCC after soya was not applied at Ficksburg. The net margins, however, are confirming the same trend of profitability of cover crops as at Marquard trial

4.1.4. Conclusions

The SCC followed by WCC grazing (as part of the best CA systems treatments) showed the highest profits on the Ficksburg trial and early Marquard SCC planting as compared to the maize and soya cash crops. Emphasis in the 2021/22 season will be on timely planting and on improved grazing management.

The late December SCC planting at Marquard with a difference of a month (3-6 weeks) of planting date resulted in an approximate 10 t /ha gap in biomass (i.e. 17 and 7.1 t ha^{-1}). The relatively late SCC planting with on average a 7.1 t DM/ ha still outperforms CT and current CA maize on profit ha^{-1}. The RA maize outperforms CT and current CA maize at Marquard due to the grazing / livestock income from the relay cover crop. The maize profit margins for CT are negative at – R1,196 ha^{-1} at Marquard. This particular relay cover crop strategy provides, based on this seasons figures, a good answer to this project's hypothesis. In this season the CT maize was at a loss whilst both the CA and RA maize (without livestock income from grazing) had positive but low profit margins. The inclusion of soya into the crop rotation with profit margins for both trials around R9,000 -10,000 ha^{-1} is a lifeline as compared to conventional maize on maize "rotation".

4.2. Assessment of soil health

4.2.1. Activities, Methods and Deliverables

Table 16: Progress and Results achieved on assessment of soil health

Activities	Deliverables	Progress and Results achieved
1.Monitoring and Sampling	Baseline samples and mid-season soil sampling	Baseline A (0-10) and B (11-30) horizon samples were taken in October 2020. Samples were taken at randomized spot in the middle of the treatment block. Neighbouring veld was sampled as reference. Analysed via Haney. A soil health score, based on biological, physical and chemical elements of soil, is included in the Ward Laboratory's report as included in this report. A-horizon (0-10cm) soil samples were taken per strip on 2&3 March 20121. NWU assisted and the following was done per strip. -soil compaction measured by using a penetrometer -at the same spots 5 sub samples were taken to determine bulk density -additional soil samples taken from same 5 spots for other soil analysis. All centre spots were geo referenced Samples were send to NWU and Ward Laboratories for analysis
2.Lab Analyses	Lab results made available to Asset research and trial farmers	Baseline data analysed by Ward Laboratories. Extract of results below.
3.Monthly meetings (project team)	Monthly – bimonthly meetings	Project team did meet on site when collecting data and sampling. Two additional zoom meetings were held.

4.Annual reference group meeting (advisory committee)	End of season Maluti committee meeting	Planned for end-of-season to discuss finding & progress and year 2 implementation
5.Annual report and admin (technical data analyses)	Mid-term report and end-of-season reports ready before deadlines	In progress
6.Participate in Awareness events	Farmer days planned at trials	A farmers' day was successfully held on 27 of April 2021 at Marquard. The planned farmers day for 29 April 2021 at Ficksburg was cancelled primarily due to Covid and immature trial conditions at that stage.

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 H2O, 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 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 analyze 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 replenishes 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 Mineralization

The amount of nitrogen being released through mineralization 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 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 mineralization. This nitrogen is immediately plant 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 are 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 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.

Table 17: Organic C:N Ratio Ranking Table

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

24 h CO_2 – Carbon respiration burst test

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 as follows:

Table 18: 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 extractant minus the inorganic phosphorus. This represents phosphorus that is not currently plant available but may become available through microbial activity.

Table 19: 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 stabilize the score as respiration rises above 100 ppm CO2-C. This score represents the overall health of your soil system. It combines 5 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 provides an indication of 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 20: Soil classification info – soil types, depth, structure - Ficksburg

Trial	Geo-reference	Soil type	Soil depth	Soil structure
Ficksburg	28°35'30.6"S27°48'00.6"E	See photo 2. Avalon[1] (dark blue), Bainsvlei[2] (small red circle), Clovelly[3] (purple)	[1] 950-1150 cm [2] 550 -750 cm [3] 750 - 950 cm	Sandy soil with 10-15% clay.

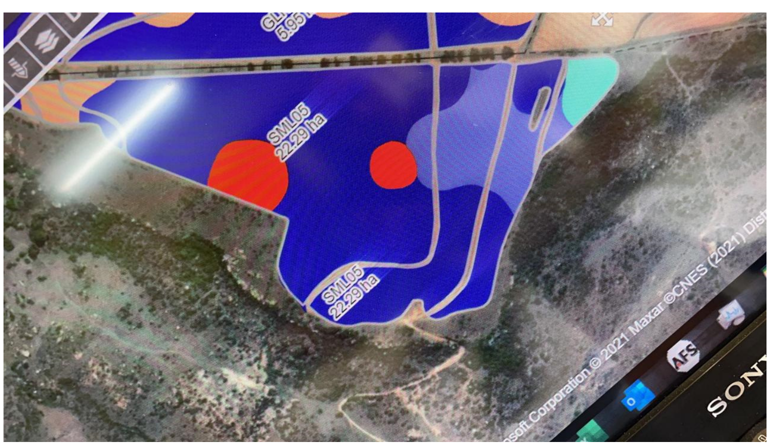


Photo 2: Soil map of Ficksburg trial

Table 21: Soil classification info – soil types, depth, structure - Marquard

Trial	Geo-reference	Soil type	Soil depth	Soil structure
Marquard	28°42'28.5"S27°23'20.1"E	Avalon (North side) Westleigh (South)	61 cm 57 cm	Sandy soil with 7% clay

Both trial areas are on the south-eastern Highveld falling within a summer rainfall area of on average 600-800 mm yr^{-1}. Marquard's average is close to 600mm and Ficksburg closer to 700 mm yr^{-1}. These areas are characterized by warm summers and cold winters. Minimum temperatures just below -3^{0} C, with exceptions up to -12^{0} C.

