# ANNUAL PROGRESS REPORT FOR PHASE 1

*Project title:*

# Determining the Carbon Footprint intensity of different winter grain farming regimes in the Western Cape

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# Executive Summary

Phase 1 of this project aimed to calculate the carbon footprint in kg carbon dioxide equivalent ($CO_2$e) per ton of different winter grain farming regimes from existing data and a predicted ideal future scenario in the Western Cape. The current scenario includes the main inputs and yields for winter grain cultivation using the conventional (CT) and conservation agriculture (CA) farming regimes. The future scenario includes an ideal but realistic CA system predicted to be adopted by most grain producers twenty years into the future with corresponding inputs and yields. The results per commodity per region is calculated using the PAS 2050:2011 methodology for annual grain crops. These results and the total tonnage per region were used to calculate a weighted average carbon footprint per region and thereafter extrapolated to a snapshot current and future carbon footprint of the winter grain region in the Western Cape.

In addition to the regionalised carbon footprint results for the current and future scenario, hotspots with regard to farming inputs and at commodity level per hectare are also identified.

The carbon footprint results on a commodity level indicate a 3.5% decline in $CO_2$e emissions per ton wheat between the CT to CA farming regime and a further 44% decline with the transition from CA to the Future CA regime. For the winter grain region as a whole, there is a 36% decline in $CO_2$e emissions from the current farming regime scenario (CT and CA) to the future farming regime scenario (CA and Future CA) for all commodities. The current scenario farming input hotspot is synthetic N fertiliser which makes up 90% of fertiliser $CO_2$e emissions. Fertilisers contribute 70% to total $CO_2$e emissions per hectare in the current farming regime scenario. In the future scenario, the hotspot remains the application of synthetic N fertiliser, however, the contribution of this input to total CO2e emissions decreases to 61%. The commodity with the highest $CO_2$e emissions per hectare is wheat, followed by canola and then barley in the current scenario. This ranking of commodities in the future scenario is first wheat followed by barley and then canola.

These findings support the transition of grain cultivation to a predominantly ideal CA farming regime in future as it is predicted to have reduced $CO_2$e emissions with further beneficial synergies with the natural environment, economic value and social impact of the industry.

To compliment the carbon footprint results, a soil health assessment was done under different practices in the regions identified. Two sampling locations were selected on specific farms in each of the seven sub-regions, one representing the local conventional tillage (CT) system and one representing the local CA system. For this assessment the Haney Soil Health Tool (SHT) was used, which is an integrated approach to soil testing using chemical and biological soil test data. The soil analyses results clearly indicate that the Swartland is more deprived in SOM than the Southern Cape and increases in severity as you move to the North, while the Southern sub-region of the Swartland starts to resemble soil health levels of the Southern Cape's soil. The results show a direct relationship between soil health score and the SOC content. From the study sites sampled the differences appear to be highly influenced by environmental factors, and less by agricultural practices on the different farms. Fertiliser practices on certain sites do have a significant effect on some of the parameters. A worrying aspect is the high levels of inorganic phosphorous and nitrogen in some soils, indicating to an over-application of fertilisers. The absence of a residue cover in various fields sampled through long periods of the year, especially the CT systems, will lead to runoff, less infiltration, lower soil water content and less SOM build-up. To alleviate this problem attention should be given to improve the quality of the application and adaptation of CA principles within each situation.

# 1. Calculation of the carbon footprint

## 1.1 Introduction

Grain SA approached Confronting Climate Change (CCC), which is an initiative managed by Blue North Sustainability (Pty) Ltd, to calculate and compare the carbon footprint of different farming systems for the different winter grain regions in the Western Cape. CCC had already developed a carbon footprint protocol, the data collection tools, database and reporting tools for grain farming in South Africa which were used to determine the kg $CO_2e$/ton of grain. Phase 1 forms part of a longer term project where the carbon footprint methodology and results can be used within the grain industry as an adaptive management tool (Figure 1.1).

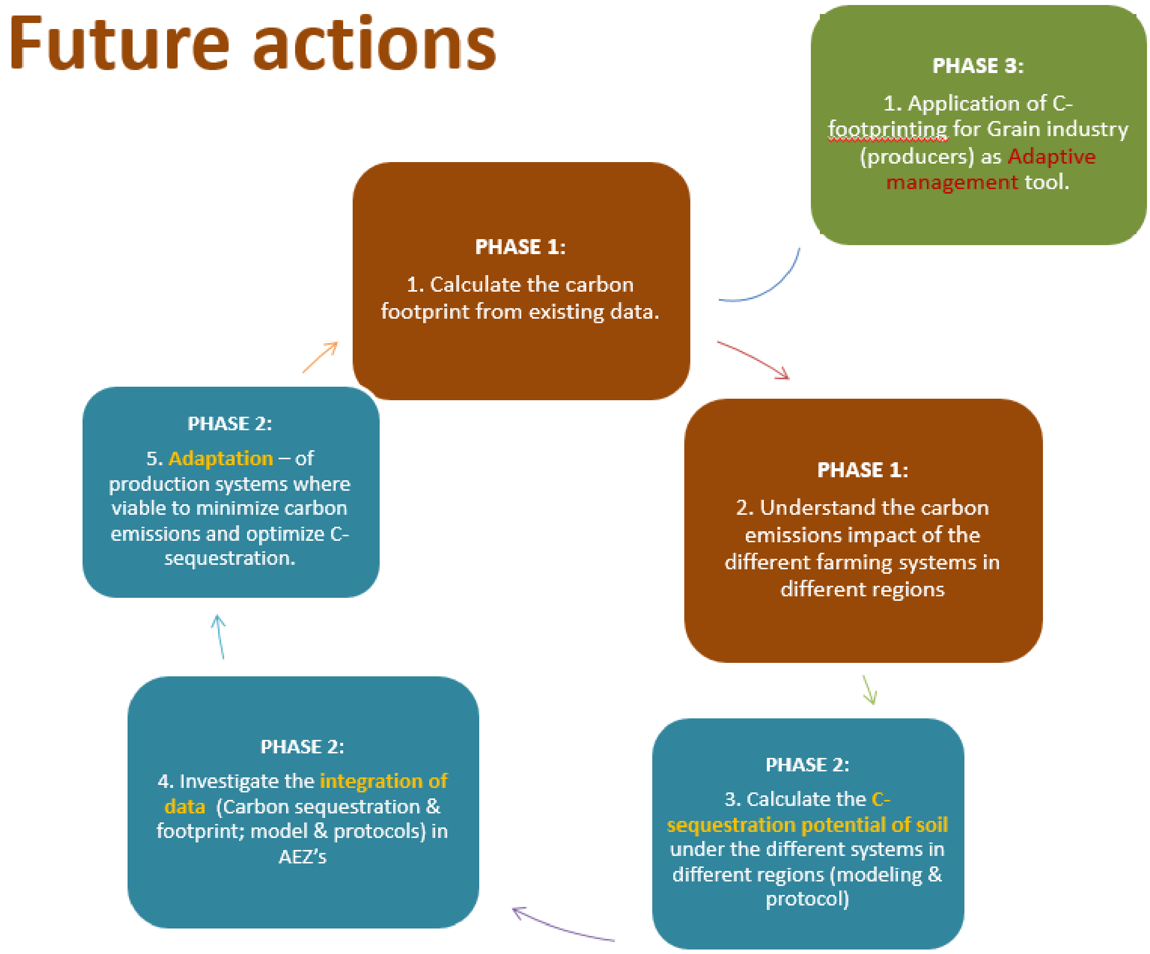


**Figure 1.1: Carbon footprint project phases envisaged by Grain SA.**

In order to calculate the carbon footprint per ton product, Grain SA completed the data collection tools for the following regions:

- Darling/Hopefield
- Northern Swartland
- Middle Swartland
- Southern Swartland
- Western Ruens (Southern Cape)

- Southern Ruens (Southern Cape)
- Eastern Ruens (Southern Cape)

The farming regimes covered in each region for the current scenario are conventional (CT) and conservation agriculture (CA). For the future scenario, an ideal but realistic CA system or regime predicted to be adopted by most grain producers twenty years into the future was calculated with corresponding inputs and yields. The CT wheat farming regime does not practise crop rotation and therefore wheat is planted every year. In the CA regime there is a crop rotation system and the commodities included in the data collection tool per region are wheat, barley, canola, medics and lupins. All inputs were specified on a per hectare basis. The carbon footprint (kg $CO_2e$/ton) per commodity per region and per farming regime was calculated.

In order to calculate a regionalised carbon footprint, the results per commodity are weighted according to the yield per farming regime. Grain SA provided the yields per commodity for each region and farming regime, as obtained from the agribusinesses. Thereafter these figures were extrapolated to provide a snapshot winter grain region carbon footprint for the current and future scenarios. In addition to the regionalised carbon footprint for the current and future farming scenarios, farming input hotspots as well as hotspots per commodity were identified.

This report discusses the data and methodologies used to determine the carbon footprint results with conclusions and recommendations.

## 1.2 Goal and Scope

The goal of this project is to determine the carbon footprint of selected crop farming systems across a few key agro-ecological regions of the Western Cape.

The project's short-term objectives are:

1. To calculate the carbon footprint of winter grains and understand it (e.g. what are the carbon hotspots).
2. To understand the carbon impact of different grain farming regimes in different regions of the Western Cape
3. To take the first steps to better understand carbon tax impacts as well as the potential farm based carbon credit income streams.
4. To identify opportunities to improve farm management systems (through the data collection process with farmers).
5. To make decisions about investing in technologies that will reduce consumption of these inputs and therefore save costs (through the detailed allocation of diesel, electricity and fertiliser data to farming activities and commodities).
6. To assess soil health under each of the different farming systems per region as an indication of the carbon sequestration potential of different crop systems.

The focus of Phase 1 of the project is to determine the snapshot carbon footprint for each farming regime of each region for the current and future scenario. From these results, a snapshot carbon footprint was calculated for the current and future scenarios for the winter grain region and hotspots regarding the inputs were identified. The functional unit is 1 ton of product at the farm gate and the carbon footprint result is specified in kg $CO_2e$/ton product as this is a product carbon footprint. The scope of the project includes all activities within the farm boundary up until the farm gate (cradle to gate). Only the farm boundary is considered and excludes seed production, storage and milling and the use phase (input of product in other product systems).

## 1.3 Materials and Methods

The protocol used to determine the greenhouse gas emissions of grain farming is the PAS 2050: 2011 developed by the British Standards Institute (BSI). This protocol is a single issue method which only determines the carbon emissions of products (British Standards Institute, 2012). GHG emissions is only one of a range of impacts that need to be taken into account to obtain a holistic view of the environmental impacts of a product or service.

The snapshot carbon footprint per ton product for the winter grain region currently and for the future was determined through a pro-rata allocation of the result to the total yield per commodity. According to best available estimates, approximately 90% of total grain yield (tonnes) in the Western Cape are under CA practises while the remaining yield is under CT practises. With the calculation of the future scenario the prediction is made that 80% of the total yield will be under ideal CA regimes with assumptions made around production inputs as depicted in Table 1.2.

## 1.4 Life Cycle Inventory

This section discusses the details of the raw data collected, the data collection process and modelling of the winter grain farming entities.

### 1.4.1 Raw data and data sources

Grain SA sourced data from the different agribusinesses in the Western Cape. The main participants who collaborated with production cost information for the different regimes include:

- Kaap Agri (Swartland);
- Overberg Agri (Southern Cape) and;
- SSK (Southern Cape).

The gathered raw data was processed by Grain SA and used to populate the Blue North Grain Data Collection tool v. 2.2. Figure 1.2 illustrates the data collection process with all the different production inputs collected to calculate the Carbon footprint.

