Developing a Suitable Carbon Calculator for Smallholder Mixed Farming Systems in Western Cape, South Africa

by
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Declaration

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Date: …March 2016.

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Abstract

With growing concerns about climate change, the measurement and monitoring of environmental impact has become a key priority. According to the World Bank, South Africa is among the top 20 global carbon dioxide emitters; and agricultural is one of the primary greenhouse gas polluters. The sector contributed approximately 21 289 tCO_2 in 2000.

Climate change, in turn, has had an adverse effect on agriculture by decreasing crop yields, creating food and water security concerns and decreasing sustainable agricultural land. Not only do farmers have to adapt to adverse climate conditions, but they also are expected to adhere to stringent retailer standards that often require them to measure their products' greenhouse gas emissions. This therefore has led to the formulation of product carbon footprinting standards (PCFs), which are required for compliance by new markets on a yearly basis. The stringent retail standards flowed from the Kyoto Protocol which was established under the United Nations Framework Convention on Climate Change (UNFCCC) to set targets for reducing or limiting emissions over the period of 2008 to 2020. South Africa committed to the protocol and as such has to contribute towards global greenhouse gas (GHG) migration efforts. Under the Copenhagen Accord South Africa also pledged an emission reduction of 34% below business as usual by 2020 and 42% by 2025.

A carbon footprint measures the total carbon dioxide (CO_2) emissions that are being released into the atmosphere by an organisation, event, product or person on an annual basis. The carbon footprint can be calculated by using online carbon calculators, or by making use of carbon consultants, who generally are expensive. Several online carbon footprinting calculators are available, but they do not accommodate smallholder mixed farming systems. This study evaluates the available farming carbon calculators, highlights their limitations and identifies the needs of a smallholder mixed farming carbon calculator for South Africa, which will facilitate compliance with environmental standards, domestic food markets and to help create awareness of the emissions and resource use of smallholder farmers.

This study thus provides the background for the development of a carbon calculator tool for mixed smallholder farming systems. The factors that were looked at were fuel and electricity usage, agro-chemicals, land-use changes, livestock, crops, processing and packhouse information, packaging, waste, cold storage information and distance travelled. The anticipated advantage of the tool is to equip smallholder farmers for the indirect effects of phase one of the anticipated carbon tax by providing them with the information needed to plan for more efficient farming activities as well as reducing input cots. An added benefit of the information gained from this calculator is that it is expected to assist smallholder farmers in identifying factors that are prohibiting them from complying with the larger retailer 'green' standards. Due to the limitations of the study a sample was taken from the Western Cape Department of Agriculture's SimFini project, the project was

selected as it provided an excellent example of proper financial recording keeping which is often lacking for smallholder farmers. The study also provides a profile of smallholder farmers in the Western Cape (WC). The sampled participants were used only to test the calculator's success and the shortcomings of the recordkeeping system. The results from the calculator could further be used to assist smallholder farmers to identify their farm's major emission sources, which if reduced could decrease their production costs and increase their retailer compliance.

The main findings of the study are:

- That although farmers have financial records in place, the operation records are not being kept; and
- Enteric fermentation, agro-chemicals (which includes fertiliser), mobile fuels and electricity were the biggest emitters.

Opsomming

Met toenemende kommer oor klimaatverandering het die meet en monitor van omgewingsimpakte 'n belangrike prioriteit geword. Suid-Afrika ervaar tans talle uitdagings, onder andere met betrekking tot klimaatverandering, voedselsekuriteit en grondhervorming. Volgens die Wêreldbank is Suid-Afrika onder die top 20 lande wat die meeste koolstofdioksied (CO_2) vrystel, waarvan die landbousektor een van die vernaamste kweekhuisgasbesoedelaars is, met 'n bydrae van 21 289t CO_2 in 2000.

Klimaatverandering, op sy beurt, het 'n nadelige effek op landbou deur opbrengste te verminder, voedsel- en watersekuriteit te bedreig en volhoubare landbougrond te verminder. Boere moet nie net by hierdie omstandighede aanpas nie, maar daar word ook van hulle verwag om streng handelaarstandaarde na te kom, wat gereeld van hulle vereis om die kweekhuisgasvrystellings van hulle produkte te meet. Hierdie het gevolglik gelei na die formulering van die "*product carbon footprinting (PCF)"* standaarde, wat op 'n jaarlikse basis deur nuwe markte nagekom moet word. Die streng handelstandaarde kom vanaf die Kyoto-protokol wat gestig is onder die Verenigde Nasies se raamwerkkonvensie oor klimaatsverandering. Die Kyoto-protokol is gestig om doelwitte te stel vir die vermindering van uitlaatgasse oor die tydperk vanaf 2008 tot 2020. Suid-Afrika is toegewyd aan hierdie protokol en behoort dus deel te neem aan pogings om globale groenhuisgasse te migreer deur mitigasiemaatreëls in plek te stel . Onder die Copenhagen Ooreenkoms het Suid-Afrika ook beloof om uitlaatgasse met 34% te verminder teen 2020 en 'n beoogde vermindering van 42% teen 2025.

'n Koolstofvoetspoor meet die totale CO_2-vrystelling van 'n organisasie, gebeurtenis, produk of persoon op 'n jaarlikse basis. Dit kan bereken word deur gebruik te maak van aanlyn-koolstofvoetspoorrekenaars of van konsultante, wat oor die algemeen duur is. Daar is baie sulke aanlynrekenaars beskikbaar, maar almal vereis internettoegang en akkommodeer ook nie gemengde kleinboerderystelsels nie. Hierdie studie evalueer die beskikbare aanlyn-koolstofvoetspoorrekenaars vir boerderye deur te fokus op hulle perke en om te identifiseer wat van so 'n rekenaar benodig word, spesifiek vir die unieke gemengde kleinboerderystelsel in Suid-Afrika. Hierdie identifikasieproses kyk na benodighede wat nakoming van omgewingstandaarde en plaaslike voedselmarkte sal fasiliteer en bewusmaking sal help skep oor die besoedeling en hulpbrongebruik van kleinboere.

Die studie verskaf dus die agtergrond vir die ontwikkeling van 'n koolstofvoetspoor vir gemengde kleinboerstelsels. Die faktore waarna gekyk word, is brandstof- en elektrisiteitverbruik, landbou-chemikalieë, verandering van grondgebruik, vee, gewasse, verwerking, pakhuis-inligting, verpakking, afval, koelkamers en afstand gereis. Die verwagte voordeel is dat dit kleinboere sal toerus met die inligting wat benodig word vir die indirekte effekte van die eerste fase van die koolstofbelasting en sodat hulle meer effektiewe boerdery aktiwiteite kan beplan en ook

insetkostes kan verminder. ’n Bykomende voordeel van die inligting wat verkry word, is die verwagting dat dit die kleinboere kan help om faktore wat hulle verhoed om groter handelaars se ‘groen’ standaarde na te kom, te identifiseer.

As gevolg van die aard van die studie en die hoeveelheid kleinboere in die Wes-Kaap het die voorafgekose deelnemers almal die kleinboerderygemeenskap in die Wes-Kaap verteenwoordig. Die studie gee ook ‘n profiel van kleinboere in die Wes-Kaap. Die deelnemers is slegs gebruik om die sukses en die tekortkominge van die optekeningstelsel te toets. Die resultate van die studie kan dan gebruik word om kleinboere te help om hulle plase se kritiese probleemareas te identifiseer en sodoende hulle koolstof vrystellings en moontlik hul produksiekostes te verminder.

Die hoof bevindinge van die studie is:

- Alhoewel boere finansiële verslae in plek het, ontbreek die operasionele verslae nog steeds; en
- Die grootste besoedelaars was enteriese fermentasie, landbou-chemikalieë (wat kunsmis insluit), mobiele brandstof en elektrisiteit.

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List of Acronyms and Abbreviations

ADAS	Agricultural and Environmental Consultancy
ASDA	Associated Dairies; the abbreviation for the merging of Asquith and Dairies
BRC	British Retail Consortium
BSCI	Business Social Compliance Initiative
BSI	British Standards Institution
CAC	Codex Alimentarius Commission
CASP	Comprehensive Agricultural Support Programme
CCC	Confronting Climate Change
CDP	Carbon Disclosure Project
CH_4	Methane
CO_2	Carbon Dioxide
COP	Conference of the Parties
CPAC	Commodity Project Allocation Committee
DAFF	Department of Agriculture, Forestry and Fisheries
DDP	Dry and Dried Produce
DEFRA	Department of Environment Food and Rural Affairs
ESG	Environmental, Social and Corporate Governance
ETI	Ethical Trade Initiative
EU	European Union
FLO	Fairtrade Labelling Organisation
FSD	Farmer Support and Development
FSSC	Food Safety Security Certification
FVO	Food and Veterinary Office
GDP	Gross Domestic Product
Gg CO_2-eq	Total Greenhouse Gas Emissions
GHG	Greenhouse Gas
Global GAP	Global Good Agricultural Practices
GM	Genetically Modified
GNP	Gross National Product
GoM	Guidelines of Modelling
GRI	Global Reporting Initiative
GWP	Global Warming Potential
GWSESP	Global Wine Sector Environmental Sustainability Principles
HACCP	Hazard Analysis and Critical Control Points
HFCs	Hydrofluorocarbons

IB	International Baccalaureate
ICM	Integrated Crop Management
IFOAM	International Federation of Organic Agriculture Movements
IFS	International Featured Standard
IO	Input-Output
IOMs	Input–Output Models
IPC	Integrated Pest Control
IPL	International Procurement and Logistics
IPM	Integrated Pest Management
IPW	Integrated Production of Wine Scheme
ISO	International Organisation for Standardisation
JSE	Johannesburg Stock Exchange
LCA	Life Cycle Assessment
LEAF	Linking Environment and Farming
M&S	Marks & Spencer
MAFISA	Micro-agricultural Financial Institutions of South Africa
N_2O	Nitrous Oxide
NAFTA	North American Free Trade Agreement
NDP	National Development Plan
NERPO	National Emerging Red Meat Producers' Organisation
NF_3	Nitrogen Trifluoride
NGOs	Non-Governmental Organisations
NO	National Outcome
OECD	Organisation for Economic Co-operation and Development
OHSAS	Occupational Health and Safety Management Systems
PACE	Promoting Access to Carbon Equity
PAS	Publicly Available Specification
PFCs	Perfluorocarbons
PPECB	Perishable Products Export Control Board
PSG	Provincial Strategic Goal
QMS	Quality Management System
QS	Quality Systems
RPO	Red Meat Producers' Organisation
SA	Social Accountability
SA	South Africa
SAATCA	Southern African Auditor and Training Certification Authority
SADC	Southern African Development Community
SAGAP	South African Good Agricultural Practices

SAN	Sustainable Agricultural Network
SAPA	South African Poultry Association
SEDEX	Supplier Ethical Data Exchange
SEQUAL	Semiotic Quality
SF_6	Sulphur Hexafluoride
SQF	Safe Quality Food
tCO_2e	Carbon Dioxide Equivalent
TNC	Tesco Nature's Choice
TQM	Total Quality Management
UK	United Kingdom
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
UTZ	It's a Dutch word meaning "good coffee"
WBCSD	World Business Council for Sustainable Development
WC	Western Cape
WCDoA	Western Cape Department of Agriculture
WMS	Workflow Management System
WRI	World Resource Institute
WHO	World Health Organization
WO	Wine of Origin
WSB	Wine and Spirits Board
WTO	World Trade Organization
WWF	World Wildlife Fund

Chapter 1: Introduction

1.1. Climate change

South Africa and the world are facing numerous environmental challenges many of which are related to climate change as well as water and air pollution (Partridge et al., 2014). According to United Nations Framework Convention on Climate Change (UNFCCC) Climate changes can be defined as "A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" (Bizikova et al., 2009).

The biophysical impacts of climate change include changes in global atmospheric temperatures, changes in sea levels, changes in sea temperatures, melting glaciers, ice sheets and permafrost, extinction of species and the removal of natural carbon reservoirs (Terra Firma Academy, 2013). Climate change not only has biophysical impacts but also social and economic impacts which include migration of people and animals, changes in world trade, global transport, legislation and protocol, food and water security, increase in poverty and adverse changes in agriculture (Terra Firma Academy, 2013). The agricultural sector is primarily vulnerable to the effects of climate change, according to Partridge et al. (2014). Some of these effects include reduced sustainable agricultural land, reduced crop yields, decreased rainfall results in increased demand for water and increased rainfall can result in soil erosion (Terra Firma Academy, 2013). The above factors could all potentially lead to a strain on food security and the economy (Partridge et al., 2014).

Climate change can be described as an example of the *"Tragedy of the Commons"* problem, where a resource is shared between a group of people (shared ownership) or they have free access to it, and the "problem of self-interest" starts to exist and causes the exploitation of specific resources because individuals try to gain full benefit of the resource, not realising the effect of their combined actions (Hardin, 1968:1244). Elinor Ostrom (2009) explained this concept further and came to the conclusion that climate change can be seen as a "global public good" in which millions of actors play a role. All of these actors will benefit from a reduction in greenhouse gas (GHG) emissions, whether or not they pay for any of the cost, because no one can be excluded from benefiting from clean air, thus the social dilemma is a result of the misalignment of individual rationality and optimal group outcomes (Ostrom, 2009). Polluters are most of the time not held accountable for the cost of the pollution and the cost of the bad decision is endure by society (Partridge et al. 2014).

1.2. Global commitments

Climate change has become an important topic on global agendas as the world is trying to mitigate and adapt to the effects of climate change by implementing certain policies. Under the UNFCCC, the Kyoto Protocol was established to set targets for reducing or limiting emissions over the period from 2008 to 2020. South Africa committed to the protocol as a non-annex country and, as such, is required to try to contribute towards global GHG mitigation efforts. Under the Convention 154 countries signed as a non-annex 1 country, while 43 countries signed as an annex 1 country (UNFCCC, 2014). The Convention also established the Congress of the Parties (COP) as it governing body with the purpose of advancing the implementation of the Convention by means of the decisions taken at the biannual COP meetings. Under the Copenhagen Accord (established at the COP 15), South Africa has pledged an emission reduction of 34% below business as usual by 2020, and 42% by 2025 (Partridge et al., 2014). COP 21 was held in Paris, France on the 30th November till the 11th December 2015 and nations had to vote on a new carbon emission reduction agreement as well as pledge their contribution to decreasing their emissions (Climate Action, 2014; UNFCCC, 2015). The agreement that was reached, stipulated the implementation of the Convention, which aims to strengthen the global response to the tread of climate change by addressing the issue through sustainable development and efforts to eradicate poverty. The key points being looked at for this agreement are:

- Holding the average global temperature increase below 2 °C for pre-industrial levels and to follow efforts that will limit the increase to 1.5 °C above pre-industrial levels. This is believed to reduce the risk and impact of climate change significantly;
- To foster climate resilience and low GHG emissions development and to increase the ability to adopt to adverse impacts of climate change in such a manner that food production is not negatively affected; and
- To make finance flow consistent with a pathway towards climate resilient development and low GHG emissions (UNFCCC, 2015).

1.3. South Africa's emissions

South Africa is ranked amongst the top global carbon dioxide emitters, with the major greenhouse gas polluters being the energy sector (78.9%), the industrial processes and product use sector (14.1%), the agricultural sector (4.9%) and the waste sector (2.1%) (DEA, 2009). South Africa's emissions are continuing to increase at an alarming rate and, in the past half century, have increased at a similar rate to the global aggregate, which in itself continues to grow (Partridge et al., 2014). This can be seen in figure 1.1 below where the annual CO_2 emissions for South Africa and the world are illustrated:

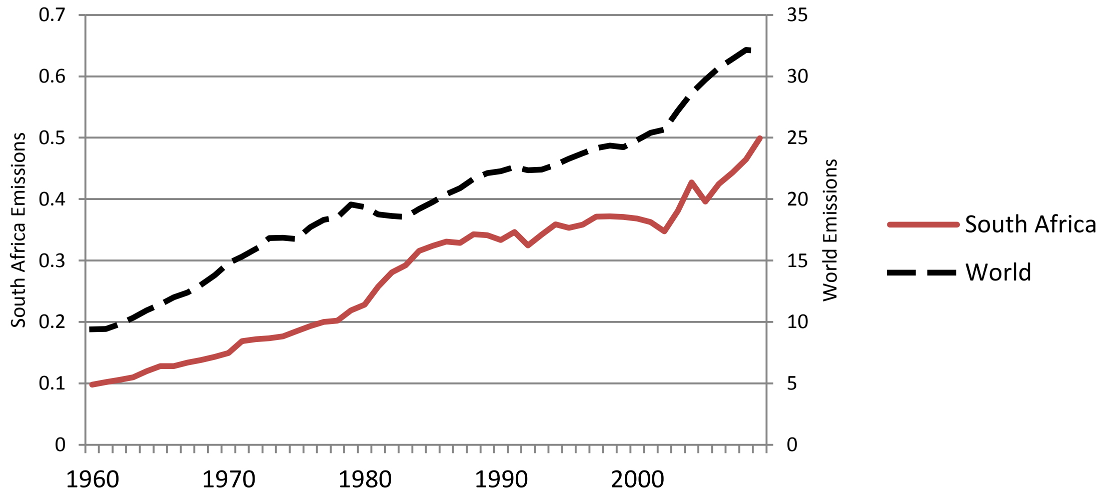


Figure 1.1: Annual CO_2 emissions, South Africa and the world, 1960-2009 (billion tons) (Source: World Bank, 2015)

Table 1.1: South Africa's CO_2 emission growth rate percentage compared with the world's CO_2 emission aggregate growth rate percentage

		1970	1980	1990	2000	2009
World	**% Growth Aggregate Rate**	36%	24%	13%	10%	23%
South Africa	**% Growth Aggregate Rate**	35%	34%	32%	10%	26%

Source: World Bank, 2015

Table 1.1 gives a summary of the World's CO_2 emission aggregate growth rate percentage compared with that of South Africa. In 1970 South Africa's emissions were approximately 1% lower than the world's aggregate growth rate percentage. In 1980 and 1990 however, South Africa's emission growth rate were much higher than the world's aggregate growth rate percentage, with 10% and 19% respectively. This therefore illustrates the urgent need for South Africa to reduce its emissions.

1.4. South Africa's political commitments

According to the South African Constitution (Constitutional Law, 1996), section 24:

> "Everyone *has the right:*
>
> *(a) to an environment that is not harmful to their health or well-being;*
>
> *(b) to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures*
>
> *that:*
>
> *(i) prevent pollution and ecological degradation;*
>
> *(ii) promote conservation; and*
>
> *(iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.*"

The above stipulates the motivation for the South African National Climate Change Response White Paper that was published in 2011, which presents the vision for an effective climate change response and the long-term transition to a climate-resilient, lower carbon economy and society (SANBI, 2011). The long-term plan is to set a performance benchmark, define carbon budgets, mitigation plans, use the market, and monitor and evaluate, while the medium term focuses on the introduction of energy efficiency in buildings and transportation, carbon capture and storage for mitigating non-energy emissions in agriculture, sustainable consumption, etc. (Partridge et al., 2014).

The White Paper further links with National Outcome (NO) 10, which addresses protecting and enhancing environmental assets and natural resources. Sub-outcomes 2 and 3 flow from NO 10, further focuses on an effective climate change mitigation and adaption response and also on an environmentally sustainable, low-carbon economy resulting from a well-managed, just transition. Chapter 5 of the National Development Plan (NDP) also considers environmental sustainability and equitable transition to a low-carbon economy. The plan looks at means to establish a balanced approached for a less energy- and carbon-intensive economy, but while still take advantage of the country's mineral resources (National Planning Commission, 2011).

A carbon tax has also been proposed by the Treasury to combat South Africa's GHG emissions and will be implemented gradually from 2016 to 2021 (Partridge et al., 2014). According to the National Treasury (2014), the intention of implementing the tax is to incentivise businesses to do business in a more environmentally friendly way. The carbon tax will have a direct impact on firms, as it will create an additional financial burden on businesses and, because it will be applied at national level sectors, it also will have indirect impacts on the prices of production inputs, like electricity and fuel for example, that which will lead to higher product and service prices (Partridge et al., 2014). Even though phase one does not have any direct implications for agriculture, phase two is expected to include agriculture. All of the above initiatives illustrate South Africa's continued commitment to reduce carbon emissions.

1.5. Climate change concerns for agriculture

Agriculture accounts for 4.9% of South Africa's emissions (21 289 total greenhouse gas emissions [Gg CO_2-eq]), of which the main sources are enteric fermentation, manure management, forest land, cropland, wetlands, biomass burning, and indirect nitrous oxide (N_2O) emissions from managed soils (Partridge et al., 2014). Agriculture is not only a contributor to climate change, but in some cases also a casualty, as climate change has resulted in crop distribution changes (summer and winter season crops), and increases in the abundance of alien vegetation and pests. The warmer conditions generally associated with climate change are also leading to soil moisture decline, which increase the need for agricultural irrigation and puts direct strain on the country's scarce water resources (Partridge et al., 2014; Terra Firma Academy, 2013). In addition, both smallholder and commercial farmers already face challenges of a shortage in productive land and limited water for agricultural purposes, as well as market pressure (Mnkeni & Mutengwa, 2013). Despite the fact that agriculture is burdened with the above factors, it also is a significant contributor to the country's gross domestic product (GDP) and employment levels. The agriculture industry is one of the top 20 sectors contributing to the labour market (GreenCape, 2015). South Africa's agriculture sector employs more than 638 000 people and it contributes 2.2% toward the country's economy, and the GDP still remains below 3% for agriculture (Partridge et al. 2014).

1.5.1. Agricultural commodities

South Africa is divided into nine provinces, with the main agricultural products including deciduous, citrus and subtropical fruit, grain, wool, cut flowers, livestock and game. This is illustrated in figure 1.2. The biggest contributor to the country's total gross agriculture production is the grain industry, which contributes between 25% and 33% (Partridge et al., 2014).

The main focus of the study is on the Western Cape (WC), of South Africa, the province is divided into six districts, which can be seen in figure 1.3. The main agricultural activities per district are: Overberg – small grains, table grapes and livestock; Eden – grains, small stock, ostriches, lucerne and beef/dairy; Central Karoo – small stock, stone fruit and pome fruit; Cape Winelands – small stock, wine grapes and table grapes; West Coast – small stock, small grains and rooibos tea; and Cape Metro/City of Cape Town – small grains and wine grapes.

Mixed farming systems are very common in the WC and are especially prevalent amongst smallholder farmers. The reason for this type of farming is to secure income on a seasonal basis and also to diversify risk.

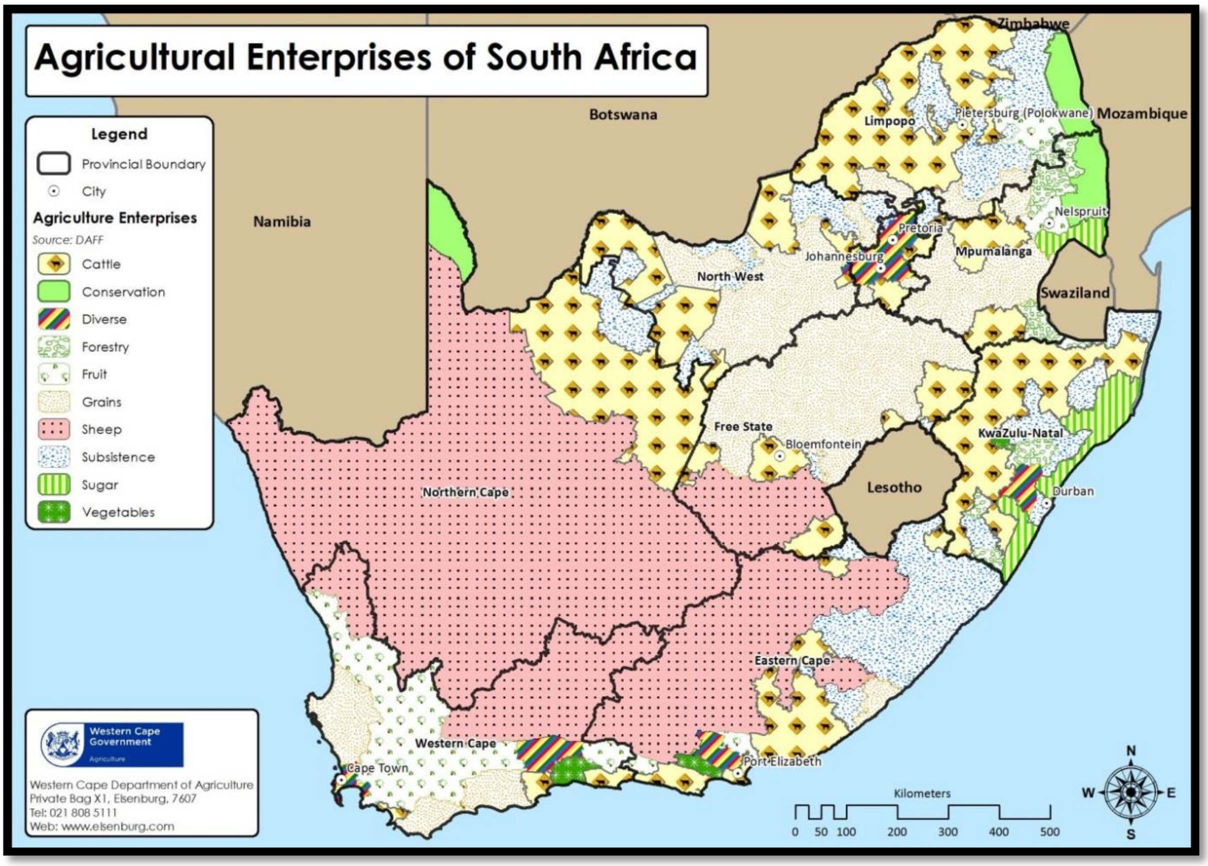


Figure 1.2: Agricultural enterprises of South Africa (Source: WCDOA, 2014a)

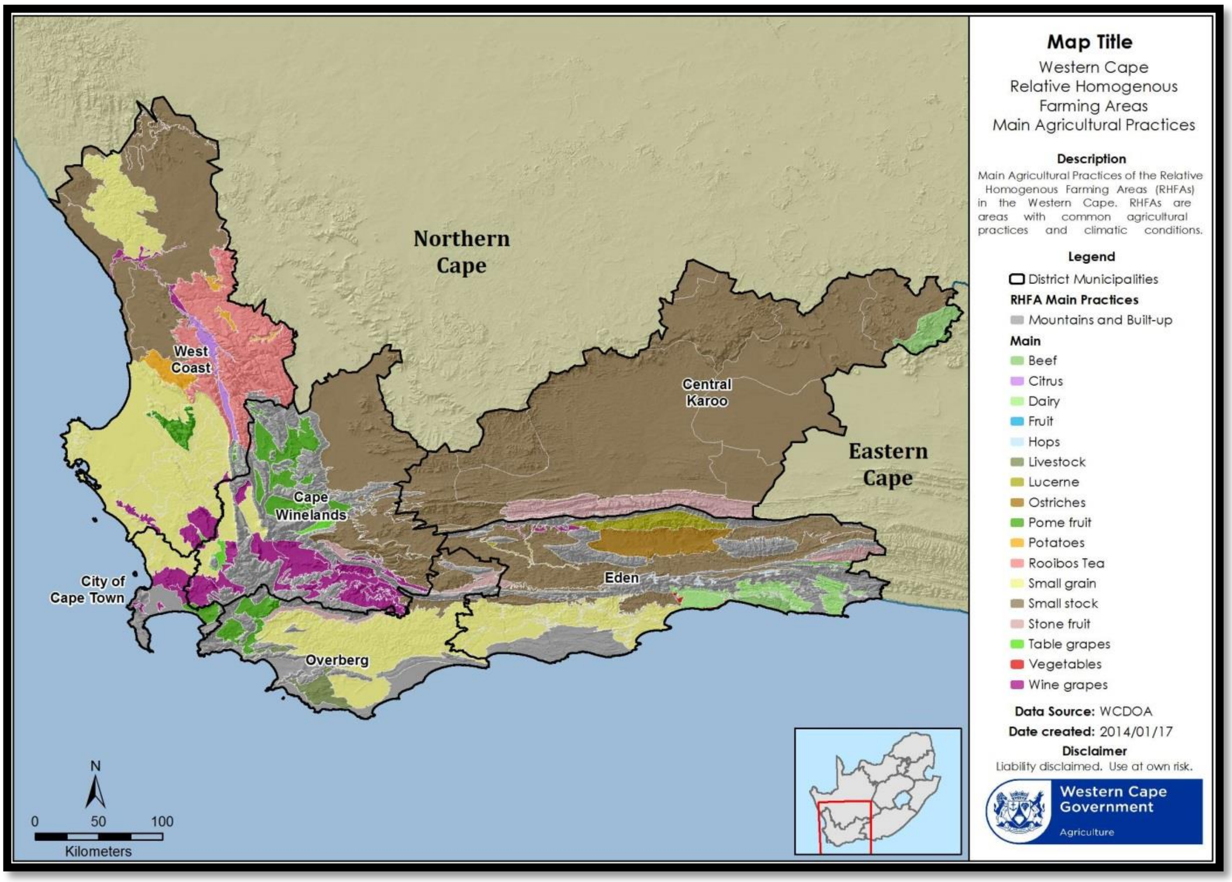


Figure 1.3: Western Cape relative homogenous farming areas – main agricultural practices (Source: WCDOA, 2014c)

1.5.2. Smallholder Farmers

Smallholder farmers can be defined as farmers who have low and erratic yields of production, produce more products than for own consumption and in many cases sell directly to consumers or supply products to bigger retail groups that will process and market the produce (AEWG, 2012). Data for the 1993 period showed that there were 57 980 commercial farmers farming on 82 759 302 hectares in South Africa (SA), and that there were 1 292 600 smallholder farmers mainly in the former homelands (Statistics SA, 1993). Mixed farming systems consisted of 5 711 farmers, farming on 4 391 563 hectares of land in SA (Statistics SA, 1993). In 2007 the commercial farming units totalled 39 966, but no breakdown was available for smallholder farmers (Statistics SA, 2007; Statistics SA 1996). No current data is available regarding the total number of farmers in South Africa for the 2013/2014 period, and also no distinction is made between smallholder and commercial farmers.

According to Statistics SA (1993, 1996, 2002, 2007), the WC had 6 653, 7 185, 9 759 and 8 352 commercial farmers respectively for the periods of 2007, 2002, 1996 and 1993. According to the

WCDoA's "database of emergent farmers[1] – Western Cape" and the "black farmer survey",[2] the Western Cape had 5 660 smallholder farmers in 2007 and the number increased to 9 844 in 2010 (WCDoA, 2007; 2010). These figures are further discussed and broken down per district in Chapter 5, under farming profiles.

It is important to note the number and placement of smallholder farms in the WC, but also imperative to consider the national and provincial obligation to assist smallholder farmers as per the NO 7, which focuses on vibrant, equitable, sustainable rural communities contributing towards food security for all, more specifically sub-outcome 4, which focuses on smallholder farmer development and support (technical, financial, infrastructure) for agrarian transformation; PSG (Provincial Strategic Goal) 1 – to create opportunities for growth and jobs, for example as in Project Khulisa, which focuses on renewables, oil, gas, etc.; PSG 4 – to enable a resilient, sustainable, quality and inclusive living environment; and objective 1 (sustainable ecological and agricultural resource base) and objective 2 (improved climate change response), which flow from this objective (WCDoTP, 2015).

1.5.2.1. Market and compliance concerns for smallholder farmers

Some of the main concerns that smallholder farmers are being faced with today are market access, finance, inconsistency in supply, poor quality and the distance to the market (Jafta, 2014). In terms of compliance with certain legal standards, for example South African Good Agricultural Practices (SAGAP) and Global GAP, market access concerns relate to selling and exporting produce, and also in terms of specific retailer standards. Financial concerns are generally in terms of capital for certification, operational costs and transportation. Inconsistency in supply can be linked to limited land, because smallholder farmers can only produce on the land that they have and sometimes try to maximise their yields, so there often is little focus on the quality of produce (Alexander, 2010). Distances to the marketplace also play a huge role, especially if the farmer does not have access to own transportation and is situated a few kilometres from the nearest town. Concerns thus exist about the environmental footprint of smallholder farmers and their use of resources.

To get access to foreign and even local markets there are certain criteria and standards that products have to meet before they can be exported and/or distributed (see Appendix A). In South

[1] The database of emergent farmers – Western Cape 2007 is a study that was conducted by the WCDoA. The purpose of the study was to source information on spatial status, demographics, farm size and enterprise types. The WCDoA then used this information for policy and resource allocation decisions to support emergent farmers. The black farmer survey was a follow up on the abovementioned database and was established for the same purpose as abovementioned.

[2] The black farmer survey is a follow up on the abovementioned database and was established for the same purpose as abovementioned.

Africa, SAGAP compliance is required, while other international markets require various other "GAP" adherences.

Smallholder farmers have to comply with SAGAP, to give the "buyers" the reassurance that the produce complies with "safe food", "environmental safety" and "social accountability and people safety" criteria, which are some of the new-era market trends in South Africa and globally (Alexander, 2010). According to Alexander (2010), SAGAP is the minimum legal requirement. Some of the stumbling block for the farmers to achieve this certification is:

- Product and water testing
- Training
- Costs of audits
- Record keeping and
- Cultural practices (Alexander, 2010).

Large national and international retailers are also increasing their commitment to reducing their supplier emissions as shown in the retailer carbon emission commitment in table 1.2. Table 1.2 describes the four major commitments that some of the international, as well as national retailers are vowing to. The compliance standards (Appendix A) are thus placing increasing pressure on farmers (commercial, semi-commercial and smallholders), as they not only have to deal with the adverse effects of climate change and economic conditions, but also have to ensure that they comply with all the necessary standards and criteria, as well as reduce emissions. It thus emphasises the need for smallholder farmers to consider their practices, methods and environmental footprint if they are to comply with national, international and retailer standards.

Table 1.2: Retailer carbon emission commitment

	Recognise need to reduce emissions	**Annually report and disclose emissions**	**Disclosure of operational emission targets**	**Commitment to reducing supplier emissions**	**National or international standard**
Sainsbury's	Yes	Yes	Yes	Yes	International
TESCO	Yes	Yes	Yes	Yes	International
ASDA	Yes	Yes	Yes	Partial	International
Marks and Spencer	Yes	Yes	Yes	Yes	International
Morrison's	Yes	Yes	Yes	Partial	International

Carrefour	Yes	Partial	Partial	No	International
Migros	Yes	Yes	Yes	No	International
Walmart	Yes	Yes	Yes	Yes	International
Loblaw	Yes	Yes	Partial	No	International
Woolworths	Yes	Yes	Yes	Yes	National
Pick n Pay	Yes	Yes	Yes	No	National

Source: Black, 2014

1.6. Study objectives

The main objective of this study thus is to develop a carbon calculator for smallholder mixed farming systems that can be used as a guidance tool to direct the Western Cape Department of Agriculture (WCDoA) in assisting smallholder farmers with their carbon footprint and also to act as guidance tool to assist industry in constructing more formal carbon calculators for smallholder mixed farming systems.

The anticipated advantage of the study was to help create awareness of the emissions and resource use of smallholder farmers. This information generated from the calculator could be used to equip smallholder farmers to hedge themselves against the indirect effects of phase one of the carbon tax as well as provide them with much needed information to plan for more efficient farming activities and so doing reduce costs, an added benefit is that the information generated from the calculator can assist smallholder farmers in identifying identify and reduce emission factors that are prohibiting them from complying with both international and larger retailer 'green' standards.

1.7. Principal source of information

In order to examine whether a mixed carbon calculator for smallholder farmers will be effective for agriculture, a literature study was conducted. Primary and secondary data was used for the study. The primary data consisted of a questionnaire that was conducted in the form of a face-to-face interview. Secondary sources of information that were used for the study included textbooks, journals, publications, previous studies, the Internet and other sources on the subject, for example DEFRA (Department for Environment, Food and Rural Affairs) tables and data from the SimFini (WCDoA financial recordkeeping program designed for agriculture) projects.

1.8. Study outline

Chapter 2 follows with a theoretical overview of carbon calculators. This will be done by looking at the different calculators that are available and then comparing these carbon tools. The focus will then shift to the process and input-output models; the two will be compared by looking at how they came into existence and their application. The closing of this chapter will discuss which model will be used for this study and why. Chapter 3 follows with a discussion of the green industry standards and tools. The chapter considers the green industry's standards and requirements, followed by what current standards and requirements smallholder farmers have to comply with to get their products to the market, as well as the standards and requirements with which they are supposed to comply. The focus also will be on how big the "gap" is they have to bridge in order for them to grow to a medium or even a commercial level. Chapter 4 addresses questionnaire design and biases. Chapter 5 discusses the carbon footprint process and steps to establish a carbon footprint. This chapter also discusses the difference between a facility carbon footprint and a product carbon footprint. The sixth chapter describes the prototype tool that was developed to measure the carbon footprint of smallholder farmers in the Western Cape. It looks at the different emission scopes and the process of developing the tool is explained. The chapter further describes the carbon profiles of the 18 farms and provides brief reduction targets for these 18 farms. The last chapter, chapter 7 concludes and lists all the recommendation made in terms of the carbon footprint tool.