Table 22: Soil texture, pH, EC, Active C and bulk density values of the Ficksburg trial and treatments

Name: Date		TP FICKSBURG Feb-21	Depth 0-10 cm						
	A	22-24	1,13,16	5,11,15	4,14,20	3,9,18	6,8,19	2,12,17	7,10,21
Sample ID		VELD	REGENERATIVE				NT/CA		CT
Lab ID		Veld	SCC+WCC	MAIZE_ Relay	SCC+WCC	SOYA + WCC	MAIZE	SOYA	MAIZE
Soil Texture (Sand %)	A 0-10 cm	**48.02**	**56.40**	**54.82**	**58.66**	**62.83**	**58.33**	**57.42**	**59.92**
Soil Texture (Silt %)		**36.16**	**27.21**	**29.74**	**25.27**	**25.99**	**25.47**	**26.74**	**23.71**
Soil Texture (Clay %)		**15.83**	**16.40**	**15.44**	**16.06**	**11.17**	**16.20**	**15.84**	**16.38**
pH		**5.03**	**5.30**	**5.73**	**5.53**	**5.60**	**5.63**	**5.53**	**5.63**
EC (uS/cm)		**123.33**	**116.67**	**73.33**	**130.00**	**73.33**	**56.67**	**80.00**	**86.67**
Active C (mg/kg)		**802.96**	**194.58**	**191.79**	**224.69**	**212.98**	**179.52**	**206.29**	**151.64**
Bulk Density (g/cm3)		**0.82**	**1.46**	**1.35**	**1.48**	**1.32**	**1.39**	**1.50**	**1.38**

Table 23: Soil texture, pH, EC, Active C and bulk density values of the Marquard trial and treatments

Name: Date		NY MARQUARD Feb-21	Depth 0-10 cm						
	A	22-24	1,13,16	5,11,15	4,14,20	3,9,18	6,8,19	2,12,17	7,10,21
Sample ID		VELD	REGENERATIVE				NT/CA		CONVEN-TIONAL
Lab ID		Veld	SCC+WCC	MAIZE_ Relay	SCC+WCC	SOYA + WCC	MAIZE	SOYA	MAIZE
Soil Texture (Sand %)	A 0-10 cm	**73.41**	**79.24**	**78.38**	**79.84**	**79.27**	**79.66**	**81.01**	**79.58**
Soil Texture (Silt %)		**18.39**	**13.66**	**14.18**	**12.87**	**13.42**	**12.96**	**12.32**	**13.28**
Soil Texture (Clay %)		**8.19**	**7.10**	**7.43**	**7.29**	**7.31**	**7.38**	**6.67**	**7.14**
pH		**6.03**	**5.20**	**4.97**	**5.20**	**5.20**	**5.30**	**5.13**	**4.93**
EC (uS/cm)		**53.33**	**80.00**	**96.67**	**76.67**	**93.33**	**63.33**	**86.67**	**83.33**
Active C (mg/kg)		**8.71**	**63.53**	**102.01**	**67.44**	**109.26**	**75.80**	**82.49**	**70.22**
Bulk Density (g/cm3)		**1.53**	**1.54**	**1.47**	**1.53**	**1.47**	**1.43**	**1.45**	**1.44**

4.2.3.2. Soil health

The baseline Haney SHT results (samples taken in October 2020 before the trial establishment) and additional Haney SHT results (samples taken in February 2021 after the implementation of all the treatments) of all the trials are shown in Appendix … . 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 was 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) horizon.

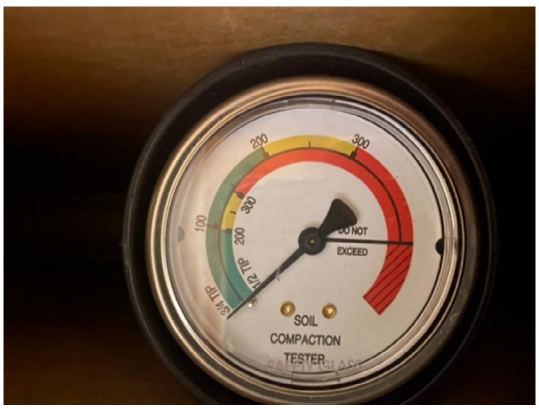


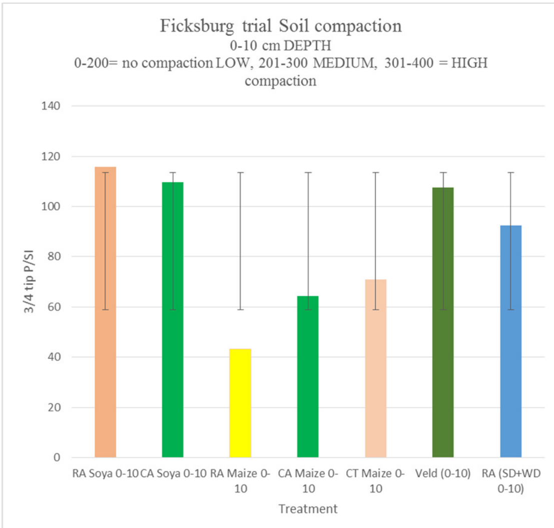
Photo 3: Example of penetrometer used for measuring soil compaction at Maluti trials

The photo above reflects:

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

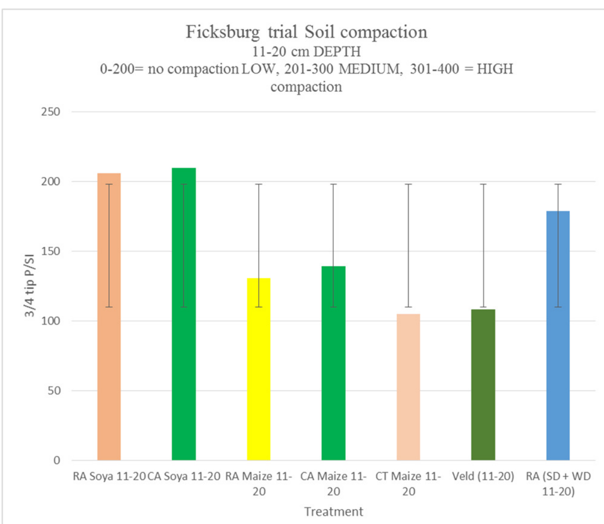
The team took five penetrometer readings per treatment around the soil sampling area.