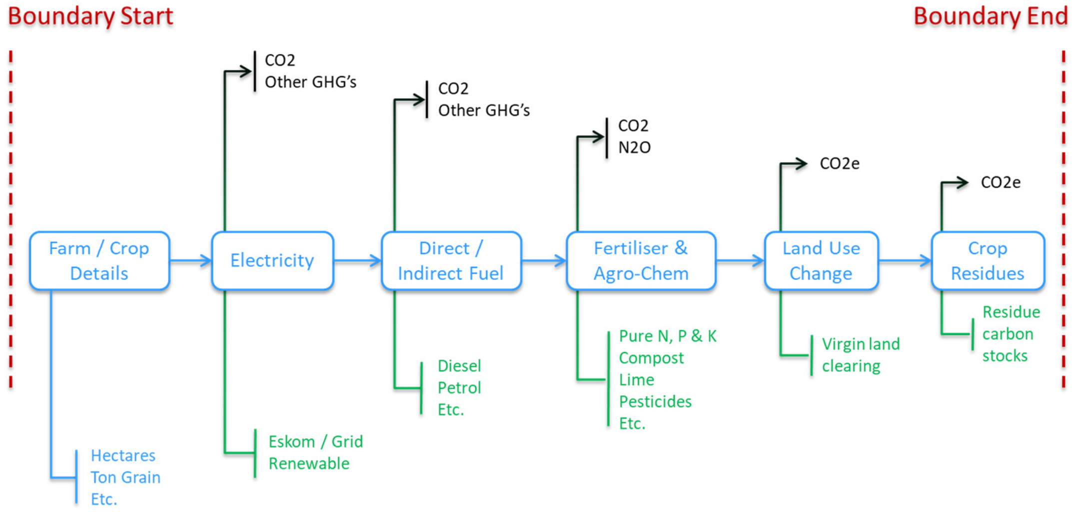


**Figure 1.2: Data collection process map for winter grain regions.**

### 1.4.2 Input data inventory

The inputs and quantities of each input per hectare for each region, commodity and farming regime is in **Appendix 1** illustrates the three different grain farming regimes with their crop rotations in the Western Cape. The commodities cultivated per regime differs from one regime to the other. In the CT regime only wheat is cultivated each year while different crops are planted in rotation with each other in the CA and Future CA regimes. The transition from the CA to the Future CA regime sees a change in the commodities cultivated in the Swartland regions but no change in the Ruens regions.

**Table 1.1:** Three different grain farming regimes in the Western Cape with their crop rotations

| Region | Farming regime | | |
|---|---|---|---|
| | **Conventional** | **CA** | **Future CA** |
| Darling/Hopefield | Wheat | Wheat | Wheat |
| | | Medics | Medics |
| | | Lupins | Canola |
| Northern Swartland | Wheat | Wheat | Wheat |
| | | Medics | Medics |
| Middle Swartland | Wheat | Wheat | Wheat |
| | | Medics | Barley |
| | | | Canola |
| Southern Swartland | Wheat | Wheat | Wheat |
| | | Medics | Medics |
| | | Canola | Canola |
| Western Ruens | Wheat | Wheat | Wheat |
| | | Barley | Barley |
| | | Canola | Canola |
| Southern Ruens | Wheat | Wheat | Wheat |
| | | Barley | Barley |
| | | Canola | Canola |
| Eastern Ruens | Wheat | Wheat | Wheat |
| | | Barley | Barley |
| | | Canola | Canola |

The following inputs, activities and outputs are included in the grain farm boundary data collection tool to calculate the carbon footprint:

- Yields and hectares;
- Electricity use;
- Fuel use;
- Fertiliser and agro-chemicals;
- Crop residues and;
- Land use change.

Wheat was the only commodity with input data on conventional farming whilst the other commodities only had input data on the CA and Future CA regimes to calculate the carbon footprint. Data to calculate the carbon footprint of medics and lupins was provided for the Swartland regions. However, the carbon footprint for medics could not be calculated as no yield data is available.

### 1.4.3 Future Conservation Agriculture scenario

Grain SA had discussions with CA researchers from the Western Cape (Johan Strauss, personal communication) for making realistic assumptions regarding production inputs under an ideal future CA scenario (see Table 1.2).

**Table 1.2:** Production input changes under a future CA regime in the Western Cape

| Inputs | Assumptions |
|---|---|
| Yield | Increase with 10% |
| Fuel | Decrease with 50% |
| Fertiliser | Decrease with 50% |
| Lime | No change |
| Fungicides | Decrease with 50% |
| Herbicides | Decrease with 50% |
| Insecticides | Decrease with 60% |
| Burning of crop residues | No burning |
| % of the above ground residue removed | 30% removed |

## 1.5 Results

### 1.5.1 Current scenario (CT and CA)

This section covers the carbon footprint results which are calculated from the inputs in the LCI (write out) for the current winter grain farming regime.

### 1.5.2 Carbon footprint result

The current farming regimes practised in the winter grain region is a combination of CT (10%) and CA (90%) systems. Information from the Crop Estimates Committee (CEC) was used in order to calculate the current regional carbon footprint for each region. Table 1.3 shows the total estimated tonnage that was produced for all the commodities for a specific practise for each region. The regional pro rata results per ton production based on yield per farming regime are shown in Table 1.3.

**Table 1.3:** Current regional carbon footprint per ton production (all commodities)

| Region | Commodity | Yield [Tonnes] | | CF per ton [kg CO2e/ton] | | Total CF for region [kg CO2e/ton] |
|---|---|---|---|---|---|---|
| | | Conventional | CA | Conventional | CA | |
| Darling/Hopefield | Wheat | 5 451 | 49 057 | 608.00 | 596.03 | 597.23 |
| Northern Swartland | Wheat | 14 622 | 131 595 | 545.56 | 533.55 | 534.76 |
| Middle Swartland | Wheat | 27 640 | 248 760 | 562.26 | 555.19 | 555.89 |
| Southern Swartland | Wheat | 1 935 | 17 419 | 561.47 | 554.56 | 609.73 |
| | Canola | 254 | 2 287 | | 1138.50 | |
| Western Ruens | Wheat | 11 661 | 104 951 | 634.77 | 627.52 | 637.92 |
| | Barley | 4 697 | 42 270 | | 590.64 | |
| | Canola | 1 887 | 16 983 | | 1069.36 | |
| Southern Ruens | Wheat | 9 958 | 89 626 | 558.63 | 476.45 | 485.85 |
| | Barley | 9 109 | 81 978 | | 460.60 | |
| | Canola | 1 857 | 16 716 | | 935.49 | |
| Eastern Ruens | Wheat | 16 962 | 152 655 | 411.64 | 403.18 | 396.22 |
| | Barley | 10 693 | 96 233 | | 304.84 | |
| | Canola | 4 904 | 44 139 | | 705.43 | |

Only wheat had a carbon footprint (CF) for the conventional and CA farming regime and it is evident that the carbon footprint for wheat declines when the CA farming regime is practised. There is on average a 3.5% decline in carbon emissions with the transition to the CA regime across all regions for wheat. The most significant decline is in the Southern Ruens region, with a 15% decline in carbon emissions. The other commodities are currently not farmed conventionally in the winter grain region and a comparison cannot be made.

Looking at wheat, the trend in carbon emissions per region for the Conventional and CA farming regimes can be seen in Figure 1.3.

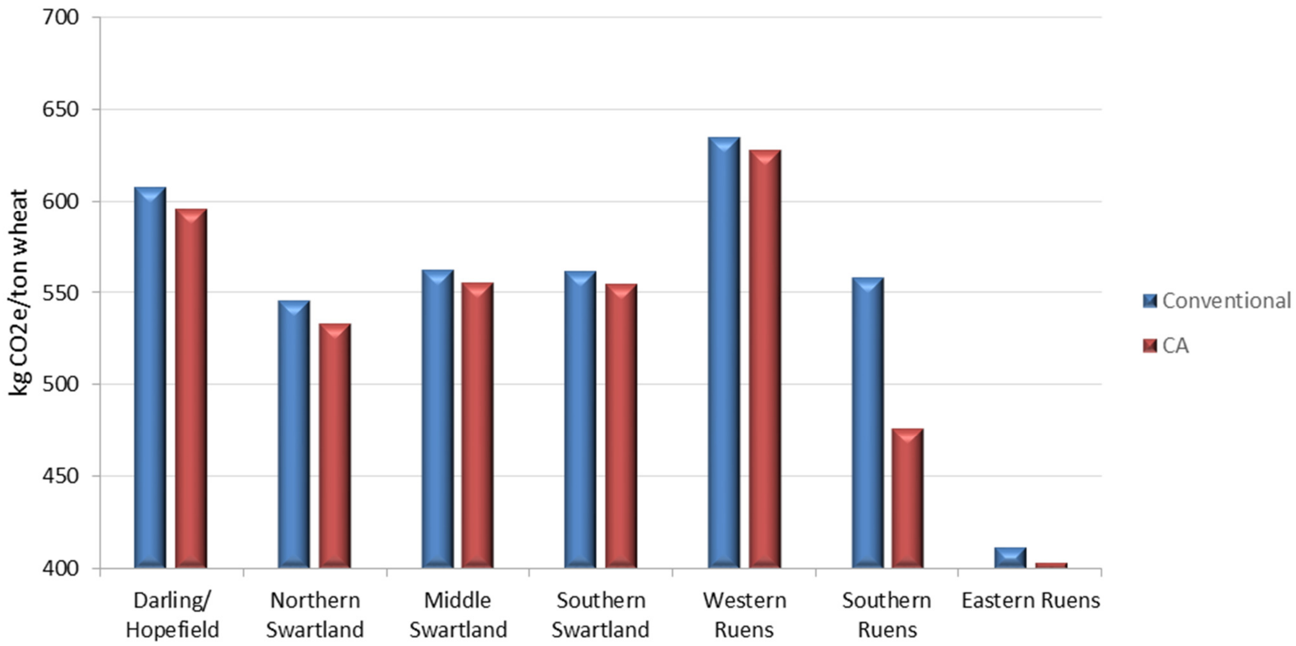


**Figure 1.3: Trends in carbon emissions per ton wheat between CT and CA farming regimes**

The current weighted average carbon footprint for the winter grain region (for all commodities) is 513.69 kg $CO_2$e/ton product (Table 1.4). A specific region might have a relatively high carbon footprint per ton product but a low annual yield. This occurs as the same amount of inputs (diesel, fertiliser) exist but with a lower yield which leads to a high carbon footprint. The formula to calculate a carbon footprint is in Section 1.2.

**Table 1.4:** Current weighted average carbon footprint for winter grain region

| Region | Total tonnages | CF for region [kg CO2e/ton] |
|---|---|---|
| Darling/Hopefield | 54 507 | 597.23 |
| Northern Swartland | 146 217 | 534.76 |
| Middle Swartland | 276 399 | 555.89 |
| Southern Swartland | 21 896 | 609.73 |
| Western Ruens | 182 449 | 637.92 |
| Southern Ruens | 209 245 | 485.85 |
| Eastern Ruens | 325 585 | 396.22 |
| **Weighted average:** | | 513.69 |

### 1.5.3 Hotspots identified in current scenario

The $CO_2$e emissions as a percentage of the total per input per hectare for each farming regime in the current scenario is shown in Figure 1.4. It is evident that the farming input with the largest contribution to overall carbon footprint is fertiliser use. More specifically synthetic Nitrogen, which makes up 90% of the total fertiliser carbon footprint. N2O, a potent Greenhouse gas (GHG), is formed from synthetic N fertilisers through nitrification and denitrification. Emissions from managed soils are, therefore, increased through the addition of fertilizers. Emissions occur through both direct (i.e.

directly from the soils), and indirect pathways. The first being through the volatilization of ammonia (NH3) and nitrogen oxides (NOx) from managed soils, fossil fuel combustion and biomass burning, and the subsequent re-deposition of these gases and their products to the soil (IPCC, 2006). The second pathway is after leaching and runoff of N from managed soils. The kg $CO_2$e/hectare for each input is in Table 1.5

**Table 1.5**: Inputs per hectare for current scenario and corresponding CO2e emissions

| Current farming regime inputs | kg CO2e /hectare |
|---|---|
| Fertilisers | 834.73 |
| Lime | 153.20 |
| Agro-chemicals | 13.44 |
| Diesel | 109.65 |
| Crop residues | 71.17 |

The carbon footprint profile in percentage contribution and kg CO2e per input per hectare for the individual farming regimes, CT and CA are shown in **Appendix 2** and in **Appendix 3**.

The $CO_2$e emissions profile per hectare in kg $CO_2$e for all commodities in the current farming regime is in Figure 1.5 and the total **$CO_2$e emitted per hectare** is approximately **1182 kg**.