Chapter 2: Theoretical overview

2.1. Introduction

As discussed in Chapter 1, the reality of global warming and climate change are starting to affect both smallholder and commercial farmers and, as a result, it is becoming imperative for these farmers to monitor and measure their impact on the environment (Little & Smith, 2010). As a result, the need has arisen for a carbon calculator and, today, numerous online carbon calculators are available for individuals, households and businesses. Although people are spoiled with options, there are a few shortcomings with the available systems and, according to Ross et al. (2010), many of the online calculators have shown to be inconsistent and lacking transparency when it comes to how the calculations are done.

2.2. Comparison of Carbon Calculators

For the purpose of this study, the focus will be only on calculators that have been developed to calculate a farm's carbon footprint. When considering different farm business calculators, there is little to no consistency, especially when it comes to the methodology and the raw data used, and this normally leads to different answers generated by the different calculators. This is also due to the fact that different calculators are suited for different purposes, which has a significant impact on the scope and methodology of the calculators (Little & Smith, 2010). A farm's footprint tends to be more complex, because:

- Farms, in general, are complex systems and organic farms often even more so because they tend to be more integrated.
- In most industries, the main greenhouse gas emitted is carbon dioxide (CO_2). However, in agriculture, methane (CH_4) and nitrous oxide (N_2O) are much more important; only about 10% of total agricultural emissions are of CO_2 (Little & Smith, 2010).

Although the process to calculate a farm's footprint is more complex, it still is important to do so in order to:

- Help farmers measure, monitor and reduce their environmental footprints and subsequently to improve the efficiency and performance of their business;
- Inform strategy and policy development
- Be used as a marketing tool to help environmentally conscious consumers choose the products they buy.

2.2.1. Tools available

The carbon calculator tools that are used for agricultural activities are listed in table 2.1. Each calculator is described and ranked according to sophistication, from most to least sophisticated. Scope 1 emissions are direct emissions; in other word the business entity has control over these emissions. Scope 1 emissions are things like fuel usage, generators, refrigeration and air conditioners. Scope 2 emissions are indirect emissions and the business entity does not have control over this emissions. For example electricity purchase from Eskom. Scope 3 emissions are other indirect emissions, like waste disposal, hiring of trucks, air travel, hotel accommodation, car rental, etc. Scope 1 and scope 2 emissions are compulsory and in SA these two scopes get measured (Terra Firma Academy, 2013).

Table 2.1: Carbon calculator tools

Tool	Developed by	Contact details/web link	Purpose	Methodology	Scope	Emission source	Format/ usability
Terra Firma Academy	Terra Firma Solutions/ Academy	info@terrafirma-academy.com & info@terrafirma-solutions.com.	Carbon footprint tool for businesses	IPCC (also the tier 1, 2 & 3 data sources) & DEFRA	1, 2 & 3	Fuel, electricity, soil/crops, livestock, etc.	Excel spreadsheet can be created – costs involved
Fruit and Wine Calculator	South African Fruit and Wine Industry	www.climatefruitandwine.co.za & Anél Blignaut - anel@bluenorth.co.za	Farm management tool for the fruit and wine industry	GHG Protocol Corporate Standard, the ISO 14064:1, the PAS 2050:2011, the International Wine Carbon Calculator Protocol, the Australian Wine Carbon Calculator and the recently released PAS 2050-1:2012	1 & 2	Fuel, electricity, crops/fruit, cold storage (gas), winery	Web based – no costs involved, unless the user wants to make use of a consultant to verify the footprint
CALM	Country, Land and Business Association (CLA)	www.calm.cla.org.uk/ & Derek Holiday: derek.holiday@cla.org.uk	Farm management tool	IPCC 2006 & UK GHG Inventory 2009 source for emission conversion factors	1, 2 and some of 3 (production of imported artificial fertilisers)	Managing Energy and Carbon Fuel, electricity, soil/crops, livestock, sequestration	Web based – no costs involved

Cool Farm Tool	Unilever and the University of Aberdeen	www.coolfarmtool.org/CftExcel & info@coolfarmtool.org	Farm management tool	IPCC Tier 1 & IPCC Tier 3 emission approaches	1, 2 & 3	Fuel, electricity, soil/crops, livestock, sequestration	Web based – free and open source, no costs involved
CFF Calculator	Climate Friendly Food (CFF) – by farmers for farmers	www.cffcarboncalculator.org.uk & Jonathan Smith: jonathan@climatefriendlyfood.org.uk	Farm management; certification; marketing	IPCC 2006, DEFRA GHG conversion factors, UK GHG Inventory 2008 and other sources to build their own methodology	1, 2 and some of 3 (transport of goods to and from the farm and the manufacturing of building materials)	Fuel, electricity, livestock, soil, crops, sequestration, organic systems	Web based – no cost involved
CPLAN	Drew and Jan Coulter and Ron Smith	http://www.see360.org.uk/				CPLAN	Drew and Jan Coulter and Ron Smith

Footprint Analysis of Blaencamel Farm	Peter Segger	Peter Segger: peter@blaencamel.com	Farm management tool	Was developed by Peter Segger	1, 2 and some of 3 (transport and manufacturing of packing material)	Fuel, electricity, livestock, transportation (customer & employee, packaging material, emissions from domestic activities and compost production	Excel Spreadsheet – no cost involved
Bangor Farm Model	Bangor University	www.senr.bangor.ac.uk	Farm management tool	LCA PAS 2050	1, 2 & 3	Fuel, electricity, livestock, soil/crops (limited)	Tool is so complex – must use a consultant (not publically available)
Agri assist-Emissions Footprint Tool	Dairy Crest Direct Ltd and Agri Assist Ltd	mmasters@edgarley.fsworld.co.uk	Farm management tool	Carbon Trust Accredited Model – LCA PAS 2050	1, 2 & 3	More focused on the dairy industry, but looks at fuel, electricity, livestock and soil/crops	Web-based calculator – cost involved
EASI	Organic Research Centre- Elm Farm	Laurence Smith: laurence.s@organicresearchcente.com	Farm management tool	Organic Research Centre – Elm Farm	1, 2 & 3	Fuel, electricity, livestock, soil/crop (limited)	Excel Spreadsheet – consultant driven

Footprints4Food	Bangor University	Ian Finlayson: ian@footprints4food.co.uk http://www.footprints4food.co.uk	Environmental footprinting services – fresh produce and water footprinting	BSI (British Standards Institution)			
Managing Energy and Carbon	Centre for Alternative Land Use (CALU)	Kerrin Buckler: k.buckler@bangor.ac.uk				Managing Energy and Carbon	Centre for Alternative Land Use (CALU)
OCIS Public Goods Tool	Organic Research Centre						Excel Spreadsheet – consultant driven
SAVEFuel and Refuel	Scottish Agricultural College (SAC)	Rod McGovern: rod.mcgovern@sac.co.uk	Farm management tool	Created by SAC	1 & 2	Fuel, electricity, livestock, soil/crop	Excel spreadsheet – consultant driven

Source: CLA, 2013; Confronting Climate Change – A South African Fruit & Wine Initiative, 2012; Cool Farm Tool, 2012; CPlan Carbon Calculator, 2014; Farm Carbon Calculator, 2012; F4F, 2010; Little & Smith, 2010; Soil Association, 2013; Terra Firma Academy, 2013; The Organic Research centre – Elm Farm, 2011

From table 2.1, Terra Firma Academy models are more sophisticated and more specific to the South African context, while SAVEFuel and REfuel can be identified as the least sophisticated carbon calculators. The carbon calculator shortcomings are identified in table 2.2. It can be seen that most of the calculators follow a "black box" approach, not enabling the farmers to do the footprint themselves, therefore making them dependent on consultants to calculate and analyse their footprint. Most of the calculators also lack transparency, because no information is available on the equations or methodology used.

Table 2.2: Carbon calculator shortcomings

Tool	Aimed at commercial and/or organic farms	Black box tool (no methodology or formula available)	Allow whole-farm calculation	Scoring system	Consultant	UK based (cannot really use it for South African farms)	Other
Terra Firma Academy	√		√		√		
Fruit and Wine Calculator	√	√	√		√		Fruit & wine industry
CALM	√	√	√				
Cool Farm Tool	√	√	√				

CFF Calculator	√	√	√				
CPLAN	√	√	√		√		
Footprint Analysis of Blaencamel Farm	√	√			√		Livestock & energy calculator has to be adjusted
Bangor Farm Model	√	√			√		Livestock
Agri assist-Emissions Footprint Tool	√	√			√		Dairy only
EASI	√	√	√		√	√	
Footprints4Food	√	√	√			√	

Managing Energy and Carbon	√		√	√		√	
OCIS Public Goods Tool	√	√	√		√		
SAVEFuel and Refuel	√				√		

Source: CLA, 2013; Confronting Climate Change – A South African Fruit & Wine Initiative, 2012; Cool Farm Tool, 2012; CPlan Carbon Calculator, 2014; Farm Carbon Calculator, 2012; F4F, 2010; Little & Smith, 2010; Soil Association, 2013; Terra Firma Academy, 2013; The Organic Research Centre – Elm Farm, 2011

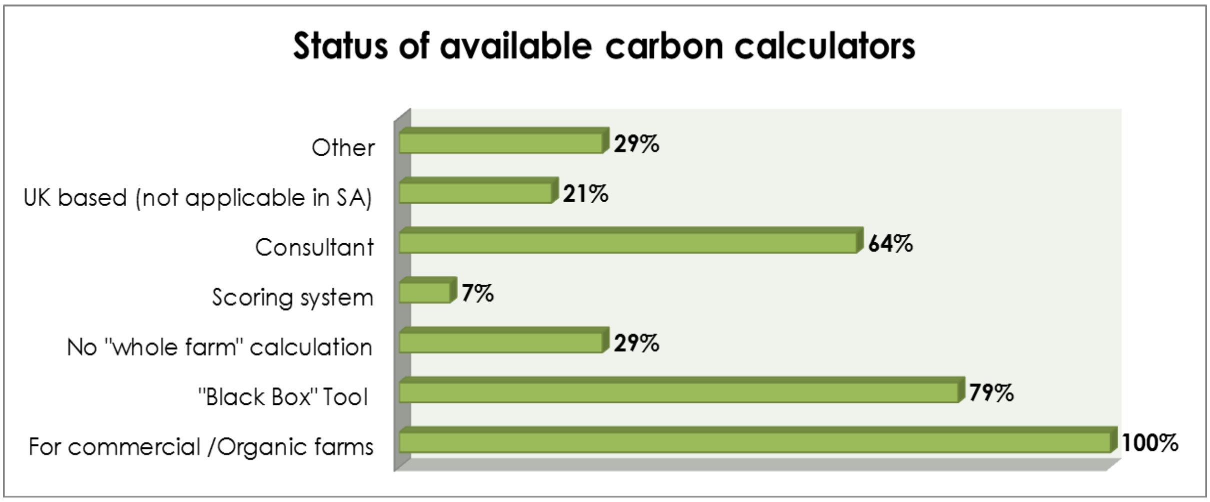


Figure 2.1: Status of available carbon calculators (Source: CLA, 2013; Confronting Climate Change – A South African Fruit & Wine Initiative, 2012; Cool Farm Tool, 2012; CPlan Carbon Calculator, 2014; Farm Carbon Calculator, 2012; F4F, 2010; Little & Smith, 2010; Soil Association, 2013; Terra Firma Academy, 2013; The Organic Research Centre – Elm Farm, 2011)

A vast number of carbon calculators are available; however, they are more popular on an international level than specific to South Africa. The status of available carbon calculators are shown in figure 2.1 above, illustrating that most of these carbon calculators focus mainly on commercial and organic farming practices. Commercial farmers have more environmental standards to adhere to, especially if they are exporting or selling to big retail groups; they have national, international and retail requirements to adhere to (as seen in Chapter 1, table 1.2). The main requirement for smallholder farmers is to adhere to food safety and food quality standards, and not so much to environmental aspects.

Figure 2.1 provides a summary of table 2.2. It indicates that 100% of the tools looked at focus on commercial/organic farmers, 79% of these tools are “black box” tools and 64% require the help of a consultant to be able to generate information from the tool. Figure 2.1 also shows that 21% of the tools are UK based. However, due to the abovementioned limitations, most of the other tools also are not applicable to South Africa.

2.3. Background and Application: The Process Model

Increasing pressure is being put on industries to reduce their environmental impacts due to climate change becoming a reality. The focus is not only on companies, but on the whole supply chain. Jensen (2012) mentions that several carbon emission accounting schemes and methods are emerging and that many of them are driven by businesses wishing to compete on “green” credentials and also wanting to document a decline in their supply chain emissions. Carbon footprinting is the way forward to help or assist establishments to reduce their environmental impact by focusing on the key emitters over which they have control. The use of the abovementioned carbon footprint initiatives has been driven by retail chains and companies that request information to provide to their consumers; however there has been a lack of consistency in terms of the definitions and methods employed to calculate a carbon footprint (Weidema et al., 2008). In recent years, two main methods have become prominent in terms of carbon calculating, namely the process model method and the input output model method (Barnett et al., 2012)

2.3.1. The Process Model

2.3.1.1. Theory behind the process model

The process model has been in existence for more than 30 years, but little is known about the act of modelling and which factors contribute to a correct and acceptable process (Mendling & Strembeck, 2008). Therefore it is important to understand that a model is an explicit representation of particular portions of reality used to represent complex human design activities. Models can be described in three phases: active, automated and manual or interactive. An active model is one that will directly influence the reality it reflects, meaning that a change in the model will change the users' attitude towards reality and also enable information systems to support business needs. An active model is ideally what one aspires to. An automated model exists when the model is formal and complete, meaning a formal approach was followed to do the modelling and no steps were left out. An automated model is used to select a suitable model for a certain studies and it also transforms agile modelling and is normally interpreted by computer software. The third phase of the model, manual and interactive activation means that the model can be partly informal and incomplete. A model activation process affects reality and involves users adjusting their behaviour, from an active model to an automated, manual or interactive model. It does not matter if the business model is active or not active; it still is considered as knowledge about the business (Krogstie et al., 2006).

There are seven main process management approaches described by Becker et al. (2000): (1.) lean management, (2.) activity-based costing, (3.) total quality management, (4.) business process reengineering, (5.) process innovation, (6.) workflow management and (7.) supply chain management.

Rouse (2013) describes lean management as a continuous improvement concept that seeks to achieve small, incremental changes in processes in order to improve efficiency and quality in the long term. The activity-based costing (ABC) approach is a method used by accountants to identify a company's activities and then assign the indirect costs of these activities to a product (Investopedia, 2015). Total quality management (TQM) is a comprehensive and structured approach to organisational management that seeks to improve the quality of products and services through continuous feedback (Rouse, 2005). A business process reengineering approach, according to Bain and Company (2013), can result in huge improvements in productivity, cycle times and quality through the redesign of core business processes. The “process innovation” approach is the implementation of a change in the production or delivery method, which can include changes in techniques, equipment or software (InnoviSCOP, 2006). The workflow management system (WMS) approach makes use of a software program that provides an infrastructure to set up, execute and monitor scientific workflows (Taverna, 2010). Lastly, the supply chain management approach can be described as the activities that are being performed to maximise customer value and to be able to achieve a sustainable competitive market advantage (Handfield, 2011).

There have been two main effects as a result of the requirements for process models. Firstly, the number and variety of model designers and users have increased vastly. Secondly, the number and variety of purposes the process models are used for has grown immensely. Traditionally, the process model was developed and used for software engineering purposes, but it is gradually moving to a more pure, organisational purpose, for example process reorganisation, certification, activity-based costing or human resource planning (Becker et al., 2000).

It should be noted that the process model is an instrument that helps with coping with the complexity of process planning and control, but problems do exist with the design of the model. This can be very problematic because it has a direct influence on the economic efficiency of the underlying process-related project. The design of process models thus is an economical risk and not only a modelling exercise (Becker et al., 2000).

2.3.1.2. Framework used

The frameworks for process modelling follow three main streams: Top-down, bottom-up, and empirical (Mendling & Strembeck, 2008). Each of the streams is discussed briefly below:

Top-down quality framework

The Semiotic Quality (SEQUAL) framework is an example of a top-down quality framework. This framework builds on semiotic theory and defines several quality aspects based on relationships between a model, a body of knowledge, a domain, a modelling language, the activities of learning, taking action and modelling (Mendling & Strembeck, 2008). According to Mendling and Strembeck (2008), the top-down framework is useful when it comes to business process modelling, even though the framework does not provide an operational definition of how to determine the quality of the model. There are certain basic guidelines that this model has to follow, namely the Guidelines of Modelling (GoM), which were inspired by general accounting principles. These guidelines consist of six principles, namely:

- *Principle of correctness*
- *Principle of relevance*
- *Principle of economic efficiency*
- *Principle of clarity*
- *Principle of comparability*
- *Principle of systematic design*

Bottom-up metrics related to quality aspects of process models

Work on the bottom-up metrics has been published by several authors in relation to the quality aspects of process models and for some of these contributions no empirical validation exists for the theory (Mendling & Strembeck, 2008). Most of the studies done focused on the relationship between metrics and quality aspects, for example a study (A family of experiments to validate metrics for software process models) that was done by Canfora, et.al in 2005, only focussed on count metrics and maintainability of software process models. Another study, "Process control-flow complexity metric: An empirical validation", that was conducted by Cardoso in 2006; focus only on the validation of the correlation between control flow complexity and perceived complexity.

Empirical surveys related to modelling techniques

The empirical survey considers the language the business process model uses and how it has matured over time, although no insight into a single, concrete process model is revealed. It should be noted that the aim of the questionnaire is to enhance the information on the process model, as opposed to limiting the knowledge base. Theory, duration, intensity, time, text and the P-score are gathered with the questionnaire and, from this information, the size, diameter, structuredness, separability, token split, cyclicity, heterogeneity, sound and M-score can be calculated. At the end, the aspects related to the textual labels of the model and correct answers to individual questions can also be measured (Mendling & Strembeck, 2008).

2.3.1.3. Empirical estimation

The process model consists of two types of dependent variables – the performance-based measures and the perception-based measures, which, according to the method evaluation model, represent the difference between actual efficiency and perceived efficiency. The performance-based variables consist of four dependent variables, namely the syntactic quality, semantic quality, pragmatic quality and overall quality, which are used to evaluate performance in the evaluation task. These variables are also used to assess the reliability and validity of the evaluation framework. The perception-based variables, on the other hand, consist of three dependent variables, which are the perceived ease of use, the perceived usefulness and the intention to use. These three variables are used to determine the perceptions of the framework by participants (Moody et al., 2002).

2.3.1.4. The process model and carbon emissions

The process model takes into account all processes in the product life cycle, so it follows a cradle-to-grave approach. The process model is the most accurate model because it requires detailed information on the entire life cycle of the product. An example of the process model is PAS 2050, which lays out how to assess the greenhouse gas emissions of a product life cycle. The shortcomings of this model approach are that it is very expensive in terms of time and calculating; the data required is not always available, affecting the accuracy of the model; and the model is a manual process and takes days per product, so is impractical for large-scale use (Barnett et al., 2012). According to Wiedmann and Minx (2007), the process model is more suited for focusing on microsystems, like a particular process, an individual product or a relatively small group of individual products.

The process model method is divided into three steps. Step one is the start-up phase, during which objectives are set, the product is chosen and supplier engagement takes place. Step two consists of a process map being built, boundaries and prioritisation being checked, data collected, the footprint being calculated and the uncertainty of the outcome being checked. A process map needs to be built first and, secondly, the boundaries and prioritisation need to be checked. Here it is important to start with the raw material production. Data collection follows; this step is still part of step two and has two important data types: activity data and emission factor data. The third step consists of four other sub-steps, that include validating the results, emissions to be reduced, footprint being communicated and reductions to take place.

The last part of step two is to calculate the footprint, and the formula used is:

Carbon footprint of a given activity = Activity data (mass/volume/kWh/km) × Emission factor (CO_2e per unit)

This method is only handy if the focus is on one commodity and not a whole-farm approach (Carbon Trust, 2008).

2.3.1.5. Summary

The process model has been in existence for years and, despite the guidelines of the model, there is still very little empirical work reported on the process model's quality and its impacting factors. The model also focuses more on software programs, which focus more on traditional businesses and less on agriculture. The process model still needs a lot of work for it to be adapted for the agricultural industry, but when focused only on carbon emissions; the PAS 2050 gives a comprehensive summary of how to use this model for a commodity or product.

2.3.2. The Input-output Model

2.3.2.1. Theory behind the input-output model

The input-output (IO) model was developed in the late 1930s, at the time of the Great Depression. According to Miller and Blair (2009), no economic theories existed to bring the economy back to harmony, so the work of Professor Leontief was used to jumpstart the economy. Professor Wassily Leontief was born in America on the 05 August 1906, the son of an economics professor who was teaching at St. Petersburg. In 1973, Professor Leontief won the Nobel Prize in Economics (The Nobel Foundation, 1973).

"Interindustry analysis" is another name for the input-output model developed by Leontief. However, Leontief's model is much newer than the original idea of developing an interindustry activity accounting model for an economy (Miller & Blair, 2009). Leontief's IO model was partly inspired by the Walrasian analysis of general equilibrium via interindustry flows, which in turn was inspired by Quesnay's Tableau Economique, but further literature shows that Leontief's model was actually inspired by Francois Quesnay (Miller & Blair, 2009). Quesnay's Tableau Economique theory was based on a "closed model" concept, where all economic sectors were considered to be producers and consumers and all households were treated as industries whose outputs are labour and whose inputs are the commodities they consume (Horowitz & Planting, 2009).

Francois Quesnay's work focused on a better understanding and clarification of the causes of growth in the economy (Library of Economics and Liberty, 2008a). His inspiration came from the leading economist of the eighteenth century, Leon Walras. According to Miller and Blair (2009), it was Quesnay who recognised the concept of a "circular flow" of productive interdependences in an economy by introducing the fact that there must be a "link" between industries in the economy. This "circular flow" concept can be traced back to Sir William Petty in the mid-1700s. Sir Petty explained the link between production, distribution and the disposal of a nation's wealth (Miller & Blair, 2009).

Quesnay focussed on three social classes: the proprietary class which where the landowners, the productive class which where the farmers and the so-called "sterile" classes (artisans and merchants), who were assumed to consume everything at once. Quesnay's argument against industry and international trade is said to be twofold. Firstly it was believed that industry does not contribute to a country's wealth. For example if labour from the agricultural sector is shifted to industry, the overall wealth of the nation will decrease (Library of Economics and Liberty, 2008a). A nations' wealth lies in its production of necessary goods and services, in other words the ability of people to transform resources (factor inputs) into desired goods and services (Ruby, 2003). Secondly, the basic Mercantilist Principle says that, for a country to gain wealth, that country must export more than what it imports; Quesnay differed from this principle, as he believed a country should only manufacture according to its raw material capacity and what its labour is suited for, which would enable the country to have a cost advantage over its overseas competitors (Library of Economics and Liberty, 2008a). Quesnay's work inspired the Walrasian analysis of general equilibrium via interindustry flows (Library of Economics and Liberty, 2008a).

Leon Walras (1834-1910) worked with the general equilibrium theory, which states that producers and consumers are both suppliers and demanders in the whole economy (Cardenette et al., 2012). Equilibrium is assumed to occur only in perfectly competitive markets, where the economy is considered a closed, interdependent system of markets in which equilibrium prices and quantities are the result of various economy-wide interactions. This type of economy will not be affected by exogenous factors and focuses only on private goods and services (Cardenette et al., 2012).

From looking at other literature, the main purpose of the input-output model can be described in simpler terms as looking at the interdependence of the different industries of in the economy, and if something happens in one industry the effect will flow to the other industries. This is also known as the ripple effect (Miller & Blair, 2009). What this articulates is that there is a high degree of interlinkages in an economy, meaning that each industry uses inputs from other industries in order to produce a final output, these inputs themselves use inputs from other industries in production, and so the circular flow illustrated in figure 2.2. This also means that income is not used in one simple transaction but is embedded in a web of interactions between different industries.

Government receives the leakages in a closed economy system, while leakages in an open system flow to the rest of the world. This makes input-output modelling an incredibly powerful tool as it allows the user to analyse the impact to the whole economy giving consideration to the specific structure of the economy in question

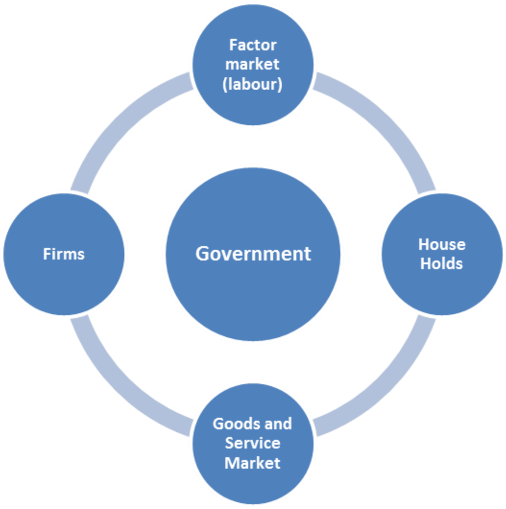


Figure 2.2: A closed economic system

(Source: Cardenette *et al*., 2012)

Leontief's input-output model was inspired by equilibrium theory, but the model also recognised that the object of economic activities is the satisfaction of final demand (Horowitz & Planting, 2009). Horowitz and Planting (2012) noted that the final demand of Leontief's input-output system was assumed to be determined by outside factors. This led to the realisation that Leontief's model is an "open" model approach. The difference between a closed and open model approach is that a closed model does not allow for trade with other countries, while an open model allows trade to take place. A percentage of income will therefore leave the country, but another percentage of income will flow back from other trading countries.

The input-output analysis thus is a tool that measures the relationships between the various industries in the economy, also known as "inter-industry analysis". The input-output tables generated give a good summary of which inputs are used by which industries to produce various outputs (Horowitz & Planting, 2009). The input-output model demonstrates the commodities used as intermediate inputs into the production for each industry. Figure 2.3 gives a brief summary of all the tables that flow from an input-output table.

A "*make*" and "*use*" table is the core of an input-output account. The production of commodities per industry is shown by the "*make*" table, while the uses of commodities by the intermediate and final users are indicted by the "*use*" table; in other words, these show the components that are necessary for production in each industry (Horowitz & Planting, 2009).

The "*make*" and "*use*" tables are prepared from two sets, namely the *direct requirements table* and the *total requirements table* respectively. According to Horowitz and Planting (2009), the *direct requirements table* indicates the amount of a particular commodity that is needed by an industry to produce a dollar of the industry's output, while the *total requirements table* looks at the relationships between the final uses and gross output. Horowitz and Planting (2009) also note that the total requirements table is made up of three sub-tables, the *commodity-by-commodity total requirement table*, the *industry-by-commodity total requirement table* and the *industry-by-industry total requirements table*. The *commodity-by-commodity total requirement table* gives an indication of the production needed. Focusing on the direct and indirect production needs, it shows the commodity at the beginning of the row per dollar of delivery to the final use of the commodity at the top of the column. The *industry-by-commodity total requirement table*, on the other hand, also indicates the production needs, but from the industry's perspective. The starting point is at the beginning of the row per dollar of delivery to the final use of the commodity at the top of the column. The *industry-by-industry total requirement table* also indicates the production need, the same as the two sub-tables above, but where it differs is that it starts showing the needs of the industry at the beginning of the row per dollar of delivery to the final use of the industry at the top of the column (Horowitz & Planting, 2009).

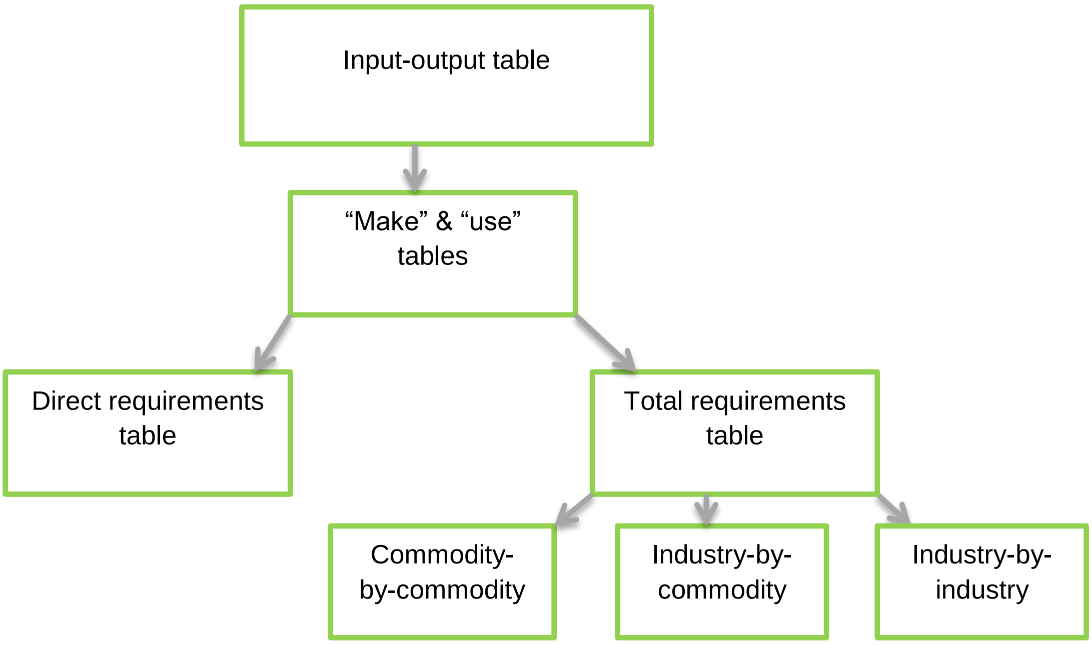


Figure 2.3: A diagram of the outflow of the different tables

(Source: Horowitz & Planting, 2009)

2.3.2.2. Framework used

Developing input-output tables or accounts is a complex process that requires data from various sources to get a clear, overall picture of the economy. According to Horowitz and Planting (2009), there are three fundamental economic principles that are vital for the development and calculating of input-output tables. These principles are *homogeneity*, *proportionality* and *consistency*.

The principle of homogeneity

Homogeneity requires a single set of inputs to produce an output for an industry. According to this statement, it can also be said that the use table will show a distinctive production function for each industry. Real-world scenarios do not tend to follow this structure, as industries might produce a variety of products, which will need a range of different inputs for production (Horowitz & Planting, 2009).

The principle of proportionality

The proportionality principle considers the ratio of each input to a unit of output, and assumes that it will remain constant over a wider range of output levels. According to Horowitz and Planting (2009), it thus can be assumed that there are no economies of scale. This principle also makes it easy to calculate the effect of a change in use per output of all industries, as each commodity has a unique input. For example, if the demand for a given product increases by 50%, all of the inputs required for the production of that product will also increase by 50%.

The principle of consistency

This principle assumes that the preparation and presentation of all data is done in a uniform manner and that all data shown in the input-output tables is consistent with the data sources used to compile the tables. Therefore all methods and/or data sources must be consistently and continuously used for the various commodities and industries so that tables can be compared with each other (Horowitz & Planting, 2009).

2.3.2.3. Empirical estimation

The input-output model is a matrix that consists of linear equations. For example: all output *A* produced by different sectors can be added together to give the final output of *B* in the economy (Miller & Blair, 2009). According to Miller and Blair (2009), it can also be said that this shows the distribution of the output throughout the economy. When looking at an input-output table it can be seen that the table only has one row and one column for each industry in the economy, as shown in table 4.3, and the goods and services are expressed in monetary (dollar) values (Christ, 1955). In table 4.3, the X values indicate the value of output, where:

- X_i = value of the output of sector I (i = 1…n)

- X_{ij} = sales by sector I to sector j (i = 1…n; j = 1…n). It represents the amount of the ith sector's output used by the jth sector to produce its output.
- W_j = wages in sector (j = 1…n). It represents the use of labour in the production of the ith product.
- R_j = interest and profits in sector j
- M_j = imports of sectors j
- C_j =personal consumption expenditure for the output of sector i
- I_j = investment expenditure for the output of sector i
- G_j = government purchases of the output of sector i
- E_j = exports of the output of sector i
- M_C, M_I and M_G = imports of final goods by consumers, firms, and the government, respectively (Tanaka, 2011).

Table 2.3: An example of a general Input-Output table

Purchases by	**Intermediate Users Sectors/Industries**					**Final Demand**				**Total Output**
	1	2	3	…	n	C	I	G	E	X
Sales by: 1	X_{11}	X_{12}	X_{13}	…	X_{1n}	C_1	I_1	G_1	E_1	X_1
2	X_{21}	X_{22}	X_{23}		X_{2n}	C_2	I_2	G_2	E_2	X_2
3	X_{31}	X_{32}	X_{33}		X_{3n}	C_3	I_3	G_3	E_3	X_3
Sectors/Industries .	.	.	.	…	.	.	.	.	.	?
.	.	.	.	…	.	.	.	.	.	?
n	X_{n1}	X_{n2}	X_{n3}		X_{nn}	C_n	I_n	G_n	E_n	X_n
Value-added imports W	W_1	W_2	W_3	…	W_n	W_C		W_G		W
R	R_1	R_2	R_3	…	R_n					R
M	M_1	M_2	M_3	…	M_n	M_C	M_I	M_G		M
Total Supply X	X_1	X_2	X_3	…	X_n	C	I	G	E	

Source: Tanaka, 2011

According to Christ (1955), the input-output model works on an analytical phase that has been built on two piers. Pier one consists of accounting equations, which represent one equation per industry, and it thus can be said that total output of an industry is equal to the sum of all the entries in that industry's row. Pier two is different from pier one in the sense that pier two focuses on the relationship between the output of the industry and the inputs it must get from various industries to be able to produce an output.

A variety of important data sources have to be considered and used in the development of input-output accounts. Different sets of tables represent the outflow of the input-output accounts, which can be said to be the interworking of the economy, with services as tools for analysing the interworking. The input-output tables can also be defined mathematically as a set of equations that must be satisfied simultaneously for the gross output of each sector to balance the intermediate and final demand for its products (Tanaka, 2011). The following section will make use of the matrix algebra function and to better understand how these tables work, one must first start with the basic formula. The following formula illustrates a symmetric industry-by-industry table, which is derived from the total requirements table. The formula states that output is equal to final demand plus industry inputs (Horowitz & Planting, 2009).

$$x = y + F \qquad (2.1)$$

where:

x = output

y = final uses, and

F = industry inputs.

Horowitz and Planting (2009) go further to simplify the formula and enable algebraic manipulation by expressing the industry inputs in terms of portions of industry output. This is done by dividing industry inputs by industry output:

$$A = F/x \qquad (2.2)$$

where:

A is the coefficient matrix, that is inputs (F) as a proportion of industry output (x). Rearranging the coefficient formula in terms of F:

$$Ax = F \qquad (2.3)$$

Substituting for F in (4.2) expresses the equation in similar terms:

$$x = Ax + y \qquad (2.4)$$

The formula is rearranged to solve for y in order to show the relationship between output and final uses. The formula is then solved to describe output as a function of final uses:

$$x - Ax = y$$

This formula can be simplified by applying the distributive rule:

$(I-A)x = y$, where I is an identity matrix of 1's.

Finally, the matrix is solved for x in terms of y by dividing (I-A) into both sides of the equation. In matrix algebra, the division is accomplished by inverting the matrix. In I-O terminology, the inverse – that is the function that relates final uses to output – is referred to as the total requirements matrix (Horowitz & Planting, 2009):

$$x = (I - A)^{-1}y \quad (2.5)$$

where:

X = output

$(I - A)^{-1}$ = total requirements table, and

Y = final demand

The main uses of the input-output models are to identify changes in final demand through the economy over short periods of time, as final demand (Y) is linked to total output (X) through the inter-industry linkages, the total requirement coefficients $(I - A)^{-1}$ (Horowitz & Planting, 2009). The relationship between final demand and total output is illustrated in table 2.3.

2.3.2.4. The input-output model and carbon emissions

Today, numerous generalised input-output models (IOMs) for the analysis of environmental flows are available and are discussed in literature. It is normal that environmental pressure data for all economic sectors in an economy are linked by the environmental input-output framework, through its financial transactions between sectors, which allows for an allocation of these pressures to the consumption of product groups. It also can be noted that it is not only the activities throughout the economy that are triggered by final demand, but also the IOMs' ability to assess the direct and indirect environmental flows (Minx et al., 2009).

The aim of carbon footprinting is to define the greenhouse gas (GHG) emissions that are an outflow of final demand, and this will include worldwide emissions that are released in the production of goods and services, making the input-output analysis a suitable methodology (Minx et al., 2010).

Formula 4.6 can be used in a carbon emission set-up; only the coefficient vectors will differ from the previously mentioned formula.

$$x = y + F \quad (2.6)$$

where:

x = total CO_2 emissions

y = farming activities and

F = emission factors

This study will focus only on the agricultural sector's carbon emissions at a provincial level. The entire WC agricultural sector will be addressed, meaning that all the different farming enterprises will be looked at for example, fruit, wine, vegetable, grains and livestock. The coefficient vectors that will be considered are all the inputs needed to run a day-to-day farming business. Table 2.4 below illustrates these day-to-day vectors that are needed to operate a farming business.