Ficksburg:



Graph 9: Soil compaction measured with a penetrometer at Ficksburg trial for 2020/21 season at 0-10 cm

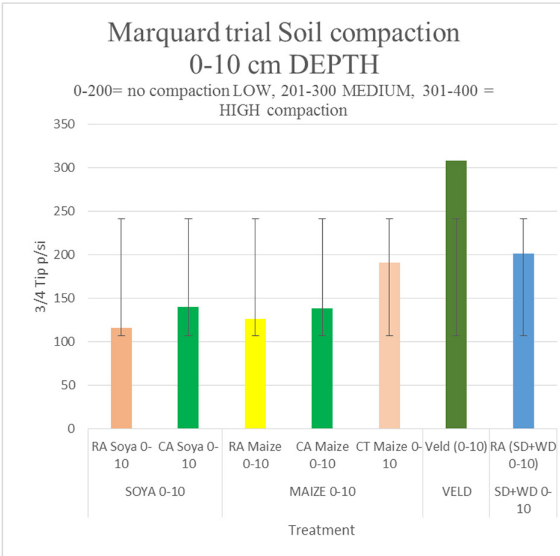
The penetrometer values are below 120 and are categorized as LOW (0-200psi)



Graph 10: Soil compaction measured with a penetrometer at Ficksburg trial for 2020/21 season at 11 - 20 cm

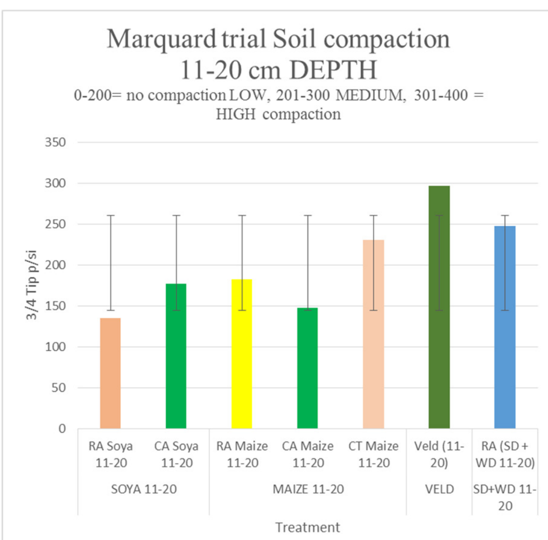
The penetrometer values between 0-200 psi (green line) are regarded as no to low compaction. The two soya treatments are just above the 200psi mark.

MARQUARD



Graph 11: Soil compaction measured with a penetrometer at Marquard trial for 2020/21 season at 0-10 cm

The penetrometer values between 0-200 psi (green line) are regarded as no to low compaction. Most of the results in graph 11 fall within the category medium compaction (0-200 psi) except for veld which is above 300psi. The reason being so high for veld was due to excessive root biomass.



Graph 12: Soil compaction measured with a penetrometer at Marquard trial for 2020/21 season at 11 - 20 cm

Most of the penetrometer values range between 0-200 psi and are regarded as no to low compaction. Veld as described under the previous appeared to have lots of root biomass which gave increased resistance when using the penetrometer. The team suspects the same is applicable for the SCC.

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 samples were much higher at both A and B soil layers, which reflects a very high "*pristine*" benchmark and reflects the potential SOM/SOC levels in the area possible under best CA practices. At the Ficksburg trial the SOM levels in the A and B layers of Veld were 5% and 3,2% respectively, while at the Marquard trial the values were 1,4% and 1%.
- SOM/SOC values under cultivated treatments were higher at the Ficksburg trial site (between 1,1% and 1,5% SOM, compared to 0,5 to 0,7% at the Marquard trial sites).
- Values of WEOC, soil respiration, MAC were all very low at all the trial sites, except at the veld sampling point in Ficksburg, which were much higher. C:N ratios were high (>15) at all the sampling points.

Nitrogen (all the N values and ratios)

- WEON (Organic N) levels were between 6 and 12,6 in all the trial sites. Inorganic N values were between 4,8 and 12,5; this shows that about 50% of the total N in the soil is from the organic pool.

Phosphorous (all the P values and ratios)

- The Total P values in soils of both trials falls in the Medium range (12-29 ppm) in both the topsoil and the subsoil. All the soil P are from the inorganic source (i.e. fertilisers). The topsoil of the Veld samples are not different from cultivated samples, all from the inorganic pool.

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

- The Haney SHS's on both of the trials are all *Average* and *Below Average* and are all below 7, primarily due to the sandy nature and poor structure of these soils, as well as many decades of tillage before they started with CA. Only the SHS's of the Ficksburg trial Veld sample are above 7, with 11,4 and 8.7 in the top- and subsoil respectively.
- The VAS values on both trials are extremely low with almost all scores below 5% (ideally they should be above 45%).
- The pH_{H2O} of the Ficksburg cultivated soils are between 4,3 and 4,7, while the pH values of the Marquard trial site are between 4,5 and 4,9.

Other Haney parameters standing out

- The Fe values on all the trials are Very High (above 20), but mostly within the acceptable range of 20 to 80 ppm.
- The Mn values of many sampling spots in both trials are between 10 and 24 ppm and falls far above the ideal range of 4-6 ppm. This might be related to fairly low pH of the soils.

- Ca levels in the Ficksburg trial site are low, ranging between 117-183 ppm, and between 88 and 127 ppm in the Marquard trial site (with one outlier of 550 ppm in the latter). Mg levels at both trials are also low, but above the critical value of 30 ppm.
- The %Ca in both trials range between 24 and 28% and are far below the recommended level of 68%.
- The Ca:Mg ratios on both trials are below the recommended value of 5.

Soil compaction

There is no soil compaction measured on Ficksburg trial in the A or B horizon.

At Marquard we found no compaction in the A horizon except for veld at 300+ psi. The only reason for that we found to be due to the root density of the veld. We found readings between 200-310 psi in the B horizon. Veld had once again the highest penetrometer readings of around 300. We assume the same high amounts of root biomass that made it difficult for the penetrometer to enter. The SD (summer cover crops) had readings of 250 which is also higher than the 0-200 readings on the other treatments. Once again the only plausible explanation we have for that is the potential root biomass with the option of a higher water uptake resulting in a slightly more compacted soil layer. The conventional maize had a third highest reading of 230 which may reflect a slightly higher compaction resistance due to the tine implement action prior to planting.

4.2.5. Conclusions

The Ficksburg Avalon soil with 15-16% clay and close to 3% SOC, is high for the soils in the trial area, although the pH of 4.5 to 4.9 is below the ideal of 5-5-6.5. The volumetric aggregate stability (VAS) of less than 5 is very low as compared to the 45 ideal level.

Marquard falls within a medium potential area and the few soil indicators highlighted in the table(s) above on the Marquard trial confirm the high sand content of the soils (+- 80%). The SOC levels are low at 0.35% and presents a real case study challenge on how to build up soil ecosystem health on sandy soils. The profitability of cover crop grazing under the various regenerative production systems reflected highest profit margins when planted early. Marquard trial, just like the Ficksburg trial, has low pH and VAS levels.

There is no significant soil compaction except under Marquard veld and summer cover crops (SCC), which we believe is a result of the high root biomass under these two respective crops.