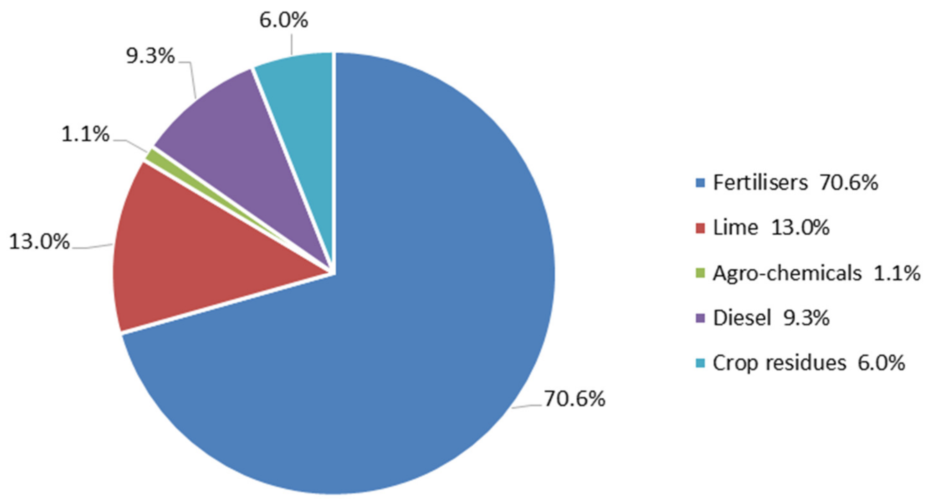


**Figure 1.4: Percentage contribution of current scenario farming regime inputs per hectare to total carbon footprint.**

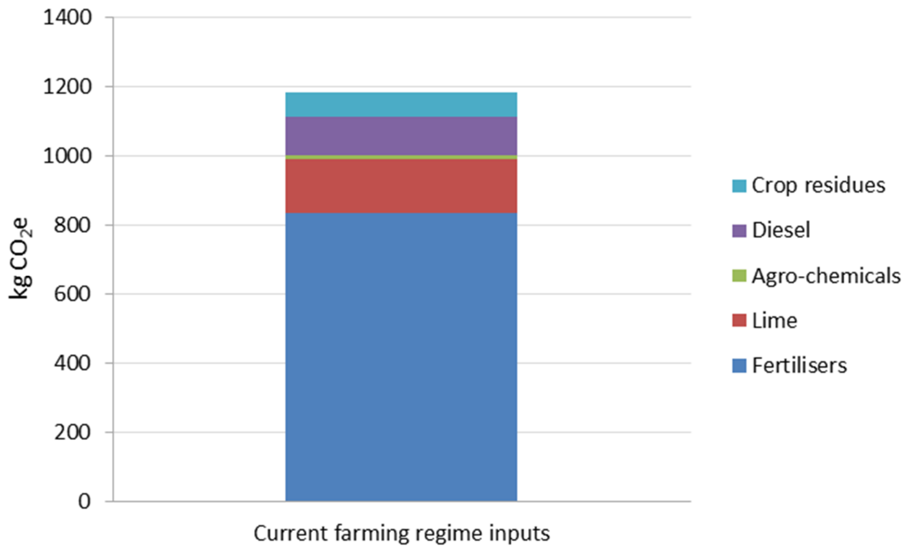


**Figure 1.5: Contribution of current scenario farming regime input $CO_2e$ emissions per hectare to total carbon footprint.**

### 1.5.4 Future scenario (CA and ideal Future CA)

It is predicted that the farming regimes practised in future will be a combination of the current CA (20%) and an ideal Future CA (80%) based on total yields for all commodities. The results per ton commodity for each region and farming regime is in Table 1.6.

**Table 1.6:** Future snapshot carbon footprint per ton production (all commodities) for each region.

| Region | Commodity | Yield [Tonnes] | | CF per ton [kg CO2e/ton] | | Total CF for region [kg CO2e/ton] |
|---|---|---|---|---|---|---|
| | | CA | FutCA | CA | FutCA | |
| Darling/Hopefield | Wheat | 10 901 | 47 967 | 596.03 | 282.35 | 339.93 |
| | Canola | 46 | 79 | | 163.74 | |
| Northern Swartland | Wheat | 29 243 | 128 671 | 533.55 | 280.89 | 327.68 |
| Middle Swartland | Wheat | 55 280 | 243 232 | 555.19 | 264.33 | 314.72 |
| | Barley | 549 | 2 163 | | 175.73 | |
| | Canola | 2 143 | 3 677 | | 345.16 | |
| Southern Swartland | Wheat | 3 871 | 17 032 | 554.56 | 334.92 | 400.70 |
| | Canola | 508 | 872 | 1138.50 | 572.54 | |
| Western Ruens | Wheat | 23 322 | 102 618 | 627.52 | 353.13 | 418.47 |
| | Barley | 9 393 | 36 991 | 590.64 | 333.64 | |
| | Canola | 3 774 | 6 476 | 1069.36 | 556.48 | |
| Southern Ruens | Wheat | 19 917 | 87 635 | 476.45 | 285.38 | 334.52 |
| | Barley | 18 217 | 71 739 | 460.60 | 276.54 | |
| | Canola | 3 715 | 6 375 | 935.49 | 508.62 | |
| Eastern Ruens | Wheat | 33 923 | 149 263 | 403.18 | 264.33 | 276.38 |
| | Barley | 21 385 | 84 214 | 304.84 | 175.73 | |
| | Canola | 9 809 | 16 832 | 705.43 | 345.16 | |

### 1.5.5 Carbon footprint result

On average, there is a 45% decline in $CO_2e$ emissions per ton product for all commodities between the CA and Future CA farming regime. For wheat, the differences in $CO_2e$ emissions for all three farming regimes is in Figure 1.6.

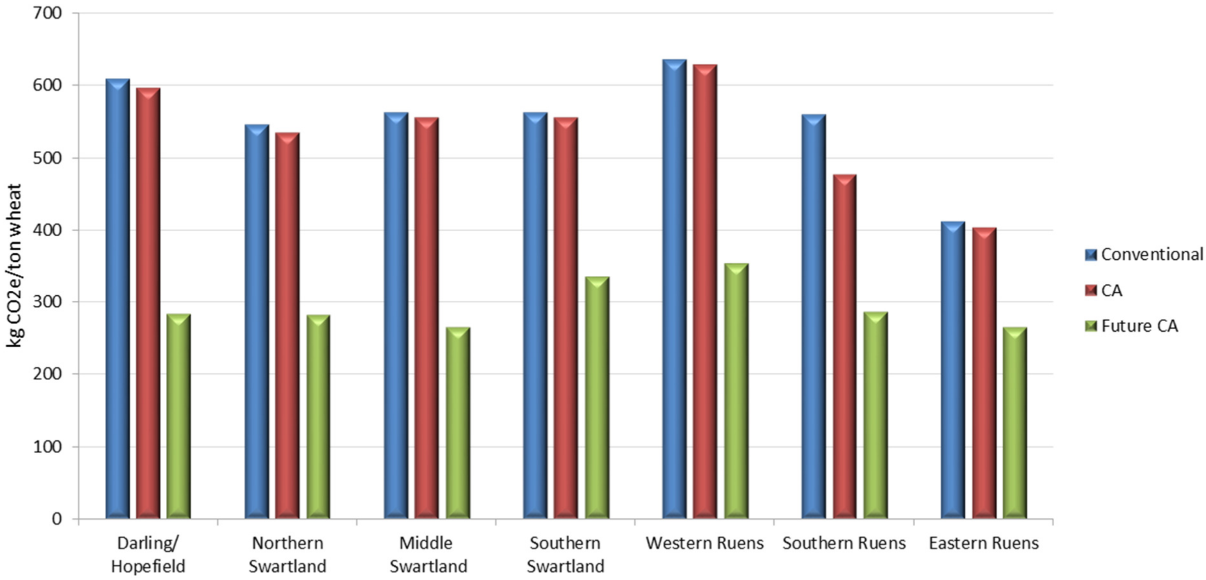


**Figure 1.6: Carbon footprint results for wheat per region for each farming regime.**

For the other commodities, a comparison can only be made between the $CO_2e$ emissions of the CA and Future CA regimes in certain regions. The results are shown in Figure 1.7.

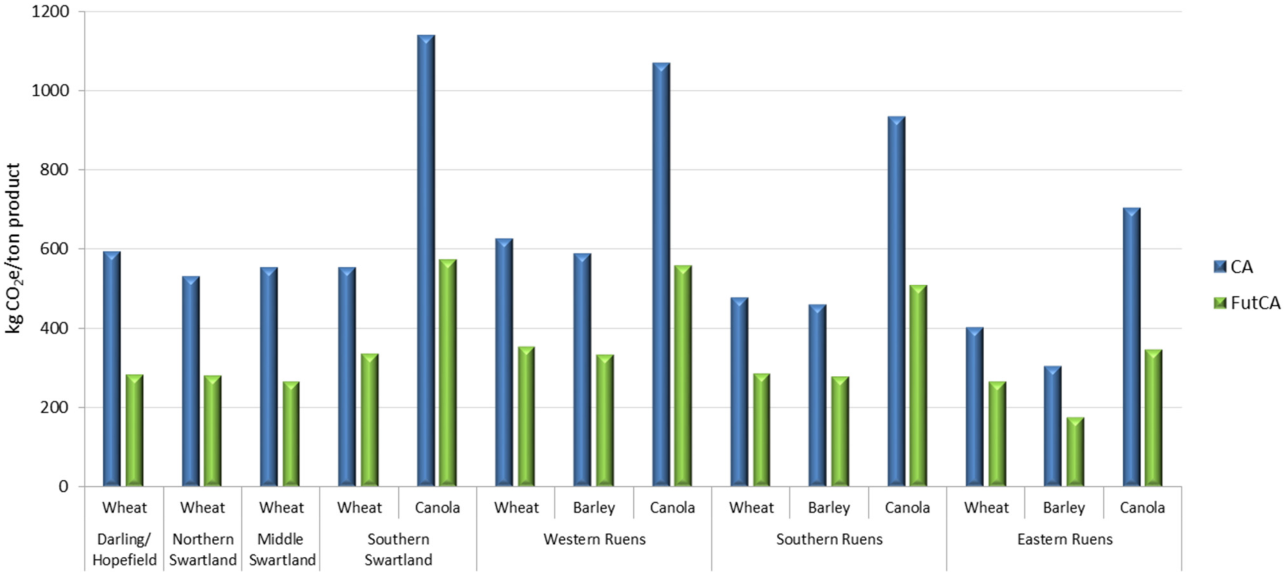


**Figure 1.7: CO2e emissions per ton Barley and Canola per farming regime.**

Using these results, the future weighted average snapshot carbon footprint for the winter grain region is predicted to be 328 kg $CO_2e$/ton product (Table 1.7).

**Table 1.7:** Future weighted average carbon footprint for winter grain region.

| | Total tonnages | CF for region |
|---|---|---|
| Darling/Hopefield | 58 993 | 339.93 |
| Northern Swartland | 157 914 | 327.68 |
| Middle Swartland | 307 043 | 314.72 |
| Southern Swartland | 22 283 | 400.70 |
| Western Ruens | 182 575 | 418.47 |
| Southern Ruens | 207 598 | 334.52 |
| Eastern Ruens | 315 426 | 276.38 |
| **Weighted average:** | | 327.83 |

### 1.5.6 Hotspots identified in future scenario

The $CO_2e$ emission contribution of each farming input as a percentage of the total carbon footprint is shown in Figure 1.8. It is clear that the largest contributor to $CO_2e$ emissions is the fertiliser input. The synthetic nitrogen component of the fertilisers contributes 90% of the total fertilisers $CO_2e$ emissions. The second largest contributor to GHG emissions is lime (calcitic, dolomite and gypsum) followed by crop residues. The carbon footprint per input per hectare is in Table 1.8.

**Table 1.8:** Inputs per hectare for future scenario and corresponding CO2e emissions

| Future farming regime inputs | kg CO2e /hectare |
|---|---|
| Fertilisers | 495.94 |
| Lime | 126.22 |
| Agro-chemicals | 4.43 |
| Diesel | 76.68 |
| Crop residues | 107.24 |

Figure 1.9 shows the emissions contribution per input per hectare to total carbon footprint in kg $CO_2e$. The total **$CO_2e$ emitted per hectare** is approximately **811 kg** for the future farming regime scenario.

The CO2e profiles of the individual farming regimes CA and ideal Future CA that make up the future scenario is in **Appendix 3** and **Appendix 4**. In addition, the CO2e profiles in kg CO2e per hectare for each of the commodities in each of the individual farming regimes is in **Appendix 5**.