Table 2.4: Coefficient vectors that contribute to agricultural carbon emissions

Day-to-day emission sources	**Sequestration sources – Coefficient vector groupings**
Fertilisers	Orchards
Pesticides	Forestry (indigenous, including riparian)
Insecticides	Forestry (non-indigenous pine spp.)
Fuel	Forestry (non-indigenous gum spp.)
Electricity	Forestry (non-indigenous acacia spp.)
Logistics (transportation of commodities/products and or labourers)	Density of the forest or orchard (number of trees per hectare)
Manure management	Average age per stand (0-5 years; 6-15 years; 15-20 years and 25+ years)
Water management	
Waste management	

Source: Confronting Climate Change, 2010

2.3.2.5. Summary

Input-output models have come a long way and there still is a lot of room for the extension of the current models, especially for addressing the carbon emissions for the different sectors of the economy. When looking at the agricultural sector, the input-output tables that are available focus on the pricing of the carbon dioxide emissions and include tax and cap-and-trade vector coefficients in the models, as well as all the sectors in the economy. There are a few models for general carbon emissions for agriculture, but a lot more work needs to be done.

2.4. Rationale for applying the process model method

Based on the arguments above it was thus decided to use the process model. The process model is an accurate model that is perfect for a carbon analysis study because it focuses on the entire life cycle of a commodity (uses a cradle-to-grave approach), as stated in section 2.3.2.4. The process model focuses on the micro-level, which is relevant for this study, because the focus is on the farm level.

2.5. Conclusion

This chapter highlights the different agricultural carbon calculators that are available and also indicates the shortcomings of each. It also motivates why a "new" calculator is needed for smallholder mixed farming systems. Chapter 2 also looked at the process and input-output models that can be used for carbon footprinting and the applications thereof. It also has highlighted why the process model is more relevant and accurate and why this model will further be used in this study.

Chapter 3: Green Industry Standards and Tools

3.1. Introduction

Modern farming is integrated with natural resources, biodiversity, ecosystems, welfare and social, global and consumer considerations and therefore highlights the dependence of sustainability and profit on socio-economic and natural system influences (SANBI, 2012). Farmers are the custodians of the environment and it is their responsibility to care for the natural resources they use on a daily basis so do to protect them for future generations (SANBI, 2012). Sustainability is becoming high on the agenda of the world and according to Werbach (2009) true sustainability consist out of four components; social, economic, environmental and cultural. Social, addressing issues such as poverty, violence, education, public health, injustice, labour and human rights; the economic component focuses on meeting the economic needs of people and businesses; protecting and rehabilitating the earth falls under the environmental component; and lastly, the cultural component looks at protecting and valuing the diversity of communities (Werbach, 2009).

A new market place is growing due to consumer behaviour and attitudes that are shifting to smarter, safer, cleaner and greener products and according to Bemporad et al. (2012) a study was done with over 6,000 consumers across six countries to provide evidence for the new market place statement. The Bemporad et al. (2012) study also indicated that not only one sector is responsible for improving the environment and society, but it is a shared responsibility between government, private sector and consumers to build a sustainable future for future generations. Government's role is to implement policies and regulations, while the private sector's role can be describe as making products and operations better for people and the planet. Consumers are part of this responsibility by purchasing environmental friendly and ethical products and by also taking actions to reduce their carbon footprint on the environment (Bemporad et al., 2012). The sustainable consumption concept, according to Bemporad et al. (2012) have a impacts from each product's development, dissemination, use and disposal on the one side, and market pressure for increasing sales volume and scale on the other hand. Consumers felt that they must consume less so that the environment can improve for future generations and the study that was done indicated that from the six markets, an overall of 66% agreed with "consuming less" (Bemporad et al., 2012). The six markets were divided into developed and developing markets and 82% from the developing market felt a sense of responsibility to purchase products that were good for the environment and society, while 49% of developed markets felt the responsibility (Bemporad et al., 2012). The price of green purchasing globally was according to 70% of respondents the top barrier for going green, according to Bemporad et al. (2012).

The sustainability concept is what led to expectations for food products to have sustainability credentials and that these credentials could be verified to ensure compliance and consistency (Tait et al., 2011).

This chapter focused on general international and national standards that suppliers have to comply with. These standards highlight what industry bodies and retailers are doing to mitigate climate change and to secure the sustainability of different industries globally and in South Africa, and how they indirectly try to promote better resource efficiency.

3.2. General International Standards

Global GAP

Global GAP (Good Agricultural Practice) is the leading standard in terms of food safety and good agricultural practices worldwide (Global GAP, 2012a). The main objective of this standard is to ensure safe, sustainable production of food, flowers and ornamentals worldwide (Global GAP, 2012b). The standard organisation is a non-profit organisation and therefore sets voluntary standards for the certification of agricultural products around the world (Global GAP, 2012a). These days, more and more producers and suppliers are linking their certification standards with Global GAP. Global GAP's (2012a) main objective is to create a growing movement towards a universal brand, where there is only one standard that identifies safe production methods, the responsible usage of resources and the welfare of employees and animals. This global standard has become quite popular on an international level, and many other standards are transforming to match the Global GAP standard.

A range of topics are covered under the Global GAP certification, as listed below:

- Food safety and traceability
- Environment (including biodiversity and carbon footprinting).
- Workers' health, safety and welfare
- Animal welfare
- Integrated crop management (ICM), integrated pest control (IPC) and
- Quality management system (QMS) and Hazard Analysis and Critical Control Points (HACCP) (Global GAP, 2012a).

According to Global GAP (2012a), their standards demand greater efficiency in production, thus assisting in business's performance by reducing the unnecessary usage of resources by the business. The Global GAP standards are put in place mainly for commercial farmers who are exporting internationally, especially your fresh fruit and wine markets in Europe, as it is an internationally recognised standard. Small and medium-sized farmers will only adhere to these certification standards if they are exporting or supplying an exporting farm or company, because this certification is not only costly, but also has to be audited on an annual basis.

Sustainable Agriculture Network (SAN)

The Sustainable Agricultural Network (SAN) is a Rainforest Alliance initiative, with the main objective being to be “an independent non-profit conservation organization that promotes the social and environmental sustainability of agriculture activities by developing standards (SAN, 2013). Africa, America and Asia have been part of this initiative from the start (since 1992), and some of the major crops included are coffee, cocoa, banana, tea, fruit, seeds, flowers and foliage, vegetables and spices (SAN, 2013). The mission of the SAN is to construct social and environmental standards that will enhance productive agriculture and cattle-production systems, biodiversity conservation as well as sustainable human development (SAN, 2013). SAN have three types of standard certification in place, namely the cattle standards, the farm standard and the group certification standard (SAN, 2015). These three certifications are based on the sustainable agriculture standard, which consist out of ten sustainability principles of SAN (SAN, 2010). These 10 principles are as follow:

- Ecosystem conservation;
- Water conservation;
- Soil conservation;
- Wildlife protection;
- Integrated crop management;
- Integrated waste management;
- Management system;
- Occupational health;
- Working conditions and
- Community relations (SAN, 2010 & 2015).

In order for farmers to obtain and maintain the general compliance certification, a 50% compliance rate for the applicable criteria of each principle must be achieved by the farm (SAN, 2010). The farm must also achieve 80% of the total applicable criteria of the Sustainable Agriculture Standard, according to SAN (2010).

The applicability of the standard gets evaluated by SAN certification bodies according to the following:

- The size and complexity of the operation (plantations or smallholder farms);
- The use or non-use of agrochemicals within the farm;
- The hiring of contracted labour or use of non-contracted family labour;
- The presence or absence of aquatic or terrestrial ecosystems within the farm and
- The presence or absence of infrastructure within the farm (SAN, 2010).

This standard has been developed for rural agriculture and is used by many agricultural communities, including small/medium and commercial agriculture. It is used mainly by farmers who are exporting internationally, and these include small, medium and commercial farmers.

3.2.1. International Retailer Standards

Grape wines, citrus fruit (fresh or dried), apples, pears, quinces (fresh) and grapes (fresh or dried) are some of the main commodities that get exported from the Western Cape to the international markets. Listed below from 1 to 4 in terms of highest to lowest export revenue are the top four countries to import the above mentioned commodities:

1. European Union, with a rand billion value of 25.43
2. SADC (Southern African Development Community), with a rand billion value of 11.79
3. Eastern Asia, with a rand billion value of 7.18
4. NAFTA (North American Free Trade Agreement), with a rand billion value of 4.84 (Western Cape Government Provincial Treasury, 2015).

To be able to export produce from one country to another and even domestically, certain rules and regulations are in place, which includes retailer standards. These retailer standards are created to ensure food safety and good agricultural practices. The sections below, international and national retailer standards, will discuss some of the international and national retailers, commodity associations and their standards in more detail.

TESCO

The Tesco Nature's Choice (TNC) standard focuses on various fruits and vegetables and the programme was designed exclusively for Tesco's suppliers (Control Union, 2009). Inspection for certification is carried out by a third party, the Control Union and according to Tesco (2015a), this standard scheme was developed to identify and recognise farmers who are implementing the best agricultural practices on their farms, while keeping the environment high on their agendas. The TNC scheme consists of five compliance documents: Nature's Choice Code of Practice, General Regulations for Tesco Nature's Choice Scheme, Tesco Nature's Choice Control Points and Compliance Criteria, Plant Protection Product Lists and Guidance Notes for Suppliers (Control

Union, 2009). According to the Control Union (2009) and Tesco (2005), the Nature's Choice Code of Practice covers seven key environmental elements:

- Rational use of plant protection products
- Rational use of fertilisers and manures
- Pollution prevention
- Protection of human health
- Efficient use of energy, water and other natural resources
- Recycling and re-use of materials
- Wildlife and landscape conservation and enhancement

The drivers of the TNC scheme are: customer food safety concerns and expectations, United Kingdom (UK) legislation, demonstration of corporate social responsibility, harmonisation of farm operation practices in the global fresh produce supply chain and the facilitation of the establishment of a level playing field for all producers (Cox, 2007).

The approach followed by Tesco to address climate change is threefold. First, the company aims to cut down their business's emissions to zero carbon by 2050, by using energy-efficient technology in their stores and depots (Tesco, 2015a). Secondly, Tesco has committed to work with its suppliers to decrease their emissions by 30% by 2020 (Tesco, 2015b). Lastly, Tesco is empowering its customers, to make smart decisions and helping them to lead low-carbon lives by making more green products available, affordable and attractive (Tesco, 2015a).

The main produce that Tesco imports from South Africa is wine and fruit, and these products are sourced in a free-trade and ethical manner (Smith, 2009). Most of the produce, especially the wine, is imported from the Western Cape (Tesco, 2015b). The contribution breakdown between commercial and smallholder farmer is not known, and the only assumption that can be made is that, in the Western Cape, most of the smallholder farmers that farm with grapes and fruit will supply the bigger farmers or companies that export to Tesco.

Sainsbury's

Sainsbury's is an international retailer that sources its products from all over the world, but its main focus is its UK customers (Sainsbury's Supermarkets Ltd., 2013). The Sainsbury's code of conduct for ethical trade outlines what is expected from its suppliers. The requirements that are addressed in the code of conduct are all based on UK, EU and international legislation and industry best practice, and include six principles[3] and twelve codes of conduct[4] (Sainsbury's Supermarkets Ltd., 2013). One of the twelve codes of conduct focuses on "Protection of the Environment". This code relates to the activities that need to be carried out in accordance with national law, regulations, administrative practices and policies that are related to the protection and conservation of the environment in the country of operation. It also looks at international agreements, principles, objectives, responsibilities and standards that focus on the environment (Sainsbury's Supermarkets Ltd., 2013).

In 2011, Sainsbury's introduced its 20 x 20 sustainability plan, which looks at 20 commitments that need to be delivered by 2020 (J Sainsbury Plc, 2014). The 20 commitments are categorised as follow:

- "Best for food and health" (2 commitments);
- "Sourcing with integrity" (7 commitments);
- "Respect for our Environment" (5 commitments);
- "Making a positive difference to our community" (2 commitments); and
- "A great place to work" (4 commitments) (J Sainsbury Plc, 2014).

Two categories out of the five, sourcing with integrity and respect for our environment, will be discussed in more detail as they relate to carbon footprinting. Under "Sourcing with integrity", the following commitments are considered, which also are vital for the suppliers:

- A self-determining standard will exist, which Sainsbury will use to source all raw materials and commodities in a the sustainable manner;
- Sainsbury's will make sure that its "own-brand" products are not contributing towards global deforestation; and
- Sainsbury's is also working on ensuring that its suppliers become leaders in meeting their social and environmental standards (J Sainsbury Plc, 2014).

The second category is "Respect for our environment", which addresses all the environmental goals that Sainsbury's are committed to reach by 2020, as follows:

- Put all waste to positive use by 2020;

[3] The six principles are commitment to ethical trade, fair terms of trading, building the capacity of ourselves and others, monitoring our supply chains, being transparent and striving for improvement (Sainsbury's Supermarkets Ltd., 2013).

[4] The twelve codes of conduct are employment is freely chosen, freedom of association and the right to collective bargaining are respected, working conditions are safe and hygienic, child labour shall not be used, living wages are paid, working hours are not excessive, no discrimination is practiced, regular employment is provided, no harsh or inhumane treatment is allowed, entitlement to work, labour agencies and protection of the environment (Sainsbury's Supermarkets Ltd., 2013)

- Reduce operational carbon emissions by 30% in total and 65% relative to the 2005 statistics;
- Ensure their supply chain is sustainable when it comes to all areas of water vulnerability by demonstrating a vigorous water stewardship; and
- Reduce carbon emissions of their own-brand products by 50% by working with their own-brand suppliers (J Sainsbury Plc, 2014).

According to J Sainsbury Plc (2009), the last-mentioned carbon footprint measurement was the first agricultural carbon footprinting model to be certified by the Carbon Trust and to achieve compliance with PAS (Public Available Specifications) 2050. Farms that are part of the Sainsbury Dairy Development Group are audited every year by an independent environmental consultant, and the audits look at every aspect of the farm, for example electricity, feedstuffs, machinery and fuel use (J Sainsbury Plc, 2009). A carbon footprint is generated for each individual farm from these audits, along with an environmental scorecard. The environmental scorecard identifies the hotspots on the farm where improvements need to take place, and this scorecard comes with a detailed greenhouse gas emissions reduction programme (J Sainsbury Plc, 2009). Although the dairy carbon footprint was only done in 2008, Sainsbury's was already busy with carbon footprinting in eight of the development groups. This was started in 2007 and carbon footprint studies have been done on more than 9 219 farms that are part of the eight development groups (J Sainsbury Plc, 2009).

The South African market supplies the Sainsbury's chain with wine, flowers and different types of fruit, like grapes, pears, oranges/soft fruit, lemons, grapefruit and apples for example (J Sainsbury Plc, 2010; NAMC & DAFF, 2011). 12% of fruit in Sainsbury is from a South African origin (NAMC & DAFF, 2011). The South African market is ranking third in terms of supplying fruit to the Sainsbury's group (J Sainsbury Plc, 2010). The South African market normally supplies the UK market in its winter months and follows a free trade and ethical standard programme (J Sainsbury Plc, 2010). Most of the produce supplied is imported from the Western Cape.

ASDA

The ASDA[5] (Associated Dairies; the abbreviation of the merging of Asquith and Dairies) Supermarket Company was found in the 1960s in Yorkshire and it is the UK's leading retailer, with 580 stores (ASDA, 2014). In 2005, ASDA was already working on a sustainability approach and decided to develop a programme under which the approach and policies would fit. The programme was called "sustainability 360", because it covered all aspects of the business (Your ASDA,

[5] ASDA is now owned by Walmart.

2011b). There are three goals that guide this programme's approach and help the programme to stay on track. These include:

- Make use of 100% renewable energy,
- Have zero waste and
- Sell products that sustain people and the environment (Your ASDA, 2011a).

After 2005, ASDA knew it could make a bigger difference to its sustainability approach by cutting the impact of the products it sells and services it offers, and also by looking at the way its product are made (Your ASDA, 2011c). ASDA's current strategy is called Sustainability 2.0 and aims to reduce the impact of operations on the environment by focusing on cutting the impact on their environment and that of their suppliers (Your ASDA, 2011b). Under this program the company aims to cut 20 million tons of CO_2 from their business by 2015. However one of its biggest challenges is to accurately measure the environmental impact of its products and that of its suppliers. To address this challenge, the company became a key member of the Product Research Forum and is working on the Sustainable Product Index with the Sustainability Consortium (Your ASDA, 2011c). ASDA is also engaging with government and non-governmental organisations (NGOs), such as Greenpeace, WWF (World Wildlife Fund) and Friends of the Earth. These organisations have helped ASDA put the right corporate policies in place (Your ASDA, 2011b).

ASDA also supports local suppliers by sourcing most of its produce locally (Your ASDA, 2011c) and looking at healthier food choices for their consumers, for example:

- *Cutting back on pesticides* – ASDA is trying to cut out a number of pesticides used to grow its products and are is working closely with LEAF (Linking Environment and Farming) to reduce chemical pesticides (Your ASDA, 2011b). According to Your ASDA (2011b), the company also is looking at natural ways to kill and keep pests under control, for example making use of ladybirds for cabbage production. ASDA has a brand called Good Natured Fruit and Veg, and this brand was established specifically for pesticide-free products (Your ASDA, 2011b).
- *All ASDA's food ingredients are from non-GM (genetically modified) sources* – When looking at GM crops, studies have shown that the benefits of these crops are increased yields, pest resistance and/or tolerance to drought, but a conflict in science exists about these benefits, so ASDA is taking a preventive approach towards GM ingredients (Your ASDA, 2011b). According to Your ASDA (2011b), the company is following a non-GM ingredient policy because of its consumers.
- *Labelling is more detailed to help consumers find healthier options* – ASDA was the first supermarket to launch a dual labelling system that puts just the right amount of information

on the product so that consumers are not overwhelmed with the information and can read up on the product within two seconds (Your ASDA, 2011b).

- ASDA removed all artificial colours and flavours, flavour enhancers and hydrogenated oil from their range of 12 000 own-brand products (Your ASDA, 2011b).

South African products that can be found on the shelves of ASDA are rooibos tea from the Western Cape, and fruits and wine. ASDA imports mainly red[6], white[7] and rose wine from SA (ASDA, 2015).

Marks & Spencer

Marks & Spencer (M&S) was built on five key principles, namely quality, value, service, innovation and trust (Marks & Spencer Company Archive, 2015).

As of 2007, M&S focused on sustainability to help them ensure a market share for the years to come. To achieve this Plan A – eco-plan was establish as part of the company's vision, comprising 100 action points, which have expanded to 160 points (McCarthy, 2010). Plan A has six objectives that are closely linked to sustainable procurement; of these, three are relevant to CO_2 footprinting:

- Helping suppliers to create 200 Plan A factories that comply with either ethical or environmental or both features;
- Ensuring that food packaging is being sourced via a single model forest programme and
- Ensuring that the palm oil, soya, cocoa, beef, leather and coffee used and sold are not contributing to deforestation and come from sustainable sources (McCarthy, 2010).

In terms of carbon footprinting M&S achieved carbon neutrality on 1 April 2013 and is the first major retailer in the world to have carbon neutral operations. Since 2007, M&S has reduced its companies' Greenhouse gas (GHG) emissions by over 160 000 tonnes a year by having improved energy efficiency, reduced emissions from refrigeration, better fuel consumption and by sending no waste to landfills (M&S, 2014b). M&S also is working on developing GHG emission reduction programmes to motivate suppliers to reduce their emissions (M&S, 2014a).

M&S has realised that most of the factors contributing to its carbon footprint are outside its boundaries and the company therefore does not have direct control over it, as the suppliers form

[6] Red wines like Pinotage, Cabernet Sauvignon, Merlot Pinotage, Shiraz, Merlot, Cabernet Shiraz and Shiraz-Merlot get exported to ASDA. The most popular brand names that can be found are First Cape, Yellowwood Mountain, Southern Point, Stormshoek, Beyerskloof and Vine Country.

[7] The most popular white wines that are being exported to ASDA are Sauvignon Blanc, Sauvignon Chenin, Chardonnay and Chenin Blanc. The most popular brand names that can be found are First Cape, Yellowwood Mountain, Southern Point, Stormshoek, Beyerskloof and Vine Country.

part of M&S's scope 3 emissions, which is their supply chain emissions. Under this scope, M&S addresses the following, which have a direct impact on the suppliers:

- Launching a supplier exchange best practice programme;
- Working with the Carbon Trust to calculate the full carbon footprint of its food business;
- Supporting the development of green supplier factories;
- Developing a range of low carbon products;
- Reduced packaging by 25% ;
- Engaging farmers and growers in the M&S Farming for the Future programme;
- Reducing home delivery packaging by 20% by 2015;
- Reducing transit packaging by 25% by 2015 (M&S, 2014a).

In addition, M&S has a list of global principles[8] that it expects its suppliers to comply with and, in order to ensure that their suppliers adhere, it undertakes regular site visits and by has strict sanctions in place if a supplier does not comply (M&S, 2013).

The South African market supplies mainly different types of red[9], white[10], sparkling and rose wine to the M&S group (M&S, 2015).

3.3. General National Standards

SAGAP

SAGAP is a South African food safety compliance standard that gives buyers reassurance about the product safety and environmental impact. The SAGAP auditing programme offers three types of auditing services (SAGAP, 2015). These services are:

- Management System Certification – the aim of this certification system is to get organisations thinking about all their process and record keeping. Accreditation is provided for four management systems, namely the Food Safety Management Systems (ISO 22000:2005); Quality Management Systems (ISO 9001:2008); Environmental Management

[8] Global principles such as land rights; healthy and safe working conditions, supply chain monitoring, sub-contracting, environment, information about employment and employee relationship, human resource policies and compliance with national law (M & S, 2013).

[9] Red wines like Pinotage, Cabernet Sauvignon, Merlot Pinotage, Shiraz, Merlot, Cabernet Shiraz and Shiraz-Merlot get exported to M&S (M&S, 2015). The most popular brand names that can be found in the M&S stores are Paarl Heights, Six Hats Fairtrade, Dolphin Bay, Cape Red, Paul Cluver and Rust En Vrede Estate (M&S, 2015).

[10] The most popular white wines that are being exported to M&S are Sauvignon Blanc, Sauvignon Chenin, Chardonnay and Chenin Blanc (M&S, 2015). The most popular brand names that can be found are Paarl Heights, Fairtrade, Zebra View, Dolphin Bay, Paul Cluver, Cape White and Crow's fountain (M&S, 2015).

Systems (ISO 14001:2004) and Occupational Health and Safety Management Systems (OHSAS 18001:2007), according to SAGAP (2015).

- Supplier Audits – this is a requirement of food safety certification and the promulgation of the Consumer Protection Act (SAGAP, 2015). SAGAP can do audits on behalf of its clients, and check suppliers' compliance with the supplier's quality assurance programme (SAGAP, 2015).
- GAP analysis/state of readiness audits – this is just to see if businesses are compliant and ready for the real GAP audits (SAGAP, 2015). According to SAGAP (2015), these GAP analysis audits are the best alternative when it comes to cost effectiveness and assist and lead companies in the right direction before the real audits, which are costly and time consuming, take place. SAGAP conducts GAP audits on facilities/management systems using Southern African Auditor & Training Certification Authority (SAATCA)-approved lead auditors in line with the following standards (SAGAP, 2015): The Food Safety Management Systems (HACCP, ISO 22000, FSSC 22000, BRC Version 6); Quality Management Systems (ISO 9001:2008); Good Agricultural Practices (SA GAP, EPM GAP, M&R GAP); Good Manufacturing Practices (SANS 10049:2011, PAS 220/ISO 22002-1, PAS 223, BRC IOP); Environmental Management Systems (ISO 14001) and Occupational Health and Safety Management Systems (OHSAS 18001).

The cost of the auditing process is calculated on an individual basis. The provincial and national departments also are assisting smallholder farmers in the auditing process and by helping the farmers getting SAGAP approval, through PPECB (Perishable Products Export Control Board) by being the link between PPECB and the farmer. The departments will organise the visits and assist the farmer with the paper work if they have to correct mistakes. The national department of agriculture pays for the entire auditing process. The auditing process is as follows:

- A food scientist from the PPECB will go out and ask questions and inspect the farm;
- The farmers has three months to correct any mistakes that are prohibiting them from getting certification; and
- After the three months, the PPECB will go back to see if everything is in order before the certification is issued (Jafta, 2014).

3.3.1. National Retailer Standards and Producer Associations Standards

Woolworths

Woolworths is one of the leading South African retailers focusing on sustainability, as the company believes that sustainability plays a fundamental role when it comes to the company's governance practices and sustainability, which can also help the company to build a positive brand (Smith, 2007). According to Smith (2007), social, environmental and economic risks can be managed well with an integrated sustainability programme, as well as provide scope for new products, services and markets. The company's sustainability commitments led to Woolworths forming the Woolworths Good Business Journey in 2007 (Smith, 2007). According to Smith (2007), the international retailers' sustainability agenda, the Global Reporting Initiative (GRI) guidelines, the Johannesburg Stock Exchange (JSE) socially responsible investment index criteria and other legislative requirements are the main drivers and motivation behind Woolworths' Good Business Journey. Four vital priorities were identified by the Woolworths Sustainability Index:

- Woolworths is speeding up transformation,
- It is driving social development,
- It is enhancing its environmental focus and
- It is addressing climate change (Smith, 2007).

For the purposes of this study the focus will be only on priorities three and four – enhancing its environmental focus and addressing climate change. Priority three focuses on Woolworths's impact on the environment, especially on biodiversity which is lessening and natural resources, which are threatened (Smith, 2007). According to Smith (2007), Woolworths wants to reduce its water consumption by 30%. Woolworths has put various programmes in place to protect biodiversity in South Africa, including 'Farming for the Future', 'Fishing for the Future', 'animal welfare' and 'sustainable fibre programmes' that look at environmentally sensitive practices and practices that will cause minimum harm to the natural environment throughout the entire supply chain (Smith, 2007; WHL, 2014). Farming for the future programme have been running for six year and Woolworths has a 98% rate of its fruit, vegetable, wine and horticulture producers that are part of this programme (WHL, 2015). Addressing climate change is the fourth priority of Woolworths, and this priority focuses on Woolworths' carbon footprint (Smith, 2007). Woolworths wants to reduce its footprint by 30% by focusing on reducing its electricity usage and its transport emissions (Smith, 2007). When it comes to waste, Woolworths is committed to reducing the amount of waste sent to landfills and is coming up with new ways to reduce landfill waste, for example using recycled material in its packaging and products (WHL, 2014). According to WHL (2014), the company is in partnership with WWF-SA and is working towards further progress and better environmental results in dairy, beef, seafood and textiles production, as well as in addressing food waste on farms. Woolworths is serious when it comes to managing sustainability and have 4 focus areas for sustainability (WHL, 2015). These 4 focus areas for sustainability are:

- Sustainable farming,
- Water,
- Waste and
- Energy and climate change (WHL, 2015).

Spar

Spar believes that its environmental impact does not lie only with the organisation, but also with those who supplies its goods. Spar thus decided to survey its top suppliers and screen new suppliers by using environmental criteria, which were compiled in a report to be released in 2015 (The Spar Limited Group, 2014). According to the Spar Limited Group (2014), its executive management team has identified the focus areas for the Spar group's sustainability strategy, and four strategic environmental imperatives and enablers have been developed that directly address the environmental component. These are:

- Spar is focus on excelling in fresh,
- Spar is socially and environmentally committed,
- Spar is reducing its direct environmental footprint, and
- Spar is closely involved with its suppliers' and retailers' business practices (The Spar Limited Group, 2014).

The Spar Group also focuses on its fuel, energy, electricity and water usage, as well as its emissions and effluents and waste, which also play a role when it comes to environmental issues (The Spar Limited Group, 2014). Spar uses the GlobalGAP standards for better management of its supply chain risks, to ensure a broader, more diverse supplier base, to encourage economic growth and to build brand loyalty amongst its stakeholders (The Spar Limited Group, 2014). Spar not only focuses on its large-scale commercial farmers, but has put a plan in place to also include smallholder emerging farmers by adopting SAGAP (The Spar Limited Group, 2014). According to the Spar Limited Group (2014), SAGAP is an entry-level food safety standard towards full compliance with GlobalGAP, which gives small-scale farmers a two-year period to fully comply with the GlobalGAP standards. Spar sources from local farmers, which includes smallholders, but these smallholders must comply with SAGAP so that there is some sense of safe food.

Pick n Pay

Pick n Pay has also realised the importance of the impact of environmental, social and corporate governance (ESG) on its business and therefore has put various strategies in place, for example a sustainability approach (John Brown South Africa, 2013). The sustainability approach focuses on six points:

- Providing safe food and sustainable product lines,
- Building strong supplier networks,
- Working towards a clean and healthy environment,
- Working towards empowering the company's people,
- Supporting local communities in their contribution towards change and

- Enhancing governance and accountability (John Brown South Africa, 2013).

Only three of these sustainability points mentioned above are directly linked with carbon footprinting namely; providing safe food and sustainable product lines, working towards a clean and healthy environment and building strong supplier networks. Reducing waste and optimising systems, driving the availability of sustainable and ethical products and addressing food security, poverty and inequality issues flow from the “providing safe food and sustainability product lines” (John Brown South Africa, 2013). Whereas reducing waste and optimising systems, accountability and transparency across the value chain, driving the availability of sustainable and ethical products, leveraging the extensive supplier network to achieve solutions at scale and inspiring and assisting millions of customers to contribute to change flow from the “working towards a clean and healthy environment” (John Brown South Africa, 2013). “Building strong supplier networks” flows from reducing waste and optimising systems, achieving transformation goals, reorienting supplier networks, adapting to and mitigating climate change, driving the availability of sustainable and ethical products, addressing food security, poverty and inequality, and leveraging the company’s extensive supplier network to achieve solutions at scale (John Brown South Africa, 2013). Some of these issues are interlinked with each other.

The v*ision* of the company consists of five key points of most importance to this study, namely “develop new products that meet evolving customer needs and environmental requirements” (John Brown South Africa, 2013). Under the company’s *engagement* policies, nine key engagement interactions are listed, but from these only four relate to the environmental issues – “annual food safety audits of all our supplier factories and production facilities, technical support, compliance training and supplier conferences” (John Brown South Africa, 2013). The six key *issues* being address by Pick n Pay with their suppliers are resource (energy, water, waste, logistics) efficiency; opportunities for cost reductions; transformation and enterprise development; fair pricing, research and development support; contracts and agreements, certification, infrastructure and logistical support; and risks and opportunities (John Brown South Africa, 2013).

Shoprite Group

Shoprite Holdings consists of various retail stores, namely Shoprite, Shoprite-Checkers, Checkers, USave, Checkers Hyper, FreshMark, Liquor Shop, MediRite and OK Franchise stores. Shoprite Holdings’ sustainability plan looks at five key elements:

- Providing customers with affordable and safe food,
- Attracting and retaining employees who are enthusiastic and passionate about the business,

- Taking its business operations and value chain's environmental impact into consideration because these play a vital role when it comes to production costs and the business's reputation,
- Working closely with suppliers to guarantee food security, sustainable supply of food, food safety and cost effectiveness and, lastly,
- Bearing in mind the group's impact on the community it serves (Shoprite Holdings LTD, 2014a).

Looking at the supplier side, the Shoprite Group has realised that it has to work with its suppliers to ensure affordable and safe food, and a stable and reliable supply of products, which would lead to lower costs in the supply chain (Shoprite Holdings LTD, 2014b).

The Shoprite Group is working proactively on food safety and is measuring its suppliers' and its own operations according to international food safety standards, which include staggered audits requirements (Shoprite Holding LTD, 2014a). According to Shoprite Holdings LTD (2014a), these audits can range from hygiene and regulatory reviews, which are more suited for smallholder suppliers, while large suppliers go through accredited certification audits. The Shoprite Group only makes use of a supplier if the supplier has passed the audit and received the food safety approval stamp, and these audited results are reported on a monthly basis, and the suppliers' compliance is monitored rigorously (Shoprite Holdings LTD, 2014b). The Shoprite Group makes use of the PPECB for the auditing of its export distribution centre and may only export products when they receive compliance from PPECB (Shoprite Holdings LTD, 2014b). It is important to note that national and provincial departments of agriculture have been mandated to assist farmers to obtain the PPECB certification with all costs covered by the applicable department.

Fruit & Veg City

Fruit and Veg City was established in 1993 the company has grown to more than 100 stores all across Southern Africa, as well as in Australia (Fruit and Veg City, 2015). The legal name of this retailer is Fruit and Veg City Holdings (Pty) Ltd, which consists of specialised service departments, such as hot foods, bakery, deli, cheese, seafood and sushi; and other specialty store positions, including groceries, kitchenware, fresh produce, butchery, etc. (Bloomberg Business, 2014). When it comes to sustainability, Fruit and Veg City is one of the leading role players in the seafood industry and is well positioned to drive change when it comes to sustainable seafood choices (Fruit and Veg City, 2013). Fruit and Veg City will not buy sea animals/seafood that is endangered and that is why the company also encourages its customers to do the same. Fruit and vegetable suppliers must be HACCP and GlobalGAP approved, and also be PPECB certified (Fruit and Veg City, 2013).

Below is brief discussion on some of the commodity association sustainability requirements and projects.

The South African Poultry Association

The South African Poultry Association (SAPA)'s vision and mission (below) show SAPA's commitment to climate change and sustainability:

- SAPA's vision is to contribute to economic growth by making sure their producers comply with the production standards and norms that exist for environmental and ethical issues;
- The mission of SAPA is to achieve sustainable profits that are generated by the producers by working with the environment to achieve such profits in the different markets (SAPA, 2012a).

SAPA has a code of practice that serves as an objective guide for its members, but states that the code does not overwrite the relevant laws, by-laws, regulations and compulsory specifications and rather should be used in conjunction with these laws and regulations (SAPA, 2012b; 2012c). These laws and regulations and the code of practice for broiler production, pullet rearing and table egg production are given in a table format in Appendix C. The same code applies to broiler and pullet rearing and table egg production (SAPA, 2012b; 2012c). See Appendix C for a breakdown of all laws, regulations and codes of best practice for South African poultry.

Confronting Climate Change Fruit and Wine Initiative

The Confronting Climate Change (CCC) fruit and wine carbon calculator was established and funded by various partners namely the Western Cape Department of Agriculture, Trade Mark Southern Africa, South African Table Grape Industry, Subtropical Growers' Association, Citrus Growers Association, Apple and Pear Producers' Association, Citrus Research International, Stone Fruit Producers Association, Winetech (Wine Industry Network of Expertise and Technology), National Agricultural Marketing Council and Post-Harvest Innovation Programme. The main aim behind the fruit and wine calculator initiative was to enable growers and service providers to calculate their own carbon footprint, which would help them to identify emission hotspots and emission reduction opportunities. There is no direct cost involved for farmers, as the calculator is funded by the various partners but a small fee is charged for their train-the-trainer workshops. The calculator is however focusing on the fruit and wine industry and requires computer literacy skills. CCC also charges a fee if they have to compile a footprint for a farm, and they do not assist with verification (CCC, 2009).

Integrated Production of Wine Scheme

The Integrated Production of Wine Scheme (IPW) was established in 1998 and is a voluntary environmental sustainability scheme (IPW, 2015). The IPW is responsible for the administration of the scheme and the compliance of the IPW's certification falls under the authority of the Wine and Spirit Board (WSB) (IPW, 2015). The IPW complies with the Global Wine Sector Environmental Sustainability Principles (GWSESP) and these principles are as follow:

- The selection of appropriate environmental sustainability programs based on the program's ability to satisfy the triple bottom line economic, environmental and social sustainability;
- The identification of environmental sustainability activities using an environmental risk assessment;
- Environmental risk assessment should consider but not limit to site selection, variety selection, soil conditions, water use efficiency, wastewater, human resource management, biodiversity, solid waste, energy use, air quality, neighbouring land use and agrochemical use;
- A process of planning for environmental sustainability activities, implementation of the activities, assessment of their effectiveness and modification of the activity for application into the future;
- Wine sector environmental sustainability programs should incorporate 'self-assessment' and other forms of evaluation to gauge environmental performance;
- The improvement of extension and education opportunities about sustainability issues and to build awareness within the global wine sector; and

The global wine sector should consider partnerships with both wine industry and natural resource management stakeholders to improve sector sustainability, including the adaptation of preferential purchasing policies from suppliers able to demonstrate a similar stewardship ethic (Caplan, 2006). A certification seal exists for producers that comply with the IPW scheme and this certification seal is also managed by the WSB (IPW, 2015). The seal certifies for both IPW and Wine of Origin (WO).