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

4.3.1. Activities, Methods and Deliverables

Table 24: Progress and results achieved of assessment of cover crops and livestock integration

Activities	Deliverables	Progress and Results achieved
1.Land preparation (finding a suitable location, sourcing materials)	2 trials laid out	Farmers received trial plans and seed to establish cover crops strips according to the trial layout
2.Purchase Materials & Equipment	Purchase Materials & Equipment	Hybrid babala was distributed to farmers for inclusion in the summer mixture to be established as a cover crop
3.Establishing and Planting of trials		The initial layout of the trials were send to the ARC biometry division to see that it is statistically viable for analyses. Two statistical trials laid out
4.Seasonal management and maintenance of trials	A trial protocol written and discussed with trial farmers	A best management manual was drawn-up by the research team and distributed to farmers.
5.Monitoring and Sampling (including harvesting, biomass and yield determination, nutrient analysis)	Ongoing monitoring	Due to financial constrains the monitoring and sampling of the cover crop strips were done in conjunction with the soil sampling, penetrometer readings and bulk density determination?
6.Lab Analyses	Soil analysis results	Baseline soil data taken in October 2020 and send to Ward Laboratories for Haney tests. Additional soil data taken per strip in February 2021 and samples send to ward laboratories and North West University (NWU) laboratory
7.Monthly meetings (project team)	Monthly meetings	Project team met monthly on site or through zoom-type meetings
8.Annual reference group meeting (advisory committee)	Annual committee meeting	There was an initial Maluti committee meeting was on 17 September 2020. A committee meeting is planned prior to trial planting of year two to discuss feedback, progress and 2021/22 protocol
9.Harvesting, biomass and yield determination, nutrient analysis	Relevant data collection	Each trial has its own research data template. The research team received the various soil lab reports.
10.Annual report and admin (production & technical data)	Annual report	Asset team drafted mid-term progress- and end-of the season reports
11.Participate in Awareness events	Farmer days and awareness events	Awareness updates (links to events, articles and promotion of regenerative crop- and grazing articles and info) send via the Maluti CA WhatsApp group . Farmers' day organized at Yzel Boerdery on April 27, 2021.

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 complimentary 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 is 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 sunnhemp
- 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 °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

We used the following figures and assumptions 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 were utilized during a grazing trial at Ottosdal. Earlier utilization for instance in a late vegetative stage will adhere to the rule of thumb that "take half, leave half". This will allow the regeneration of the cover crop faster because sufficient leave 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 Free State. Hence the assumptions to use the value of 30% utilization 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 this report the financial analysis includes grazing on summer cover crops (SCC) based on a farm case study of 351 lambs grazed on a 14ha block at Yzel farm as described elsewhere in the report, which resulted in a profit margin of R17, 002 $ha^{-1.}$ The farmer kept sufficient records of inputs and animal gains for financial analysis but neglected the DM production calculations. No values for t DM ha^{-1} were determine by the farmers that lead to gabs in the data.

For WCC the picture painted for SCC 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 that less wastage due to trampling occurs. 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 Mpumalanga it was observed that 70% of available cover crop material were used during the trial period, which included two grazing events. Hence the assumptions to use the value of 70% utilization 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 tha-1 * 30%) 1: 10 (10kg fodder results in 1 kg meatha-1 produced)

For WCC 70% (DM tha-1 * 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 produce from one hectare. Multiply kg meat ha-1 produced with the actual live weight prices of lambs (R48) and beef (R38) gave us the opportunity to calculate margins for WCC and SCC.

Livestock income is based on cover crop assessments, which is reflected under crop budgets and net margin analysis. Dry matter content of SCC treatments were measured on 3 March and 15 April at Ficksburg and Marquard respectively, whiles the double crop WCC were harvest on the 23 June 2021 with a 1m2 square quadrant. In table 22 the plot numbers (Nr.) and the DM t ha-1 (DM) for the different location for the SCC and WCC planted as double crops display.

Table 25: Dry Matter yield (t ha^{-1}) for the CC treatments at trials in Maluti

	Ficksburg			Marquard			Ficksburg	Marquard
Nr.	*DM t ha^{-1}	**DM t ha^{-1}	Nr	*DM t ha^{-1}	**DM t ha^{-1}	Nr	***DM t ha^{-1}	***DM t ha^{-1}
1	17.0	1.00	1	6.32	1.3	5	-	1.00
4	12.8	0.6	4	10.94	2.0	11	-	2.64
13	9.7	0.6	13	7.25	2.55	15	-	1.89
14	10.3	0.5	14	8.34	0.61	5	0.5	-
16	-	0.9	16	5.32	1.28	11	0.6	-
20	-	0.5	20	4.32	1.17	15	0.4	-
AVG	12.5	0.7		7.1	1.50		0.5	1.84

* SCC harvest 03/03/ , 15/04/2021
* * WCC harvest 23/06/2021
*** Delayed intercrop 22/06/21

The contribution in terms of dry matter production at Marquard and Ficksburg were as follows: grasses were (67%), legumes (18%) and brassicas (15%) and grasses (70%), legumes (24%) and brassicas (6%), respectively, for the plants that were harvest to determine DM%. At Marquard the WCC after harvesting soya's were still small at the time of reporting and a DM yield of 0.5 t ha^{-1} was estimated.

4.3.3. Results and discussion

The Asset Research team is busy developing the system of measuring the monetary value of the various cover crops in the RA systems. We hope 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.

As shown in Table 22, dry matter production for the location Ficksburg was satisfactory at 12.5 t ha^{-1}. At Marquard yield for the SCC was lower at 7.1 t ha^{-1} and can be attributed to the fact that the CC was planted too late. The financial implications (profits) are discussed under the gross margin analysis

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.

The SCC as described above in this case was planted as early and convenient in the commercial context of the Yzel farm. In order to achieve this kind of meat production per ha one needs to plant early in the season. The financial analysis as following below included the grazing of SCC of on average 7.1 t ha-1. Income per ha is then around R10195 ha^{-1}. Profit levels are then around R4751 ha^{-1} as compared to the R17, 002 ha^{-1} for SCC in the case study.

4.3.4. Conclusions

The financial implications (profits) are discussed under the gross margin analysis.

Grazing the SCC and WCC on the treatment strips posed challenges in terms of fencing, water supply and livestock was not staying overnight on the strips (Marquard). That resulted in part-time hit-and-run grazing where fodder was trampled a bit more than ideal. Lambs were fenced in on the strips on the Ficksburg trials. The lambs were not familiar with strip grazing and the water supply was done manually. This resulted in excess movement inside the summer cover crop strips. It was also a learning curve in terms of making the trade-off between feed available and leaving adequate levels behind for satisfactory regrowth.