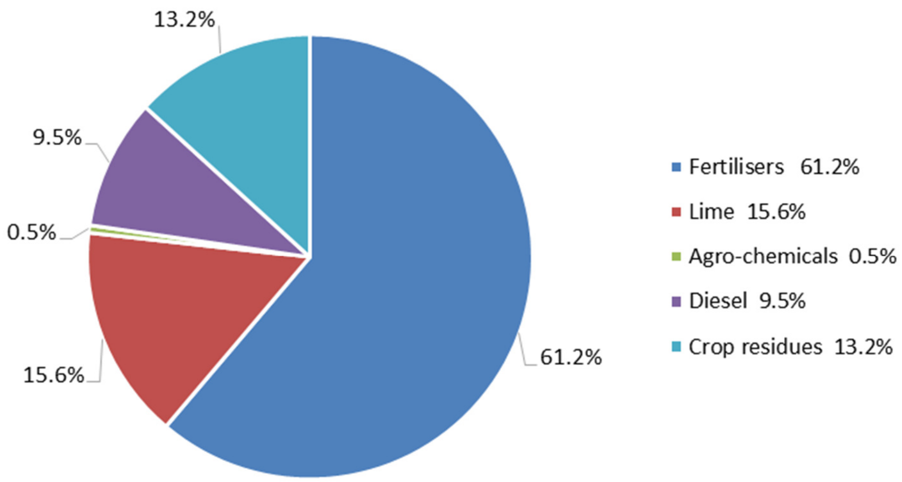


**Figure 1.8: Percentage contribution of future scenario farming regime inputs per hectare to total carbon footprint.**

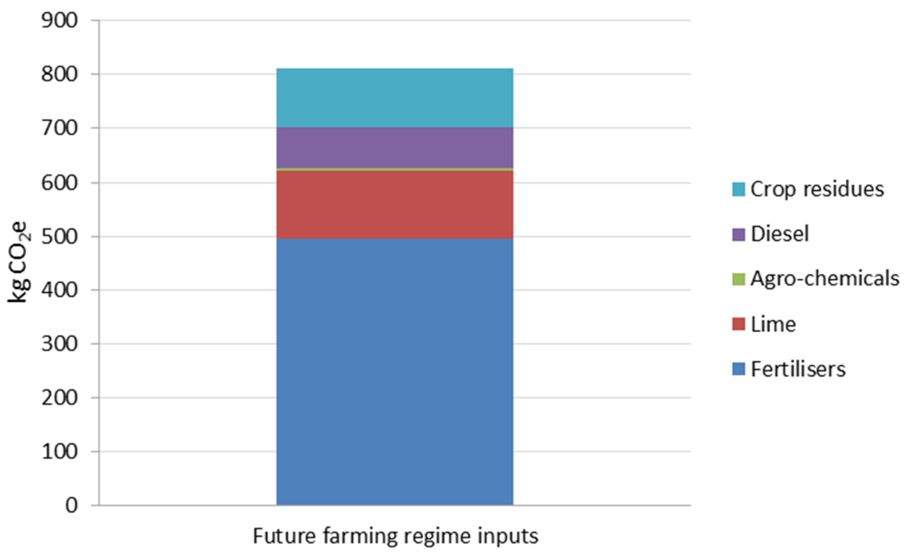


**Figure 1.9: Contribution of future scenario farming regime inputs in kg $CO_2e$ per hectare to total carbon footprint.**

## 1.6 Conclusions and Recommendations

The commodity carbon footprints for each farming regime (CT, CA and Future CA) and region were calculated on a per ton basis for the commodities specified. These results are weighted based on the yields per regime (yields only available for wheat, barley and canola) to give a regional carbon footprint result.

The results per region are further extrapolated to obtain a current and predicted future snapshot result for the entire winter grain region. This result is a weighted average based on current and future yields per region.

In the current system, there is an average 3.5% decline in carbon emissions per ton wheat with the transition from the CT to CA farming regime. For the predicted ideal future scenario, there is a more significant decline of 45% in carbon emissions per ton product (all commodities) with the transition from CA to the future CA farming regime. With the transition of farming regimes from the current CT (10%) and CA (90%) mix to a future scenario of CA (20%) and Future CA (80%), there is predicted to be a 36% decline in carbon emissions per ton product across all commodities. This result is due to an overall increase in yield from CT and CA to Future CA farming regimes and a decrease in inputs such as diesel and fertilisers as indicated in Table 1.2. It is evident that there will be a significant decrease in carbon emissions from the winter grains industry as a whole and other environmental, economic and social benefits with implementation of the Future CA farming regime including the protection of biodiversity, increase in net yields and farm income and improving human nutrition (Putter, Smith & Lange, 2014).

The key hotspot identified in the current and future farming regimes is the synthetic N fertiliser input. Synthetic Nitrogen contributes approximately 90% to the total CO2e emissions from fertilisers and includes the production phase, $N_2O$ emissions after application and atmospheric deposition. These emissions account for 70% of CO2e emissions in the current farming regime and 61% in the future farming regime per hectare. The total CO2e emissions per hectare decreases from 1 182 kg per hectare in the current farming regime to 811 kg in the future farming regime. At a commodity level, wheat cultivation emits the most $CO_2$e per hectare in all farming regimes followed by canola and barley.

From the perspective of the environmental impact and climate change, the transition to a higher level and quality of CA (defined here as Future CA) is highly beneficial for the winter grain region in the Western Cape. The synergies between the Future CA farming regime and the environmental, economic and social benefits will ensure the sustainability of future grain cultivation in the region.

# 2. Assessment of soil health under different Western Cape farming systems as an indication of the carbon sequestration potential

## 2.1 Background

This objective was to compliment the C-footprint results by data on soil health under different practices in the regions identified, as a) an indication of their potential to sequestrate soil carbon, b) to stimulate thinking and awareness on more sustainable and climate-smart agricultural options, and c) to provide partial baseline and/or input data for C-sequestration modelling in Phase 2 (2018). This soil health assessment was not aimed to be a comprehensive regional soil health study, but rather to provide a snapshot idea of soil health and C- sequestration supporting the overall C-footprint study.

There are two distinct regions within the Western Cape's Grain producing area known as the Swartland or West coast region and the Ruens or Southern Cape region. The following seven sub-regions (or agro-ecological regions) were identified as a sampling framework for the assessment:

- **Swartland:** Sandveld (Darling), Rooi Karoo (Northern), Middle Swartland and Southern sub-regions
- **Southern Cape:** Western Ruens, Southern Ruens and Eastern Ruens sub-regions

Two sampling locations were selected on specific farms in each of the seven sub-regions, one representing the local conventional tillage (CT) system and one representing the local CA system. Grain SA structures and knowledge of farmers' practices were used to make this selection. Since CA awareness and adoption among grain producers in the Western Cape is far more advanced than the rest of the country, there is in most cases little difference between CT and CA systems in a specific sub-region. This is also mirrored by the C-footprint results in Section 1 of this report, which show very little difference. For example, most of the CT farming operation practices are using no-till planters, but burn, or cut and bale the wheat straw after harvest. On only one of the selected CT farms has the soil been tilled with a disc plough, however, cover crops were still being used in this particular system. The distinction was therefore not truly between CA and CT practices as normally defined, but rather as it is presently understood and implemented in the Western Cape grain production context.

## 2.2 Methods and materials

Composite soil samples were taken on a representative field on each of the selected farms per sub-region, whereby a range of twenty-eight soil samples were taken in the top 5 cm of a specific area in the field, mixed together and used for the composite sample and further analyses. See **Appendix 6** for the list of farms and owners sampled.

For this specific assessment, it was decided to use the Soil Health Tool (SHT) developed by Rick Haney (Haney *et al.,* 2008; Haney and Haney, 2010). The SHT is an integrated approach to soil testing using chemical and biological soil test data; it is designed to mimic nature's approach to soil nutrient availability as best we can in the lab. This tool is the culmination of nearly 20 years of research in soil fertility and is widely believed to represent the next step in soil testing for the 21st century.

The SHT is designed to work with any soil under any management scenario because the programme asks simple, universally applicable questions. The methods use nature's biology and chemistry, in that, the soil analysis is performed using a soil microbial activity indicator, a soil water extract (nature's solvent), and H3A extractant, which mimics organic acids produced by living plant roots to temporarily change the soil pH thereby increasing nutrient availability. These organic acids are then broken down by soil microbes since these are excellent soluble carbon source, which returns the soil pH to its natural, ambient level. The SHT doesn't measure just one thing to arrive at the plant available NPK, it uses an integrated approach.

## 2.3 Soil Health Test Results

Table 2.1 below summarises the SHT results for the parameters listed in all the regions and sub-regions, comparing CA and CT practices.

### 2.3.1 Definition of SHT parameters and interpretation of results measured

#### *2.3.1.1 Soil organic matter (SOM)*

***Definition:*** SOM is expressed in % as determined by the Loss on Ignition method. As a rule of thumb, the carbon content can be derived by dividing this value by 1.72 or multiplying by 0.58. This is a total inclusive of non-decomposed and completely decomposed organic particles and all substances between these two distinct points which incorporates the water insoluble and water soluble organic carbon compounds.

***Results:*** The average SOM values of CA systems in the Southern Cape is higher than that of CT systems (5% vs 3%) indicating significant higher soil C-sequestration rates through a transition from CT to CA. In the Swartland there is no difference between average SOM levels (both are on 2%), showing that the two systems are actually very similar and that CA practices have much room for improvement.

#### *2.3.1.2 Water soluble organic carbon (WEOC)*

***Definition:*** WEOC is expressed in ppm and 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 C pool (which is 0.58 % of SOM) and reflects the energy/food source that is driving soil microbes. The most common of these compounds are sugars and sugar-like substances, also called liquid carbon. The number typically ranges from 100-300 ppm C.

***Results:*** The average WEOC values (ppm) is substantially higher under CA than CT systems in both regions (234 vs 169 in Southern Cape and 235 vs 186 in Swartland), which is a very positive indicator. The more aggressive soil disturbance and residue removal practices under CT might be the cause for lower WEOC levels. However, the values in Southern Swartland are much higher than the other three sub-regions in Swartland, which illustrates the influence of climatic factors between the different agro-ecological regions (Southern Swartland has a higher rainfall with lower temperatures).

**Table 2.1:** Haney Soil Health Test results summary for grain regions in the Western Cape

| Areas | Southern Cape | | | | | | | | Swartland | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Regions** | **West** | | **South** | | **East** | | **Average** | | **North** | | **Middle** | | **Darling** | | **South** | | **Average** | |
| **Practice** | **CA** | **CT** | **CA** | **CT** | **CA** | **CT** | **CA** | **CT** | **CA** | **CT** | **CA** | **CT** | **CA** | **CT** | **CA** | **CT** | **CA** | **CT** |
| **Soil pH** | 8 | 7 | 8 | 7 | 7 | 7 | 7 | 7 | 6 | 7 | 8 | 6 | 8 | 7.2 | 6 | 7 | 7 | 7 |
| **Soil Organic Matter (%)** | 7 | 3 | 4 | 3 | 5 | 3 | 5 | 3 | 1 | 1 | 3 | 2 | 0.9 | 1.3 | 4 | 4 | 2 | 2 |
| **Solvita CO2-C 24 hr** | 69 | 128 | 16 | 48 | 63 | 36 | 49 | 71 | 11 | 8 | 42 | 29 | 10 | 23 | 55 | 75 | 29 | 34 |
| **Tot WEN (ppm)** | 130 | 189 | 51 | 186 | 128 | 96 | 103 | 157 | 29 | 51 | 65 | 80 | 30 | 26 | 154 | 73 | 69 | 52 |
| **WEON (ppm)** | 22 | 12 | 14 | 12 | 21 | 19 | 19 | 14 | 22 | 21 | 21 | 11 | 19 | 11 | 22 | 27 | 21 | 18 |
| **WEOC (ppm)** | 279 | 154 | 180 | 99 | 244 | 253 | 234 | 169 | 177 | 120 | 207 | 139 | 202 | 119 | 355 | 310 | 235 | 186 |
| **H3A Inorg N (ppm)** | 101 | 179 | 41 | 74 | 118 | 82 | 87 | 111 | 8 | 30 | 49 | 67 | 10 | 23 | 137 | 44 | 51 | 35 |
| **H3A Inorg P (ppm)** | 32 | 20 | 17 | 10 | 33 | 55 | 27 | 28 | 21 | 35 | 25 | 52 | 39 | 46 | 162 | 85 | 62 | 51 |
| **H3A Org P** | 12 | 8 | 6 | 8 | 13 | 16 | 10 | 11 | 23 | 16 | 11 | 14 | 14 | 11 | 35 | 23 | 21 | 18 |
| **H3A Total P** | 43 | 28 | 23 | 17 | 46 | 71 | 37 | 39 | 44 | 51 | 36 | 66 | 54 | 46 | 198 | 108 | 83 | 66 |
| **Org P Min (Release)** | 7 | 8 | 2 | 8 | 7 | 4 | 5 | 6 | 2 | 2 | 6 | 3 | 1 | 6 | 1 | 9 | 3 | 5 |
| **Org P Reserve** | 5 | 0 | 5 | 0 | 5 | 12 | 5 | 4 | 21 | 14 | 5 | 12 | 13 | 5 | 34 | 14 | 18 | 13 |
| **Organic C:N** | 13 | 12 | 13 | 8 | 12 | 12 | 12 | 11 | 8 | 6 | 10 | 13 | 11 | 11 | 17 | 11 | 11 | 11 |
| **Organic N Release (ppm)** | 19 | 12 | 3 | 12 | 19 | 9 | 14 | 11 | 4 | 4 | 15 | 6 | 3 | 8 | 8 | 26 | 7 | 11 |
| **Organic N Reserve (ppm)** | 4 | 0 | 11 | 0 | 2 | 10 | 6 | 3 | 18 | 17 | 6 | 5 | 16 | 0 | 14 | 1 | 13 | 6 |
| **Haney N (Tot avail org+inorg)** | 240 | 382 | 88 | 172 | 273 | 181 | 200 | 245 | 24 | 68 | 128 | 146 | 24 | 73 | 290 | 140 | 117 | 96 |
| **Lbs N Difference** | 58 | 42 | 31 | 29 | 49 | 28 | 46 | 33 | 11 | 12 | 43 | 22 | 18 | 26 | 39 | 62 | 28 | 30 |
| **Soil Health Score** | 11 | 13 | 5 | 8 | 10 | 7 | 8 | 9 | 5 | 5 | 9 | 5 | 5 | 6 | 9 | 12 | 7 | 7 |
| **SLAN** | 348 | 198 | 358 | 135 | 255 | 203 | 320 | 179 | 28 | 0 | 125 | 73 | 35 | 158 | 225 | 195 | 103 | 114 |
| **Aggregate stability** | 33 | 44 | 33 | 9 | 31 | 14 | 32 | 22 | 19 | 19 | 19 | 6 | 14 | 19 | 19 | 19 | 18 | 16 |

#### 2.3.1.3 Organic Nitrogen

***Definition:*** Organic N is the total water extractable N (WEN) minus inorganic N (NO3 and NH4) in ppm. The organic N pool is replenished by fresh plant residues, manure, composts, and dying soil microbes.