RPO and NERPO

The Red Meat Producers' Organisation (RPO) and National Emerging Red Meat Producers' Organisation (NERPO) have acknowledged that farming is not only about sustenance and profitability, but that the environment and natural resources also are important (SANBI, 2012). By focusing on the environment, the RPO and NERPO have realised that livestock farming is one of the most intense activities that contributes the most to GHG emissions, and they have realised that mitigation methods have to be put in place (RPO/NERPO, 2014). According to RPO/NERPO (2014), some of the advised mitigation methods that can be implemented on the farm:

- Improved production efficiency;
- Minimum or no tillage methods must be incorporated in farming practices;
- Solar power and energy-saving appliances must be used to save energy;
- Good fuel efficiency vehicles must be used and trips must be decreased;
- Animals must be given higher quality feed that will be more digestible;
- “Using home-grown feeds and by-products from the human food chain such as hominy chop, wheaten bran, defatted maize germ and brewer’s grains rather than cultivated feeds such as maize and protein sources such as soybeans to support livestock production”; and
- “Including feed additives such as oils and fats and ionophores such as monensin in feeds. They reduce CH_4 production during rumen fermentation, but the potential is modest”.

A code of best practice was established to ensure that the industry and farmers are committed to the principles and imperatives that address the environmental and natural resources issues (SANBI, 2012). There are several laws and regulations, as well as codes of practices, that are relevant to RPO and NERPO and that have to be adhered to. These are set out in the laws, regulations and codes of practice table in table 3.1.

Table 3.1: Laws, regulations and codes of practice to which NERPO and RPO have to adhere

Laws and regulations	Codes of practice
Animal Diseases Act, No 35 of 1984	The Handling and Transport of Animals [e.g. Code: SANS 1488 – Humane Transport of Livestock by Road]
Animal Identification Act, No 6 of 2002	Feedlots
Animal Improvement Act, No 62 of 1998	The Handling of Livestock at Auctions, Shows and Vending Sites [e.g. Code: SANS 1469 – Humane Handling and Facility for the Protection of Livestock at Shows, Auctions, Vending Sites and Pounds]
Animal Protection Act, 1962, No 71 of 1962	
Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act, No 36 of 1947	
Meat Safety Act, No 40 of 2000	
Veterinary and Para-Veterinary Professions Act. No 19 of 1982	

Source: RPO/NERPO, 2014

3.4. Market and Avenues for Smallholder Farmers

There are two market types, formal and informal markets. Looking at formal markets first, it is clear from the international retailer standards and the national retailer standards there are standards in place that smallholder farmers have to adhere to before they can sell in the formal market sphere. The formal market is taxed and monitored by the government. It also is included in the country's gross domestic product (GDP) and gross national product (GNP) (IB Economics, 2015).

Normally the smallholder farmers will sell to local shops in their area, like Spar, Fruit and Veg and Pick n Pay, or to local restaurants (Jafta, 2014). Smallholder farmers must have SAGAP accreditation to be able to sell their produce to most of the domestic formal markets. According to Jafta (2014), the DAFF (Department of Agriculture, Forestry and Fisheries) is helping smallholder farmers with SAGAP certification by running a SAGAP accreditation programme. This programme is offered in conjunction with PPECB, which conducts the SAGAP audits on the farms (Jafta, 2014). This accreditation works as follows: fertiliser and harvest records must be in place, and there must be a chemical storage room and toilet facilities for workers (Jafta, 2014). Secondly, PPCEB first conducts pre-audits to see if all the records are in place and to see if the rules/regulations are being met and, if not, farmers are given three months to correct what is wrong before the final audit takes place (Jafta, 2014). The SAGAP standards were discussed in detail in the general national standards section 3.3.

As this study focuses on the Western Cape it is important to note that the WCDoA assists smallholder farmers to gain access to formal markets under the Market Access Programme. Currently there are eight retailers/buyers on the WCDoA's Market Access Programme list that buy from the local smallholders, as can be seen in the list of buyers on the market access programme table in table 3.2 (Jafta, 2014).

Table 3.2: List of Buyers on the Market Access Programme

Name of the company/buyer	Place
Roelcor	Kraaifontein
Spar	Tulbagh/Caledon
FoodBank SA	Cape Town
Freshmark	Cape Town
Beaufort West Abattoirs	Beaufort West
Tomis Abattoirs	Wellington
Pick n Pay Retailers	Cape Town
Agrow Fresh	Malmesbury

Source: Jafta, 2014

The buyers in table 3.2 do not focus much on environmental standards, but mainly on food safety standards, so suppliers to these retailers and markets have to comply with food safety regulations and standards. SAGAP is the standard required by most of the local retailers.

The informal market sphere is an important alternative for most smallholder producers who do not meet the standards of the formal markets. Informal market platforms are street vendors, hawkers, neighbourhood and farmer markets (Jafta, 2014). An informal market, according to International Baccalaureate (IB) Economics (2015), is the sector in the economy that is not taxed, monitored by government or included in any GDP or GNP. The risk to food security plays a major role in these informal markets, because no one focuses on food safety. Farmers will sell produce at the farm gate, fruit and vegetable stalls in town or townships, and also sell to hawkers (Jafta, 2014).

3.5. Conclusion

The sustainability standards that have been put in place nationally and internationally confirm that retailers and industry bodies have realised that the effects of climate change and consumers and stakeholders are becoming more aware and environmentally savvy. In order for these retailers to maintain their market share and their reputation, they have to address climate change-related issues, as well as put standards and policies in place to mitigate the effects on the environment and to be able to compete on an international level. Retailers also are trying to reduce their environmental impact, not only by looking at their business operations, but also by informing and educating their customers and stakeholders, as well as putting measures in place for their suppliers. This reduces their overall impact and lowers production costs. It thus will become harder for smallholder farmers to get into the formal marketplace if proper practices and compliances are not maintained. Proper practices could also result in a reduction in input costs and thus help support the longevity of their operations. Despite the challenges faced by smallholder farmers, they can still rely on the assistance of both the national and provincial departments of agriculture in relation to compliance with the market standards Chapter four will discuss the sample and questionnaire design.

Chapter 4: Sample and Questionnaire Design

4.1. Introduction

According to Leedy and Ormrod (2010), the sample size of any study must be based on the research question asked and what the researcher is trying to answer. This study is trying to answer these following questions: Is there a need for a smallholder mixed farming carbon calculator? What information is available on the farm currently and is it enough to conduct a footprint for smallholder farmers? In order to extract information from a sample, a questionnaire is used most of the time. However, having to construct and administer a questionnaire can be a complex job. The main purpose of the questionnaire is to collect data (Leedy & Ormrod, 2010; Quelhas et al., 2011). One false step can lead to uninterpretable data or a low return rate, thus high levels of precision and caution are needed when constructing and administering a questionnaire. This chapter will firstly discuss the sample of the study, and possible biases that could occur. Secondly, the focus will shift to the questionnaire and the possible questionnaire design, the pilot questionnaire and the questionnaire biases that might exist during the interviews.

4.2. Sample Design Methods

Different sampling designs exist for different situations, and the sampling design that gets chosen must fit the specific situation that is being looked at (Leedy & Ormrod, 2010). The purpose of the study and the study's research methodology must be taken into consideration when selecting the sample design. This section looks at probability sampling and nonprobability sampling.

4.2.1. Probability Sampling

Probability sampling can specify that each unit within the target population will have an equal chance of being presented in the sample and this probability is what sets this method apart from nonprobability sampling (Leedy & Ormrod, 2010; Pearce & Özdemiroglu, 2002). Probability sampling makes use of random sampling, which means each member in the targeted population will have an equal chance of being selected for the sample, and the data collected at this point will have a clear assumption that the characteristics of the sample are approximately the characteristics of the targeted population (Leedy & Ormrod, 2010; Pearce & Özdemiroglu, 2002; Westfall, 2008). In some cases, random sampling cannot be used because of practical, theoretical or financial issues, but according to Cloete (2012), random sampling is more accurate and rigorous in general, and that is why it still gets used today. Under the probability category falls the following sample methods:

- Simple random sampling
- Stratified random sampling
- Proportional stratified sampling
- Cluster sampling
- Systematic sampling (Leedy & Ormrod, 2010)

4.2.2. Nonprobability Sampling

Nonprobability sampling is a sampling method, in which there is no guarantee that all elements of a population will be represented in the sample. There is no equal chance for the members of the population to be chosen for the sample; chances are little or zero (Leedy & Ormrod, 2010). Certain scenarios can exist where nonprobability sampling is preferred above probability sampling, and in cases like that, nonprobability sampling might be more sensible and more efficient than the probability approach (Cloete, 2012). Another name for nonprobability sampling is purposive sampling. The aim of purposive sampling is to sample a predefined group, because the main concern of the study is not the proportionality of the targeted population. This approach can be applied to various areas, for example to sample various groups, to sample diversity or to use in cases where it is difficult to identify or locate the respondents (Cloete, 2012). Under the nonprobability category falls the following sampling methods:

- Convenience sampling
- Quota sampling
- Snowball sampling
- Modal sampling
- Expert sampling
- Heterogeneity sampling (Leedy & Ormrod, 2010)

4.2.3. Study sample

The SimFini project is a financial management program for the present-day farmer and agricultural business (Softwarefarm, 2011). The Western Cape Department of Agriculture uses this tool to assists smallholder farmers with record keeping, allowing them to get audited financial statements at the end of their financial year. Currently there are 30 smallholder farmers listed on the SimFini electronic project for the 2013/14 cycle, which represents 54% of the 55 smallholder farmers who are funded by Farmer Support and Development programme of the department (Martin, 2015). This is not the total number of smallholder farmers in the Western Cape, but only the farmers supported and/or funded by the Western Cape Department of Agriculture for the 2013/2014 cycle.

The study thus will use the 18 preselected SimFini farmers to test the success of the calculator. These 18 farmers were selected on the criteria that they are part of the department's SimFini programme, meaning they have records in place that will make the questionnaire process easier, and they also were scored as excellent, good or average in terms of record keeping by Exceed (the auditor company for the department). These questions do not need a large sample size, because sampling is only needed to test current record keeping. As mentioned in chapter 1, only 18 farmers were selected from the 30 SimFini farmers to take part in this study. The 18 that were selected were from all over the Western Cape, with three farmers per district, and this sample indicated the different farming scenarios per district. The 18 farmers where selected based on their recordkeeping scores (indications that data collected will be accurate because there is a paper trail) and their variety of farming activities. To answer the research questions, a questionnaire had to be administered. Convenience sampling was used, due to the availability and accessibility of the of the SimFini farmers. The definition of convenience sampling is a process that is also known as accidental sampling, and this sampling occurs according to availability and accessibility, meaning this sampling is suitable for less demanding research (Leedy & Ormrod, 2010).These farmers already had audited records and they got scored based on the records they keep, so as a result the top three ranked farmers from each district in terms of record keeping were picked for this study.

The sample size of any research can influence the quality and accuracy of the research and can lead to inadequate and inappropriate information if the sample size is not correct (Bartlett et al., 2001). As indicated in Chapter 1, the Western Cape had 9 844 smallholder farmers in 2010. A smaller sample size therefore is acceptable, as due to the nature of this study it was not deemed necessary to prove that the sample was representative of the population, as the preselected sample was only used to test the success of the proposed calculator and to identify any shortcomings in terms of the current recordkeeping system.

Farm Profiles

The study looked at six districts in the Western Cape, and three smallholder farms from each district were chosen. The six districts were the Overberg, Cape Winelands, Cape Metro, West Coast, Eden and Central Karoo. The real names of the farms are withheld due to the confidentiality factor and they therefore are referred to as the district name and a number, for example Overberg 1. According to the WCDOA (2010; 2014a), there were 9 844 smallholder farms in the WC in 2010, and this number included 681 individual farms (one owner) and 9 163 group member farms (one farm with a few members). Eighty percent of these farms were fully active, 18% were semi-active and 2% were dormant, while the status of the other 6% was not known (WCDOA, 2010).

Percentage contribution of Western Cape smallholder farmers to total provincial agricultural output are described in table 4.1.

Table 4.1: Percentage contribution of Western Cape smallholder farmers to total provincial agricultural output for 2013

Western Cape economy		
Sector	**Total value of production 2013 (current prices in millions)**	**% contribution to total output**
Agriculture, Forestry and Fisheries	***40 721.23***	***4.062***
Smallholder farming sector	***1 289.39***	***0.129***
Cape Metro Area	35.67	0.004
Eden	49.77	0.005
Central Karoo	51.11	0.005
Overberg	110.80	0.011
West Coast	435.48	0.043
Cape Winelands	606.56	0.061
Total output Western Cape (all sectors)	***1 002 513.00***	***100***

Source: Estimate of total output from smallholder farming based on own calculations using emerging farming data from 2007[11]

The percentage contribution of the WC Agriculture, Forestry and Fisheries sector to the total economic output is 4.062%, while the smallholder farming sector contributes 0.129%. This market segment consists of 21% formal markets, 71% informal markets, 1% own consumption and 7% unknown (WCDoA, 2010). The sample of this study includes farmers from across the province to test the effectiveness of a carbon calculator for smallholder mixed farming enterprises:

- to re-develop what is out there in a simpler format that will be easy to use by “high level” and “low level” educated farmers,
- to see what level of “green knowledge” farmers do have, and
- to create awareness of climate change and sustainability among the sample group.

Each district’s three farm projects are explained below in a brief farm profile:

<u>Overberg</u>

The Overberg region is a winter rainfall region and consists of four municipal areas, namely Theewaterskloof, Overstrand, Cape Agulhas and Swellendam. The Overberg is known mostly for

[11] Source: WCDoA (2007) output data was used.

sheep, cattle and grain production (mainly wheat) and also for fruit, canola and vegetable production (African Conservation Photodestination, 2014; WCDOA, 2014b). The Overberg is also called "the country's breadbasket" because of the area's large wheat capacity (SouthAfrica.info, 2012).

In 2013, the leading sectors in the Overberg were finance and business services (27.1%), manufacturing (16.2%), wholesale (13.9%) and agriculture (11.6%) (Western Cape Government Provincial Treasury, 2013e). The contributions to the Overberg economy from agriculture, hunting, forestry and fishing in the different municipal areas for the 2011 period were: 21.3% for the Theewaterskloof area, 3.9% for Overstrand, 7.0% for Cape Agulhas and 11.3% for Swellendam (Western Cape Government Provincial Treasury, 2013e). Their contributions to the Overberg district municipality's annual growth (real GDPR growth) for the period 2000 to 2011 were: -0.4% for the Theewaterskloof area, -0.3% for Overstrand, 1.0% for Cape Agulhas and -3.3% for Swellendam; while the whole Overberg showed a -0.7% growth rate for the same period for the agriculture, forestry and fishing sector (Western Cape Government Provincial Treasury, 2013e). Unfortunately no current data was available when this study was conducted.

The number of smallholders in the Overberg is estimated at 960, which includes 80 individual farmers and 880 farmers who are members of groups (WCDOA, 2010). The Overberg's contribution to provincial total output is 0.011% (estimate of total output from smallholder farming based on own calculations using emerging farming data from 2007). The three sample farms of the Overberg are discussed briefly below:

Overberg 1

Overberg 1 is situated close to Elim and falls within the Cape Agulhas municipal boundary. It is 84.4420 hectares (ha) in size. Only 3 ha of the total hectares are virgin land and another 1 ha is non-active land; the rest is actively used for farming businesses. The main activities of the farm are sheep, pigs and grains for animal feed. Overberg 1 sells its produce to butcheries in Elim and in surrounding towns, to the local community and also at auctions.

Overberg 2

Overberg 2 is situated between Barrydale and Montagu and falls in the Swellendam municipal boundary. The farm size is 400 ha and all of the 400 ha is used actively. The main activities are cattle (meat), sheep and the planting of lucerne, wheat, barley and oats for animal consumption. Overberg 2 sells its produce mainly on auction and the rest to the local community.

Overberg 3

Overberg 3 is situated in Botriver near Caledon and falls within the Theewaterskloof municipality. The farm size is 9 ha and all 9 ha are used actively for production. The main activities of the farm are tunnelled tomatoes, and cold storage and packing facilities for vegetables and fruit. Overberg 3 sells its produce to shops in the surrounding areas.

Cape Winelands

The Cape Winelands region is a winter rainfall region and is known mostly for its wine grapes, table grapes, pome fruit, stone fruit, small stock and small grain (Cape Winelands District Municipality, 2010; WCDOA, 2014b). The Cape Winelands consists of five municipal areas, namely Witzenberg, Drakenstein, Breede Valley, Stellenbosch and Langeberg. The leading sectors in the Cape Winelands that contribute to employment are manufacturing (24.2%) and finance, insurance, real estate and business (22.9%) (Western Cape Government Provincial Treasury 2013a).

The contributions to the Cape Winelands district municipality's annual growth for the period from 2000 to 2011 were: 0.8% for the Witzenberg area, 0.6% for Drakenstein, 0.1% for Stellenbosch, -0.3% for Breede Valley and -0.1% for Langeberg area, while the whole Cape Winelands showed a growth rate of 0.3% for the same period for the agriculture, forestry and fishing sector (Western Cape Government Provincial Treasury, 2013a).

The number of smallholders in the Cape Winelands is 4 601, which include 142 individual farmers and 4 459 farmers who are members of groups (WCDOA, 2010). The Cape Winelands' contribution to total output is 0.061% (estimate of total output from smallholder farming based on own calculations using emerging farming data from 2007). The three sample farms of the Cape Winelands are discussed briefly below:

Cape Winelands 1

Cape Winelands 1 is 15 ha in size and only 13 ha are used actively for the farming business. The main outputs of the farm are table grapes, and the preparation and packing of table grapes. Cape Winelands 1 supplies its produce to a big commercial farm in the area, which exports the produce to Europe, other African countries.

Cape Winelands 2

Cape Winelands 2 is situated close to Paarl. The farm size is 1 ha and the entire 1 ha is used actively. The main activities of the farm are tunnel and outside vegetables and herbs. Cape Winelands 2 sells its produce to restaurants and retailers in the surrounding areas.

Cape Winelands 3

Cape Winelands 3 is situated close to Worcester and the farm is 52 ha big. Six hectares currently are used by "this project", 23 ha belong to the owner of the farm, 18 ha is non-active land and 5 ha are virgin lands. The main activity that is currently taking place on the 6 ha is table grape production. Cape Winelands 3 supplies its grapes to a large exporting company, which exports the produce to Europe.

Cape Metro/City of Cape Town

The Cape Metro region is a winter rainfall region and is mostly known for its small grain, wine grapes and pome fruit, and also for vegetables, which are becoming a very popular farming commodity amongst the smallholder farmers (Geyer et al., 2011; WCDOA, 2014b). The Cape Metro district consists of one municipal boundary area, namely the City of Cape Town. The leading sectors in the Cape Metro that contributed to employment in 2011 were the finance, insurance, real estate and business services (36.1%), wholesale and retail trade, catering and accommodation (15.2%), manufacturing (15.9%) and transport, storage and communication (10.9%) (Western Cape Government Provincial Treasury, 2013c).

The contribution to the Cape Metro district annual economic growth (real GDPR growth) for the period of 2000 to 2011 was 10.0% for agriculture, forestry and fishing, which is the highest sector contribution in the Cape Metro area. The total real GDPR growth for the Cape Metro area was 4.1% (Western Cape Government Provincial Treasury, 2013c).

The number of smallholders in the Cape Metro is 291, which includes 163 individual farmers and 128 farmers who are members of groups (WCDOA, 2010). Cape Metro's contribution to total output is 0.004% (estimate of total output from smallholder farming based on own calculations using emerging farming data from 2007). The three sample farms in the Cape Metro area are discussed briefly below:

Cape Metro 1

Cape Metro 1 is situated close to Kraaifontein and is 8 ha in size. All 8 ha are used actively for cattle production, sheep production, a piggery, chickens (for own consumption), guava production and grazing for the animals. Cape Metro 1 sells its guava produce to the juice factory and the livestock to individual buyers.

Cape Metro 2

Cape Metro 2 is situated in Philippi and is 20.6 ha big and all 20.6 ha are used actively. The main activities are vegetable and herb production. Cape Metro 2 sells its produce to retailers in the surrounding areas.

Cape Metro 3

Cape Metro 3 is situated in Philippi and is 26 ha in size. Only 20 ha are used for farming activities. The main farming outputs are vegetables and the processing of vegetables. Cape Metro 3 sells its produce to local retailers in the surrounding areas and also has a government contract to supply to the local hospitals.

West Coast

The West Coast region is a winter rainfall region and is mostly known for its small grain, potatoes, wine grapes, rooibos tea, pome fruit and citrus production (WCDOA, 2014b). The West Coast consists of five municipal areas, namely Matzikama, Cederberg, Bergrivier, Saldanha Bay and Swartland. The leading sectors in the West Coast that contributed to employment in 2011 were finance and business services (25.6%), manufacturing (17.7%) and agriculture, hunting, forestry and fishing (14.6%) (Western Cape Government Provincial Treasury, 2013f).

The contributions to the West Coast district annual economic growth (real GDPR growth) for the period 2000 to 2011 was -0.4% for agriculture, forestry and fishing, and the total real GDPR growth for West Coast area was 3.3% (Western Cape Government Provincial Treasury, 2013f).

The number of smallholders in the West Coast are 2 724, which include 173 individual farmers and 2 551 farmers who are members of groups (WCDOA, 2010). West Coast's contribution to total output was 0.043% (estimate of total output from smallholder farming based on own calculations using emerging farming data from 2007). The three sample farms in the West Coast area are discussed briefly below:

West Coast 1

West Coast 1 is situated near Piketberg and is 850 ha in size. Only 20 ha of the 850 ha are used actively for farming. The farms' main outputs are potatoes, oats, lupines, rye and barley. They also have livestock, Merino sheep and Bonsmara and Lumosin cattle. West Coast 1 sells its livestock to local abattoirs, at auctions and at one of the biggest feedlots in the surrounding area. The potatoes go to a chips factory.

West Coast 2

West Coast 2 is situated near Hopefield and is 2 528 ha in size. The entire 2 528 ha is actively used for farming. The main outputs are lupines, canola and grains (like wheat), meat and wool production from sheep, and the planting of grazing for animal feed. West Coast 2 sells its livestock to local abattoirs, individual buyers and at actions. The grain is delivered to the silo.

West Coast 3

West Coast 3 is situated near Hopefield and is 2.465 ha in size. 1.05 ha is used actively and the main activities on the farm are pig production and chickens for own consumption. West Coast 3 sells its produce to local individual buyers and the local abattoirs.

Eden

The Eden region is a winter rainfall region and is known mostly for its lucerne, ostriches, small grains, dairy production, stone fruit, vegetables and small stock (WCDOA, 2014b). In the Eden district there also are niche markets due to this district's topographical and climatic diversity, for example for aloe and other essential oils that are cultivated and processed in this region (WESGRO, 2013). The Eden district consists of seven municipal areas, namely Hessequa, Mossel Bay, Knysna, Bitou, George, Oudtshoorn and Kannaland. The leading sectors in the Eden district that contributed to the employment sector from 2010 to 2011 were finance and business services (26.4%), wholesale and retail and catering (29.6%), and general government (18.8%) (Western Cape Government Provincial Treasury, 2013d).

The contributions of the Eden district to annual economic growth (real GDPR growth) for the period from 2000 to 2011 was 1.1% for agriculture, forestry and fishing, and the total real GDPR growth for the Eden area was 5.2% (Western Cape Government Provincial Treasury, 2013d).

The number of smallholders in Eden is 952, which includes 110 individual farmers and 744 farmers who are members of groups (WCDOA, 2010). Eden's contribution to total output is 0.005% (estimate of total output from smallholder farming based on own calculations using emerging farming data for 2007). The three sampled farms in Eden are discussed briefly below:

Eden 1

Eden 1 is situated in Freeheim, close to Groot Brak, and the farm is 1.2 ha in size. Only 0.9 ha is being used actively and the main activities on the farm are egg production and the selling of chicken manure. Eden 1 sells to Malmesbury (main client) and to the local community.

Eden 2

Eden 2 is situated close to George and the farm is 79 ha in size. Only 53.1 ha of the total are being used actively for farming activities. The main activities on the farm are cattle production and meat and milk production. Eden 2 sells its livestock to local abattoirs and at auctions.

Eden 3

Eden 3 is situated close to George and the farm size is 62 ha. The entire 62 ha are used actively and the main activity is livestock, as in cattle production. Eden 3 sells its livestock to local abattoirs and at auctions.

<u>Central Karoo</u>

The Central Karoo region is a winter rainfall region and is known mostly for its small stock, beef and stone fruit (WCDOA, 2014b). The Karoo is also known for its mutton (SouthAfrica.info, 2012) and has registered the name "Karoo Lamb". The Central Karoo district consists of three municipal areas, namely Beaufort West, Laingsburg and Prince Albert. The five largest leading sectors that contributed to employment in the Central Karoo in 2011 were finance, insurance, real estate and business services (27.4%), general government (13.1%), wholesale and retail trade, catering and accommodation (12.2%), transport, storage and communication (11.6%) and manufacturing (11.1%) (Western Cape Government Provincial Treasury, 2013b).

The contribution of the Central Karoo district's annual economic growth (real GDPR growth) for the period 2000 to 2011 was -1.2% for agriculture, forestry and fishing. Total real GDPR growth for the Central Karoo area was 4.0% (Western Cape Government Provincial Treasury, 2013b).

The number of smallholders in Central Karoo is 414, which includes 13 individual farmers and 401 farmers who are members of groups (WCDOA, 2010). Central Karoo's contribution to total output is 0.005% (estimate of total output from smallholder farming based on own calculations using emerging farming data for 2007). The three sampled farms in the Central Karoo are discussed briefly below:

Central Karoo 1

Central Karoo 1 is situated close to Laingsburg and is 280 ha in size. A total of 246 ha are actively used by the farmers and the other 34 ha are rented to another party. The main activities on the farm are sheep production, piggery, grazing for the animals, wood production and production of onions. Central Karoo 1 sells its livestock at the local abattoirs in the surrounding area, as well as at auctions. The onion seeds are sold to a well-known seed company.

Central Karoo 2

Central Karoo 2 is situated near Beaufort West and is 3 107 ha in size. The whole 3 107 ha is being used actively by the farmer. The main activities on the farm are Dorper sheep production, Angora goat production and having a few animals that are not for trading, two horses, two geese and two peacocks. Central Karoo 2 sells its livestock to local abattoirs (20%) and 80% of production goes to auctions. The owner sometimes works through the local meat association to sell the livestock.

Central Karoo 3

Central Karoo 3 is close to Matjiesfontein and is 2 500 ha in size. The entire 2 500 ha is used actively and the main activities are cattle production, ostrich production, sheep production, wild buck, lucerne production, a vegetable garden for the house and apricot orchards. Central Karoo 3 sells its apricots to a well-known dried fruit company; the livestock is sold to the local abattoirs and the community, as well as at auctions.

4.2.4. Sample bias

Bias can have different forms, for example it can be a systematic error, an influence, a condition or it can be a set of conditions that singly or in combination distort the data or the findings (Leedy & Ormrod, 2010; Taylor-Powell, 2009). A sampling bias is described by Leedy and Ormrod (2010) as any influence that affects the random selection of a sample population. Looking out for sample bias is important because it leads to questioning of the facts' integrity and the data collected may be inaccurate and not a true representation of the sample group (Leedy & Ormrod, 2010; Taylor-

Powell, 2006). To avoid sample bias in sampling, a person should always re-look and compare the respondents chosen for the sample to what is known about the targeted population in general, focusing on demographic characteristics (Taylor-Powell, 2006). Here gender might play a role; for example, if the number of women and men in the targeted population are the same, than you cannot have a lesser presentation of one gender. To overcome sample bias, the difference between the sample and the targeted population must be highlighted, and when it comes to reporting the focus must be on the sample that responded, so no assumptions can be made about the ones that did not respond (Taylor-Powell, 2006).

When looking at this study's sample, 50% of the surveyed farmers were women and 50% were men. It was the same with the age distribution, with 50% of the farming sample being under the age of 50 and the rest above the age of 50. Looking at the education levels, it can be seen that 50% of the sampled farmers were highly educated, meaning they had at least grade 12 and had furthered their education in some way, while the other 50% had barely finished high school and or had not completed grade 12. The farmers were also spread throughout the Western Cape and the different district boundaries were used to make sure there were three representatives from each district.

4.3. Questionnaire

As mentioned in section 4.1, questionnaires can be complex to construct and administer, thus proper guidelines are needed. Leedy and Ormrod (2010:194-197) provide the following 11-step guide that will help smooth the process and at the same time encourage people to be cooperative:

- Keep questionnaire short.
- Keep the respondent's task simple by making questions easy to read and understand.
- Provide clear instructions on how you want them to answer the questions.
- Give a rationale for any items whose purpose may be unclear.
- Check for unwanted assumptions implicit in your questions.
- Word your questions in a way that does not give clues about preferred or more desirable responses.
- Determine in advance how you will code the responses.
- Check for consistency.
- Conduct one or more pilot tests to determine the validity of your questionnaire.
- Scrutinise the almost-final product one more time to make sure it addresses your needs.
- Make the questionnaire attractive and professional looking (Leedy & Ormrod, 2010).

There are six main data collection method, according to Pearce and Özdemiroglu (2002), and these are mail surveys, telephone interviews, face-to-face interviews, drop-off survey, telephone surveys, and computer-assisted interviews. This study made use of face-to-face interviews, follow-up telephonic interviews and computer-assisted interviews.

4.3.1. Pilot questionnaire

According to Cloete (2012), it is important and internationally recommended that a pilot study should first be conducted so that inconsistency, unclearness, etc. are eliminated. It also helps to determine the level of difficultness of the questions and where to simplify the questions.

A pilot study was carried out and attention was given to the way the questions were structured and asked, and also to the length of the questionnaire. The pilot questionnaire consisted out of three sections. Section 1 which asked farm-specific questions, section 2 which focused on general green agricultural questions and section 3 focused on socio-economic information about the respondent. Two approaches were tested to see the respondents' rate and ease of completing the questionnaire. These two approaches were: Approach one was to complete only section 2 and section 3 on the farm with the respondent, and then to leave section 1 with the respondent to complete within a two-week time frame. The other approach, approach two, was to complete all the sections at once; this approach took approximately an hour, so no part of the questionnaire was left with the respondent. The response rate of the first approach was low and the respondents did not comply with the two-week deadline. Thus, the sit-down approached worked better, it also proved beneficial in terms of explaining definitions and terms that caused confusion.

4.3.2. Final questionnaire

The final questionnaire comprised a brief summary of the background of the study and consisted of three sections: Section 1, which asked farm-specific questions relating to the farm and activities; Section 2, which focused on general green agricultural questions; and Section 3, which focused on socio-economic information about the respondent, including questions regarding age, gender and education level. A copy of the final questionnaire can be found in Appendix E.

4.3.3. Questionnaire bias

According to Quelhas et al. (2011), developing a questionnaire is not easy and biases can easily occur, therefore the person constructing and administering the questionnaire must try to prevent or at least minimise these biases from occurring. There are three main categories of bias:

- The *way the questionnaire is built* – look for problems with wording, for example unclear question, technical jargon and uncommon words. Also look for faulty scales, leading questions, intrusiveness and missing or inadequate data for the intended purpose;
- The *way the questionnaire is designed* – formatting problems; and
- The *way the questionnaire is administered* – look for neutral opinion options and respondent's conscious reaction (Quelhas et al., 2011). Focusing on the way a questionnaire is administered includes questionnaire interview bias, which will be the next focus point. Questionnaire interview bias can also take the form of the way a person asks questions, as the researcher's tone of voice or the emphasis in the sentence may influence how a respondent replies. It therefore is important to be cautious about the language that is used (Leedy & Ormrod, 2010).

According to Leedy and Ormrod (2010) there are three useful ways of identifying possible bias in your questionnaire research:

- Always look out for factors that will distinguish respondents from non-respondents, for example look for items in the questionnaire that might influence them, such as their education levels and their interest in the topic.
- Always compare the responses of questionnaires received on time and the ones that were returned late. Biases might exist.
- Always make contact with the non-respondents through the random selection of a smaller sample from the group. Contact can be made via telephone or e-mail, and those answers can then be compared with those of the current respondent group.

The pilot questionnaire prepared for this study allowed the researcher to identify possible bias that may occur as a result of the way the questionnaire was constructed and designed. The final questionnaire was also reviewed by the CCC (Confronting Climate Change) project team and senior staff at the WCDOA. Secondly, the questionnaire was administered by the researcher on a face-to-face basis to ensure consistency in its administration. The questionnaire was prepared and administered in English and any additional questions from respondents were addressed by the researcher on the spot. The study had a 100% response rate.

4.4. Conclusion

To ensure the success of any study, it is important to follow the correct sample and questionnaire design guidelines. This study made use of nonprobability sampling by means of the convenience sampling of 18 farmers from the SimFini project of the WCDOA. The preselected sample was used to test the success of the proposed calculator and to identify any concerns with the current recordkeeping system.

The sample bias was overcome by making use of convenience sampling, with a 50/50 gender ratio, age distribution and education level distribution. In addition, the top three SimFini farmers from each district were chosen, therefore ensuring farm records were sufficient. A pilot questionnaire was constructed to identify design biases and the final questionnaire was administered by the researcher to ensure consistency, thereby reducing administration bias. The response rate to the questionnaire was 100%.

Chapter 5 looks at the entity and product carbon footprint and examines all the different steps that must be followed to obtain a reliable carbon footprint.

Chapter 5: Carbon Footprint

5.1. Introduction

Climate change and the proper management of natural resources is a topic hot on the agenda of governments (international, national and provincial), suppliers, retailers and citizens. Along with climate change and natural resource management awareness increasing, comes terms like carbon footprinting, carbon off-setters, carbon trading and carbon tax. This chapter focuses on carbon footprinting, standards and steps and the profiles of the 18 farms selected for this study. A carbon footprint is used:

- To establish a baseline and carbon profile,
- To embark on an environmental efficiency programme,
- To understand potential carbon liabilities,
- To identify opportunities,
- To set targets and measure performance, and
- To enhance the business brand (BSI, 2015; Greenhouse Gas Protocol (a), 2012; Terra Firma Academy, 2013).

5.2. Carbon footprinting

Carbon footprinting measures the impact of an individual, business or product on the environment (Wiedmann & Minx, 2008).

A carbon footprint can have many definitions, for example:

- It is the total set of greenhouse gas emissions caused directly and indirectly by an individual, organization, event, or product, according to the Carbon Trust (2012).
- "… a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product" (Wiedmann & Minx, 2008:4).
- A carbon footprint can be describe as the total greenhouse gas emissions caused directly and indirectly by a person, organisation, event or product (Center for Sustainable Systems, University of Michigan, 2014).
- "The total set of greenhouse gas emissions caused by an organisation, event, product or person" (Terra Firma Academy, 2013:39).

Looking at the above definitions, they all conclude that it measures "the total set of greenhouse gas emissions caused by an organisation, event, product or person" (Terra Firma Academy, 2013:39).

A carbon footprint is reported in tons of carbon dioxide equivalent (tCO_2e), which is the internationally recognised measure for greenhouse gases. The tCO_2e can further be described as the method to compare the different greenhouses gases to one unit of CO_2 (Carbon Trust, 2012; Pandey et al., 2010; Terra Firma Academy, 2013). According to the Carbon Trust (2012), the tCO_2e is calculated by taking each greenhouse gas's emission and then multiplying it by its global warming potential (GWP). The greenhouse gases and their global warming potentials are shown in table 5.1. In the past, only six greenhouse gases were accounted for by the Kyoto Protocol, namely CO_2, CH_4, N_2O, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) (Carbon Trust, 2012), but one more greenhouse gas was added to the Kyoto Protocol greenhouse gas list, nitrogen trifluoride (NF_3) (Terra Firma Academy, 2013). The seventh gas was added in 2012, at the beginning of the second compliance period of the Kyoto Protocol (Ecometrica, 2012).

Table 5.1: Greenhouse gases and their global warming potentials

Gas	Abbreviation	Global warming potential
Carbon dioxide	CO_2	1
Sulphur hexafluoride	SF_6	23 900
Methane	CH_4	21
Nitrous oxide	N_2O	310
Hydrofluorocarbons	HFCs	> 100
Perfluorocarbons	PFCs	> 6 000
Nitrogen trifluoride	NF_3	> 100

Source: DEFRA, 2014; PACE, 2015; Terra Firma Academy, 2013

Basic activities such as transport, land-use change, the production and consumption of food, fuel combustion, manufactured goods, material consumption, waste disposal and the use of services are always expressed in terms of one of the gases mentioned in table 5.1 and then converted to their GWP (DEFRA 2014; PACE, 2015; Terra Firma Academy, 2013).

Carbon footprinting should be an important aspect of any business and, as with business processes and accounting practices, certain standards and approaches are also required for carbon footprinting (Carbon Disclosure Project, 2011; Terra Firma Academy, 2013).

5.2.1. Balloon standards

South Africa does not have any formal standards or carbon footprinting legislation in place, and thus makes use of the global best practice standards, which are the Greenhouse Gas Protocol, the International Standards Organisation 14064 (ISO 14064) and the Publicly Available Specification (PAS) 2050 (Ponstein & Reeler, 2014; Terra Firma Academy, 2013).