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 are good guidelines to follow. Special skills and knowledge are of importance when changing from a conventional to an integrated approach. Farmers should gain skills and farmer-to-farmer knowledge transfer will improve implementation of certain practises in the following years.

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.

Appendix 1: Haney soil health test results, February 2021, Ficksburg trial, A-horizon

Name:	TP FICKSBURG	Depth									
Date	Feb-21	0-10 cm									
			A	22-24	1,13,16	5,11,15	4,14,20	3,9,18	6,8,19	2,12,17	7,10,21
Sample ID				VELD	REGENERATIVE				NT/CA		CT
Lab ID			A 0-10 c	Veld	SD + WD	MAIZE_ Relay	SD + WD	SOYA + WD	MAIZE	SOYA	MAIZE
SOIL HEALTH	Score	Ideal > 7		17.25	4.65	4.65	5.64	5.15	4.65	5.39	5.19
	Comment										
Volumetric Aggregate Stability %		Ideal > 45		11.68	2.11	1.93	2.11	2.11	2.11	2.81	2.57
Soil pH		Ideal 5,5 -		4.46	4.52	4.87	4.86	4.94	4.85	4.81	4.56
BIOLOGICAL ANAL	Organic Matter %	Ideal >		5.80	1.33	1.37	1.43	1.30	1.33	1.40	1.27
	Soil respiration CO2-C	Ideal > 50		143.08	26.87	30.27	35.00	31.48	28.47	35.73	32.81
	H2O Total Organic C			103.33	68.33	59.00	69.33	72.33	66.67	62.33	69.00
	Soil Organic Carbon %			3.37	0.78	0.79	0.83	0.76	0.78	0.81	0.74
	Water Extractable Organic C % of Tot SOC			0.32	0.88	0.74	0.83	0.96	0.86	0.76	0.93
	% Microbially Active Carbon	Ideal > 20		157.47	39.34	53.44	50.42	43.47	43.61	58.26	49.47
	Organic C:N			11.60	11.48	13.12	9.25	13.36	14.14	10.91	14.08
NITROGEN	H2O Total N			28.43	24.33	10.17	28.33	12.60	10.57	12.17	9.77
	H2O Organic N			8.80	6.00	4.47	7.50	5.50	4.70	5.70	5.33
	H3A Nitrate			11.13	12.33	3.93	13.80	4.67	4.10	4.77	2.87
	H3A Ammonium			7.77	11.27	2.40	6.60	3.00	2.37	2.97	2.73
	H3A Inorganic Nitrogen			18.90	23.60	6.33	20.40	7.67	6.47	7.73	5.60
	Total N (Organic + Inorganic)			27.70	29.60	10.80	27.90	13.17	11.17	13.43	10.93
	Organic N: Inorganic N ratio			0.54	0.42	0.71	0.53	0.75	0.74	0.73	0.93
	Organic N Release			8.80	6.00	4.47	7.50	5.50	4.70	5.70	5.33
	Organic N Reserve			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total available N			27.70	29.60	10.80	27.90	13.17	11.17	13.43	10.93
	N kg/ha			62.05	66.30	24.19	62.50	29.49	25.01	30.09	24.49
PHOSPHOROUS	H3A Total Phosphorus			9.33	58.67	47.33	37.67	57.33	48.00	60.00	46.67
	H3A Inorganic Phosphorus			5.23	48.63	38.53	36.73	46.17	37.60	47.77	36.63
	H3A Organic Phosphorus			4.10	10.03	8.80	0.93	11.17	10.40	12.23	10.03
	Total available Phosphorous			9.33	58.67	47.33	34.43	57.33	48.00	60.00	46.67
	P kg/ha			10.58	66.50	53.65	39.03	64.98	54.41	68.01	52.89
	P Organic: Inorganic			0.81	0.21	0.23	0.05	0.24	0.28	0.26	0.27
	Organic P Release			4.10	10.03	8.80	-2.30	11.17	10.40	12.23	10.03
	Organic P Reserve			0.00	0.00	0.00	3.23	0.00	0.00	0.00	0.00
POTA	H3A Potassium	Ideal 120 -		112.67	148.67	123.67	151.67	135.67	116.33	156.67	111.67
	K kg/ha			125.68	165.84	137.95	169.19	151.34	129.77	174.76	124.57
OTHER NUTRIENT FACTORS	H3A Calcium			255.33	186.33	185.67	85.67	219.00	214.00	254.67	110.00
	H3A Aluminum			147.00	411.33	339.00	311.67	345.33	374.00	397.00	397.67
	H3A Iron	20 - 80		14.33	130.00	135.67	113.33	104.33	141.67	129.67	145.00
	H3A Sulfur	< 12		7.80	10.50	6.47	6.30	4.93	8.00	4.77	7.67
	H3A Zinc	1 - 3		1.75	1.50	1.56	1.47	1.78	1.82	1.82	1.29
	H3A Manganese	4 - 6		16.87	17.90	27.33	17.23	17.97	22.10	25.03	22.97
	H3A Copper	0,5 - 1,0		0.25	0.92	1.03	0.90	1.07	1.10	1.11	1.10
	H3A Magnesium			72.67	51.67	115.67	65.33	180.33	93.67	75.67	29.33
	H3A Sodium			10.67	19.67	9.67	10.67	9.67	11.67	10.67	11.33
	% P Saturation (Al/Fe)			6.29	11.17	10.48	8.77	12.67	9.62	11.34	8.60
	% P Saturation (Ca)			4.82	36.29	42.41	77.14	55.77	27.78	33.62	65.77
KEY CHEM	Calcium: Magnesium	> 5		4.89	29.33	1.26	0.68	0.90	4.17	2.25	3.85
	Calcium: Magnesium/ Aluminium	> 1,7		3.66	0.89	1.72	0.80	2.05	1.46	1.35	0.54
	Magnesium: Potassium	1 - 2		2.40	1.28	2.76	1.31	4.23	2.26	1.61	0.83
	Potassium: Sodium	> 1		6.20	4.80	7.83	8.41	8.26	5.87	8.66	5.81
PLANT EFFECTIVE CEC SATURATION ANALYSE	Calcium	> 68		44.70	27.64	25.01	14.07	24.96	28.50	32.73	19.86
	Magnesium	10 - 20		22.67	12.77	23.94	19.75	35.11	16.15	16.50	8.47
	Potassium	> 5		10.53	11.24	9.25	16.03	8.18	8.98	10.52	11.30
	Sodium	< 2		1.72	2.50	1.34	2.01	1.00	1.53	1.23	1.95