***Results:*** The average organic N (ppm) under CA is higher than CT in both regions (19 vs 14 in Southern Cape and 21 vs 18 in Swartland) which would be expected and commonly demonstrated under strict comparisons of these two systems elsewhere.

#### 2.3.1.4 Inorganic Nitrogen:

***Definition:*** This is a sum of the NO3-N and NH4-N expressed in ppm N and graphically illustrated as below. For this report total inorganic content will be reported, which is also an indication of the amount of N-fertilisers in the soil. We typically do not want to see large amounts of inorganic N present in your soil.

***Results:*** Average inorganic nitrogen is higher under CT than CA in Southern Cape (111 vs 87 ppm) with the reverse of these results in the Swartland (35 vs 51 ppm). A quantum difference can be seen between the two regions and probably reflects the differences fertilizer application practices between the (sub)regions, for example, in the Western sub-region of the Southern Cape (179 vs 101, CT vs CA).

#### 2.3.1.5 Total Nitrogen

***Definition:*** Total N is the total water extractable N (WEN) from your soil expressed in ppm.

***Results:*** Average WEON is higher in CT group than CA group in the Southern Cape (157 and 103 ppm) with the reverse of these results in the Swartland (52 vs 69 ppm). A quantum difference in the two regions as also reflected in the inorganic N can be seen and corresponds with the results of the inorganic fraction being the dominant component, especially in certain sub-regions (e.g. 179 vs 101, CT vs CA) in the Western sub-region of Southern Cape.

#### 2.3.1.6 N - Mineralization

***Definition:*** The amount of N being released through mineralization expressed in ppm N. The N min estimates how much N will be immediately available to the crop based on microbial activity and the organic C Organic N value. When the organic C organic / N value is above 20, N will remain tied up in the bacterial biomass with a certain portion being released into the soil as plant available organic nitrogen components; as these microbes die. This process quantifies the proportion being released as the **organic N release** component and the **organic N reserve** quantity.

#### 2.3.1.7 Organic N Release

***Definition:*** The total amount of N being released through microbial activity from the organic N pool expressed as ppm N. It is the sum of MAC, WEON, which is the fraction of the organic N pool acted upon by the microbes over 24 hours, and N mineralization. This immediately plant available and never reflected in conventional chemical analysis. The N released here is counted as a credit to the next crop and is subtracted from recommendations made on the Haney Test. The amount of N being released is dependent on how much water extractable organic N we can measure, how high the soil respiration or microbial biomass value is and how balanced the organic C: organic N ratio is. Overall, the organic N release value typically increases as the soil system gets healthier.

***Results:*** Average organic nitrogen released is higher in CA group than CT group (14 vs 11 ppm) in Southern Cape with the reverse of these results in the Swartland (7 vs 11 ppm).

#### *2.3.1.8 Organic N Reserve*

***Definition:*** The amount of N left in the organic N pool in ppm N following the release by microbes. The organic N reserve or organic N pool is replenished by fresh plant residues, manure, composts, and dying soil microbes.

***Results:*** Average organic nitrogen reserve is higher in CA than CT group (6 vs 3 ppm) in Southern Cape as well as in the Swartland (13 vs 6 ppm).

#### *2.3.1.9 Organic C:Organic N*

***Definition:*** This is the ratio of organic C to organic N in your soil based on the water extraction. This number is a very sensitive indicator of the health of your soil and has a significant impact on the activity of soil microbes. We like to see number below 20. When the value is above 20, we will suggest a higher percentage of legumes in the system to help build organic N and lower the ratio over time. We want to see this value between 8 and 15 and we consider it to be ideal when it falls between 10 and 12.

***Results:*** All the values in both regions are ideal for both CA and CT: 12 and 11 for Southern Cape and 11 and 11 for Swartland.

#### *2.3.1.10 Solvita/One Day C/Microbial Activity*

***Definition:*** This number is ppm CO2-C 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. In general the higher the number the better. This value can range anywhere from about 0 to nearly 1000, but we typically don't see values higher than 400 for most soils and management scenarios. The rankings would be as follows:

| | |
|---|---|
| 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 |

Notice that we do not list a true average because these rankings are on a sliding scale, which is dependent on soil types and climate. Sandier soils or dryer climates tend to score poorer. Therefore, we need to focus on the relative differences between samples and track change in time as a response to management rather than be entirely focused on an actual number.

***Results:*** The results reflect a higher level of CO2 release in both areas under CT production than under CA cultivation as selected in this comparative evaluation (71 vs 49 in the Southern Cape and 34 vs 29 for the Swartland). The Southern Cape's results once again being a reasonable quantum better than the Swartland. The slightly more aggressive soil disturbance under CT probably result in the marginally higher microbial activity in those soils (resulting in higher Solvita CO2 release levels).

#### 2.3.1.11 Inorganic Phosphorus

***Definition:*** The amount of P in your soil extracted with H3A and measured as orthophosphate (PO4-P) expressed in ppm P and is an indication of soil fertiliser levels in the soil. The desired soil test level will depend on the crop you are growing and the desired/expected yield goal.

***Results:*** The inorganic phosphorous measured is in most instances higher than organic phosphorous as a result of the inorganic applied phosphorous as fertilizer. In this instance the reverse of the inorganic nitrogen amounts between the two regions are found with higher amounts in the Swartland than the Southern Cape and some small differences between cultivation practices. Southern Cape CA=27 and CT =28; Swartland CA =62 and CT=51. These are reflections of the applied fertilizers within the regions.

#### 2.3.1.12 Total Phosphorus

***Definition:*** The amount of elemental P (ppm) in your soil extracted with H3A and analysed on ICAP in ppm P.

***Results:*** The total phosphorous mirrors the inorganic phosphorous results which includes the non-available elemental component. Southern Cape CA=37 and CT =39; Swartland CA =83 and CT=68. The levels are in general very high and in some cases extremely high, such as the 198 (CA) and 108 (CT) in the southern sub-region of Swartland. The latter situation is most probably due to the application of cattle manure from dairies. These high Total soil-P levels also reflects the high soil fertiliser application guidelines or recommendations provided by advisors and/or the fertiliser industry.

#### 2.3.1.13 Organic Phosphorus

***Definition***: The total P minus inorganic P expressed in ppm P. This represents P that is not currently plant available but may become available through microbial activity.

***Results:*** As per the definition as follows; Southern Cape CA=10 and CT=11; Swartland CA=21 and CT=18.

#### 2.3.1.14 P – Mineralization (release)

**Definition:** The amount of P that will be released through mineralization of organic P by soil microbes depending on their activity and the organic C Organic / N ratio expressed in ppm P. The same principal applies as with organic nitrogen mineralization.

***Results:***

#### 2.3.1.15 Organic P Reserve

***Definition:*** is the amount of P that remains in the organic P pool following the release by microbes expressed in ppm P.

#### 2.3.1.16 Soil Health Calculation

***Definition:*** This number is calculated as 1-day CO2-C divided by organic C: N ratio plus a weighted organic carbon and organic N addition. It represents the overall health of your system. We like to see this number above 7. Keeping track of this number will allow you to gauge the effects of your management practices. Haney has revised this soil health calculation, which has been used in this study.

***Results:*** These results clearly indicate the similarity within the different sites of each region with Southern Cape scoring a fractional higher average score of 9 for CT and 8 for CA and Swartland scoring an average of 7 within both CT and CA cultivation sites.

#### *2.3.1.17 SLAN (Solvita Labile Amino Nitrogen)*

***Definition*****:** Labile amino – N is the total Nitrogen from the amino (NH2) groups from decaying organic material's proteins', peptides, amino acids and other water soluble and insoluble organic matter containing amino groups. In soils it is commonly referred to as the organic nitrogen reserves present as amino-sugars in soil and represent the upstream organic bound nitrogen in process to become water soluble and plant available amino acids through microbial decomposition of these larger organic nitrogen molecules.

***Results:*** These results indicate a substantially higher SLAN number from the Southern Cape plots compared to the Swartland plots. The results indicate that the CA plots in the Southern Cape represent a SLAN of 320 and the CT 179. In the Swartland the results are more evenly matched with CA measuring 103 and CT 114. This correlates quite well with organic material content measured in the two regions as well as between cultivation practices in the Southern Cape.

#### *2.3.1.18 Volumetric Aggregate stability percentage (VAS)*

***Definition:*** This is a measure of resistance that soil particles exhibit to dispersing when subjected to water immersing and expressed in volumetric terms or the percentage volume loss during the immersion process. It serves as a valuable proxy indicator of general soil health.

***Results:*** The Southern Cape region as well as the Swartland regions' CA farms exhibited somewhat improved ***VAS*** over the CT farms with the Southern Cape once again being better as a region on this parameter (Southern Cape CA=32% and CT=22%; Swartland CA=18% and CT=16%).

## 2.4 General discussion and conclusions

Various soil health indicators, such as SOM (%) and Soil Health Index scores, show the big influence of environmental factors (soil, climate, topography) on their scores, varying between different regions and sub-regions, (see Table 2.2).

**Table 2.2:** The influence of regional environmental factors on soil health parameters

| | Southern Cape | | | Swartland | | |
|---|---|---|---|---|---|---|
| | **West** | **South** | **East** | **North** | **Middle** | **South** |
| **SOM (%) Median** | 5.15 | 3.75 | 4.1 | 0.9 | 2.35 | 4.15 |
| **Soil Health Score** | 11.8 | 6.2 | 8.6 | 5.05 | 6.6 | 10.65 |

What the results in **Table 2.2** clearly indicate is that the Swartland is more deprived in SOM than the Southern Cape and increases in severity as you move to the North, while the Southern sub-region of the Swartland starts to resemble soil health levels of the Southern Cape's soil.

**SOM and water holding capacity**

Table 2.3 illustrates the influence of SOM and SOC on **water holding capacities** of the soil at the study sites using the known conversion rate of 1% of SOM having the potential to hold around 130 000 litres of soil water in the 200 mm topsoil layer.

**Table 2.3:** Water holding capacity at the various study sites as influenced by SOM

| | **Southern Cape** | | | **Swartland** | | |
|---|---|---|---|---|---|---|
| | **West** | **South** | **East** | **North** | **Middle** | **South** |
| **SOM (%)** | 5.15 | 3.75 | 4.1 | 0.9 | 2.35 | 4.15 |
| **SOC in tons / ha to a depth of 200 mm.** | 72 | 52 | 57 | 13 | 33 | 58 |
| **Water holding capacity in 000' liters** | 669 | 487 | 533 | 117 | 305 | 540 |

Table 2.4 can also be used to calculate the impact of an increase in SOM or SOC on available water holding capacity (AWHC) and yield.