Greenhouse Gas Protocol (GHG Protocol)

The GHG Protocol is used to understand, quantify and manage GHG emissions; it is also an international tool that is widely used and respected (Greenhouse Gas Protocol, 2012a).

International Standards Organisation 14064 (ISO 14064)

The ISO 14064 assists industries and government to establish emission reduction programmes and also helps organisations to do business in the emissions trading schemes (Terra Firma Academy, 2013). This standard consist of three parts: the GHG inventory entity level; the requirements for quantifying, monitoring and reporting on emission reduction; and the requirements and guidelines for the validation and verification process (Terra Firma Academy, 2013).

Publicly Available Specification (PAS) 2050

The PAS 2050 describes the specification for the assessment of the life cycle of a product or service's greenhouse gas emissions (Terra Firma Academy, 2013). This standard is a British Standard that was developed by the British Standard Institution (Terra Firma Academy, 2013).

Taking the GHG Protocol, ISO 14064 and PAS 2050 into account, it is important to note that a carbon footprinting process also consists of five principles: relevance, completeness, consistency, transparency and accuracy (Greenhouse Gas Protocol, 2012b). Relevance focuses on working with the relevant information, methodologies and reporting styles that will address the need of the user (Greenhouse Gas Protocol, 2012b). Completeness and consistency look at making sure that everything is covered in the inventory report for each specific boundary, even the removals, and also disclosing and justifying the GHG emissions and removals that have been excluded from the whole process, while consistency looks at methodologies, data and assumptions that can be used over time and still will have credibility for comparisons (Greenhouse Gas Protocol, 2012b). According to the GHG Protocol (2012b), transparency and accuracy focus on the following respectively: having a clear audit trail, that assumptions being made will be disclosed, and that methodologies and data sources used for the inventory report will be acknowledged and referenced; and that uncertainties will be reduced and accuracy will be achieved so that users will have the confidence to make use of the report data knowing that the information is reliable.

5.2.2. Carbon footprinting steps

The carbon footprinting process consists of eight steps for an "entity footprint", but the eight steps are expanded to 12 for a detailed product footprint. The entity carbon footprint looks at the farm as a whole and no breakdowns are made between the commodities on the farm, while the product carbon footprint looks at a commodity level and indicates how much each commodity is contributing to the total CO_2 emissions. According to the Greenhouse Gas Protocol (2012b), the product life-cycle footprint is very interactive and each step's results or methodology are independent of each other.

The product footprint, also known as the product life-cycle footprint, differs from the entity footprint. The steps are stipulated in table 5.2.

Table 5.2: Entity carbon footprint steps versus product carbon footprint steps

Entity carbon footprint	**Product carbon footprint**
Step 1 – Workshops	Step 1 – Define business goals
Step 2 – Boundaries	Step 2 – Review principle
Step 3 – Identifying emission resources	Step 3 – Review fundamentals
Step 4 – Data collection	Step 4 – Define the scope of the product inventory
Step 5 – Calculations	Step 5 – Set boundaries
Step 6 – Reporting	Step 6 – Collect data and assess data quality
Step 7 - Carbon footprint verification and control	Step 7 – Perform allocation
Step 8 – Carbon reduction and offsetting	Step 8 – Access uncertainty
	Step 9 – Calculate inventory results
	Step 10 – Perform assurance
	Step 11 – Report inventory results
	Step 12 – Set reduction targets

Due to the purpose of this study, namely to develop a product life-cycle carbon footprint calculator for smallholder mixed farming, this section will focus only on the twelve steps of a product life-cycle footprint. These steps are discussed below:

Step 1 – Define business goals

The first step is crucial, as it brings clarity in terms of which methodology is most suitable and which data will be used to develop the inventory list. It therefore is important that a company/establishment clearly identifies its business goals before starting with the product carbon footprint process inventory (Greenhouse Gas Protocol, 2012b). According to the Greenhouse Gas Protocol (2012b) there are four main business goals served by a product GHG inventory, namely climate change management, performance tracking, supplier and customer stewardship, and product differentiation. Looking first at climate change management, the aims are opportunities for new markets and incentives, looking at the product's life cycle and determining the climate-related physical and regulatory risks associated with it, and for the company to identify the risks from fluctuations in energy costs and material availability (Greenhouse Gas Protocol, 2012b). Secondly, performance tracking includes GHG emission reduction throughout the product's life cycle through efficiency improvements and cost-saving opportunities; the setting of GHG reduction targets and developing a strategy for how to reach those targets; measurement of and reporting on GHG performance over time; and tracking efficiency improvements throughout the product's life cycle over time (Greenhouse Gas Protocol, 2012b). Thirdly, the supplier and customer stewardship goal includes achieving GHG reductions by building partnerships with suppliers; looking at the supplier's performance for the GHG aspects of green procurement effort taken by the supplier; reducing the GHG emissions, the usage of energy, the costs, the risks in the supply chain and avoiding extra costs in the future related to energy and emissions; and encouraging reductions in GHG emissions through customer education campaigns (Greenhouse Gas Protocol, 2012b). Fourthly and lastly, the product differentiation goal includes creating low-emitting carbon products that will save costs and also looking for GHG reduction opportunities that will give the company a competitive advantage; getting better customer response by redesigning a product that addresses the customer's preferences; using GHG performance to strengthen the company's brand image; focusing on product stewardship pride to enhance employee retention and recruitment; and lastly disclosing publicly the goals of the company to strengthen the corporate reputation and accountability (Greenhouse Gas Protocol, 2012b).

Step 2 – Review principle

Step 2 describes the five accounting principles that are supposed to strengthen all the aspects of GHG accounting, the reporting for the product and the correct use of the principles that will ensure a true and fair representation of its GHG emissions and removals for the product inventory (Greenhouse Gas Protocol, 2012b). According to the Greenhouse Gas Protocol (2012b), the primary function of the five principles is to guide the users when it comes to the implementation of the standards, especially making accounting decisions where the standards do not give guidance. The only requirement for this step is that GHG accounting and reporting of a product inventory must adhere to the principles of relevance, accuracy, completeness, consistence and transparency (Greenhouse Gas Protocol, 2012b), and these principles are described in the balloon standards section 5.2.1, under the "Publicly Available Specification" (PAS) 2050 heading.

Step 3 - Review fundamentals

Step 3 looks at the accounting for the product life cycle GHG as a subdivision of the life-cycle assessment (LCA), while LCA strives to quantify and address the environmental aspects and possible impacts throughout the product's life cycle, from the extraction of raw material to the end-of-life waste treatment (Greenhouse Gas Protocol, 2012b). The ISO with the 14040 publication series of life-cycle assessment standards is the platform where the LCA become internationally standardised, according to the Greenhouse Gas Protocol (2012b). PAS 2050 was established in 2008, when the British Standards Institution (BSI), in partnership with DEFRA (Department of Environment Food and Rural Affairs in the UK) and the Carbon Trust published the PAS for the assessment of the life-cycle greenhouse gas emissions of goods and services (Greenhouse Gas Protocol, 2012b). The ISO 14064 (updated from the ISO 14040 series) and PAS 2050 were discussed in the balloon standards section 5.2.1. The only requirement for step 3 is that the company must follow the life cycle and attributional approaches for a GHG product inventory (Greenhouse Gas Protocol, 2012b).

Step 4 - Define the scope of a product inventory

A scope that is well defined can address the stakeholder's needs if it is well aligned with the five accounting principles mentioned previously and the business goals of the company (Greenhouse Gas Protocol, 2012b). There are four sub-steps to follow: *the base* being for the company to report and account for the six greenhouse gases, namely carbon dioxide, methane, nitrous oxide, sulphur hexafluoride, perfluorocarbon and hydrofluorocarbon emissions. The GWP of each gas is identified by the IPCC (Greenhouse Gas Protocol, 2012b; Terra Firma Academy, 2013). The *second sub-step* is to define the product being studied, to determine the unit of analysis and to reference the flow of the product (Greenhouse Gas Protocol, 2012b). It is important to bear in mind that the studied product is the product whose life cycle is being accessed. The *third sub-step* looks at the unit of analysis as a functional unit for the final products, and can be defined as goods and services that are being consumed by the end user, meaning that it is not used in the production process of another product (Greenhouse Protocol, 2012b). The unit analysis must be defined as functional units by companies and, according to the Greenhouse Gas Protocol (2012b), is the functional unit defined as the performance characteristics and services delivered by the product being studied. It includes the service being fulfilled by the product, the time needed to fulfil the service, and the expected quality level. The *last sub-step* looks at defining the unit of analysis as the reference flow for the intermediate products (Greenhouse Gas Protocol, 2012b). The intermediate products can be define according to the Greenhouse Protocol (2012b) as goods being used in the production of good and services as inputs.

Step 5 - Set the boundary

Step 5 looks at the emission sources that will be included in the GHG inventory, as well as the removals (Greenhouse Gas Protocol, 2012b). According to the Greenhouse Gas Protocol (2012b), this step can be broken down further into smaller steps, in which the company should look at the following:

- To include all attribute processes, meaning looking at services, materials and energy flows which become the product until the end of its life cycle;

- To report on the life-cycle stages (dividing the attributable processes into the product's life-cycle stages) and to clearly define and describe these stages; according to the Greenhouse Gas Protocol (2012b), there are five general life-cycle stages, namely material acquisition and pre-processing, production, distribution and storage, use, and end of life;
- To disclose and justify any exclusions of attributable processes in the inventory report, which means that attributable processes can only be exclude if gaps exists in the data, extrapolated and proxy data cannot be determined and insignificant data exists;
- To report on attributable processes in a process map format – the process map shows the needs for developing a product through its life cycle. The needs are things like services, materials and energy, and the map should showcase the defined life-cycle stages, the different stages with their generalised attributional processes, the flow of the product through its different life cycles, and the attributable processes that will be excluded from the inventory;
- To report non-attributable processes included in the boundary – it is not required to be included, except if it is included in the boundary. A non-attributable process can be a service, material or energy flow, but will not be involved directly in the making or becoming and/or carrying the product through its life cycle. For example, it can be things like overhead costs or capital goods;
- To have the entire life cycle, from the cradle to the grave, included in the boundary for the final product;
- To disclose and justify when a cradle-to-grave boundary approach is being used in the inventory report, because a partial life-cycle inventory should not be included in final product use or end-of-life processes in the results;
- To report the time period of the inventory – the amount of time it takes for a product to complete its life cycle; and
- To report on the method used to calculate the land-use change impacts as applicable.

According to Terra Firma Academy (2013), there are three different scopes for a general carbon footprint. It has been noted that, to comply with the Greenhouse Gas Protocol, businesses must account for and report separately on their scope 1 and scope 2 emissions, and it is not required to report on scope 3 (Carbon Disclosure Project, 2011; Terra Firma Academy, 2013). For verification purposes, only scope 1 and scope 2 are verified and accepted into the Carbon Performance Leadership Index programme (Carbon Disclosure Project, 2011). Scope 1 emissions can be described as direct greenhouse gas (GHG) emissions, which the company has control over, and can include emissions from fossil fuels burned on the premises, emissions from vehicles used, livestock manure, process emissions, etc. (Terra Firma Academy, 2013; U.S. Protection Environmental Agency, 2012). Scope 2 comprises indirect GHG emissions from the generation of electricity, heating and cooling, or steam generated off site but purchased for use by the business (U.S. Protection Environmental Agency, 2012), for example buying electricity from Eskom. Scope 3 also can be defined as indirect GHG emissions, but it is from sources not owned or controlled by the business (U.S. Protection Environmental Agency, 2012), for example waste that gets disposed of at landfills, hiring of trucks or cars, etc. (Terra Firma Academy, 2013).

Step 6 - Collect data and assess data quality

Step 6 is probably the most resource-intensive step and plays a major role when it comes to the quality of the GHG inventory (Greenhouse Gas Protocol, 2012b). The process of collecting the carbon footprint consists of a five sub-processes:

- Design input sheets and surveys
- Collect and collate data
- Review initial data collection
- Data collection round two and extrapolation
- Final sign off on data

Design input sheets and surveys

To design input spreadsheets is the first step in the data collection process and it is very important to label the tabs of the spreadsheets so as to avoid confusion (Terra Firma Academy, 2013). The design of input sheets and surveys can take different forms, for example Excel spreadsheets, emails, survey monkey and manual collection (Terra Firma Academy, 2013).

Collect and collate data

The data collection process can specify the standard units that must be used for collating data, and it is important to organised data in spreadsheets, which makes it easier to calculate later (Terra Firma Academy, 2013).

Review initial data collection

The most time-consuming part of a carbon footprint is data collection; therefore it always is wise to check the completeness of the data, the quality of the data, the integrity of the data and also to graph the data to see if there is any incorrectness (Terra Firma Academy, 2013).

Data collection round two and extrapolation

When data is incomplete, it is important to try to source data to complete the data sets. If all sources have been exhausted and there are no other options, then making assumptions is the next step. This means that the data collector make use of known information by doing estimation (Terra Firma Academy, 2013).

Final sign off on data

Data that gets collected must be signed off by all the parties so that potential problems further down the line are prevented (Terra Firma Academy, 2013).

When it comes to a product life-cycle footprint there are three requirements to take into consideration (Greenhouse Gas Protocol, 2012b):

- To collect primary data for all processes that are included in the inventory boundary and activities under the companies' ownership or control;
- To use data quality indicators to check the quality of activity data and emission factors. There are five data quality indicators, namely technological representativeness, geographical representativeness, temporal representativeness, completeness and reliability; and
- To report on data sources, the quality of data and any efforts that the company takes to improve the quality of the data in a descriptive statement way.

Step 7 - Perform allocation (if needed)

For most product life cycles it is not easy or possible to get individual input- or output-level data for a common process with multiple valuable products, and therefore the total emissions and removals derived from the common process must be divided between the multiple inputs and outputs. This step is known as allocation and is an important, as well as a challenging, element of product inventory process (Greenhouse Gas Protocol, 2012b). There are six requirements that step 7 has to adhere to according to the Greenhouse Gas Protocol (2012b), and these requirements are:

- To accurately allocate emissions and removals to show the contributions of the product and its co-products to the common process's total emissions and removals;
- To use subdivisions where possible so that allocations are avoided. Redefining the functional unit or the system expansion can also help to avoid allocations from occurring;
- To allocate emissions and removals on the basis of the physical relationship between the product being studied and the co-product being used, only when allocation cannot be avoided.
- To apply methods used for allocation to the inputs and outputs that are similar in a product life cycle;
- To use the closed loop approximation method or the recycled content method, which has been described by the standard for allocation that is occurring due to recycling; and

- To avoid allocation from occurring due to recycling or co-products, companies must disclose and justify the methods that they used. Displaced emissions and removals must be reported on, but separately from the inventory of the end-of-life stage of the product being studied when using the closed loop approximation method.

Step 8 – Access uncertainty

The uncertainty from a product inventory can be quantified or qualified by using a systematic procedure when it comes to uncertainty assessments (Greenhouse Gas Protocol, 2012b). For a company to interpret inventory results correctly, the company needs to understand the term uncertainty in all its facets and, to make the process easier, companies must be able to document and identify sources of uncertainty and, by doing this, it will help companies to improve the inventory quality and boost the confidence levels of users, because the steps for improvement are clear and known (Greenhouse Gas Protocol, 2012b).

The Greenhouse Gas Protocol (2012b) acknowledges that a great deal of diversity comes to play in a product inventory report and therefore it is important for companies to make the confidence level and the key sources of uncertainty known in the inventory results. The main requirement under step 8 is for companies to make their sources of inventory uncertainty and methodological choices known, and for methodological choices to focus on the use and end-of-life profile, allocation methods, including allocation due to recycling, sources of GWP values used, and calculation models.

Step 9 - Calculate inventory results

This step looks at the key requirements, the steps needed to be calculated and the procedures involved in the quantifying of the GHG inventory results of the studied product (Greenhouse Gas Protocol, 2012b). The GWP and the tCO_2e have already been discussed in the carbon footprinting section (5.2) and in the greenhouse gases and their global warming potentials table (table 5.1.) The standard and internationally known CO_2 emission factor formula is:

CO_2 emissions = activity data x emission factor (EF) 5.1

A list of all the emission factors used for the development of this calculator is attached in Appendix A. For this step to be completed, five requirements have to be adhered to (Greenhouse Gas Protocol, 2012b):

- To report the inventory results in units of CO_2 equivalent (CO_2e) by applying the 100-year GWP factor to the GHG emissions and removals data. The sources and the data used for the GWP and emission factors must be reported on and made known by the company.

- To report the inventory results in CO_2e per unit of analysis. Reporting should include the boundary from biogenic sources, as well as non-biogenic sources and land-use change impacts.
- Companies should not only report on the inventory results, but also must quantify and report on the following:
    - Life-cycle stage's percentage of the total inventory results;
    - Biogenic and non-biogenic emissions and removals, which should be reported on separately where applicable;
    - Land-use change impacts, which should be reported on separately where applicable; and
    - The cradle-to-gate and gate-to-gate inventory results, which should be reported on separately, or to give a clear statement that confidentiality is a limitation to obtaining this information.
- When quantifying the inventory results, companies should not include weighting factors for delayed emissions, offsets and avoided emissions.
- If applicable, companies must report on carbon not released to the atmosphere during the waste treatment process, and especially for the cradle-to-gate inventories, companies must report on the amount of carbon contained in the intermediate product.

Step 10 - Perform assurance

Assurance can be defined as the level of confidence the inventory results show and the level of completeness that the report shows, as well as its accuracy, consistency, transparency and relevancy, and showing that the material is without misstatements. When it comes to making decisions and using the inventory results as the basis for those decisions, it is of the utmost importance that assurance is obtained about the product inventory data (Greenhouse Gas Protocol, 2012b). According to the Greenhouse Gas Protocol (2012b), a vital step when it comes to the preparation for assurance is to carefully and comprehensively document the inventory process in a data management plan. There are three main requirements that must be adhered to under this step:

- To determine the confidence and credibility of the product GHG inventory, a first or third party must verify it (Carbon Disclosure Project, 2011; Greenhouse Gas Protocol, 2012b; Terra Firma Academy, 2013). According to the Greenhouse Gas Protocol (2012b), the assurance process includes three key parties, namely the reporting company, stakeholders and the assurer.
- When it comes to the product GHG inventory process, the company must choose an assurance provider that is independent and has no conflict of interest with the company's product GHG inventory process (Carbon Disclosure Project, 2011; Greenhouse Gas

Protocol, 2012b; Terra Firma Academy, 2013). The benefits of the verification process includes penalties being avoided, so the business is saving costs, sales will go up due to the business being more environmental friendly, attracting more social responsibility investment, as well as an improvement in the corporate image and reputation of the business (BSI, 2015; Carbon Disclosure Project, 2011). Another advantage of the verification process is compliance; this process also helps businesses to trade within the carbon trading platform (Carbon Disclosure Project, 2011). The carbon trading platform is not that common in SA, but SA as a country is slowly moving towards that platform. There is a programme running in Africa, called Promoting Access to Carbon Equity (PACE) – credible carbon solutions in for Africa. Credible carbon falls under the type 2 voluntary carbon registry (Atkins & Prasad, 2013). PACE focuses on making carbon markets work for Africa and forms part of the credible carbon project.

Two verifications exist, according to the Terra Firma Academy (2013): ISO 14064-3 and ISO 14065, but verification is being steered under the ISO 14064-3 standard. Besides the ISO standards, there are various levels of assurance that can be followed in a verification process to ensure the accuracy of the results, for example internal assurance, external assurance, parameters and site visits (Terra Firma Academy, 2013). To ensure that the verification process is quick and smooth, a carbon footprint team must make sure that their data trail is clear and accessible for the verifier to use (Terra Firma Academy, 2013). As mentioned under step 2, only scope 1 and scope 2 are verified, although the Carbon Disclosure Project (CDP) requests scope 3 data on emissions and some businesses do report on it (Carbon Disclosure Project, 2011). The GHG Protocol team at the World Resource Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), as well as the ISO (Carbon Disclosure Project, 2011) are all working on how scope 3 can be accounted for.

Step 11 - Report inventory results

The reporting step of every GHG inventory is crucial, as it creates the platform for accountability and effective engagement with stakeholders (Greenhouse Gas Protocol, 2012b). The carbon footprint report, or in other words the GHG inventory results, round off the process and describe all the processes that were followed, from the activities to the data collated (Terra Firma Academy, 2013). According to the Greenhouse Gas Protocol (2012b), it is of the utmost importance that the reported information is based on the five key accounting principles. Under step 11, one requirement is to adhere to the reporting standards, but under this requirement there are eight sub-steps. The requirement stipulates that companies must report information in such a manner that it conforms with the GHG Protocol Product Standards. The information that must be reported on is as follows:

- General information and scope – under this heading flow the following:

  - Contact information;
  - Studied product name and description;
  - The unit of analysis and reference flow;
  - Type of inventory, cradle-to-grave or cradle-to-gate;
  - Additional GHGs included in the inventory;
  - Any product rules or sector-specific guidance used;
  - Inventory data and version;
  - For subsequent inventories, a link to previous inventory reports and descriptions of any methodological changes; and
  - A disclaimer stating the limitations of various potential uses of the report, including product comparison.
- Boundary settings - under this heading flow the following:
  - Life-cycle stage definitions and descriptions;
  - A process map, including attributable processes in the inventory;
  - Non-attributable processes including in the inventory;
  - Excluding attributable processes and justification for their exclusion;
  - Justification of a cradle-to-gate boundary, where applicable;
  - The time period; and
  - The method used to calculate land-use change impacts, where applicable.
- Allocation - under this heading flow the following:
  - Disclosure and justification of the methods used to avoid or perform allocation due to co-products or recycling; and
  - When using the closed loop approximation method, any displaced emissions and removals separate from the end-of-life stage.
- Data collection and quality - under this heading flow the following:
  - For significant processes, a descriptive statement on the data source, data quality, and any efforts taken to improve data quality.
- Uncertainty - under this heading flow the following:
  - A quality statement on inventory uncertainty and methodological choices included and end-of-life profile; allocation methods, including allocation due to recycling; sources of global warming potential (GWP) factors used and calculation models.
- Inventory results - under this heading flow the following:
  - The source and data of the GWP factors used;
  - Total inventory results in units of CO_2e per unit of analysis, which includes all emissions and removals included in the boundary from biogenic sources, non-biogenic sources, and land-use change impacts;
  - Percentage of total inventory results by life cycle stage;
  - Biogenic and non-biogenic emissions and removals separately. where applicable;

  - Cradle-to-gate and gate-to-gate inventory results separately (or clear statement that confidentiality is a limitation to provide this information);
  - The amount of carbon contained in the product or its components that is not released into the atmosphere during waste treatment, where applicable; and
  - For cradle-to-gate inventories, the amount of carbon contained in the intermediate product.
- Assurance – the assurance statement includes
  - Whether the assurance was performed by a first or third party;
  - The level of assurance achieved (limited or reasonable) and assurance opinion or the critical review findings;
  - A summary of the assurance process;
  - The relevant competencies of the assurance providers; and
  - An explanation of how many potential conflicts of interest were avoided for first-party assurance.
- Setting reduction targets and tracking inventory changes – companies that report a reduction target and/or track performance over time shall report the following:
  - The base inventory and current inventory results in the updated inventory report;
  - The reduction target, if established;
  - Changes made to the inventory, if the base inventory was recalculated;
  - The threshold used to determine when recalculation is needed;
  - Appropriate context-identifying and describing significant changes that trigger base inventory recalculation;
  - The change in inventory results as a percentage change over time between the two inventories on the unit of analysis basis; and
  - An explanation of the steps taken to reduce emissions based on the inventory results.

Step 12 - Set reduction targets

After the carbon footprint is done, it has been verified and the report on the different scopes has been issued, the different scopes can then be looked at to determine where to reduce the emissions or where to put an off-setter in place so that it can neutralise the carbon being released. Carbon reduction and carbon offsetting are part of the recommendation process.

Step 12 is designed to help companies to improve the quality and consistency of their product, but also to assist companies to reduce the emissions they release either in the design of the product, the manufacturing of the product, the selling of the product, or the purchasing of the product and/or the use of the product. For companies to track their reduction targets over time, as well as to track their inventory changes, they have to adhere to the following requirements:

- The requirements of this standard by developing and reporting on a base inventory;
- Changes that might occur due to significant changes in the methodology, by firstly recalculating the base inventory;
- To complete and disclose an updated inventory report, which must include the updated results, the base inventory results and the context for significant changes; and
- To track performance over time, for which the company must use a consistent unit of analysis that also is comparable (Greenhouse Gas Protocol, 2012b).

5.3. Conclusion

This chapter looked at the entity and product carbon footprint and examined all the different steps that must be followed in order for the company/farm to obtain a reliable footprint and also to emphasise the importance of these steps and that no step can be left out. Chapter 6 addresses the footprinting of each of the sampled farms.

Chapter 6: Carbon Footprinting: Tool and Results

6.1. Introduction

The phases and processes of the carbon footprint were discussed in Chapter 5. This chapter presents the carbon calculator for mixed smallholder farmers and the results generated by the preselected sample.

6.2. Product Carbon Calculator for Smallholder Mixed Farming Systems

6.2.1. Development process

Two tools were developed, a paper-based tool and an Excel tool. The paper-based tool was developed for the purpose of supporting the Excel tool and also to allow the researcher to assess what information was available and what information farmers were willing to share. The paper-based questionnaire was discussed in the final questionnaire section 4.3.2, and serves as the paper-based tool. The development of the Excel tool was modelled on tools that were already available, as discussed in Chapter 2, more specifically on the fruit and wine carbon calculator.

South Africa already has a fruit and wine carbon calculator, which addresses certain sections of the agricultural sector, so the decision was made to pair with Blue North, the consultancy company that manages the fruit and wine calculator, to provide guidance in the planning and development of a carbon calculator tool for smallholder mixed farming systems.

The Excel tool thus was developed to suit the needs of smallholder mixed farming systems. The aim of the tool was not to reinvent the wheel, but to adjust it to the needs of smallholder farmers. The accuracy and effectiveness of the tool were evaluated and approved by Blue North. The development steps for the prototype carbon tool were as follows:

1. Identifying the gaps in relation to previous calculators – discussed in Chapter 2;
2. Identifying farmers to take part in the study – Chapters 1 and 4;
3. Identifying what data is needed to conduct an entity and product footprint;
4. Designing a pilot questionnaire to collect and see what type of data is available and to identify the literacy level of the participants – pilot questionnaire was discussed in Chapter 4, section 4.3.1;
5. Redesigning the final questionnaire – Chapter 4 discusses the pilot and final questionnaire in sections 4.3.1 and 4.3.2, and the pilot and final questionnaire can be seen in Appendix F;

6. Conducting final interviews to collect data by using the paper-based tool (final questionnaire);
7. Getting Blue North on board with the development of the Excel tool;
8. Expanding on the fruit and wine tool for the Excel tool by adding crops, livestock, grains, land management changes, processing (for example vegetables and wood production), other alternatives (for example flower picking), office and domestic waste, and expanding on the fruit tab;
9. The Excel tool consists out of various tabs: new farm unit, crops (which include fruit, grain and vegetables), livestock, electricity/energy usage, allocation of fuel resources, fertilisers and chemicals, LUC and carbon sequestration, processing and packhouse information, packhouse waste, cold storage information and distribution (see Appendix E);
10. Drawing up the emission factor list for the calculation part and using sources like UNFCCC 2014 tables, UK government 2012 tables, DEFRA tables, CCC tool, etc. – can be seen in Appendix D;
11. Adding all the data collected from the questionnaires to the database and multiplying it by the emission factors; and
12. Using the outcome of step 11 to generate the entity and product footprint report (Appendix G).

General comments

For this tool to be utilised by farmers, the author notes that farmers will need training in "what data to keep record of" and why the carbon footprint is important. Users of the tool also will require assistance if they have little to low levels of literacy. If this tool is to be utilised on a provincial level, then assistance and support will have to be provided by provincial extension officers and commodity associations. Extension staff will also play a role in advising farmers on the outcomes of the report generated from the footprint.

6.2.2. Sample of the calculator

The tool consists of various parts – the paper-based tool, the Excel tool and the emission source list. The emission source list that was used to determine the emission factors is attached as Appendix D, and the paper-based tool (questionnaire) can be seen in Appendix F. Snapshots of the Excel tool can be seen in Appendix E.

6.3. Results of Farms' Carbon Footprint

The product carbon footprints of the 18 farmers were calculated according to the methodology of the Greenhouse Gas Protocol (2012b), which also was the methodology used to develop the calculator. Each farm's footprint is dependent on the accuracy of the data supplied by the farmers via the questionnaire, and also on the emission factors used. It is important to note that South Africa does not have its own emission factors, so different sources were used to draw up a list of relevant emission factors for the activity data (see Appendix D). Each of the steps mentioned in Chapter 5 will be applied briefly to the sample.

Step 1: Define business goals

The general goals of the sampled farms were to grow to a commercial level and, secondly, to farm in a sustainable manner to provide their children and grandchildren with a secure source of income.

Step 2: Review principles

When the interviews were conducted, a brief amount of time was spent on the five principles of relevance, accuracy, completeness, consistence and transparency. Unfortunately, two of the five principles were not accounted for due to the lack of proper record keeping, and assumptions had to be made where accuracy and completeness were lacking.

Step 3: Review fundamentals

An inventory list, otherwise known as an emissions factor source list, was drawn up (see Appendix D).

Step 4: Define the scope of the product inventory

Table 6.1 below identifies all the scope sources that were considered in this study.

Table 6.1: Different scope sources

Scope 1	**Scope 2**	**Scope 3**
Mobile fuel	Electricity	Office and domestic waste to the landfill
Stationary fuel		Organic waste to the landfill
Manure management		Agro-chemicals (including fertilisers)
Enteric fermentation		
Organic waste to compost		

Step 5: Set boundary

The farm boundaries were identified by means of the questionnaire. Of the 18 participants, seventeen farms' boundaries included only the farm, while the eighteenth one had a packhouse forming part of its boundary.

Step 6: Collect data and assess data quality

Data was collected on the farms by means of the questionnaire. Farmers had to answer questions using information from their financial records and where allocation splits had to be made, percentage assumptions where used. In some instances, data quality was not of a high standard due to assumptions that had to be made in cases of poor record keeping.

Step 7: Perform allocation if needed

Allocations had to be performed where a lack of records could not distinguish between the different commodity allocations.

Step 8: Access uncertainty

The GWP and emission factors were compared with other calculators' methodologies that were available, but due to the nature of the trial run, the uncertainty level was high.

Step 9: Calculate inventory results

As seen in the 2013/14 GHG emissions table 6.2 below the calculated results for all 18 farms. The results were obtained by means of the developed calculator.

Step 10: Performance assurance

This study's confidence level for the entity carbon footprint's confidence level is much higher and more accurate than for the product carbon footprint, due to the assumptions made and the lack of proper record keeping.

Step 11: Report inventory results

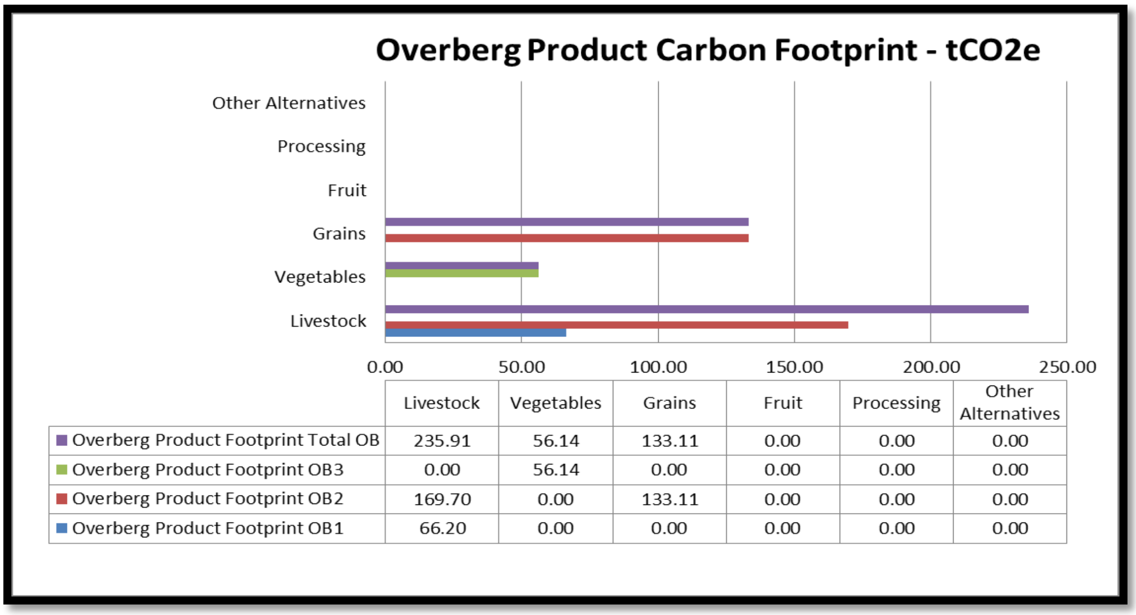
The 2013/14 GHG emissions table 6.2 below provides a summary of the entity carbon footprint that was compiled for the different sampled farms in each of the six districts. Table 6.2 shows that enteric fermentation is the highest emission source, while organic waste to compost is the lowest emission source.

Table 6.2: 2013/14 GHG emissions of all 18 farms

Tonnes of CO_2 equivalent																		
	OB1	**OB2**	**OB3**	**CW1**	**CW2**	**CW3**	**CM1**	**CM2**	**CM3**	**WC1**	**WC2**	**WC3**	**ED1**	**ED2**	**ED3**	**CK1**	**CK2**	**CK3**
Scope 1																		
Mobile fuel	27.2	34.7	12	16	8	7.3	5.1	23.1	5.1	39.3	26.3	0	6.2	8.5	29.5	19.4	5.8	24.6
Stationary fuel	0	1.1	0.6	0	0.6	0	0.2	0	0.8	0	0.1	0.1	0	0	0.6	0	0.5	10
Manure management	20.3	4.3	0	0	0	0	2.2	0	0	5.7	7.5	22.2	4	5	2.8	34.1	4.3	9
Enteric fermentation	35.8	122.8	0	0	0	0	38	0	0	162.4	214.7	2.6	0.7	70.9	80.7	482.8	119.8	197
Organic waste to compost	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0	0
Scope 2																		
Electricity	5.5	9.1	5.2	17.4	2.4	12.6	9.4	35.6	43.5	97.3	14.6	10.4	1.6	17.2	0.8	13.2	0	0
Scope 3																		
Office & domestic waste	12.6	1.6	19.3	8.6	1.3	1.9	0.1	1	281	1.4	1.4	21.8	2.5	0.6	0	2.9	0.1	7.2
Agro-chemicals	10.1	137.7	19	17.3	15	5	12.8	3.3	225.2	72.8	20.2	0.5	0	0	34.4	0.2	0.2	53.4
Farm Total	**111.5**	**311.3**	**56.1**	**59.3**	**27.2**	**26.9**	**68**	**63**	**556**	**379.1**	**284.9**	**57.5**	**15**	**102.3**	**148.9**	**552.6**	**130.5**	**301.2**

Taking this entity carbon footprint a step further, a product carbon footprint can be compiled for each commodity using the developed tool. The results from the product carbon footprint are more detailed in nature and can highlight the hotspots on a product farm level. Figures 6.1 to 6.6 below show the results of the product carbon footprints per farm per district, and illustrates which "product" is contributing more to the entity carbon footprint.

Overberg

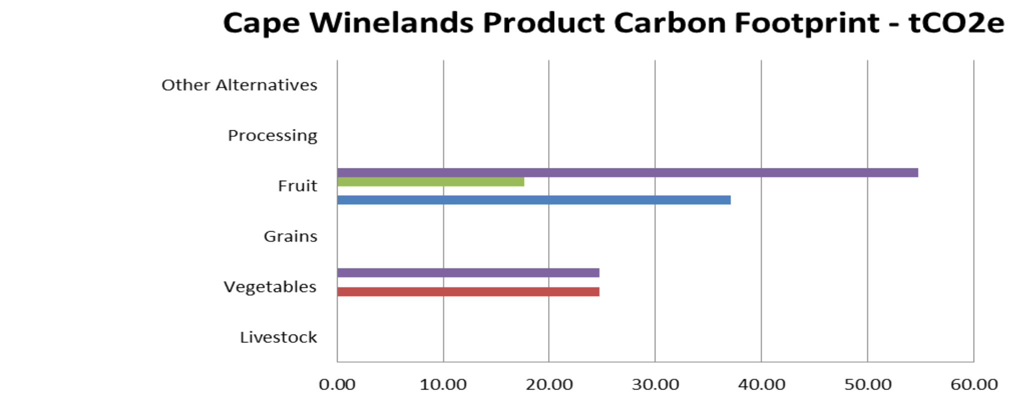


	Livestock	Vegetables	Grains	Fruit	Processing	Other Alternatives
Overberg Product Footprint Total OB	235.91	56.14	133.11	0.00	0.00	0.00
Overberg Product Footprint OB3	0.00	56.14	0.00	0.00	0.00	0.00
Overberg Product Footprint OB2	169.70	0.00	133.11	0.00	0.00	0.00
Overberg Product Footprint OB1	66.20	0.00	0.00	0.00	0.00	0.00

Figure 6.1: Overberg product carbon footprint – tCO_2e

In the Overberg product carbon footprint in figure 6.1 it can be noted that livestock is the highest emitter source of the farms sampled in the Overberg (235.91 tCO_2e), followed by grains (133.11 tCO_2e). OB1's product that contributes the most to the entity footprint is livestock, while that of OB2 is livestock and grains and the biggest product emission contribution of OB3 is vegetables.