Appendix 2: Haney soil health test results, February 2021, Marquard trial, A-horizon

Name:	NY MARQUARD	Depth									
Date	Feb-21	0-10 cm									
			A	22-24	1,13,16	5,11,15	4,14,20	3,9,18	6,8,19	2,12,17	7,10,21
Sample ID				VELD	REGENERATIVE				NT/CA		CT
Lab ID			A 0-10 cm	Veld	SD+WD	MAIZE_ Relay	SD+WD	SOYA + WD	MAIZE	SOYA	MAIZE
SOIL HEALTH	Score	Ideal > 7		3.21	2.98	2.63	3.53	3.42	3.19	2.93	2.66
	Comment										
Volumetric Aggregate Stability %		Ideal > 45		2.81	2.11	1.93	2.11	2.11	2.11	2.11	1.93
Soil pH		Ideal 5,5 -		5.51	4.48	4.11	4.47	4.45	4.21	4.35	4.10
OLOGICAL ANALYS	Organic Matter %	Ideal >		0.77	0.60	0.67	0.63	0.67	0.63	0.63	0.67
	Soil respiration CO2-	Ideal > 50		18.86	15.05	12.76	19.11	17.53	18.13	13.33	15.02
	H2O Total Organic C			46.00	48.00	45.00	54.33	57.33	43.67	55.00	38.00
	Soil Organic Carbon %			0.45	0.35	0.39	0.37	0.39	0.37	0.37	0.39
	Water Extractable Organic C %			1.03	1.36	1.16	1.50	1.51	1.20	1.51	0.98
	% Microbially Active	Ideal > 20		41.27	33.95	28.96	38.44	32.50	42.69	26.70	39.29
	Organic C:N			11.39	9.27	10.20	10.10	10.97	8.72	10.82	10.13
NITROGEN	H2O Total N			9.23	20.93	26.80	18.53	25.10	21.10	23.23	22.33
	H2O Organic N			4.03	5.17	4.50	5.30	5.23	5.00	4.97	3.93
	H3A Nitrate			3.57	11.17	14.20	10.67	11.13	10.73	10.90	11.27
	H3A Ammonium			3.20	3.73	13.13	3.50	14.93	6.43	10.13	8.37
	H3A Inorganic Nitrogen			6.77	14.90	27.33	14.17	26.07	17.17	21.03	19.63
	Total N (Organic + Inorganic)			10.80	20.07	31.83	19.47	31.30	22.17	26.00	23.57
	Organic N: Inorganic N ratio			0.61	0.38	0.16	0.39	0.24	0.31	0.25	0.20
	Organic N Release			4.03	4.60	4.13	5.28	4.56	5.00	4.19	3.93
	Organic N Reserve			0.00	0.57	0.37	0.02	0.67	0.00	0.78	0.00
	Total available N			10.80	19.50	31.46	19.45	30.63	22.17	25.22	23.57
	N kg/ha			24.19	43.68	70.47	43.57	68.61	49.65	56.49	52.79
PHOSPHOROUS	H3A Total Phosphorus			4.33	23.00	40.67	24.00	18.33	37.00	21.33	29.00
	H3A Inorganic Phosphorus			1.70	17.27	32.07	18.00	13.37	29.60	16.03	22.47
	H3A Organic Phosphorus			2.63	5.73	8.60	6.00	4.97	7.40	5.30	6.53
	Total available Phosphorous			4.33	22.27	38.87	23.49	17.56	36.74	19.78	28.77
	P kg/ha			4.91	25.24	44.06	26.63	19.90	41.64	22.42	32.61
	P Organic: Inorganic			2.97	0.34	0.27	0.34	0.38	0.26	0.33	0.29
	Organic P Release			2.63	5.00	6.81	5.49	4.19	7.14	3.75	6.31
	Organic P Reserve			0.00	0.73	1.79	0.51	0.78	0.26	1.55	0.23
POTASSIUM	H3A Potassium	Ideal 120 -		127.00	118.33	111.33	134.67	124.33	112.33	120.67	102.00
	K kg/ha			141.67	132.00	124.19	150.22	138.70	125.31	134.61	113.78
IER NUTRIENT FACT	H3A Calcium			250.67	99.67	86.67	117.67	102.33	98.67	92.00	87.67
	H3A Aluminum			227.33	339.33	401.67	377.33	369.33	407.67	360.67	372.67
	H3A Iron	20 - 80		106.00	169.67	190.33	180.00	177.67	193.33	175.67	176.33
	H3A Sulfur	< 12		3.03	5.40	6.67	5.43	5.33	4.03	6.47	6.87
	H3A Zinc	1 - 3		0.48	1.31	2.61	1.43	1.34	1.57	1.27	1.42
	H3A Manganese	4 - 6		16.50	28.60	26.53	29.97	28.37	27.57	25.73	25.00
	H3A Copper	0,5 - 1,0		0.97	0.79	0.84	0.85	0.86	0.88	0.80	0.86
	H3A Magnesium			92.67	36.67	37.00	42.67	37.33	39.67	35.00	33.33
	H3A Sodium			12.33	11.67	12.33	12.33	11.67	12.67	11.33	12.00
	% P Saturation (Al/Fe)			1.30	4.48	6.96	4.31	3.35	6.18	4.11	5.38
	% P Saturation (Ca)			1.95	23.44	48.21	20.44	17.86	37.51	24.00	34.17
EY CHEMICAL RATIO	Calcium: Magnesium	> 5		1.78	1.66	1.41	1.68	1.67	1.52	1.60	1.60
	Calcium:	> 1,7		2.41	0.64	0.50	0.67	0.60	0.54	0.60	0.54
	Magnesium:	1 - 2		2.41	1.00	1.07	1.02	0.99	1.13	0.96	1.07
	Potassium: Sodium	> 1		6.29	5.97	5.33	6.41	6.28	5.24	6.23	5.00
PLANT EFFECTIVE CEC SATURATION ANALYSES	Calcium	> 68		38.08	20.73	16.81	21.54	20.04	18.52	19.38	18.53
	Magnesium	10 - 20		22.81	12.48	11.79	12.81	11.98	12.17	11.91	11.44
	Potassium	> 5		10.43	12.56	11.12	12.60	12.44	10.82	12.55	10.84
	Sodium	< 2		1.76	2.11	2.09	1.97	1.99	2.09	2.04	2.18