**Table 2.4:** SOM, SOC, AWHC and yield relationships (from Blignaut *et al.*, 2015)

| **Change in soil organic matter** | **Change in soil organic carbon** | **Change in available water holding capacity** | **Change in yield** |
|---|---|---|---|
| | Ruehlmann & Körschens (2009) | Reicosky (2005), Hudson (1994) | Lal (2010) |
| 1.0% | 0.58% | 3.7% | 2.76% |
| 1.5% | 0.87% | 5.6% | 4.14% |
| 2.0% | 1.16% | 7.4% | 5.52% |
| 2.5% | 1.45% | 9.3% | 6.91% |
| 3.0% | 1.74% | 11.1% | 8.29% |
| 3.5% | 2.04% | 13.0% | 9.67% |
| 4.0% | 2.33% | 14.8% | 11.05% |
| 4.5% | 2.62% | 16.7% | 12.43% |
| 5.0% | 2.91% | 18.5% | 13.81% |

The absence of a residue cover in various fields sampled through long periods of the year, especially the CT systems, will lead to runoff, less infiltration, lower soil water content and less SOM build-up. To alleviate this problem attention should be given to improve the quality of the application and adaptation of CA principles within each situation. One example is the seeding of a summer cover crop into the wheat stubble before the last August rains, which could improve soil carbon build-up for 3 to 4 months thereafter.

**Conservation Agricultural principles and practice - confusion of interpretation.**

It became notably obvious from the discussion with farmers during the field sampling that the understanding of the principles of CA is fairly poor; however, the desire to improve that understanding and application is very strong, but not without reservations about the applicability of some of the principles in their situation or area. One of the major concerns is that growing plants in the "off season" will deplete the soil moisture levels.

The soil analyses results discussed above show a direct relationship between soil health as calculated by the Haney protocol and the SOC content. This strengthen the case to sequester more carbon, leading to healthier soils, which in turn will make soils more drought resistant and resilient; this is a very important soil function and service for sustainable wheat farming in the Western Cape.

From the study sites sampled the differences appear to be highly influenced by environmental factors, and less by agricultural practices on the different farms. Fertiliser practices on certain sites do have a significant effect on some of the parameters. A worrying aspect is the high levels of inorganic phosphorous and nitrogen in some soils, indicating to an over-application of fertilisers.

**Improving the Soil Health of Western Cape soils**.

It must be remembered that No-till and limited crop rotation without cover crop inclusion cannot be regarded as a holistic, regenerative CA system. Furthermore, the effects of soil disturbance and bare fallow soils (without crop or residue cover over long periods) are negative on soil health, affecting important soil functions and services, particularly water infiltration and storage as reflected by the soil aggregate stability. The constraints of establishing and maintaining a plant cover with limited moisture is well understood and has been receiving attention by the CA research projects run by the Western Cape Department of Agriculture at Elsenburg.

This study should be seen as a preliminary screening assessment and should ideally be expanded or continued by a) using more sampling sites in the regions and b) in different soil depths. Phase 2 of this C-footprint study will focus on the soil C-sequestration potential of the different systems in the different (sub-) regions through modelling exercises.

# 3. Budget and costs summary for 2017

**Table 3.1:** Summary of budget and costs for 2017

| Carbon Footprint **Project activities** | **Total Actual YTD 2016/17** | **Total Budget YTD 2016/17** | **Available to use** |
|---|---|---|---|
| Data collection: GSA | 13 424 | 16 000 | 2 576 |
| Data collection: CCC | 30 360 | 30 360 | - |
| Data warehousing: CCC | 11 040 | 11 040 | - |
| Calculation and reporting: CCC | 44 160 | 44 160 | - |
| Soil health assessment: SHS | 45 000 | 45 120 | 120 |
| Project close out workshop: GSA | 14 934 | 18 542 | 3 608 |
| Project close out workshop: CCC | - | 17 040 | 17 040 |
| Travel & Accommodation: CCC | 4 373 | 12 000 | 7 627 |
| **Total** | **163 291** | **194 262** | **30 971** |

# 4. References

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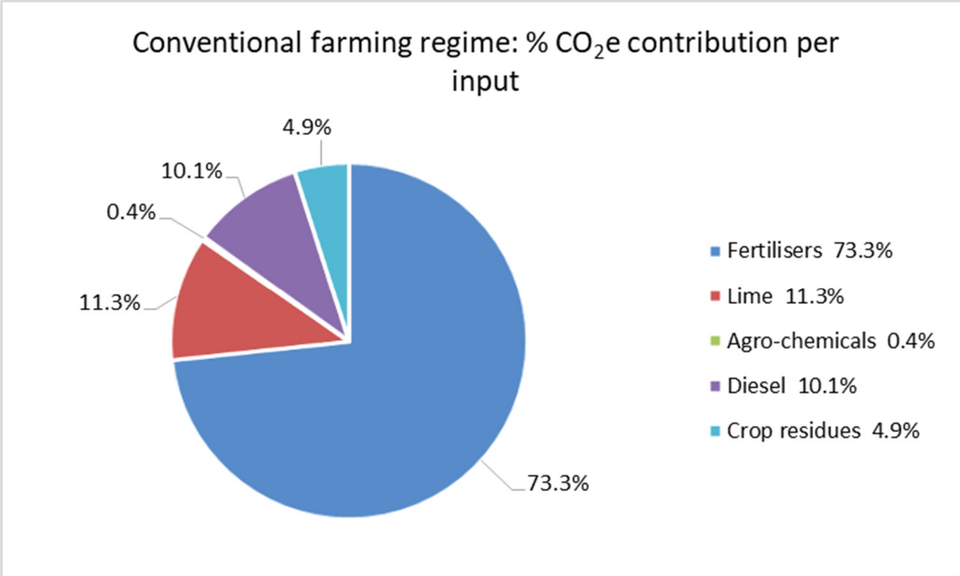
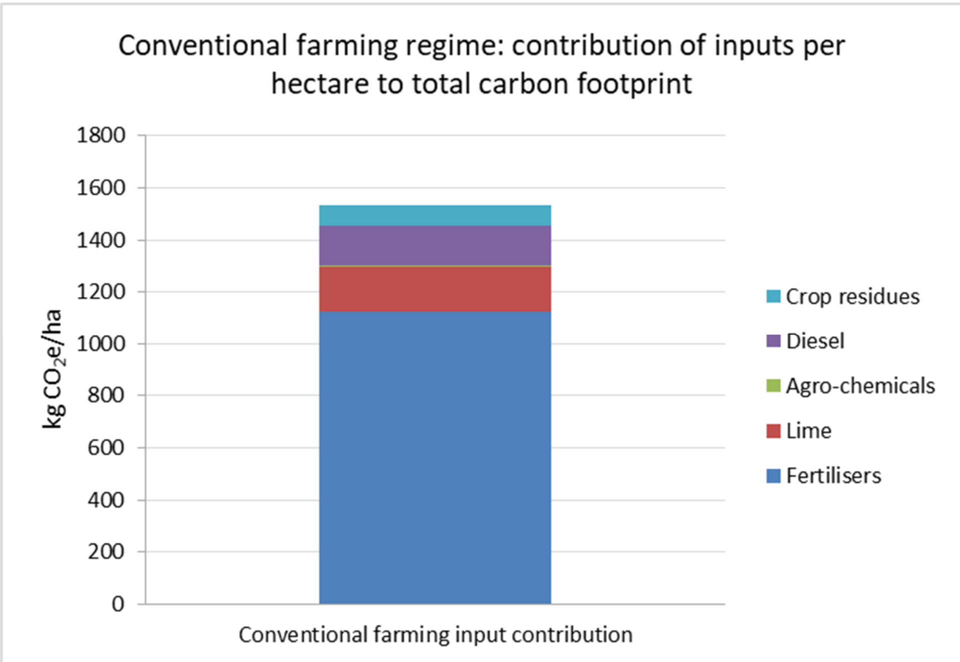
# Appendices