Cape Winelands

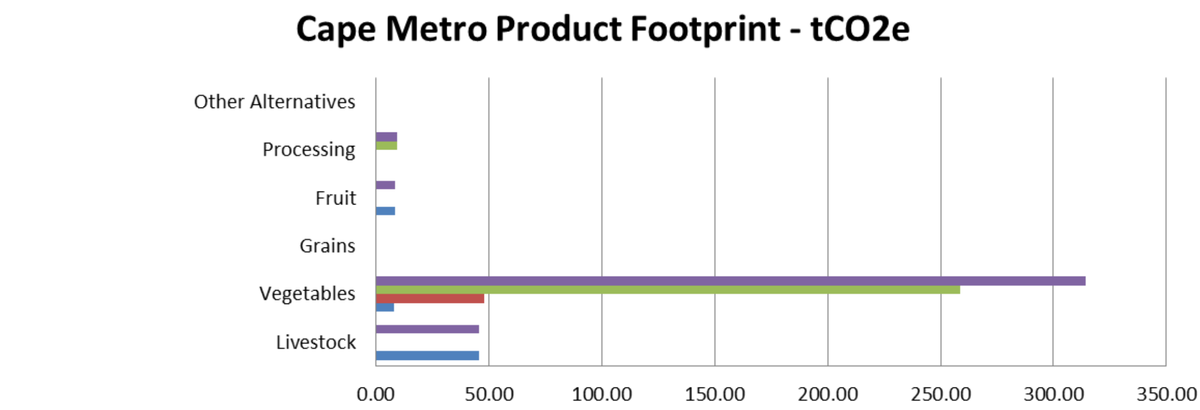


	Livestock	Vegetables	Grains	Fruit	Processing	Other Alternatives
Cape Winelands Product Footprint Tot CW	0.00	24.71	0.00	54.72	0.00	0.00
Cape Winelands Product Footprint CW3	0.00	0.00	0.00	17.64	0.00	0.00
Cape Winelands Product Footprint CW2	0.00	24.71	0.00	0.00	0.00	0.00
Cape Winelands Product Footprint CW1	0.00	0.00	0.00	37.08	0.00	0.00

Figure 6.2: Cape Winelands product carbon footprint – tCO_2e

In the Cape Winelands product carbon footprint in figure 6.2 it can be noted that fruit is the highest emitter source of the farms sampled in the Cape Winelands district (54.72 tCO_2e), followed by vegetables (24.71 tCO_2e). The product in CW1 that contributes the most to the entity footprint is fruit, while that of CW2 is vegetables and of CW3 is fruit.

Cape Metro

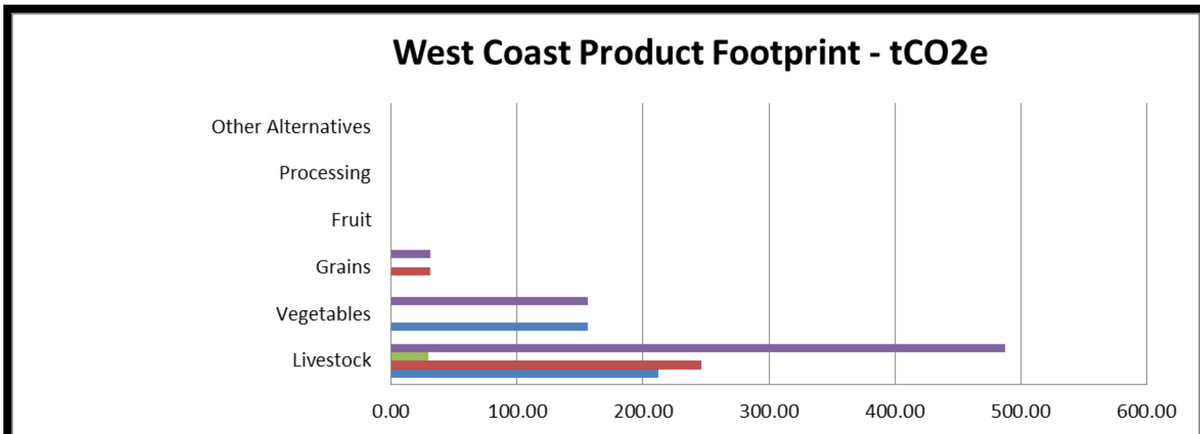


	Livestock	Vegetables	Grains	Fruit	Processing	Other Alternatives
Cape Metro Product Footprint Tot CM	45.64	314.33	0.00	8.50	9.49	0.00
Cape Metro Product Footprint CM3	0.00	258.56	0.00	0.00	9.49	0.00
Cape Metro Product Footprint CM2	0.00	47.74	0.00	0.00	0.00	0.00
Cape Metro Product Footprint CM1	45.64	8.03	0.00	8.50	0.00	0.00

Figure 6.3: Cape Metro product carbon footprint – tCO_2e

In the Cape Metro product carbon footprint in figure 6.3 it can be noted that vegetables are the highest emitter source of the farms sampled in the Cape Metro (314.33 tCO_2e), followed by livestock (45.64 tCO_2e), processing (9.49 tCO_2e) and fruit (8.50 tCO_2e). CM1's product that contributes the most to the entity footprint is livestock, while that of CM2 is vegetables and CM3's biggest product emission contribution is vegetables.

West Coast

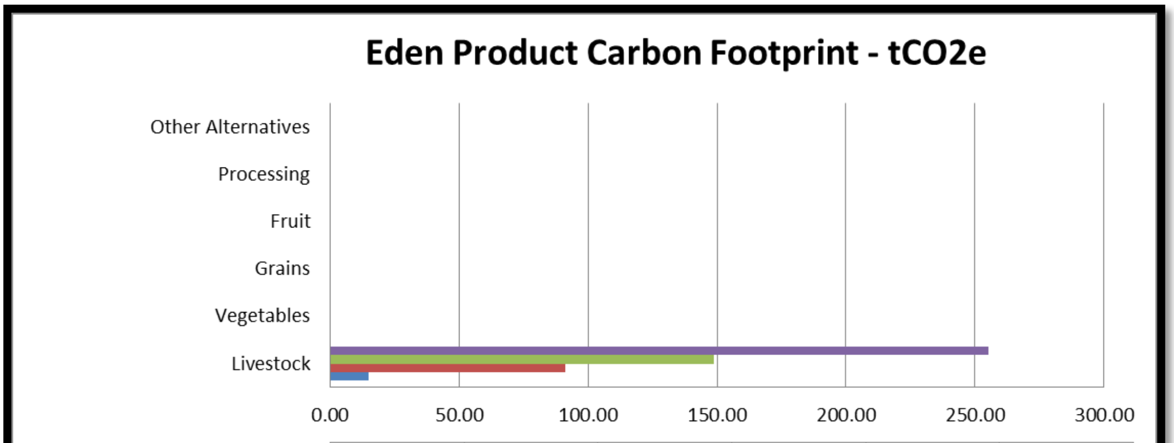


	Livestock	Vegetables	Grains	Fruit	Processing	Other Alternatives
West Coast Product Footprint Tot WC	488.00	156.00	30.81	0.00	0.00	0.00
West Coast Product Footprint WC3	29.37	0.00	0.00	0.00	0.00	0.00
West Coast Product Footprint WC2	246.75	0.00	30.81	0.00	0.00	0.00
West Coast Product Footprint WC1	211.88	156.00	0.00	0.00	0.00	0.00

Figure 6.4: West Coast product carbon footprint – tCO_2e

In the West Coast product carbon footprint in figure 6.4 it can be noted that livestock is the highest emitter source for the farms sampled in the West Coast (488.00 tCO_2e), followed by vegetables (156.00 tCO_2e) and grains (30.81 tCO_2e). WC1's product footprint that contributes the most to the entity footprint is livestock, followed by vegetables, WC2's product contribution is livestock and WC3's biggest product emission contribution is livestock.

Eden

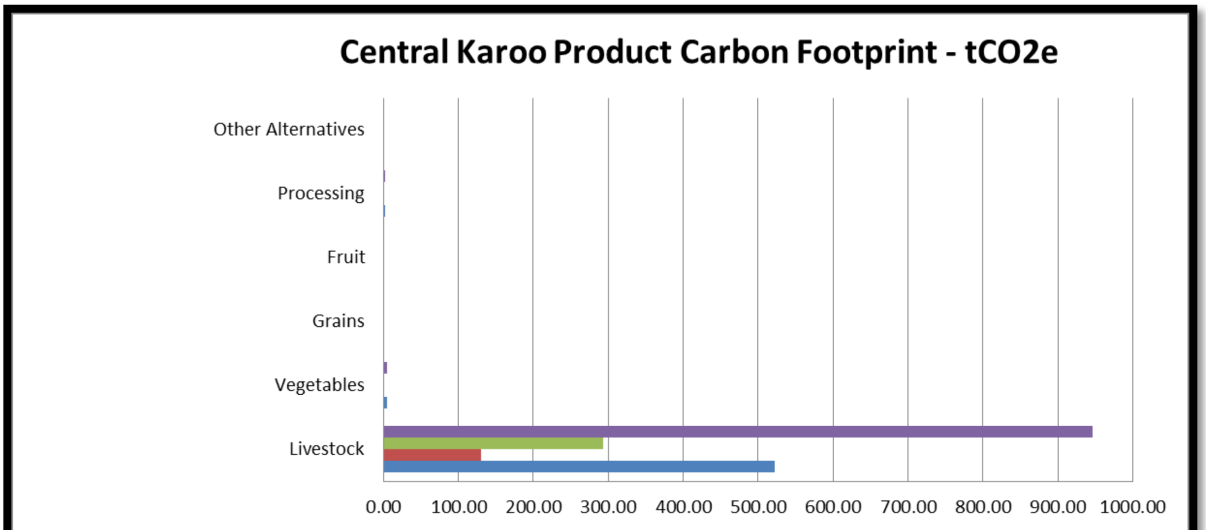


	Livestock	Vegetables	Grains	Fruit	Processing	Other Alternatives
Eden Product Footprint Tot ED	255.27	0.00	0.00	0.00	0.00	0.00
Eden Product Footprint ED3	148.94	0.00	0.00	0.00	0.00	0.00
Eden Product Footprint ED2	91.34	0.00	0.00	0.00	0.00	0.00
Eden Product Footprint ED1	14.99	0.00	0.00	0.00	0.00	0.00

Figure 6.5: Eden product carbon footprint – tCO_2e

In the Eden product carbon footprint in figure 6.5 it can be noted that livestock is the highest emitter source for the farms sampled in Eden (255.27 tCO_2e). ED1's product that contributes the most to the entity footprint is livestock, ED2's biggest product contribution is livestock and ED3's is livestock.

Central Karoo



	Livestock	Vegetables	Grains	Fruit	Processing	Other Alternatives
Central Karoo Product Footprint Tot CK	946.25	5.49	0.00	0.35	1.66	0.00
Central Karoo Product Footprint CK3	293.59	0.00	0.00	0.35	0.00	0.00
Central Karoo Product Footprint CK2	130.44	0.00	0.00	0.00	0.00	0.00
Central Karoo Product Footprint CK1	522.22	5.49	0.00	0.00	1.66	0.00

Figure 6.6: Central Karoo product carbon footprint – tCO_2e

In the Central Karoo product carbon footprint in figure 6.6 it can be noted that livestock is the highest emitter source for the farms sampled in the Central Karoo (946.25 tCO_2e), followed by vegetables (5.49 tCO_2e), processing (1.66 tCO_2e) and fruit (0.35 tCO_2e). The product that contributes the most to the entity footprint in CK1, CK2 and CK3 is livestock.

The farm with the highest total emissions is Cape Metro 3, with 556 tCO_2e, followed by Central Karoo 1, with 552.6 tCO_2e, while the third largest emitter farm is West Coast 1, with 379.1 tCO_2e. Hotspots that can be identified for the entity footprint are agro-chemicals, electricity and fuel emissions. The information from tables 6.2, as well as from figures 6.1 to 6.6 were used to compile the farm reports (see Appendix G for carbon footprint reports of the 18 farms). These carbon footprint reports thus can assist smallholder farmers to identity their farm and commodity hotspots and help create awareness of better resource use.

Step 12: Set reduction targets

Emission reduction targets need to be set by each farmer according to what is possible on the farm, referring to activities that do not affect profit and/or daily operations. A few general target reductions that can be applied to source hotspots for emission reduction are:

- ***Electricity***

  General electricity usage awareness aimed at reducing unnecessary wastage and promoting the use of PV solar panels, wind turbines and energy efficient lightbulbs and appliances.

- ***Mobile fuel***

  Reducing unnecessary use of vehicles and aligning going to the market with going to town to buy supplies. This will ensure maximum use of vehicles by having full bakkie or truckload into town, as well as a full bakkie or truckload back to the farm. Also avoid unnecessary driving of tractors and switch off when not in use.

- ***Stationary fuel***

  Use implements only when necessary and make use of other alternatives, like PV solar panels on water pump and minimal use of generators.

- ***Manure management***

  Use manure in a biogas digester or as fertiliser.

- ***Enteric fermentation***

  Enteric fermentation refers to the digestive process of animals and it is this process in which methane emissions are produced and therefore it is important to look at the type of feed that is used in the diet of livestock.

- ***Organic waste to compost***

Organic waste must be composted as far as possible to avoid organic waste going to landfills or being burned.

- ***Agro-chemicals***

Make use of more natural or organic fertilisers that are not harmful to nature or the soil. Also by making use of only registered chemicals that are needed to ensure crop safety on the Integrated Pest Management (IPM) scoring charts. Farmers must also use cover crops and rotation to break disease cycles and they should not use monoculture as a production option. Moving away from conventional farming to conservation farming is a better option and also to reduce tillage to a minimum.

General comments

When the data was collected, a few shortcomings were picked up, for example the lack of proper operation records and the split between commodities. Farmers will need to keep operation records if they want an accurate footprint that can be verified at a later stage.

6.4. Conclusion

The carbon calculator tool that was developed in this study has proven useful in terms of measuring the carbon footprint of smallholder mixed farming systems. The paper-based tool assists with the data collection, as users can complete it themselves. Extension staff then will be required to input the data into the Excel tool and to generate a report. This role ideally would be performed by the provincial department of agriculture if they were to adopt the tool.

The reports generated from the tool assists farmers in identifying entity level emissions, product emissions and, by doing so, can help identify farm hotspots and potential carbon tax obligations. The results from the preselected sample reports on the entity carbon footprint results for the total CO_2 emissions for the whole farm, while the product carbon footprint results reports on the different commodities on the farm and each commodity's contribution to the farm's total emissions. Enteric fermentation, agro-chemicals, mobile fuels and electricity were identified as the biggest emitters across the different districts, while the product carbon footprint showed that livestock was the main contributor to the emissions of the farms sampled in the study.

Chapter 7: Conclusion and Recommendations

7.1. Conclusion

The objective of the study was to develop a product carbon footprint tool that could be utilised by smallholder mixed farming systems. The results of the tool could then be used to identify possible resource 'hotspots', the reduction of these hotspots potentially could assist in a reduction of production costs, as well as assist with the stringent sustainability requirements of retailers and associations, and also help farmers to hedge the indirect effects of phase 1 of the 2017 carbon tax.

First, an entity carbon footprint was used to identify the possible hotspots in the sampled farms, and this led to the development of a product carbon footprint, which can assign the identified hotspots to a specific commodity on the farm. The different steps in the facility and product carbon footprint that need to be followed in order to obtain an accurate footprint are described in Chapter 5. The preselected sample showed that there were gaps in the records that were kept, and this made the product carbon footprint steps difficult to follow. Assumptions had to be made for some steps, for example where the farmer had to split electricity or fuel usage between farm activities. The tool did allow for percentage splits where no real figure could be given. In Chapter 6, the carbon results were given for each farm, first by using the facility carbon footprint and then by using the product carbon footprint so that each farmer can see which enterprise is emitting the most CO_2. The study also created profiles for the selected smallholder farms spread across the WC. It thus can be said that the purpose of the calculator was achieved, but some recommendations have to be followed before the tool can be launched to the public and used to obtain carbon footprint verification.

7.2. Recommendations

7.2.1. Recommendations from entity footprint for smallholder sample

Recommendations that can be made from the results by focusing only on the highest emitters, which are addressed in Chapter 6, are:

- Proper records must be kept, and not only financial records, so that a 100% accurate carbon footprints can be obtained that also can be verified at a later stage for certification;
- Mobile fuel usage can be decreased by lessening trips to town or the market, for example by coordinating the two;

- Energy (electricity) efficiency can be improved by looking at other alternatives, for example solar panels, wind turbines, etc., as well as by switching to more energy-efficient lights and appliances;
- The "outside decomposing, methane releasing" manure from livestock, especially dairy cattle can be reduced by establishing a biogas digester.[12] Manure gets fed into the biogas digester that creates two by-products of the manure, energy (in a form of a gas) and fertiliser; and
- Agro-chemicals can be decreased by looking at more organic and environmentally friendly products. Also by making use of only registered chemicals that are needed to ensure crop safety on the IPM scoring charts. Farmers must also use cover crops and rotation to break disease cycles and they should not use monoculture as a production option. Moving away from conventional farming to conservation farming is a better option and also to reduce tillage to a minimum.

7.2.2. Recommendation for product carbon tool

As mentioned in Chapter 5, a product carbon tool will require additional development for it to be modified for public use. A pilot phase will be required to test and fine-tune the tools (paper based and Excel tool) and the resources that were developed in phase 1. It also is recommended that this project be carried out by and with the support of the Western Cape Department of Agriculture's extension officers (Farmer Support and Development [FSD]), the Agricultural Economics Division and external consultants. The following sub-steps thus are recommended for the pilot phase:

- A piloted group of farmers that are representative of the WC smallholder population should be used. Workshops and information sessions will have to be hosted for the farmers to address issues such as why carbon footprinting is necessary, how and what data to collect, an explanation of the results, and the interpretation thereof to assess the farmers' willingness to use this tool and to determine its effectiveness.

[12] Enteric fermentation is the fermentation process where methane is produced as a by-product through the normal digestive process of livestock (Gibbs et al). Anaerobic digestion is a process characterised by the breakdown of organic matter by micro-organisms in the absence of oxygen and during that process biogas is produce, which is a by-product of the anaerobic digestion (Fourie, 2010). An anaerobic digester, which is also called a biogas digester, is the place where within the process takes place. The biogas digester not only produces biogas but also sludge from the manure (Fourie, 2010). The biogas can be used as a direct source of energy or can be fed into the electricity grid, while the sludge can be used as a fertiliser. This digester not only acts as an energy generating source, but it also acts as a manure and organic waste treatment system (Fourie, 2010).

- Workshops for extension officers are also recommended. The workshops will have to address issues such as how to collect data from farmers, how to fill in the paper-based questionnaires, and explanations of the results to assess the effectiveness of the tools to be used by extension officers.
- Review the functionality of the tool.
- A third party assurer must get on board so that no data biases occur. The third party assurer must also be the host of the tool, due to the WCDOA not having the resources to update the methodologies, emission factors and policies on a yearly basis. The third party assurer will already have all the licencing in place to run such an operation. The only cost for the WCDOA will then be the annual maintenance cost if the third party assurer takes control of the tool and all the logistics that goes with the tool.
- Verification of the footprint will be the final step that the WCDOA will have to look at if the need arises for farmers to have carbon footprint certification.

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Appendix A - Standards and codes of conduct matrix

Name	Standard	Accreditation	Products covered	Green requirements
WTO/WHO (World Trade Organization/World Health Organization):				
CAC (*Codex Alimentarius Commission*)	Standard, code of practice and guidelines	Very limited certification	Strawberries, tomatoes, pineapples, table olives, asparagus, raspberries	No
UNECE (United Nations Economic Commission for Europe):				
Fresh fruit and vegetables	Food quality standards	Certification	Fruit and vegetables, dry and dried produce, seed potatoes, meat, cut flowers, eggs and egg products	No
Dry and dried produce *(DDP)*	Food quality standards	Certification	Almonds, apples, apricots, cashews, dates, figs, grapes, hazelnuts, macadamias, peaches, pears, pine, pistachio, prunes, tomatoes, walnuts	No
Seed potatoes	Food quality standards	Certification	Potatoes	No
Meat	Food quality standards	Certification	Bovine meat, caprine meat, chicken meat, duck meat, edible meat, llama/alpaca meat, ovine meat, porcine meat, turkey meat	No
Cut flowers	Food quality standards	Certification	Cut foliage, unifloral roses, cut unifloral carnations, multifloral carnations, chrysanthemums, gladioli and strelitzias	No

Eggs and egg products	Food quality standards	Certification	Edible hen eggs in shell, hen egg products for use in the food industry, eggs in shell, eggs in shell for processing, chilled eggs in shell, hen egg products for use in the food industry	No
OECD (Organisation for Economic Co-operation and Development) codes and schemes:				
Seed	Standard (7)	OECD labels and certificates	Grasses and legumes, crucifers and other oil or fibre species, cereals, maize and sorghum, beet, subterranean clover, vegetables	No
Fruit and vegetables	Export quality inspection systems	-	Apples, apricots, artichokes, asparagus, cherries, citrus fruit, figs, grapes, peaches and nectarines, plums, garlic, etc.	No
ISO (International Organisation for Standardisation):				
ISO (*International Organisation for Standardisation*) 9000	Quality, processing and farm standards			No
ISO (*International Organisation for Standardisation*) 14000	Environmental standards	Systematic framework		Yes
ISO (*International Organisation for Standardisation*) 22000	Food safety management standards	Audit report and certification	Covers all the organisations in the food supply chain (crop production, processing, distribution and related operations)	No
SUPRANATIONAL STANDARDS (EU/ European Union):				
FVO (*Food and Veterinary Office*)			Foodstuffs of animal origin, foodstuffs of vegetable origin	No

COLLECTIVE INTERNATIONAL STANDARDS:				
BRC (*British Retail Consortium*)	Food safety and technical standard	Audit report and certification		No
IFS (*International Featured Standard*)	Food quality standard	Audit report and certification		No
SQF (*Safe Quality Food*)	Food safety standards	Audit report and certification		No
SQF (*Safe Quality Food*) 1000	Code based on HACCP principles	Certification	Raw seed sprouts, bean sprouts, alfalfa sprouts, oysters and mussels	No
SQF (*Safe Quality Food*) 2000	Code (HACCP-based quality management system)	Certification	Generic	No
FSSC *(Food Safety Security Certification*) 22000	Food safety management system	Audit report and certification		No
GLOBALGAP (*Good Agricultural Practices*)	Food safety standard	Certification	Generic	No
HACCP (*Hazard Analysis and Critical Control Points*)	Quality management standard	Certification		No
ETI (SEDEX) [*Ethical Trade Initiative – Supplier Ethical Data Exchange*]	Ethical trade initiative		Generic	No
BSCI (*Business Social Compliance Initiative*)	Code of conduct	Cover page of audit report display	Generic	No

SA (*Social Accountability*) 8000	Social responsibility standard	Certification	Generic	No
FAIRTRADE INTERNATIONAL FLOCERT	Social responsibility standard	Certification plus labels	Bananas, cocoa, coffee, cotton, flowers, fresh fruits, honey, juices, rice, spice and herbs, sugar, tea, wine	No
FLO [*Fairtrade Labelling Organisation*] generic trader standards (GTS)			Wine, fruit and tea	No
FLO (*Fairtrade Labelling Organisation*) product-specific standards			Food: bananas, cocoa, coffee, dried fruit, fresh fruit and vegetables, fruit juices, herbs and spices, honey, nuts and oilseeds, quinoa, rice, sugar (cane), soybeans and pulses, tea and wine grapes. Non-food: flowers and plants, seed cotton and sports balls	No
FLOverde (Global GAP benchmarked)	Certification, a sectorial information system, and a mark of conformity	15 topics classified under three types of control points (level 1 at 100%, 2 at 95% and level 3)	Flowers (roses, carnations, chrysanthemums, lilies, hydrangeas, Ornithogalum, limonium/statize, etc.) and ornamentals (leatherleaf ferns, tree ferns, eucalyptus, pine, etc.)	No
Marine Stewardship Council	Environmental and chain of custody standard for seafood traceability	Certificate, label of brand mark (logo)	Cockles, cod, halibut, hake, herring, hoki, ice fish, lobster, mackerel, nephrops, pikeperch, plaice, pollock, saithe, salmon, scallops, seabass, shrimp, sole and tuna, etc.	Yes
COLLECTIVE NATIONAL STANDARDS:				
LEAF (*Linking Environment and Farming*)	Environmental			Yes
China GAP	Code, certification standard			No
CHILE GAP				No

KENYAGAP				No
SWISSGAP				No
NZGAP				No
QS (*Qualität und Sicherheit GmbH (origin) / Quality Systems*)	Food quality and safety standard			No
SA GAP	Food safety standard	Certificate		No
SECTOR STANDARDS:				
IFOAM (*International Federation of Organic Agriculture Movements*)	Organic standard	Certification	Crop production, livestock, wild products, processing, fibre processing and aquaculture.	Yes
UTZ Certified good inside (*UTZ is a word meaning "good" originated from Utz Kapeh (good coffee) in the language Quiche*)	Code of conduct and traceability system	Certification	Rooibos, coffee, cocoa, tea	No
INDIVIDUAL FIRM STANDARDS:				
FRUITNET	Retail standard			No
NATURE'S CHOICE	Food safety standard	Certification	Generic	No
FIELD TO FORK	Retail standard			No
IPM (*Integrated Pest Management*)	Retail standard			No
Colibri	Retail standard			No
IPL (International Procurement and Logistics) food hygiene	Retail standard			No

Source: Pheeha, 2011

Appendix B - Management systems and processes of M&S

Management processes and systems	
Compliance with national law	In addition to these principles, suppliers must comply with all relevant local and national laws and regulations. Unless there is conflict between national law and any supplier obligation in these principles, the supplier must adhere to the standard that promotes the higher level of protection for workers, communities and other rights holders.
Human resource policies	Suppliers must adopt and implement human resources policies and procedures appropriate to their size and workforce, which are consistent with the requirements of national law and these principles.
Information about employment and employee relationship	Work performed must be on the basis of a recognised employment relationship established in compliance with national legislation and practice and international labour standards. Suppliers must ensure all workers on their sites are provided with written and understandable information about their employment conditions, including wages, hours and holidays, before they enter into employment; and about details of their wages for the pay period concerned each time that they are paid.
Healthy and safe working conditions	- Suppliers must provide safe and clean conditions for all workers on site in all work and residential facilities and must establish and must follow a clear set of procedures regulating occupational health and safety. - Suppliers must take adequate steps to prevent accidents and injury to health arising out of, associated with, or occurring in the course of work, by minimising the causes of hazards inherent in the working environment. Appropriate and effective personal protective equipment must be provided as needed. - Suppliers must provide all workers with access to clean toilet facilities that respect worker dignity and to drinkable water and, if applicable, sanitary facilities for food preparation and storage. - Suppliers must provide regular and recorded health and safety training to workers and management, and such training must be repeated for all new or reassigned workers and management.

	- Suppliers must assign the responsibility for health and safety to a senior management representative and must carry out regular risk assessments. - Suppliers must provide adequate safeguards against fire, and must ensure the strength, stability and safety of buildings and equipment, including residential facilities where provided. All sites must have an effective fire safety management system in place. This must include but not limited to: - Responsibility of general manager for overall fire safety - Ongoing risk assessments - Training for fire safety personnel - Appropriate and reliable equipment - Clear and safe evacuation systems - Regular fire drills for all shifts and all types of workers (site must keep a list of trained personnel) - All systems must be reviewed on a frequent basis. - Suppliers must provide access to adequate medical assistance and facilities.
Environment	At the very least, suppliers must comply with all local and national environmental regulations and complete a supply chain risk assessment to understand their impact on the environment. In addition, they must meet all relevant Marks & Spencer standards relating to the environment.
Land rights	We expect all suppliers to adhere to the practice of free and prior informed consent for land rights and suppliers must conform to local, national and international standards of land tenure when working in communities. Where applicable, this may include evidence of a due diligence process within communities to understand where established rights to property and land lie.
Supply chain monitoring	It is our supplier's responsibility to enforce these standards with their own supply chain. As part of their supply chain risk

	assessment they must be aware of more vulnerable groups like women, smallholders and homeworkers, and subcontracting and have adequate monitoring in place to ensure the rights of these groups are upheld.
Sub-contracting	Sub-contracting to other suppliers, sites, or units is not permitted without pre-authorised permission from M&S.

Source: M&S, 2013

Appendix C - Laws, regulations and code of practice for South African poultry

Laws and regulations	**Code of practice**
Animal Improvement Act (Act no. 62 of 1998)	All paperwork should be completed prior to catching and loading so that the vehicle may leave the premise immediately after loading is complete.
Animal Disease Act (Act no. 35 of 1984)	With each batch of birds the depleted bird buyer will receive a health declaration stating that the birds originate from a flock that conforms to the requirements as per the following DAFF-approved documents: • Movement control protocol in case of an outbreak of Newcastle disease • Movement control protocol in case of an outbreak of *Salmonella enteritidis* or *Salmonella gallinarum/ pullorum* • Contingency plan in the case of an outbreak of Notifiable Avian Influenza and • Are free of visible signs of disease at the time of catching
Animal Protection Act (Act no. 71 of 1962)	During hot weather, birds should be loaded and transported during the cooler parts of day, either in the early morning, late afternoon or at night
Meat Safety Act (Act no. 40 of 2000)	The birds should not be deprived of feed and water before transport. During the transport phase the birds must not be without food or water for more than an absolute maximum of 24 hours, measured from the time of last feeding/drinking to placement in the retail live bird seller's lairage with accessible feed and water. This condition must be applied with discretion, as the welfare implications of handling birds immediately post-feeding must also be considered
Meat Safety Act (Act no. 40 of 2000)	The birds are to be transported in clean and sanitised standard size crates (770 mm long, 500 mm wide and 300 mm high), in trolleys or in containers that qualify for use in terms of the relevant part of SAPA's Code of Practice. This applies to both the producer and the live bird buyer. Live bird sellers should not allow the loading of

	birds into damaged or otherwise unsuitable containers and are also responsible to ensure that stocking densities do not exceed the guideline limits
Agriculture Products Standards Act (Act no. 119 of 1990)	The number of birds per standard-sized crate should not exceed six broiler breeder birds and 10 layer birds. During hot weather the number should be reduced to five for broiler breeders and nine for layer birds. If other containers are used, a similar stocking density should be applied
Foodstuffs, Cosmetic and Disinfectant Act (Act no. 54 of 1972)	Birds are to be treated with respect and dignity
National Health Act (Act no. 62 of 2003)	Birds injured on the farm must be killed humanely, cervical dislocation being an acceptable practice, conditional to the farm having staff competent to carry out the procedure. Any birds injured during transport may not be sold but must be disposed of humanely
Occupational and Safety Act (Act no. 85 of 1993)	Birds must be caught individually. Birds will only be handled by their legs and not any other part of the body. Not more than four hens may be carried per person at any one time
Fertiliser, Farm Feeds, Agriculture Remedies and Stock Remedies Act (Act no. 36 of 19947)	The legs of the birds will not be tied as a measure of restraint when sold by any of the live bird sellers, live bird buyers or the retail live bird sellers
GMO Act and Regulation (Act no. 36 of 1983)	The onus is on the live bird buyer to insist on healthy birds and not accept any visibly sick (or injured) birds
Livestock Brands Act (Act no. 25 of 1977)	The live bird buyer must ensure that the containers are properly secured on the vehicle before it leaves the premises and ensure the birds cannot escape from crates/containers during transport
Sterilization Facility Act (Act no. 36 of 1947)	The birds must be taken to a lairage where food, water and shelter is provided or to an abattoir
Water Treatment Chemicals for Use in	All birds must be kept in similar conditions to those in which they lived their productive lives, i.e. floor-based birds must be kept on floor systems and caged birds must be kept in cages. If held in a facility for longer than 24 hours,

the Food Industry (SANS 1827)	broiler breeders must be allowed free movement in a pen large enough for the purpose, this being defined as six birds/m² (ca. 27 kg/m²). If layer hens are to be held in a facility for longer than 24 hours they should be kept in cages complying with the SAPA Code of Practice specifications (currently 450 cm²/bird floor space)
Cleaning Chemicals for Use in the Food Industry (SANS 1828)	When abnormal rates of mortality occur after receipt of birds, the local state veterinarian, or the Poultry Reference Centre at the Faculty of Veterinary Science, Onderstepoort or a consulting veterinarian should be requested to investigate the cause of the mortalities and to report to the original seller as well as the buyer
Disinfections and Detergent – Disinfections for Use in the Food Industry (SANS 1853)	All mortalities should be disposed of in line with local health regulations
Application of Pesticides in Food-Handling, Food-Processing and Catering Establishments (SANS 10133)	No mortalities will be sold or made available for human consumption
Food Hygiene Management (SANS 1049)	At lairages, instant decapitation (or cervical dislocation if competent staff is on site) is accepted as a means of culling injured or sick birds
Food Safety Management Systems – Requirements for Organizations throughout the Food Chain (ISO 22000)	
Requirement for HACCP Systems (SANS 10330)	

Source: SAPA, 2012b; 2012c

Appendix D – Emission Source Table

Emission Source Table 2015				
Description	**Vlook up**	**Value**	**Unit**	**Source**
South African Electricity Emission Factor		0.869	kg CO_2e/kWh	DEFRA 2014
Kyoto Protocol - Standard: Carbon dioxide (CO_2)		1	kg CO_2e/kg	DEFRA 2014; National Greenhouse Accounts Factors 2014 - Australian, p 58
Kyoto Protocol - Standard: Methane (CH_4)		21	kg CO_2e/kg	DEFRA 2014; National Greenhouse Accounts Factors 2014 - Australian, p 58
Kyoto Protocol - Standard: Nitrous oxide (N_2O)		310	kg CO_2e/kg	DEFRA 2014; National Greenhouse Accounts Factors 2014 - Australian, p 58
Kyoto Protocol - Standard: HFC-134		1000	kg CO_2e/kg	DEFRA 2014; National Greenhouse Accounts Factors 2014 - Australian, p 58
Kyoto Protocol - Standard: HFC-134a		1300	kg CO_2e/kg	DEFRA 2014; National Greenhouse Accounts Factors 2014 - Australian, p 58
Kyoto Protocol - Standard: HFC-152a		140	kg CO_2e/kg	DEFRA 2014; National Greenhouse Accounts Factors 2014 - Australian, p 58
Kyoto Protocol - Standard: Sulphur hexafluoride (SF_4)		23900	kg CO_2e/kg	DEFRA 2014; National Greenhouse Accounts Factors 2014 - Australian, p 59
Kyoto Protocol - Blends: R407c		1526	kg CO_2e/kg	DEFRA 2014
Montreal Protocol - Standard: HCFC-22/R22		1810	kg CO_2e/kg	DEFRA 2014
Montreal Protocol - Standard: HCFC-142b		2310	kg CO_2e/kg	DEFRA 2014
R -318		10090	kg CO_2e/kg	Confronting Climate Change 2014, p 27
Ammonia - NH_3		0	kg CO_2e/kg	Confronting Climate Change 2014, p 27
Other perfluorinated gases: Nitrogen trifluoride (NF_3)		17200	kg CO_2e/kg	DEFRA 2014
Other perfluorinated gases: Perfluorocarbons (PFC 9-1-18)		7500	kg CO_2e/kg	DEFRA 2014
Cars - Small car		0.14701	kg CO_2e/km	DEFRA 2014
Cars - Medium car		0.1772	kg CO_2e/km	DEFRA 2014
Cars - Large car		0.23049	kg CO_2e/km	DEFRA 2014