Appendix 3: Net margins for treatments at Ficksburg for 2020/21 season

	MIXED FARMING SYSTEM CASH CROP & LIVESTOCK						
		RA MAIZE_ Relay	RA SOYA + WCC	NT MAIZE	NT SOYA	CT MAIZE	SCC+WCC
	NET MARGINS	**R 8 904**	**R 10 146**	**R 7 724**	**R 9 649**	**R 5 129**	**R 16 279**
PROD SYST		**Maize**	**Soya**				**Wcc**
	Production system	**RA (relay)**	**RA (relay)**	**CA**	**CA**	**CT**	**RA**
	type of Cover crop	WD_intercrop	EW				WD
INCOME	**1a CASH CROPS**	**R 17 710**	**R 17 617**	**R 18 575**	**R 17 127**	**R 17 818**	**R 0**
	Yield	6.00	2.52	6.30	2.45	6.04	
	SAFEX PRICE	3250	R 7 300	3250	R 7 300	3250	
	Total deductions	**R 300**	**R 300**	**R 300**	**R 300**	**R 300**	
	Transport differential	*R 300*	*R 300*	*R 300*	*R 300*	*R 300*	
	Net Farm Gate Price	R 2 950	R 7 000	R 2 950	R 7 000	R 2 950	
	1b GRAZING CROP RESIDUE	**R 982**	**R 227**	**R 1 030**	**R 220**	**R 988**	**R 0**
	Harvesting index (HI)	**0.91**	**0.75**	**0.91**	**0.75**	**0.91**	
	Available t of crop residue based on HI	5.46	1.89	5.72	1.84	5.49	
	% residue consumed (remainder left as % soil cover)	0.30	0.30	0.30	0.30	0.30	
	Quantity used (t/ha)	1.64	0.57	1.72	0.55	1.65	
	Value of 1 ton of crop residue	R 600	R 400	R 600	R 400	R 600	
	1c GRAZING INCOME (CC)	**R 2 585**	**R 0**	**R 0**	**R 0**	**R 0**	**R 25 707**
	GRAZING 1, SCC						R 17 971
	GRAZING 2, WCC						R 7 736
	GRAZING 3, intercrop	R 2 585					R 0
	GRAZING 4, WCC after soya		0				R 0
	GROSS INCOME (1a+1b+1c)	**R 21 277**	**R 17 843**	**R 19 606**	**R 17 347**	**R 18 806**	**R 25 707**
	2) VARIABLE EXPENDITURES						
	2a CASH CROPS	**R 9 444**	**R 5 260**	**R 9 444**	**R 5 260**	**R 10 677**	**R 0**
	Fertilizer	R 3 301	R 1 512	R 3 301	R 1 512	R 3 301	
	Seed	R 1 843	R 472	R 1 843	R 472	R 1 843	
	Fuel	R 655	R 626	R 655	R 626	R 1 078	
	Herbicide	R 1 113	R 444	R 1 113	R 444	R 1 113	
	Repairs and maintenance	R 1 832	R 1 815	R 1 832	R 1 815	R 2 552	
	Interest on production credit	R 700	R 390	R 700	R 390	R 791	R 0
	2b COVER CROPS	**R 492**	**R 0**	**R 0**	**R 0**	**R 0**	**R 6 791**
	Fertilizer						R 3 944
8%	Seed	R 492	R 0				R 1 244
	Fuel						R 239
	Herbicide						R 334
	Repairs and maintenance						R 1 030
	Interest on production credit	R 0	R 0	R 0	R 0	R 0	R 0
	2c LIVESTOCK RELATED	**R 0**	**R 0**	**R 0**	**R 0**	**R 0**	**R 200**
	Vetenarian costs						R 150
	licks						R 50
	Interest on production credit	R 0	R 0	R 0	R 0	R 0	R 0
	TOTAL VARIABLE EXPENDITURE	**R 9 936**	**R 5 260**	**R 9 444**	**R 5 260**	**R 10 677**	**R 6 991**
	3.1) GROSS MARGIN	**R 11 341**	**R 12 583**	**R 10 162**	**R 12 087**	**R 8 129**	**R 18 717**
							100%
	OVERHEAD COSTS	R 2 438	R 2 438	R 2 438	R 2 438	R 3 000	R 2 438
	NET MARGIN	R 8 904	R 10 146	R 7 724	R 9 649	R 5 129	R 16 279

Appendix 4: Net margins for treatments at Marquard for 2020/21 season (based at DM 7.1 t ha[-1] – trial data)