## Appendix 1: Inputs per hectare for farming regimes

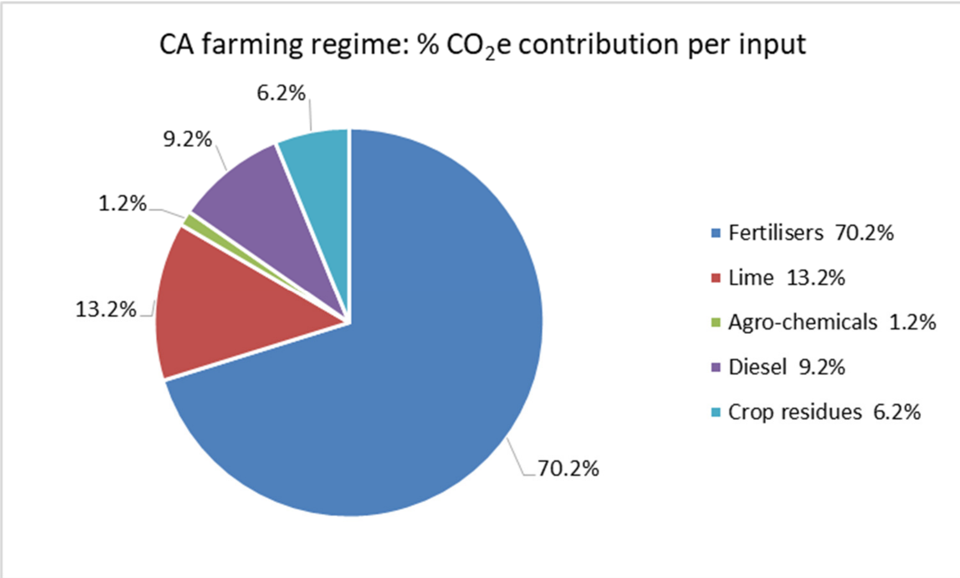
| Region | Regime | Commodity | Yield per hectare | Direct fuel- Diesel [L] | | | Fertilisers [kg] | | | | | | Agro-chemicals | | | Crop residues | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Total fresh tonnage | Farming activities | Delivery to silo | Farm management | Nitrogen | Phosphorus | Potassium | Calciltic Lime | Dolomitic Lime | Gypsum Lime | Fungicides | Insecticides | Herbicides | Dry matter per ha [kg] | % total area burnt | % residues removed |
| Overberg - Eastern Rûens | CT | Wheat | 2.7 | 52.6 | 3.6 | 2.5 | 40 | 12 | | 500 | | | 0.30 | 0.25 | 0.36 | 2403 | 1% | 70% |
| Overberg - Eastern Rûens | CA | Wheat | 2.7 | 38.6 | 3.6 | 2.5 | 40 | 12 | | 500 | | 500 | 0.30 | 0.25 | 4.10 | 2403 | 1% | 70% |
| Overberg - Eastern Rûens | CA | Barley | 2.8 | 38.6 | 3.7 | 0.8 | 40 | 12 | | 0 | | 500 | 0.48 | 0.01 | 4.83 | 2492 | 1% | 70% |
| Overberg - Eastern Rûens | CA | Canola | 1.5 | 39.1 | 2.0 | 0.3 | 55 | 12 | | 0 | | 500 | 0.16 | 0.78 | 4.76 | 1365 | - | - |
| Overberg - Eastern Rûens | Future CA | Wheat | 3.0 | 19.3 | 3.6 | 2.5 | 20 | 6 | | 500 | | 500 | 0.15 | 0.10 | 2.05 | 2643 | 0% | 30% |
| Overberg - Eastern Rûens | Future CA | Barley | 3.1 | 19.3 | 3.7 | 0.8 | 20 | 6 | | 0 | | 500 | 0.24 | 0.00 | 2.42 | 2741 | 0% | 30% |
| Overberg - Eastern Rûens | Future CA | Canola | 1.7 | 19.6 | 2.0 | 0.3 | 28 | 6 | | 0 | | 500 | 0.08 | 0.31 | 2.38 | 1502 | 0% | 30% |
| Overberg - Southern Rûens | CT | Wheat | 2.8 | 60.3 | 4.05 | 2.64 | 70 | 25 | 7 | 400 | | | 0.37 | 0.34 | 0.52 | 2492 | 1% | 70% |
| Overberg - Southern Rûens | CA | Wheat | 2.9 | 40.9 | 4.1 | 3.0 | 60 | 20 | 5 | 400 | | 500 | 0.37 | 0.54 | 3.19 | 2572 | 1% | 60% |
| Overberg - Southern Rûens | CA | Barley | 2.8 | 40.9 | 4.1 | 1.0 | 54 | 20 | 5 | 400 | | 500 | 0.65 | 0.17 | 3.19 | 2492 | 1% | 60% |
| Overberg - Southern Rûens | CA | Canola | 1.5 | 37.7 | 2.2 | 0.3 | 64 | 20 | 5 | 400 | | 500 | 0.16 | 0.53 | 3.01 | 1365 | 0% | 0% |
| Overberg - Southern Rûens | Future CA | Wheat | 3.2 | 20.4 | 4.1 | 3.0 | 30 | 10 | 3 | 400 | | 500 | 0.19 | 0.22 | 1.59 | 2829.31 | - | 30% |
| Overberg - Southern Rûens | Future CA | Barley | 3.1 | 20.4 | 4.1 | 1.0 | 27 | 10 | 3 | 400 | | 500 | 0.33 | 0.07 | 1.59 | 2741.2 | - | 30% |
| Overberg - Southern Rûens | Future CA | Canola | 1.7 | 18.9 | 2.2 | 0.3 | 32 | 10 | 3 | 400 | | 500 | 0.08 | 0.21 | 1.51 | 1501.5 | - | 30% |
| Overberg - Western Rûens | CT | Wheat | 3.0 | 58.2 | 5.5 | 2.6 | 96 | 22 | 8 | 400 | | | 0.51 | 0.58 | 0.70 | 2670 | 1% | 70% |
| Overberg - Western Rûens | CA | Wheat | 3.0 | 42.9 | 5.5 | 2.6 | 96 | 22.4 | 8 | 400 | | 500 | 0.51 | 0.80 | 2.32 | 2670 | 1% | 60% |
| Overberg - Western Rûens | CA | Barley | 3.0 | 42.9 | 5.5 | 0.9 | 88 | 22.4 | 7.2 | 400 | | 500 | 0.42 | 0.55 | 2.51 | 2670 | 1% | 60% |
| Overberg - Western Rûens | CA | Canola | 1.6 | 41.1 | 5.5 | 0.3 | 86 | 17 | 7 | 400 | | 500 | 0.23 | 1.18 | 2.65 | 1456 | 0% | 0% |
| Overberg - Western Rûens | Future CA | Wheat | 3.3 | 21.5 | 5.5 | 2.6 | 48 | 11.2 | 4 | 400 | | 500 | 0.26 | 0.32 | 1.16 | 2937 | - | 30% |
| Overberg - Western Rûens | Future CA | Barley | 3.3 | 21.5 | 5.5 | 0.9 | 44 | 11.2 | 3.6 | 400 | | 500 | 0.21 | 0.22 | 1.25 | 2937 | - | 30% |
| Overberg - Western Rûens | Future CA | Canola | 1.8 | 20.6 | 5.5 | 0.3 | 43 | 8.5 | 3.5 | 400 | | 500 | 0.11 | 0.47 | 1.32 | 1601.6 | - | 30% |
| Swartland - Darling/Hopefield | CT | Wheat | 2.4 | 38.4 | 2.6 | 1.7 | 80 | 12 | 6 | 140 | 120 | 20 | 0.26 | 0.25 | 0.80 | 2091.5 | 60% | 80% |
| Swartland - Darling/Hopefield | CA | Wheat | 2.4 | 30.0 | 2.0 | 1.0 | 80 | 12 | 6 | 140 | 120 | 20 | 0.26 | 0.25 | 0.91 | 2091.5 | 60% | 80% |
| Swartland - Darling/Hopefield | CA | Medics | - | 13.2 | 0.9 | 0.3 | 5 | 10 | - | 200 | 100 | 35 | 0.00 | 0.20 | 1.49 | - | - | 60% |
| Swartland - Darling/Hopefield | CA | Lupins | 1.4 | 26.7 | 1.8 | 0.1 | 5 | 10 | - | 140 | 120 | 20 | 0.23 | 0.25 | 1.80 | - | - | 30% |
| Swartland - Darling/Hopefield | Future CA | Wheat | 3.3 | 36.1 | 2.2 | 1.1 | 40 | 6 | 3 | 140 | 120 | 20 | 0.21 | 0.10 | 0.51 | 2937 | - | 30% |
| Swartland - Darling/Hopefield | Future CA | Medics | - | 28.0 | 0.9 | 0.4 | 2.5 | 5 | - | 200 | 100 | 35 | - | 0.08 | 0.75 | | - | 30% |
| Swartland - Darling/Hopefield | Future CA | Canola | 1.6 | 10.0 | 1.9 | 0.1 | 2.5 | 5 | - | 140 | 120 | 20 | - | 0.09 | 1.28 | 1451.5 | - | 30% |
| Swartland - Middle Swartland | CT | Wheat | 3 | 38.4 | 2.6 | 1.7 | 95 | 14 | 8 | 200 | 100 | 35 | 0.33 | 0.25 | 0.80 | 2670 | 40% | 80% |
| Swartland - Middle Swartland | CA | Wheat | 3 | 32 | 2.2 | 1 | 95 | 14 | 8 | 200 | 100 | 35 | 0.33 | 0.25 | 1.02 | 2670 | 40% | 80% |
| Swartland - Middle Swartland | CA | Medics | - | 13.2 | 1.0 | 0.5 | 5 | 10 | - | 200 | 100 | 35 | - | 0.20 | 1.49 | - | - | 80% |
| Swartland - Middle Swartland | Future CA | Wheat | 3.0 | 19.3 | 3.6 | 2.5 | 20 | 6 | | 500 | | 500 | 0.15 | 0.10 | 2.05 | 2643.3 | - | 30% |
| Swartland - Middle Swartland | Future CA | Barley | 3.1 | 19.3 | 3.7 | 0.8 | 20 | 6 | | - | | 500 | 0.24 | 0.00 | 2.42 | 2741.2 | - | 30% |
| Swartland - Middle Swartland | Future CA | Canola | 1.7 | 19.6 | 2.0 | 0.3 | 27.5 | 6 | | - | | 500 | 0.08 | 0.31 | 2.38 | 1501.5 | - | 30% |
| Swartland - Northern Regions | CT | Wheat | 2.2 | 38.4 | 2.6 | 1.7 | 60 | 10 | 4 | 100 | 170 | 30 | 0.26 | 0.25 | 0.80 | 1913.5 | 30% | 80% |
| Swartland - Northern Regions | CA | Wheat | 2.2 | 32.0 | 2.2 | 1.0 | 60 | 10 | 4 | 100 | 170 | 30 | 0.26 | 0.25 | 0.12 | 1913.5 | 30% | 80% |
| Swartland - Northern Regions | CA | Medics | - | 13.2 | 1.0 | 0.5 | 5 | 10 | - | 200 | 100 | 35 | - | 0.20 | 1.49 | - | - | 70% |
| Swartland - Northern Regions | Future CA | Wheat | 2.4 | 16.0 | 2.2 | 1.0 | 30 | 5 | 2 | 100 | 170 | 30 | 0.13 | 0.10 | 0.06 | 2104.9 | - | 0.3 |
| Swartland - Northern Regions | Future CA | Medics | - | 6.6 | 1.0 | 0.5 | 3 | 5 | - | 200 | 100 | 35 | 0.00 | 0.08 | 0.75 | - | - | - |
| Swartland - Southern Swartland | CT | Wheat | 3.3 | 38.4 | 2.6 | 1.7 | 105 | 16 | 10 | 250 | 100 | 50 | 0.42 | 0.25 | 0.80 | 2937 | 50% | 80% |
| Swartland - Southern Swartland | CA | Wheat | 3.3 | 33 | 2.2 | 1.1 | 105 | 16 | 10 | 250 | 100 | 50 | 0.42 | 0.25 | 1.02 | 2670 | 50% | 80% |
| Swartland - Southern Swartland | CA | Medics | - | 13.2 | 0.9 | 0.37 | 5 | 10 | - | 200 | 100 | 35 | - | 0.20 | 1.49 | - | - | 80% |
| Swartland - Southern Swartland | CA | Canola | 1.45 | 27.9 | 1.9 | 0.12 | 90 | 16 | 10 | 250 | 100 | 50 | - | 0.23 | 2.57 | 1319.5 | - | 30% |
| Swartland - Southern Swartland | Future CA | Wheat | 3.3 | 16.5 | 2.2 | 1.1 | 52.5 | 8 | 5 | 250 | 100 | 50 | 0.21 | 0.10 | 0.51 | 2937 | - | 30% |
| Swartland - Southern Swartland | Future CA | Medics | - | 6.6 | 0.9 | 0.4 | 2.5 | 5 | - | 200 | 100 | 35 | - | 0.08 | 0.75 | - | - | 30% |
| Swartland - Southern Swartland | Future CA | Canola | 1.595 | 14.0 | 1.9 | 0.1 | 45 | 8 | 5 | 250 | 100 | 50 | - | 0.09 | 1.28 | 1451.45 | - | 30% |

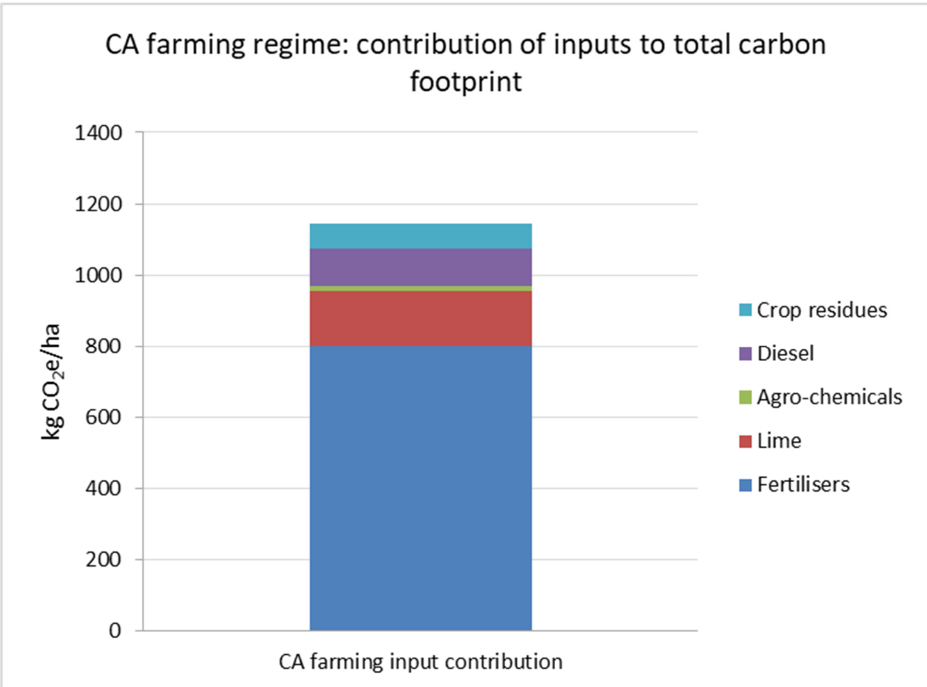
## Appendix 2: Carbon footprint profile per hectare for conventional farming regime.



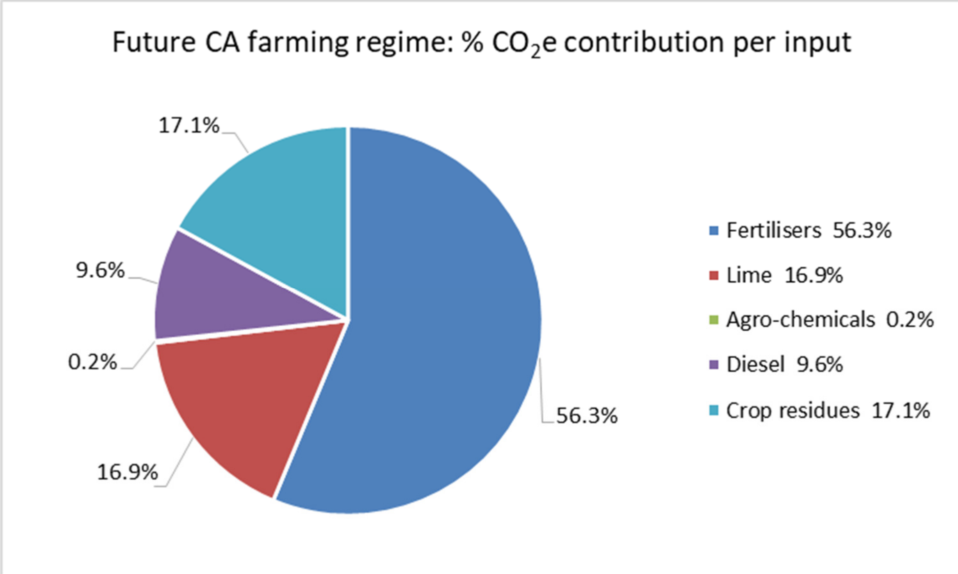



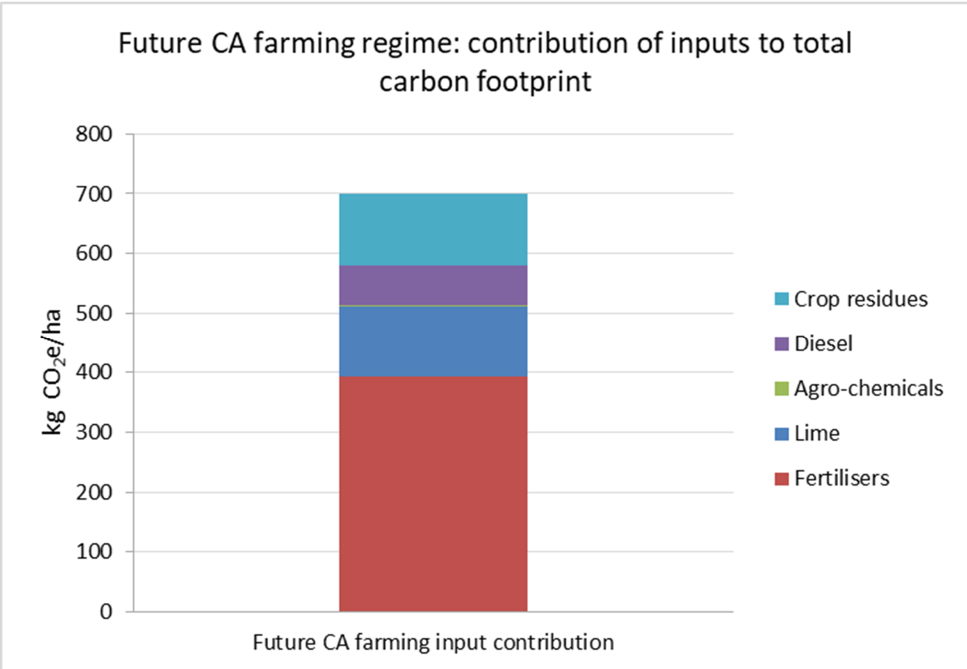
## Appendix 3: Carbon footprint profile per hectare for CA farming regime.