Cars - Average car		0.18546	kg CO_2e/km	DEFRA 2014
Waste - Organic waste to landfill		804	kg CO_2e/tonnes	Confronting Climate Change 2014, p 27
Waste - Organic waste to compost		0	kg CO_2e/tonnes	Confronting Climate Change 2014, p 27
Waste - Non-organic waste recycled		0.02	kg CO_2e/kg waste	Confronting Climate Change 2014, p 27
Waste - Refuse: municipal waste (Open Loop)		21	kg CO_2e/tonnes	DEFRA 2014
Waste - Plastics: average plastics (Open Loop)		21	kg CO_2e/tonnes	DEFRA 2014
Waste - Plastics: average plastic film (Open Loop)		21	kg CO_2e/tonnes	DEFRA 2014
Waste - Plastics: average plastic rigid (Open Loop)		21	kg CO_2e/tonnes	DEFRA 2014
Waste - Plastics: HDPE (incl. forming) (Open Loop)		21	kg CO_2e/tonnes	DEFRA 2014
Waste - Plastics: LDPE and LLDPE (incl. forming) (Open Loop)		21	kg CO_2e/tonnes	DEFRA 2014
Waste - Plastics: PET (incl. forming) (Open Loop)		21	kg CO_2e/tonnes	DEFRA 2014
Waste - Plastics: PP (incl. forming) (Open Loop)		21	kg CO_2e/tonnes	DEFRA 2014
Waste - Plastics: PS (incl. forming) (Open Loop)		21	kg CO_2e/tonnes	DEFRA 2014
Waste - Plastics: PVC (incl. forming) (Open Loop)		21	kg CO_2e/tonnes	DEFRA 2014
Waste - Metal: aluminium cans and foil (excl. forming) (Closed Loop)		21	kg CO_2e/tonnes	DEFRA 2014
Waste - Metal: mixed cans (Closed Loop)		21	kg CO_2e/tonnes	DEFRA 2014
Waste - Metal: scrap metal (Closed Loop)		21	kg CO_2e/tonnes	DEFRA 2014
Waste - Metal: steel cans (Closed Loop)		21	kg CO_2e/tonnes	DEFRA 2014
Liquid fuels - Diesel (100% mineral diesel)		2.66914358	kg CO_2e/litres	DEFRA 2014
Liquid fuels - Petrol (100% mineral petrol)		2.29990286	kg CO_2e/litres	DEFRA 2014
EF - Enteric fermentation: Dairy cows		117	kg CO_2e/CH_4	IPCC 2006
EF - Enteric fermentation: Non-dairy cows		57	kg CO_2e/CH_4	IPCC 2006
EF - Enteric fermentation: Growing cattle		57	kg CO_2e/CH_4	IPCC 2006
EF - Enteric fermentation: Mature ewes		8	kg CO_2e/CH_4	IPCC 2006
EF - Enteric fermentation: Grown/mature sheep		8	kg CO_2e/CH_4	IPCC 2006
EF - Enteric fermentation: Growing lambs		5	kg CO_2e/CH_4	IPCC 2006

EF - Enteric fermentation: Mature swine		1.5	kg CO_2e/CH_4	IPCC 2006
EF - Enteric fermentation: Growing swine		1	kg CO_2e/CH_4	IPCC 2006
EF - Enteric fermentation: Goats		5	kg CO_2e/CH_4	IPCC 2006
EF - Enteric fermentation: Chickens		0.02	kg CO_2e/CH_4	The Norwegian Emission Inventory 2013
EF - Enteric fermentation: Other - horses		18	kg CO_2e/CH_4	IPCC 2006
EF - Enteric fermentation: Other - ostrich		0.02	kg CO_2e/CH_4	The Norwegian Emission Inventory 2013
EF - Manure management: Dairy cows		28	kg CO_2e/CH_4	IPCC 2006
EF - Manure management: Non-dairy cows		2	kg CO_2e/CH_4	IPCC 2006
EF - Manure management: Mature ewes		0.28	kg CO_2e/CH_4	IPCC 2006
EF - Manure management: Grown/mature sheep		0.28	kg CO_2e/CH_4	IPCC 2006
EF - Manure management: Growing lambs		0.15	kg CO_2e/CH_4	IPCC 2006
EF - Manure management: Mature swine		13	kg CO_2e/CH_4	IPCC 2006
EF - Manure management: Growing swine		13	kg CO_2e/CH_4	IPCC 2006
EF - Manure management: Goats		0.2	kg CO_2e/CH_4	IPCC 2006
EF - Manure management: Chickens		0.12	kg CO_2e/CH_4	The Norwegian Emission Inventory 2013
EF - Manure management: Other - horses		2.34	kg CO_2e/CH_4	IPCC 2006
EF - Manure management: Other - ostriches		4.69	kg CO_2e/CH_4	The Norwegian Emission Inventory 2013
Material used - Glass (Consol)		1.09	kg CO_2e/kg product	Confronting Climate Change 2014, p 28
Material used - Glass (Other)		0.9	kg CO_2e/kg product	Confronting Climate Change 2014, p 28
Material used – Cardboard		1.79	kg CO_2e/kg product	Confronting Climate Change 2014, p 28
Material used - Corrugated cardboard (Cartons)		1.04	kg CO_2e/kg product	Confronting Climate Change 2014, p 28
Material used - Paper (Labels)		0.96	kg CO_2e/kg product	Confronting Climate Change 2014, p 28
Material used - PS (Polystyrene)		4.55	kg CO_2e/kg product	Confronting Climate Change 2014, p 28
Material used - PP (Polypropylene)		3.25	kg CO_2e/kg product	Confronting Climate Change 2014, p 28
Material used - PET (Punnets and other clear plastic wine bottles)		4.37	kg CO_2e/kg product	Confronting Climate Change 2014, p 28
Material used - LDPE (Stretch wrap, plastic bags and other film plastic)		2.61	kg CO_2e/kg product	Confronting Climate Change 2014, p 28
Material used - HDPE (Cloudy plastic - wine containers)		2.79	kg CO_2e/kg product	Confronting Climate Change 2014, p 28
Material used - Bulk wooden bins (number used)		2.53	kg CO_2e/unit	Confronting Climate Change 2014, p 28
Material used - Bulk plastic bins (number used)		3.56	kg CO_2e/unit	Confronting Climate Change 2014, p 28

Material used - Disposable wooden pallets (number used)		12.32	kg CO_2e/unit	Confronting Climate Change 2014, p 28
Material used - Reusable wooden pallets (number used)		4.88	kg CO_2e/unit	Confronting Climate Change 2014, p 28
Material used - Reusable plastic pallets (number used)		2.65	kg CO_2e/unit	Confronting Climate Change 2014, p 28
Material used - CHEP pallets (number used)		0.31	kg CO_2e/unit	Confronting Climate Change 2014, p 28
Gaseous fuel – LPG		1.50225 244	kg CO_2e/litres	DEFRA 2014
Liquid fuels - Burning oil		2.53797 128	kg CO_2e/litres	DEFRA 2014
Pure N - Synthetic (nitrogen/stikstof)		12.04	kg CO_2e/kg pure N applied	Confronting Climate Change 2014, p 27
Pure P - Phosphorus/Fosfor		4.82	kg CO_2e/kg pure P applied	Confronting Climate Change 2014, p 27
Pure K - Potassium/Kalium		1.35	kg CO_2e/kg pure K applied	Confronting Climate Change 2014, p 27
Compost		0.02	kg CO_2e/kg applied	Confronting Climate Change 2014, p 27
Solid manure		0.02	kg CO_2e/kg applied	Confronting Climate Change 2014, p 27
Liquid manure (Slurry)		0.01	kg CO_2e/litre applied	Confronting Climate Change 2014, p 27
Lime		0.49	kg CO_2e/kg lime	Confronting Climate Change 2014, p 27
Fungicides		3.28	kg CO_2e/kg act. ingr. applied	Confronting Climate Change 2014, p 27
Insecticides		4.71	kg CO_2e/kg act. ingr. applied	Confronting Climate Change 2014, p 27
Herbicides		5.05	kg CO_2e/kg act. ingr. applied	Confronting Climate Change 2014, p 27
Land-use change: Forest land		25000	kg CO_2e/ha/yr	Confronting Climate Change 2014, p 27
Land-use change: Grass land (i.e. Fynbos, Savannah, Bushveld)		1200	kg CO_2e/ha/yr	Confronting Climate Change 2014, p 27
Distribution: Road freight: Petrol average van up to 3.5 t		0.84	kg CO_2e/km travelled	Confronting Climate Change 2014, p 30
Distribution: Road freight: Diesel average van up to 3.5 t		0.64	kg CO_2e/km travelled	Confronting Climate Change 2014, p 30
Distribution: Road freight: Rigid truck > 3.5 - 7.5 t		0.54722 109	kg CO_2e/km travelled	DEFRA 2014

Distribution: Road freight: Rigid truck > 7.5 - 17 t		0.6546675	kg CO_2e/km travelled	DEFRA 2014
Distribution: Road freight: Rigid truck > 17 t		0.78822717	kg CO_2e/km travelled	DEFRA 2014
Distribution: Road freight: Articulated truck 3.5 - 33 t		0.73060231	kg CO_2e/km travelled	DEFRA 2014
Distribution: Road freight: Refrigerated - Rigid truck > 3.5 - 7.5 t		0.6512551	kg CO_2e/km travelled	DEFRA 2014
Distribution: Road freight: Refrigerated - Rigid truck > 7.5 – 17 t		0.77908762	kg CO_2e/km travelled	DEFRA 2014
Distribution: Road freight: Refrigerated - Rigid truck > 17 t		0.93783625	kg CO_2e/km travelled	DEFRA 2014
Distribution: Road freight: Refrigerated - Articulated truck 3.5 - 33 t		0.84750648	kg CO_2e/km travelled	DEFRA 2014

Appendix E – Snapshots of the Carbon Calculator

New Farm Unit

GUIDANCE
- Please use the drop-down menus in the green cells.
- Please fill in all commodities and information below.

Farm Unit Name	
Contact Person Name	
Farm Telephone Number	
Contact Persone Cell	
Growing Area	

Select Boundaries	Farm	Yes
	Packhouse	Yes
	Coldstore	Select

Select Commodities	**Livestock**	Ostriches
		Cattle
		Pigs
		Dairy cattle
		Select
	Grains	Select
		Select
		Maize
		Select
		Select
	Fruit	Guava
		Select
		Select
		Appricot
		Select
	Vegetables	Select
		Tomatoes
		Select
		Herbs
		Select
	Processing	Milk
		Select
		Wood
		Select
		Vegetables
	Other Alternatives	Rooibos Tea
		Select
		Flower picking (Fynbos)
		Prickly Pear
		Select

Data Collection Period Start	April	2013
Data Collection Period End	March	2014

Guidance:
- **If annual or perennial crops then 12 month period.**
- **For other crops with less than 1 year select period.**

Farm Information

Commodity group	Commodity	Total Tonnage Produced	Productive Hectare	Non-Productive Hectares	Total Hectares
Grains	Select				0
	Select				0
	Maize				0
	Select				0
	Select				0
Fruit	Guava				0
	Select				0
	Select				0
	Appricot				0
	Select				0
Vegetables	Select				0
	Tomatoes				0
	Select				0
	Herbs				0
	Select				0
Other Alternatives	Rooibos Tea				0
	Select				0
	Flower picking (Fynbos)				0
	Prickly Pear				0
	Select				0
		0	0	0	0

Crop Residue

Commodity Group	Commodities	Method	Unit	Number
Grains	Select	Exported off farm	Select	
	Select	Select	Select	
	Maize	Select	Select	
	Select	Select	Select	
	Select	Select	Select	
Vegetables	Select	Select	Select	
	Tomatoes	Select	Select	
	Select	Select	Select	
	Herbs	Select	Select	
	Select	Select	Select	

Livestock

		Length of phase				
Commodity group	Commodity	Juvenile Phase	Adult Productive Phase	Adult Non-productive Phase	Time Unit	Number of animals
Livestock	Ostriches				Select	
	Cattle				Select	
	Pigs				Select	
	Dairy cattle				Select	
	Select				Select	
	Total	0	0	0		0

Land Use Changes

Commodity Group	Commodity	Has any of the orchards/vineyards/plantations been converted from virgin (natural) land to agricultural land within the past 5 years?	What was the previous land use?	What area of land was subject to this land-use change? [Hectares]
Livestock	Ostriches			
	Cattle			
	Pigs			
	Dairy cattle			
	Select			
Grains	Select			
	Select			
	Maize			
	Select			
	Select			
Fruit	Guava			
	Select			
	Select			
	Appricot			
	Select			
Vegetables	Select			
	Tomatoes			
	Select			
	Herbs			
	Select			
Other Alternatives	Rooibos Tea			
	Select			
	Flower picking (Fynbos)			
	Prickly Pear			
	Select			
	Total			0

Feeding Characteristics:

Juvenile Phase:

CommodityGroup	Commodity	Type of grazing if applicable: Quality	Type of grazing if applicable: Type
		Select	Select
Livestock	Ostriches		
	Cattle		
	Pigs		
	Dairy cattle		
	Select		

Adult Productive Phase:

Commodity Group	Commodity	Type of grazing if applicable: Quality	Type of grazing if applicable: Type
		Select	Select
Livestock	Ostriches		
	Cattle		
	Pigs		
	Dairy cattle		
	Select		

Adult Non-productive Phase:

Commodity Group	Commodity	Type of grazing if applicable: Quality	Type of grazing if applicable: Type
		Select	Select
Livestock	Ostriches		
	Cattle		
	Pigs		
	Dairy cattle		
	Select		

Non-Organic Waste

Commodity Group	Commodity				
Fruit	Guava	Recycled	Kg		
	Select	Recycled	Kg		
	Select	Recycled	Kg		
	Appricot	Recycled	Kg		
	Select	Recycled	Kg		
Fruit	Guava	Landfill	Kg		
	Select	Landfill	Kg		
	Select	Landfill	Kg		
	Appricot	Landfill	Kg		
	Select	Landfill	Kg		
Vegetables	Select	Recycled	Kg		
	Tomatoes	Recycled	Kg		
	Select	Recycled	Kg		
	Herbs	Recycled	Kg		
	Select	Recycled	Kg		
Vegetables	Select	Landfill	Kg		
	Tomatoes	Landfill	Kg		
	Select	Landfill	Kg		
	Herbs	Landfill	Kg		
	Select	Landfill	Kg		
		Total	**Kg**	**0**	**0**

Appendix F – Smallholder Mixed Farming Carbon Calculator Questionnaire

Conducted by Vanessa Barends, Department of Agricultural Economics, University of Stellenbosch

E-mail: vanessab@elsenburg.com or 15137430@sun.ac.za

Tel no: 021 808 7752

Cell no: 073 1222 053

Area…………………………………………………………………

Questionnaire No………………………………………………

Date…………………………………………………………………

Background Information:

Climate change can be described as changes in the earth's weather, including changes in temperature, wind patterns and rainfall, especially the increase in the temperature of the earth's atmosphere that is caused by the increase of particular gases, especially carbon dioxide (Oxford Dictionary, 2011). Climate change is having many direct and indirect effects on the agricultural sector in South Africa. Climate change is leading to:

- Crop distribution changes (summer and winter season crops)
- Reduced crop yields
- Increases in the abundance of alien vegetation and pests
- Reduced sustainable agricultural land
- Decreased rainfall, resulting in increased demand for water
- The warmer conditions are also leading to soil moisture decline, which increases the need for agricultural irrigation and directly puts strain on the country' scarce water resources
- Increased rainfall can result in soil erosion

The main objective of this study is to create a guidance tool:

- That will to direct the department in assisting smallholder farmers with their carbon footprint; and
- Assist industry in constructing carbon calculators for smallholder mixed farming systems.

The purpose of the study is:

- To help create awareness of emissions and resources used by smallholder farmers.
- To provide information than can be used to equip smallholder farmers for the indirect effects of phase 1 of the anticipated carbon tax by providing them with the information needed to plan for more efficient farming activities as well as cutting down on costs, for example electricity and fuel.

An added benefit of the information gained from this calculator is that it can assist smallholder farmers with identifying certain factors that are prohibiting them from complying with bigger retailer's 'green' standards.

This questionnaire is confidential and will only be used for research purposes. The questionnaire will be administrated to approximately 18 smallholder farmers from the Western Cape, three farmers per district. Therefore, your cooperation is highly appreciated. The questionnaire will take approximately 60 minutes and I want to thank you in advance for your help.

Section 1: ***Farm-specific Questions (To be filled in by respondent)***

1. **What is the farm size?**

……………………………………………………………………………………..

2. **Of the abovementioned hectare size, please divide accordingly:**

Land actively used	Land used by another party	Non-active land	Virgin land	Total land size

3. **What farming activities took place on the farm from 1 April 2013 till 31 March 2014?**

Farming activity	Hectares allocated to activity

4. **Please fill in table below regarding the allocation of resources:**

a. **Electricity on farm for the period 1 April 2013 till 31 March 2014:**

Source	kWh
Eskom	
Renewable	

b. **What % of resources are allocated to each farm activity?**

Farming activity	% allocated

5. **Did any land-use changes take place for the past 5 years and for the period 1 April 2013 till 31 March 2014? Please complete the table.**

Changes	Yes	No
Tillage changes		
Cover changes		
Compost		
Manure additions		
Residue incorporation		
Other:		

6. **Please complete the vehicle table below for the period 1 April 2013 till 31 March 2014. These include tractors, trucks, etc. (**Note: list only the vehicles primarily used on the farm*):**

Type of vehicle	Activity that vehicle is used for	Engine size	Fuel type		Amount of fuel used (litre)	Distance travelled (km)
			Petrol	Diesel		

7. **Please complete the stationary fuel-use table below for the period 1 April 2013 till 31 March 2014 by listing all the stationary implements that were used for the previously mentioned period. (**Note: Stationary fuel is fuel that is being used in implements such as generators, weed eaters, chain saws, mowers, etc. Sources of fuel include petrol, diesel, wood pellets, natural gas and bituminous coal*):**

Implement	Type of fuel used	Quantity of fuel used	Measurement unit (litre)

8. **Please complete the fertiliser used table below:**

Chemical grouping	Amount used	Unit	Commodities on which it was used
Organic fertilisers:			

9. **Were any pesticides used?** (Tick one please)

Yes	**No**

10. **If yes, please complete table:**

Name of pesticide	Amount used	Unit	Commodities on which it was used

11. **Do you have organic waste on your premises that you use to make compost?** (Tick one please)

Yes	**No**

12. **If yes, are you currently doing so?**

Yes	**No**

13. **Please complete the office and domestic waste table below (*Note: Only if household/office is on the farm property):**

	Quantity (kg)	Key components of waste	Disposal method (composted, recycle, dumped, etc.)
Office waste			
Domestic waste			

14. **Do you have a waste management system on your farm?** (Tick one please)

Yes	**No**

15. Please complete the livestock table below (*Note: Please indicate if animal is young or an adult):

Type of livestock	Number of livestock	Grazing patterns (pasture/feedlot)

16. Do you have a manure management system in place? (Tick one please)

Yes	No

17. If yes, please explain

____

____

____

18. How do you dispose of livestock carcasses on your farm?

____

____

____

19. **Please complete the cold-store information table below (*Note: Only complete this section if you also farming with vegetables and or fruits):**

a. **Storage information:**

Commodity	Volume stored (tons)	Average period in storage

b. **Commodity output:**

Commodity	Yield volume	Waste

Questionnaire no:……..

<u>Section 2:</u> General Green Agricultural Questions

20. Do you know what global warming is? (Tick one please)

Yes	**No**

21. Have you heard of the term carbon footprinting? (Tick one please)

Yes	**No**

22. Do you know what a carbon off-setter is? (Tick one please)

Yes	**No**

23. Are you using any renewable energy on your farm (for example solar panels, bio-fuels and/or wind power)? (Tick one please)

Yes	**No**

24. What savings do you have on electricity (kWh)?

……………………………………………………………………………………

25. Are you applying any organic practices? (Tick one please)

Yes	**No**

26. Are you using any sustainable traditional agricultural practices? (Tick one please)

Yes	**No**

27. Have you heard about the 2015 carbon tax? (Tick one please)

Yes	**No**

28. Please describe your past and current green initiatives by completing the following table:

Initiative	**Financial year implemented**

29. **Are you planning on implementing any green initiatives in the future?** (Tick one please)

Yes	**No**

30. Protection of the environment is one of the most important tasks in government policy….

_1 **_2** **_3** **_4** **_5** (Tick one please)

31. **Problems associated with global warming are exaggerated….**

_1 **_2** **_3** **_4** **_5** (Tick one please)

Key:	
Completely disagree	= 1
Disagree	= 2
Indifferent	= 3
Agree	= 4
Completely agree	= 5

Section 3: ***Socio-economic information***

32. Respondent gender: (Tick one)

Male	**Female**

33. Respondent race: (Tick one please)

African	**White**	**Coloured**	**Indian**	**Other**

34. Respondent age: ……………………..

35. What is the highest level of education that you have attained? (Tick one please)

No schooling	**Std 8/Grade 10**	**Matric/ Grade 12**	**Diploma**	**Degree**	**Honours degree**	**Master's degree**	**Doctoral degree**

Please Note: We realise these questions are of a personal nature and therefore the questionnaire is anonymous and as such absolute confidentiality is assured.

Thank you for your cooperation!

Appendix G – Carbon Footprinting Reports

Carbon Calculator Results vs 5.0

Western Cape Government
BETTER TOGETHER.

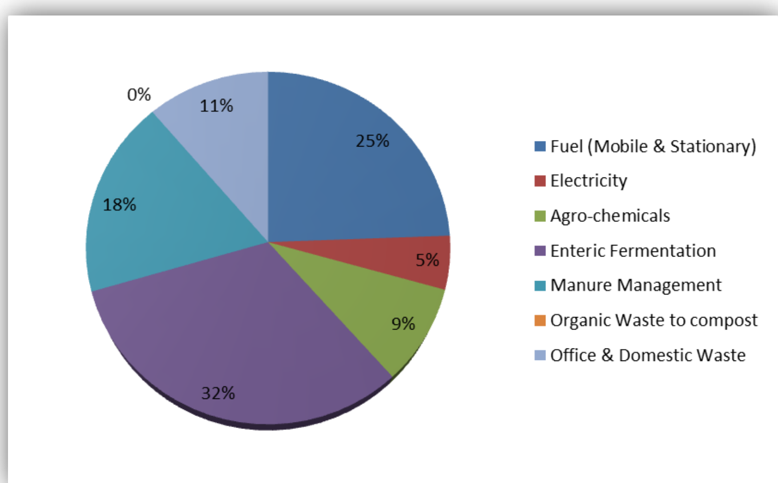
Farm ID: OB1

Audit start: March 2013

Audit end: April 2014

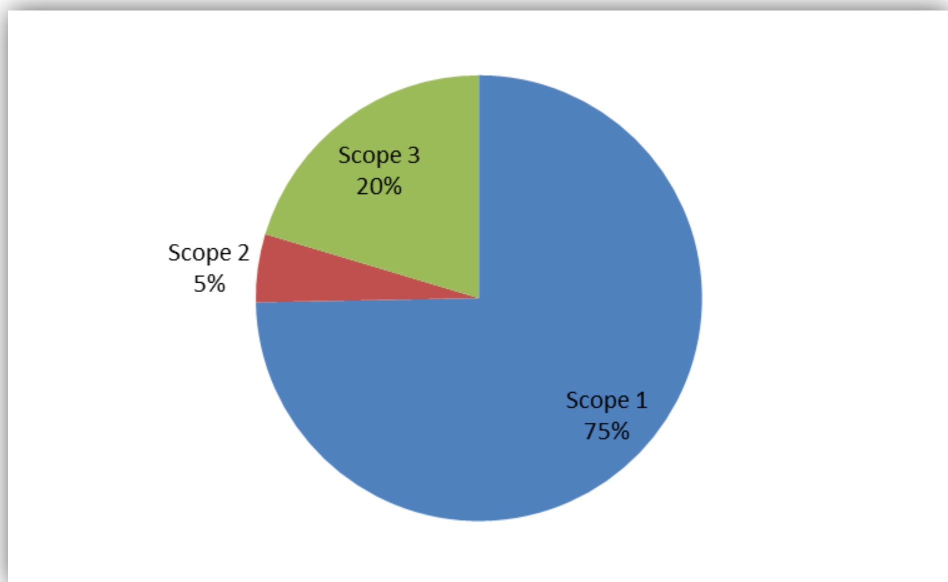
Generation date: 08-08-2015

FARM BOUNDARY



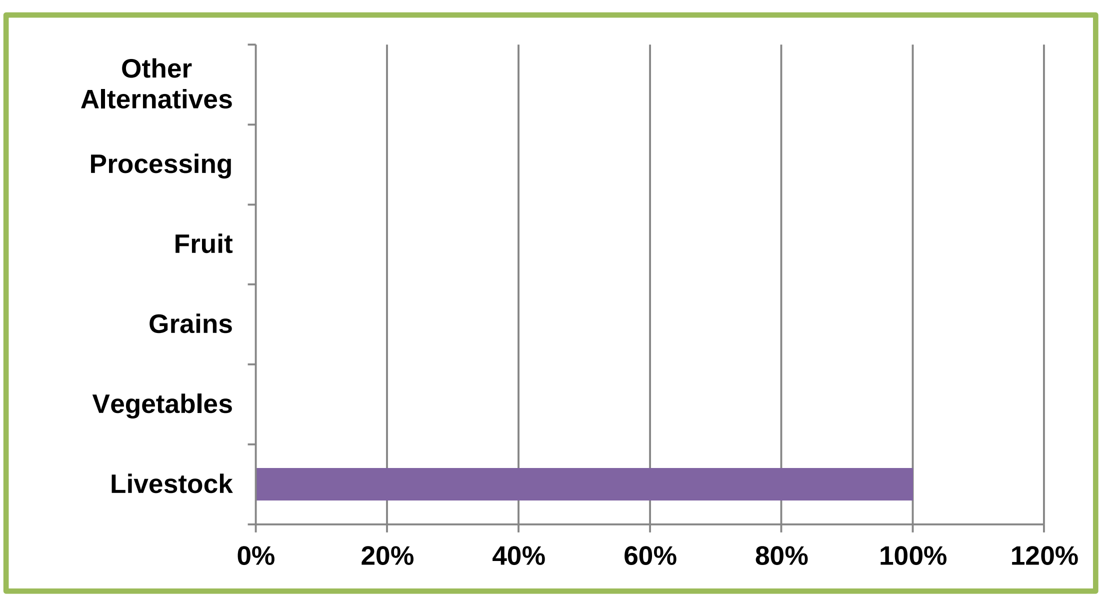
The three main hotspots identified are enteric fermentation (32%), fuel (25%) and manure management (18%).

FARM SCOPE BREAKDOWN



Scope 1 emissions are the highest, 75% as can be seen in pie chart above.

FARM PRODUCT BREAKDOWN



Livestock is the main product and the source that contributes the most to total CO_2 emissions.

Carbon Calculator Results vs 5.0

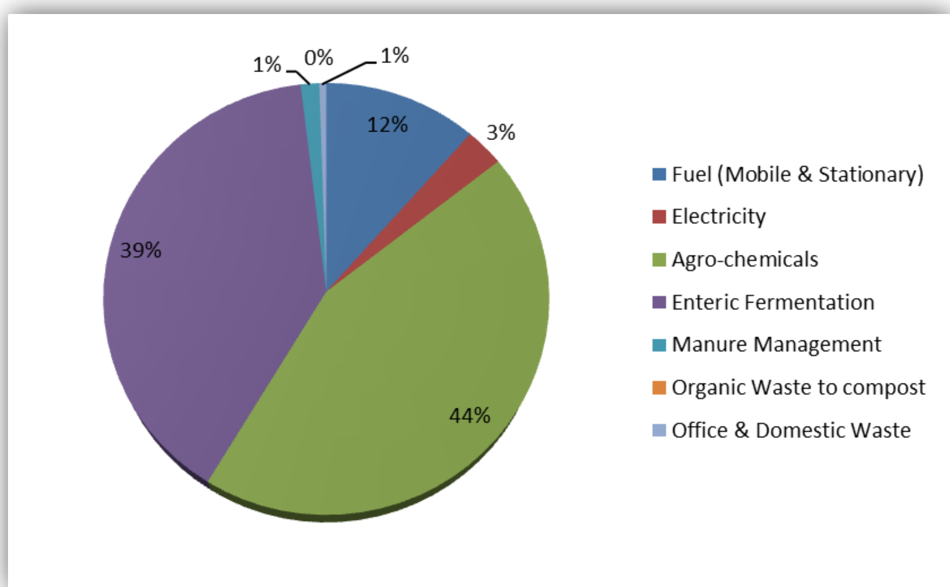
Farm ID: OB2

Audit start: March 2013

Audit end: April 2014

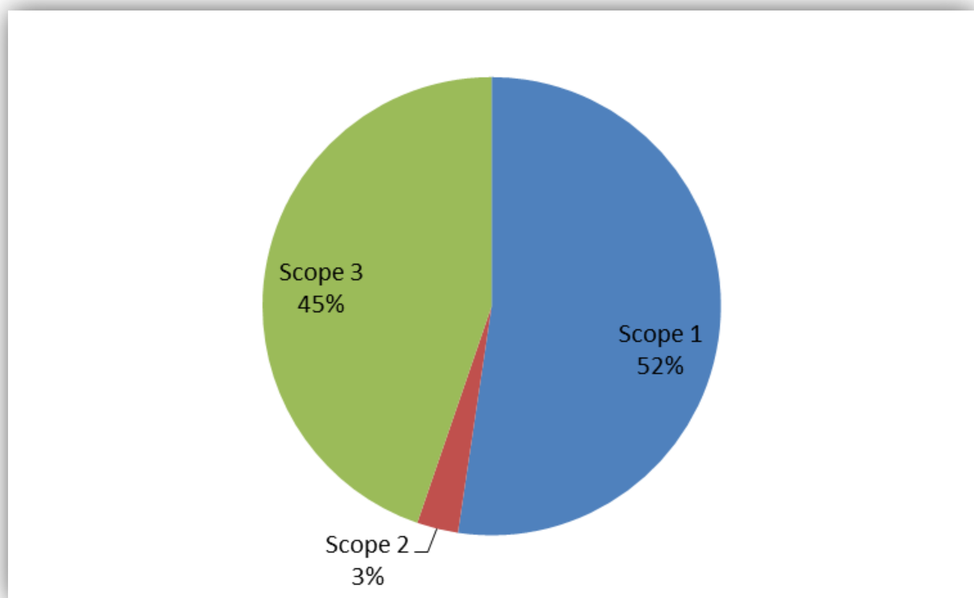
Generation date: 08-08-2015

FARM BOUNDARY



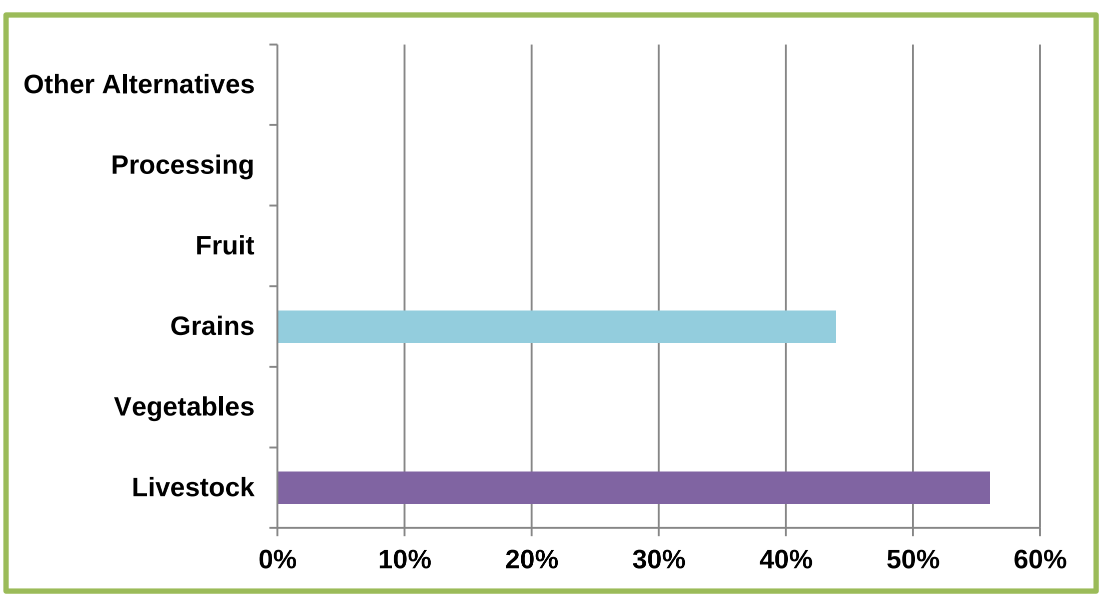
The three main hotspots identified are agro-chemical which includes fertiliser (44%), enteric fermentation (39%) and fuel (12%).

FARM SCOPE BREAKDOWN



Scope 1 emissions are the highest, 52% as can be seen in pie chart above.

FARM PRODUCT BREAKDOWN



Livestock is the main product (56%), followed by grains (44%) that contribute the most to total CO_2 emissions.

Carbon Calculator Results vs 5.0

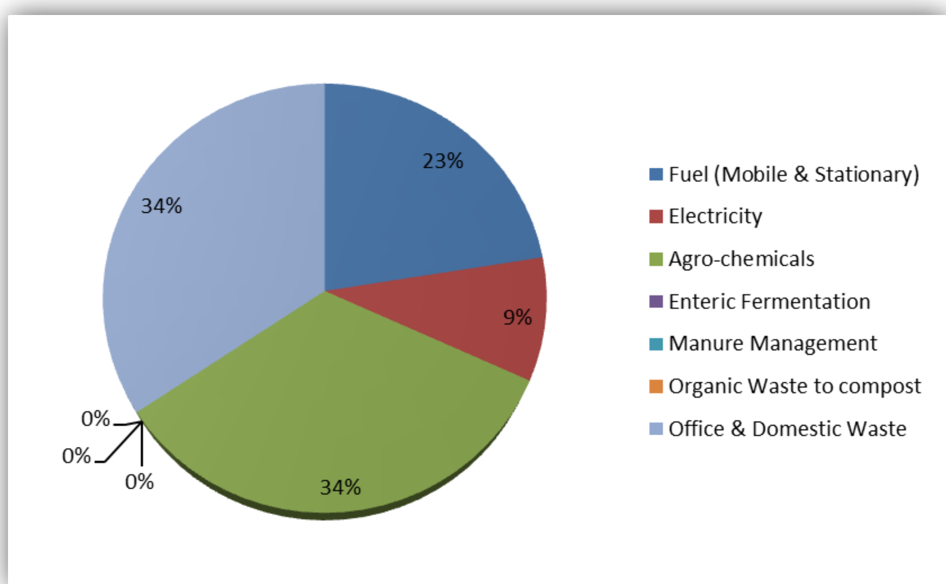
Farm ID: OB3

Audit start: March 2013

Audit end: April 2014

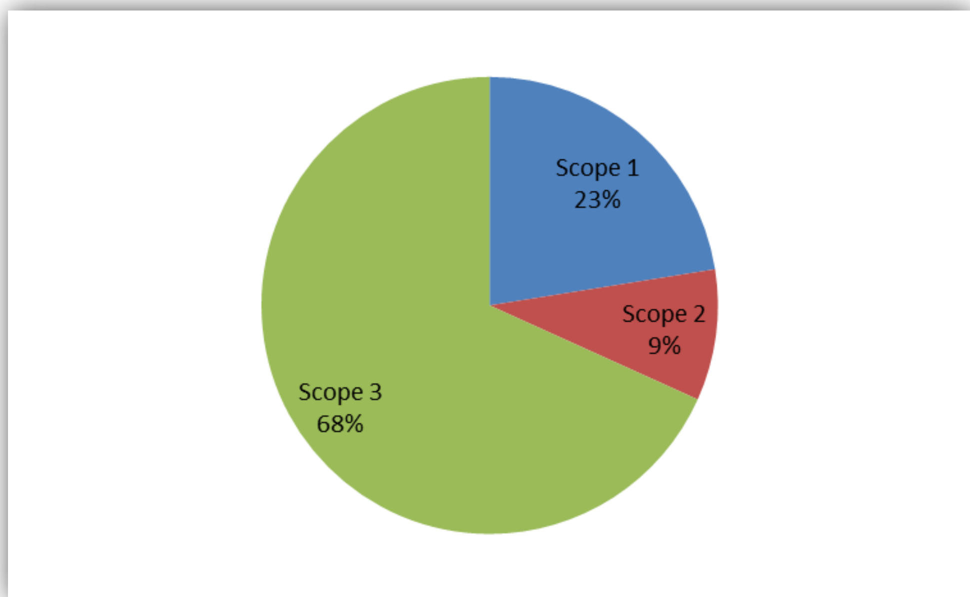
Generation date: 08-08-2015

FARM BOUNDARY



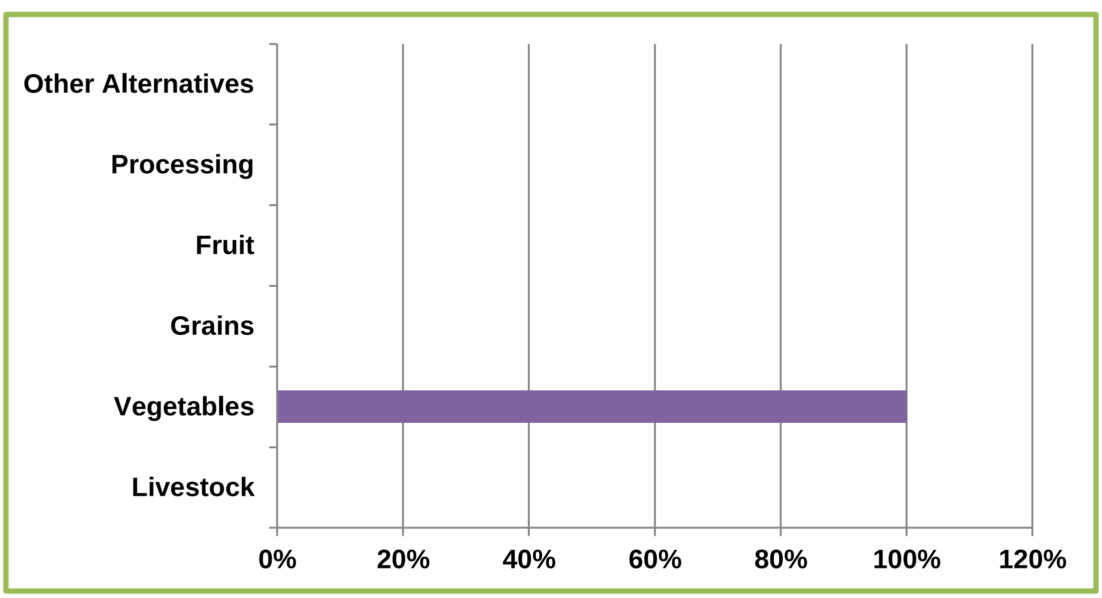
The three main hotspots identified are office & domestic waste (34%), agro-chemicals (34%) which include fertiliser and fuel (23%).