	MIXED FARMING SYSTEM CASH CROP & LIVESTOCK						
		RA MAIZE_ Relay	RA SOYA + WCC	NT MAIZE	NT SOYA	CT MAIZE	SCC + WCC
	NET MARGIN	R 10 112	R 10 915	R 2 672	R 9 183	R -1 196	R 20 124
PROD SYST		Maize	Soya				SCC
	Production system	RA (relay)	RA (relay)	CA	CA	CT	RA
	type of Cover crop	WD_intercrop	EW				SD
INCOME	1a CASH CROPS	R 11 376	R 15 836	R 12 470	R 15 836	R 9 281	R 0
	Yield	3.79	2.14	4.16	2.14	3.09	
	SAFEX PRICE	3300	R 7 700	3300	R 7 700	3300	
	Total deductions	R 300	R 300	R 300	R 300	R 300	
	Transport differential	*R 300*	*R 300*	*R 300*	*R 300*	*R 300*	
	Net Farm Gate Price	R 3 000	R 7 400	R 3 000	R 7 400	R 3 000	
	1b GRAZING CROP RESIDUE	R 621	R 193	R 680	R 193	R 506	R 0
	Harvesting index (HI)	0.91	0.75	0.91	0.75	0.91	
	Available t of crop residue based on HI	3.45	1.61	3.78	1.61	2.81	
	% residue consumed (remainder left as % soil cover)	0.30	0.30	0.30	0.30	0.30	
	Quantity used (t/ha)	1.03	0.48	1.13	0.48	0.84	
	Value of 1 ton of crop residue	R 600	R 400	R 600	R 400	R 600	
	1c GRAZING INCOME (CC)	R 9 531	R 2 585	R 0	R 0	R 0	R 32 592
	GRAZING 1, SD						R 24 916
	GRAZING 2, WD						R 7 676
	GRAZING 3, intercrop	R 9 531					R 0
	GRAZING 4, WD after soya		2 585				R 0
	GROSS INCOME (1a+1b+1c)	R 21 528	R 18 613	R 13 150	R 16 029	R 9 787	R 32 592
	2) VARIABLE EXPENDITURES						
	2a CASH CROPS	R 8 649	R 5 371	R 8 415	R 4 783	R 7 983	R 0
	Fertilizer	R 1 496	R 0	R 1 496	R 0	R 1 496	
	Seed	R 2 400	R 417	R 2 400	R 417	R 1 600	
	Inoculent	R 72	R 146	R 72.0	R 146	R 48	
	Fuel	R 609	R 627	R 533	R 533	R 906	
	Herbicide	R 806	R 874	R 806	R 874	R 606	
	Repairs and maintenance	R 1 601	R 1 910	R 1 460	R 1 460	R 1 711	
	rent land	R 1 000	R 1 000	R 1 000	R 1 000	R 1 000	
	Transport	R 25	R 0	R 25.2	R 0	R 25	
8%	Interest on production credit	R 641	R 398	R 623	R 354	R 591	R 0
	2b COVER CROPS	R 705	R 265	R 0	R 0	R 0	R 4 424
	Fertilizer						R 0
	Seed	R 653	R 245				R 1 500
	Fuel						R 236
	Herbicide						R 400
	Repairs and maintenance						R 1 160
	Rent land	R 0	R 0				R 800
8%	Interest on production credit	R 52	R 20	R 0	R 0	R 0	R 328
	2c LIVESTOCK RELATED	R 0	R 0	R 0	R 0	R 0	R 5 982
	rent land						R 800
	Feed mix (SS200)						R 4 739
8%	Interest on production credit	R 0	R 0	R 0	R 0	R 0	R 443
	TOTAL VARIABLE EXPENDITURE	R 9 354	R 5 636	R 8 415	R 4 783	R 7 983	R 10 406
	3.GROSS MARGIN	R 12 174	R 12 978	R 4 735	R 11 246	R 1 804	R 22 187
							100%
	OVERHEAD COSTS	R 2 063	R 2 063	R 2 063	R 2 063	R 3 000	R 2 063
	NET MARGIN	R 10 112	R 10 915	R 2 672	R 9 183	R -1 196	R 20 124

Appendix 5: Net margins for treatments at Marquard for 2020/21 season (based at DM 17 t ha-1 - farm case study)

	MIXED FARMING SYSTEM CASH CROP & LIVESTOCK	RA MAIZE_ Relay	RA SOYA + WCC	NT MAIZE	NT SOYA	CT MAIZE	SCC+ WCC
	NET MARGINS	R 10 112	R 10 915	R 2 672	R 9 183	R -1 196	R 5 637
PROD SYST		Maize	Soya				SCC
PROD SYST	Production system	RA (relay)	RA (relay)	CA	CA	CT	RA
PROD SYST	type of Cover crop	WD_intercrop	EW				SD
INCOME	1a CASH CROPS	R 11 376	R 15 836	R 12 470	R 15 836	R 9 281	R 0
INCOME	Yield	3.79	2.14	4.16	2.14	3.09	
INCOME	SAFEX PRICE	3300	R 7 700	3300	R 7 700	3300	
INCOME	**Total deductions**	R 300	R 300	R 300	R 300	R 300	
INCOME	Transport differential	*R 300*	*R 300*	*R 300*	*R 300*	*R 300*	
INCOME	Net Farm Gate Price	R 3 000	R 7 400	R 3 000	R 7 400	R 3 000	
INCOME							
INCOME	1b GRAZING CROP RESIDUE	R 621	R 193	R 680	R 193	R 506	R 0
INCOME	Harvesting index (HI)	0.91	0.75	0.91	0.75	0.91	
INCOME	Available t of crop residue based on HI	3.45	1.61	3.78	1.61	2.81	
INCOME	% residue consumed (remainder left as % soil cover)	0.30	0.30	0.30	0.30	0.30	
INCOME	Quantity used (t/ha)	1.03	0.48	1.13	0.48	0.84	
INCOME	Value of 1 ton of crop residue	R 600	R 400	R 600	R 400	R 600	
INCOME							
INCOME	1c GRAZING INCOME (CC)	R 9 531	R 2 585	R 0	R 0	R 0	R 17 871
INCOME	GRAZING 1, SD						R 10 195
INCOME	GRAZING 2, WD						R 7 676
INCOME	GRAZING 3, intercrop	R 9 531					R 0
INCOME	GRAZING 4, WD after soya		2 585				R 0
	GROSS INCOME (1a+1b+1c)	R 21 528	R 18 613	R 13 150	R 16 029	R 9 787	R 17 871
	2) VARIABLE COSTS						
	2a CASH CROPS	R 8 649	R 5 371	R 8 415	R 4 783	R 7 983	R 0
	Fertilizer	R 1 496	R 0	R 1 496	R 0	R 1 496	
	Seed	R 2 400	R 417	R 2 400	R 417	R 1 600	
	Inoculent	R 72	R 146	R 72.0	R 146	R 48	
	Fuel	R 609	R 627	R 533	R 533	R 906	
	Herbicide	R 806	R 874	R 806	R 874	R 606	
	Repairs and maintenance	R 1 601	R 1 910	R 1 460	R 1 460	R 1 711	
	rent land	R 1 000	R 1 000	R 1 000	R 1 000	R 1 000	
	Transport	R 25	R 0	R 25.2	R 0	R 25	
8%	Interest on production credit	R 641	R 398	R 623	R 354	R 591	R 0
	2b COVER CROPS	R 705	R 265	R 0	R 0	R 0	R 4 190
	Fertilizer						R 0
	Seed	R 653	R 245				R 1 284
	Fuel						R 236
	Herbicide						R 400
	Repairs and maintenance						R 1 160
	Rent land	R 0	R 0				R 800
8%	Interest on production credit	R 52	R 20	R 0	R 0	R 0	R 310
	2c LIVESTOCK RELATED	R 0	R 0	R 0	R 0	R 0	R 5 982
	rent land						R 800
	Feed mix (SS200)						R 4 739
8%	Interest on production credit	R 0	R 0	R 0	R 0	R 0	R 443
	TOTAL VARIABLE COST	R 9 354	R 5 636	R 8 415	R 4 783	R 7 983	R 10 172
	3.GROSS MARGIN	R 12 174	R 12 978	R 4 735	R 11 246	R 1 804	R 7 699
							100%
	OVERHEAD COSTS	R 2 063	R 2 063	R 2 063	R 2 063	R 3 000	R 2 063
	NET MARGIN	R 10 112	R 10 915	R 2 672	R 9 183	R -1 196	R 5 637