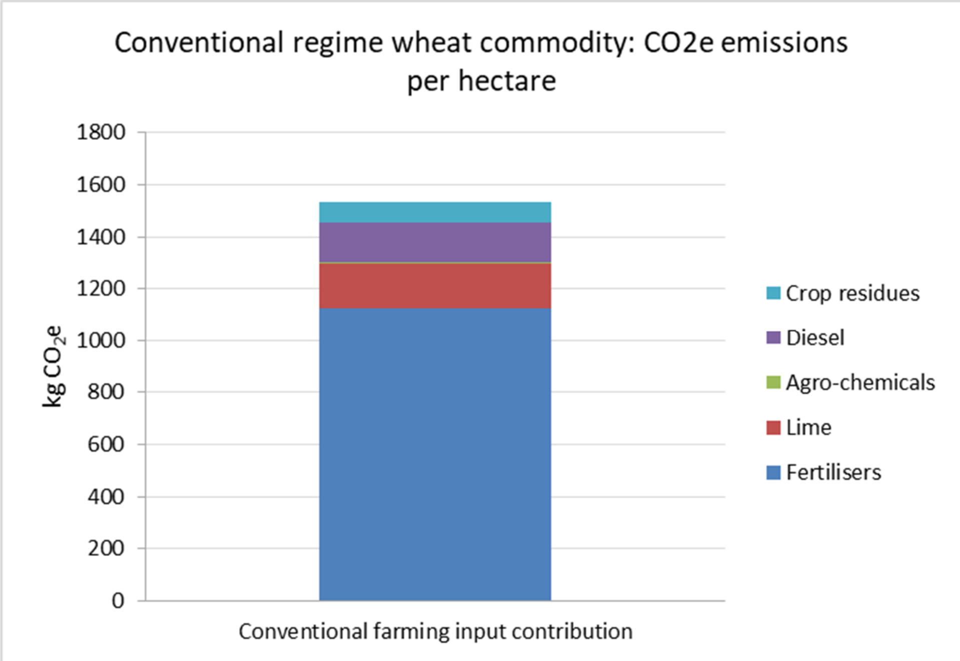



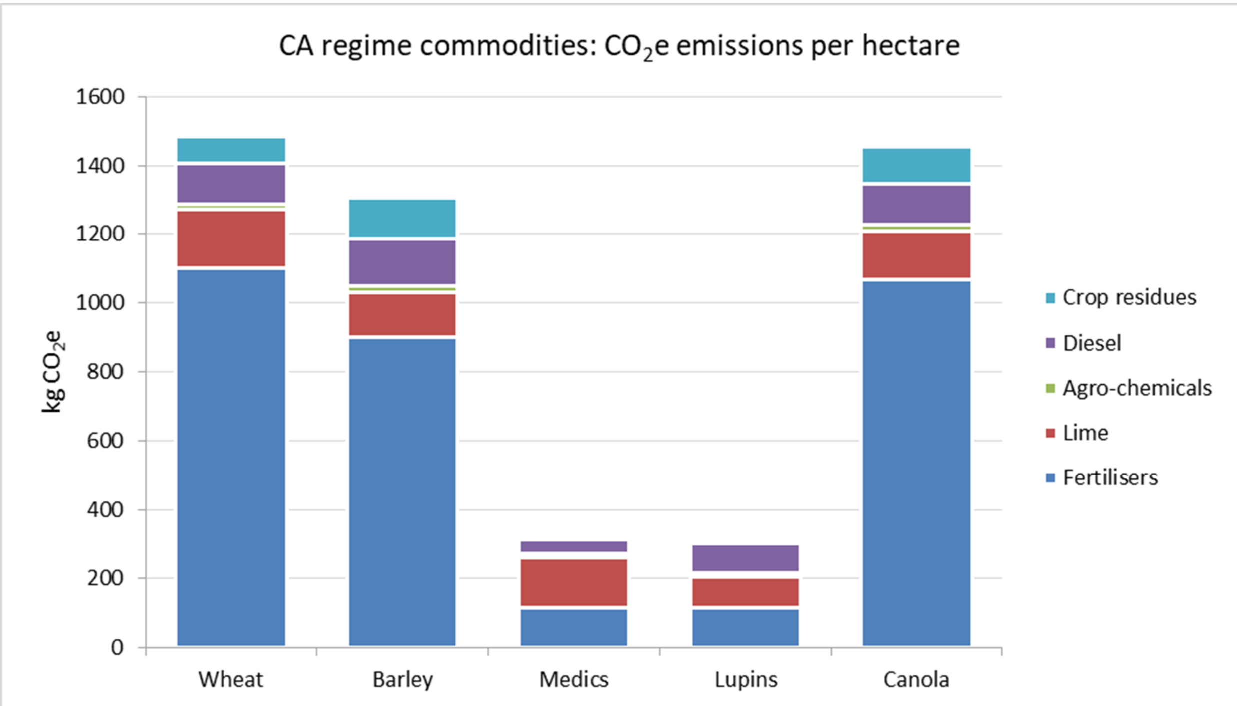
## Appendix 4: Carbon footprint profile per hectare for Future CA farming regime.

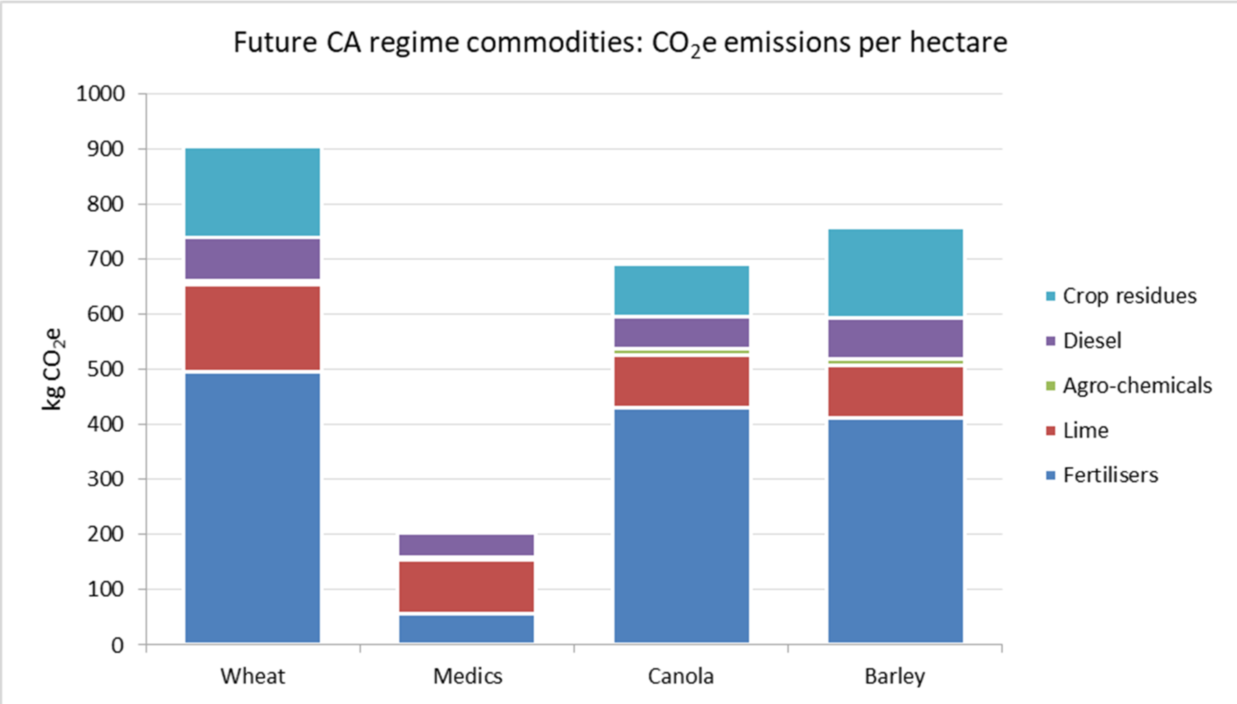


## Appendix 5: CO2e emissions per commodity per hectare for each farming regime





Future CA regime commodities: CO2e emissions per hectare
kg CO2e
1000
900
800
700
600
500
400
300
200
100
0
Wheat
Medics
Canola
Barley
Crop residues
Diesel
Agro-chemicals
Lime
Fertilisers

## Appendix 6: Farm localities sampled per region.

**SOUTHERN CAPE**

| REGION | FARMERS' NAME - CA | FARMERS' NAME - CT | PROGRESS / COMMENTS |
|---|---|---|---|
| ***Western region*** | **JURIE GROENEWALD**<br>E-mail: juriewg@gmail.com<br>Cell: 072 299 4512<br>Area : Riviersonderend | **PAUL NEETHLING**<br>E-mail:<br>Cell : 082 473 3721<br>Area : Caledon | All 6 farmers' were sampled by end of June 2017. |
| ***Southern region*** | **JOSE DE KOCK**<br>E-mail: josedekock@gmail.com<br>Cell : 082 572 0109<br>Area : Napier | **SENSAKO TRIAL SITE**<br>Area : Napier | |
| ***Eastern region*** | **NICO UYS**<br>E-mail: nu@vodamail.co.za<br>Cell : 082 577 2502<br>Area : Heidelberg | **ALFRED RADEMAN**<br>E-mail:<br>Cell : 082 625 5933<br>Area: Heidelberg, Nuwerus farm<br>Stubble mulch with light tillage | |

**SWARTLAND**

| **REGION** | **FARMERS' NAME - CA** | **FARMERS' NAME - CT** | **PROGRESS / COMMENTS** |
|---|---|---|---|
| ***Northern region*** | **KASSIE ROSSOUW**<br>0823163210<br>Wheat fallow<br>GPS: S 32 34 / E 18 51 | **HERMAN ROSSOUW**<br>E-mail:<br>Cell : 082 523 9898<br>Area : Eendekuil,<br>Plaas: Meerlandsvlei | Both Herman and Cassie Rossouw were sampled on the 21st of June and awaiting their completed questionnaire.<br>Drone images were done their fields and will be imaged in due course. |
| ***Middle Swartland*** | **FRIKKIE THERON**<br>E-mail: frikkietheron@soutkloof.co.za<br>Cell : 072 104 3457<br>Area : Moorreesburg | **GERT CLAASSEN**<br>E-mail: gert@claassenboerdery.co.za<br>Cell : 082 524 9003<br>Area : Malmesbury<br>(Tillage) | Frikkie Theron and Gert Claassen were sampled on 27th June 2017. |
| ***Darling*** | **JURIANNE SCHREUDER**<br>E-mail: theebo94@gmail.com<br>Cell : 082 829 6901<br>Area : Hopefield | **ANDRE KIRSTEN**<br>E-mail: andre@kirstenbdy.co.za<br>Cell: 0832268749<br>Area: Darling | Jurianne Schreuder was sampled on the 5th of June.<br>Andre Kirsten was sampled in October 2017. |
| ***Southern Swartland*** | **KOOS BLANCKENBERG**<br>E-mail: koos@jhblanck.co.za<br>Cell : 083 303 3590<br>Area : Durbanville | **HENNIE EKSTEEN**<br>E-mail :<br>Cell : 083 658 2646<br>Area : Durbanville<br>Practice: fire, wheat monoculture | Soil samples were taken from the above two farms' allocated lands on the 26th of May 2017. |