FARM SCOPE BREAKDOWN



Scope 3 emissions are the highest (68%) as can be seen in pie chart above.

FARM PRODUCT BREAKDOWN



Vegetables are the main product and the main emission source that contributes the most to total CO2 emissions.

Carbon Calculator Results vs 5.0

Western Cape Government
BETTER TOGETHER.

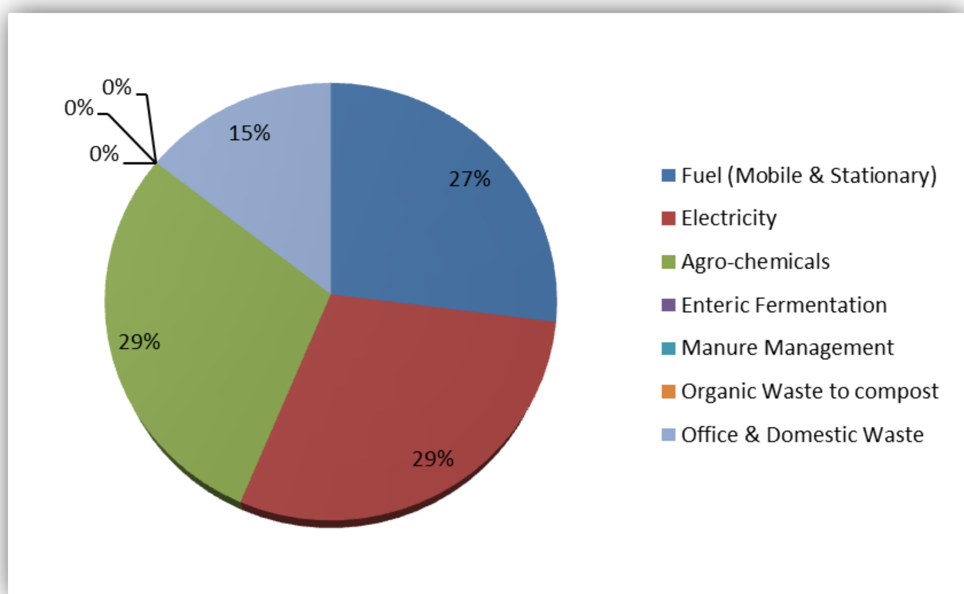
Farm ID: CW1

Audit start: March 2013

Audit end: April 2014

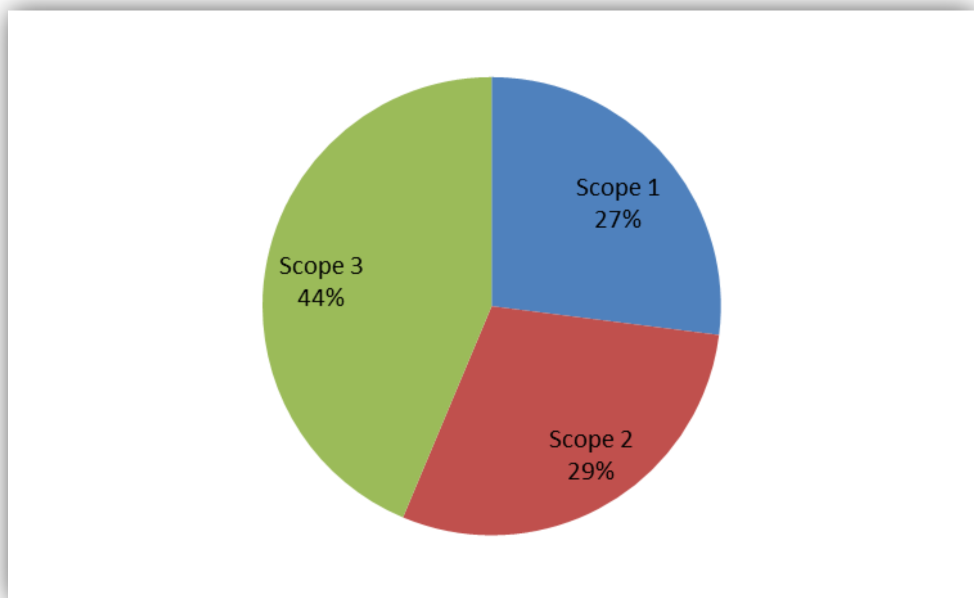
Generation date: 08-08-2015

FARM BOUNDARY



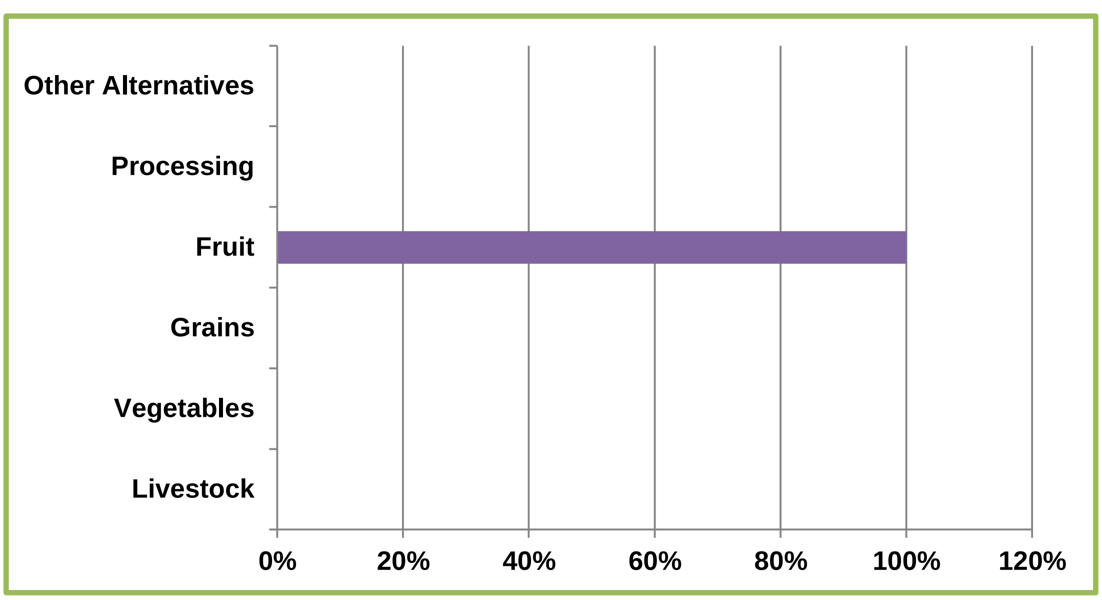
The three main hotspots identified are electricity (29%), agro-chemicals (29%) which include fertiliser and fuel (27%).

FARM SCOPE BREAKDOWN



Scope 3 emissions are the highest (44%) as can be seen in pie chart above.

FARM PRODUCT BREAKDOWN



Fruit is the main product and the main emission source that contributes the most to total CO2 emissions.

Carbon Calculator Results vs 5.0

Western Cape Government BETTER TOGETHER.

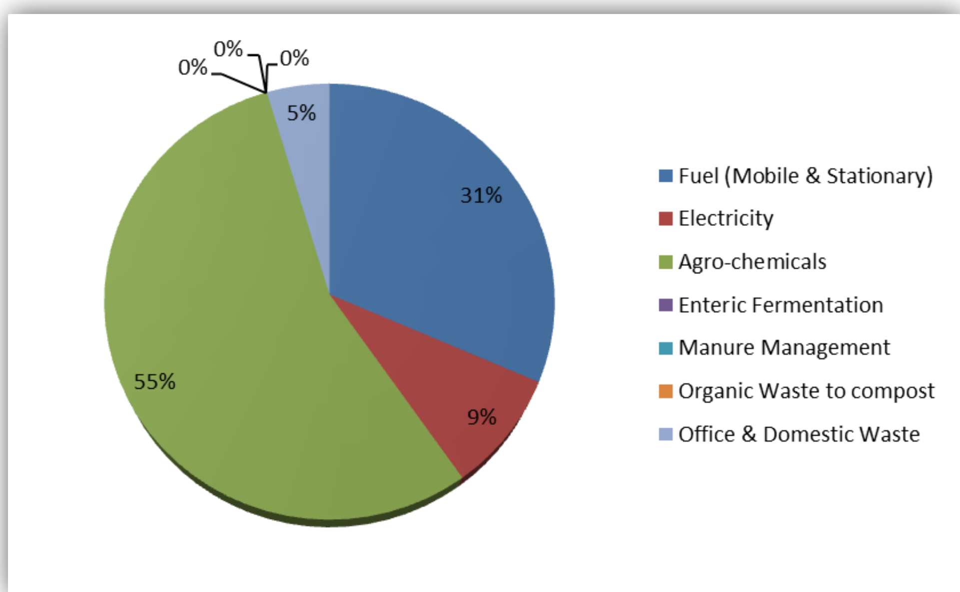
Farm ID: CW2

Audit start: March 2013

Audit end: April 2014

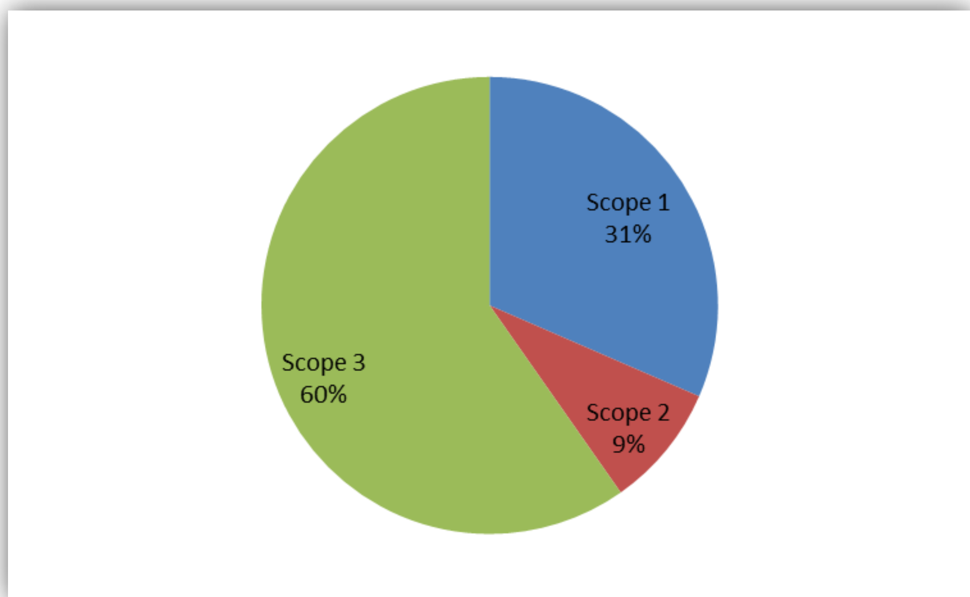
Generation date: 08-08-2015

FARM BOUNDARY



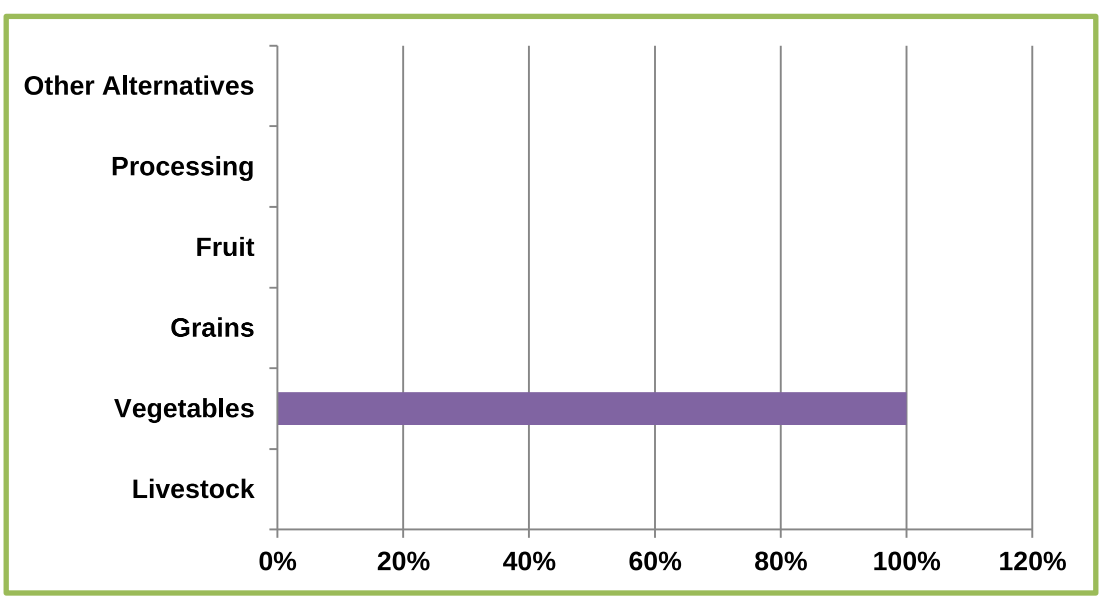
The three main hotspots identified are agro-chemicals (55%) which include fertiliser, fuel (31%) and electricity (9%).

FARM SCOPE BREAKDOWN



Scope 3 emissions are the highest (60%) as can be seen in pie chart above.

FARM PRODUCT BREAKDOWN



Vegetables are the main product and the main emission source that contributes the most to total CO_2 emissions.

Carbon Calculator Results vs 5.0

Western Cape Government
BETTER TOGETHER.

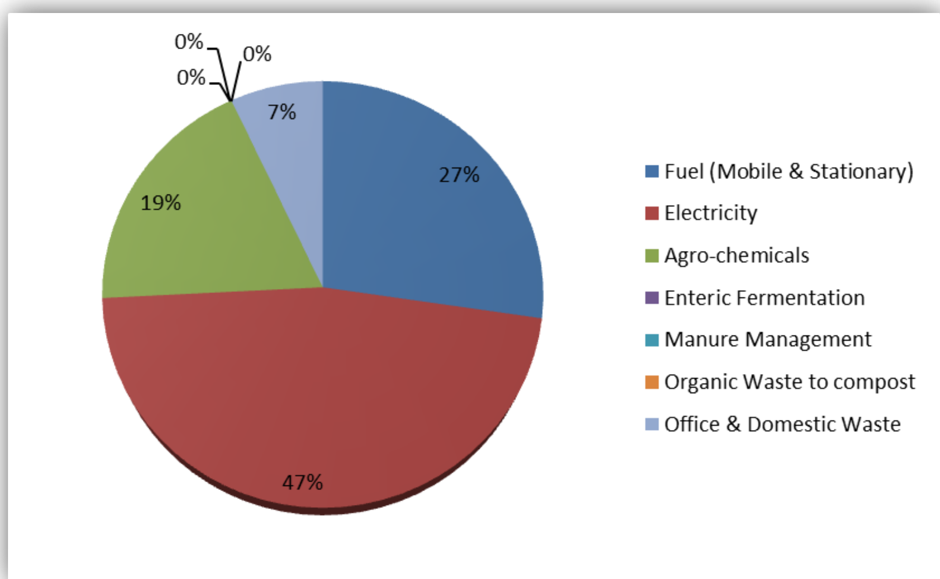
Farm ID: CW3

Audit start: March 2013

Audit end: April 2014

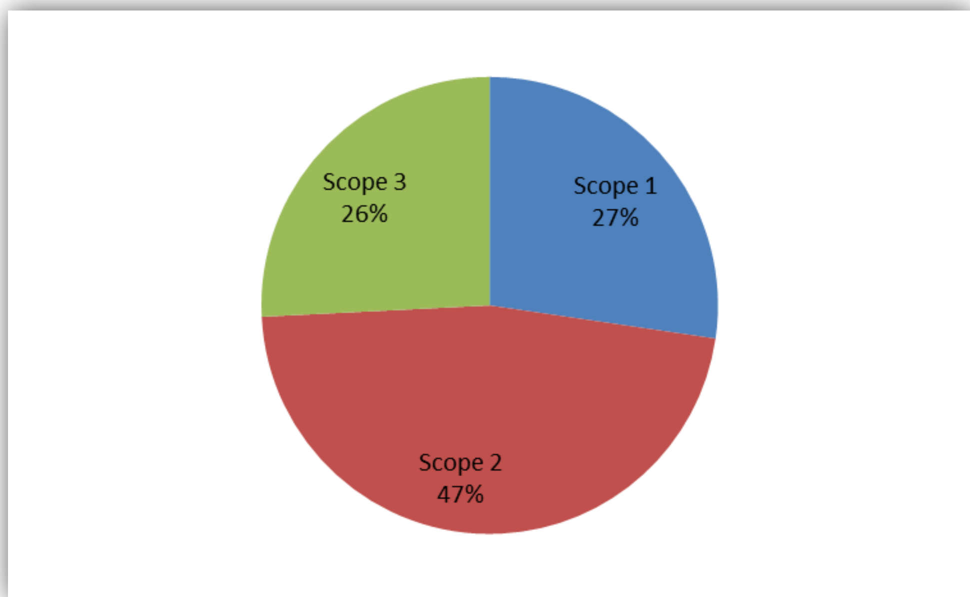
Generation date: 08-08-2015

FARM BOUNDARY



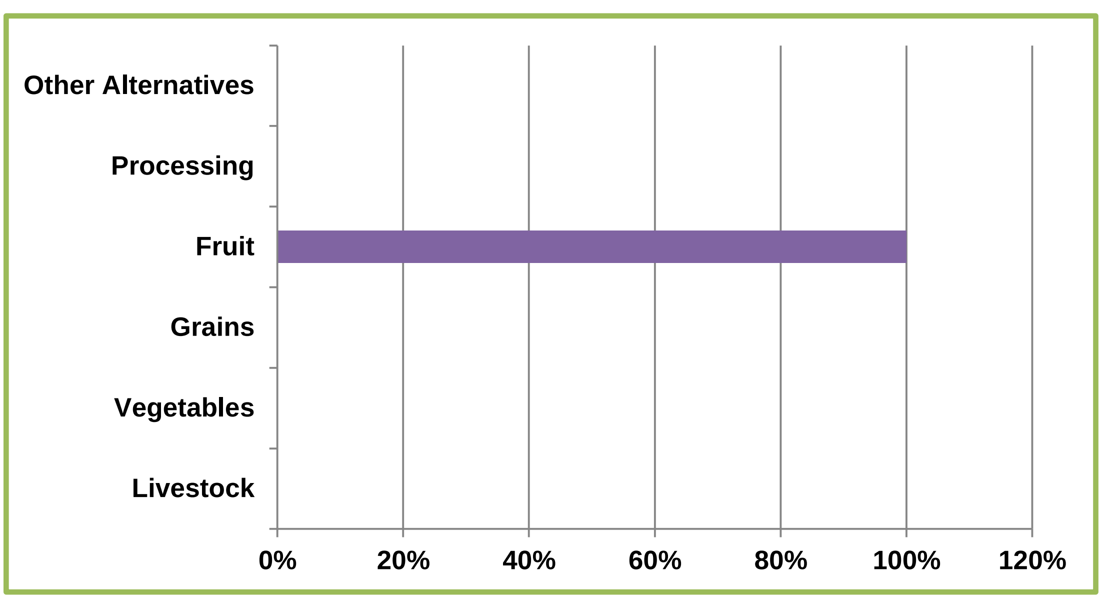
The three main hotspots identified are electricity (47%), fuel (27%) and agro-chemicals (19%) which include fertiliser.

FARM SCOPE BREAKDOWN



Scope 2 emissions are the highest (47%) as can be seen in pie chart above.

FARM PRODUCT BREAKDOWN



Fruit is the main product and the main emission source that contributes the most to total CO_2 emissions.

Carbon Calculator Results vs 5.0

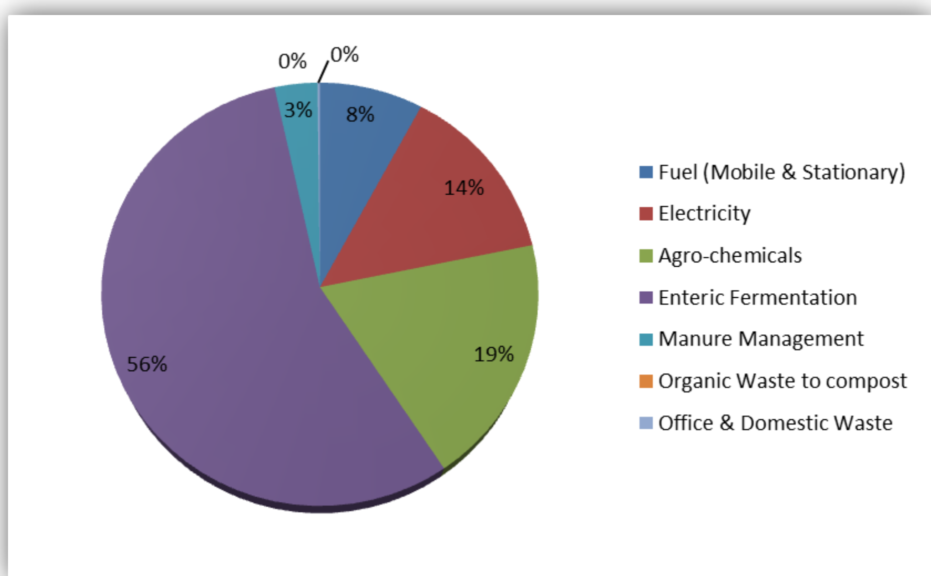
Farm ID: CM1

Audit start: March 2013

Audit end: April 2014

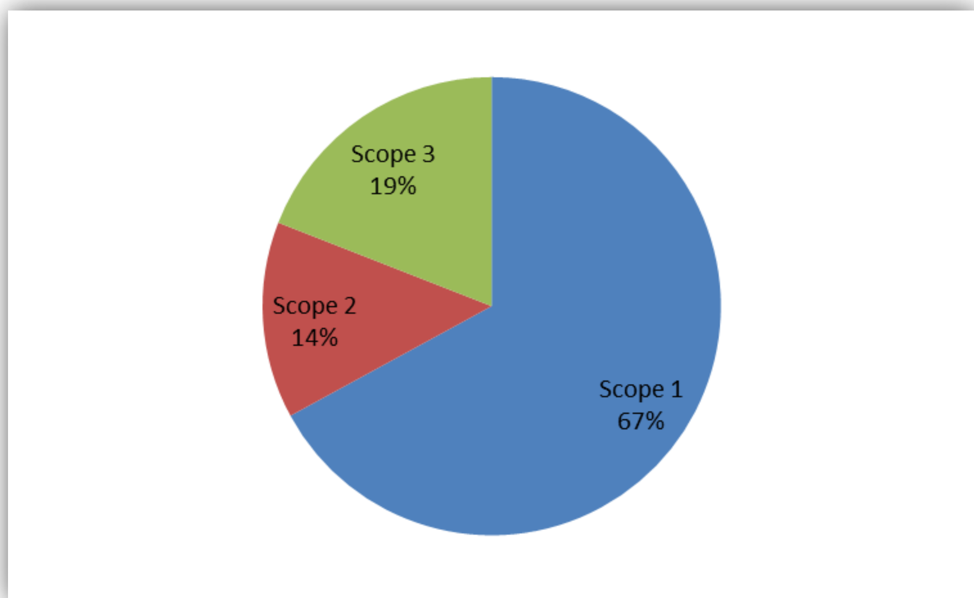
Generation date: 08-08-2015

FARM BOUNDARY



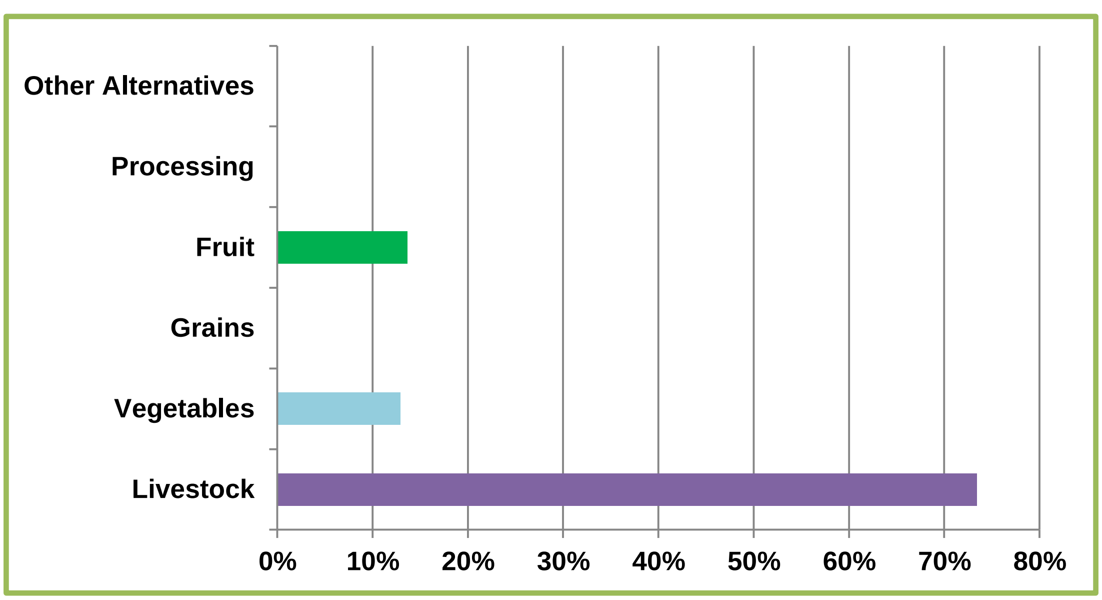
The three main hotspots identified are enteric fermentation (56%), agro-chemicals (19%) which include fertiliser and electricity (14%).

FARM SCOPE BREAKDOWN



Scope 1 emissions are the highest (67%) as can be seen in pie chart above.

FARM PRODUCT BREAKDOWN



Livestock (73%), followed by fruit (14%) and vegetables (13%) are contributing the most to total CO_2 emissions.

Carbon Calculator Results vs 5.0

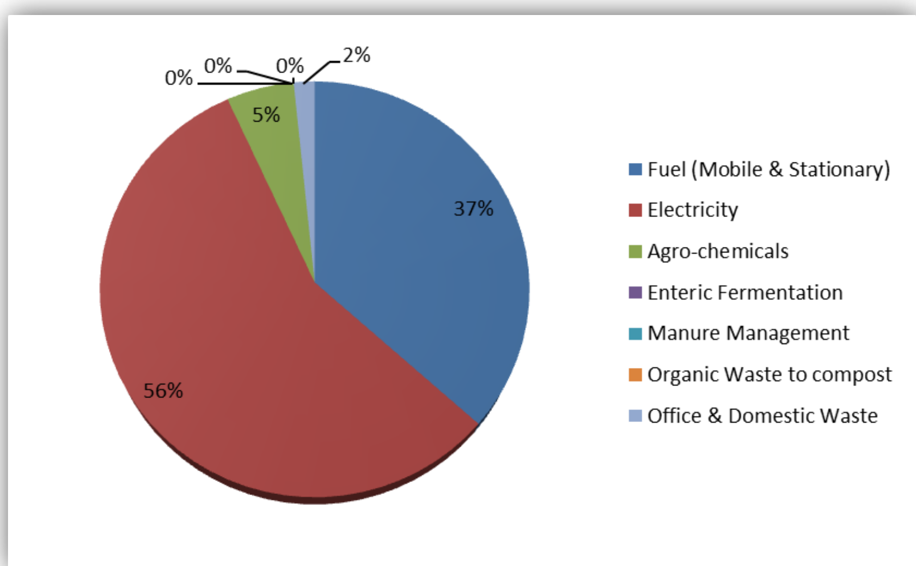
Farm ID: CM2

Audit start: March 2013

Audit end: April 2014

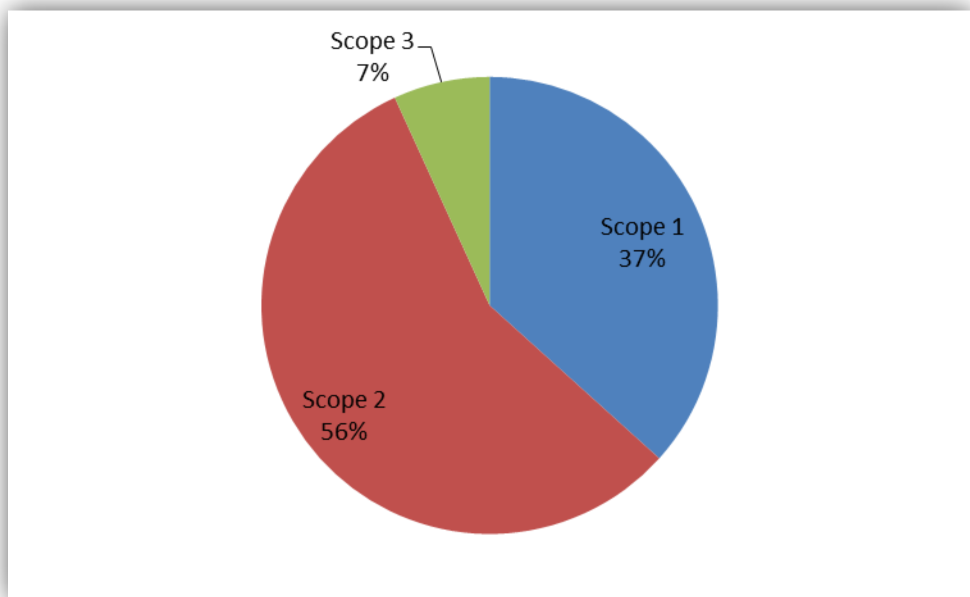
Generation date: 08-08-2015

FARM BOUNDARY



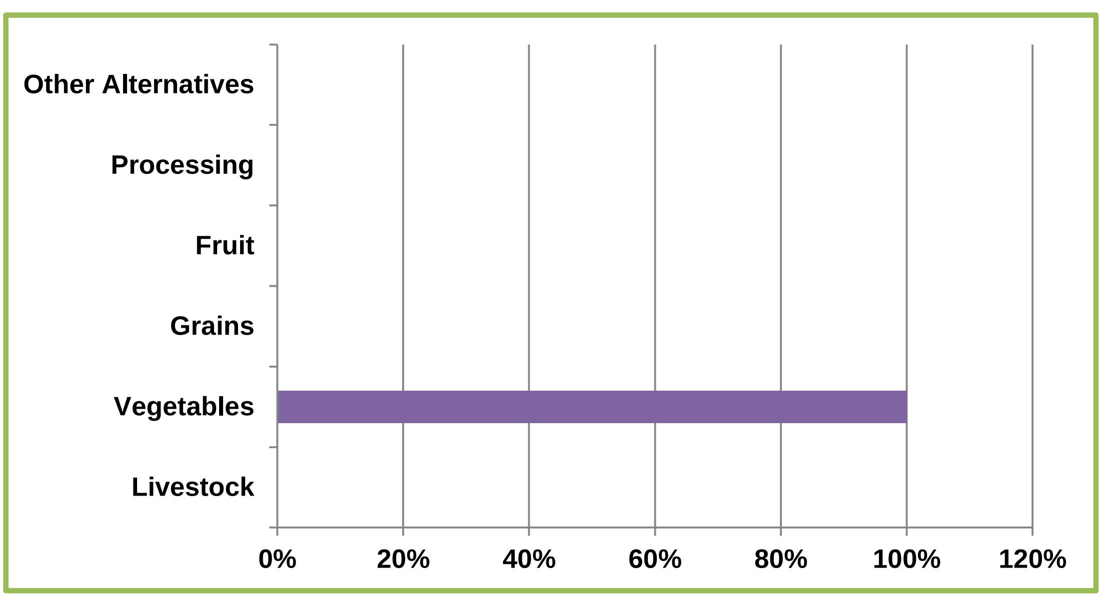
The three main hotspots identified are electricity (56%), fuel (37%) and agro-chemicals (5%) which include fertiliser.

FARM SCOPE BREAKDOWN



Scope 2 emissions are the highest (56%) as can be seen in pie chart above.

FARM PRODUCT BREAKDOWN



Vegetables are the main product and the main emission source that contributes the most to total CO_2 emissions.

Carbon Calculator Results vs 5.0

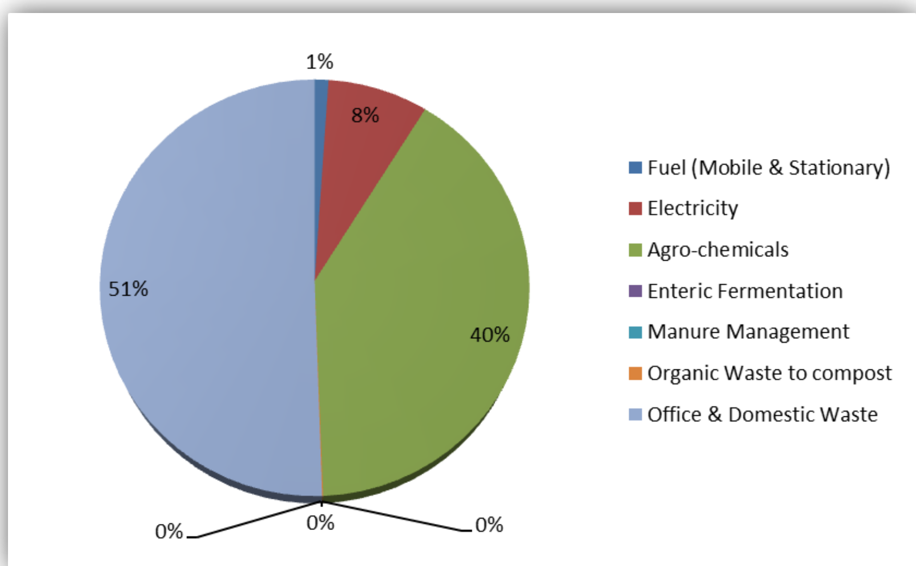
Farm ID: CM3

Audit start: March 2013

Audit end: April 2014

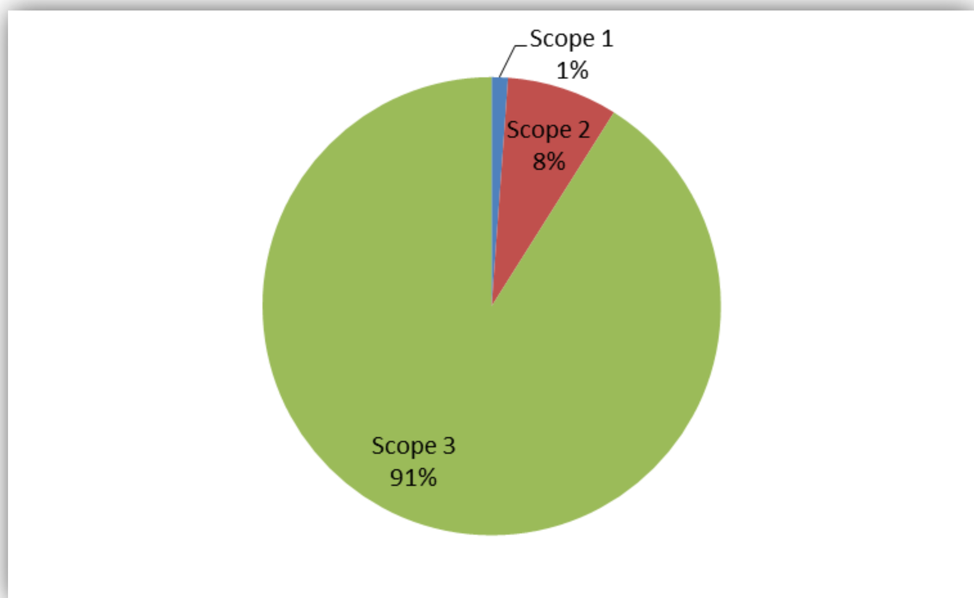
Generation date: 08-08-2015

FARM BOUNDARY



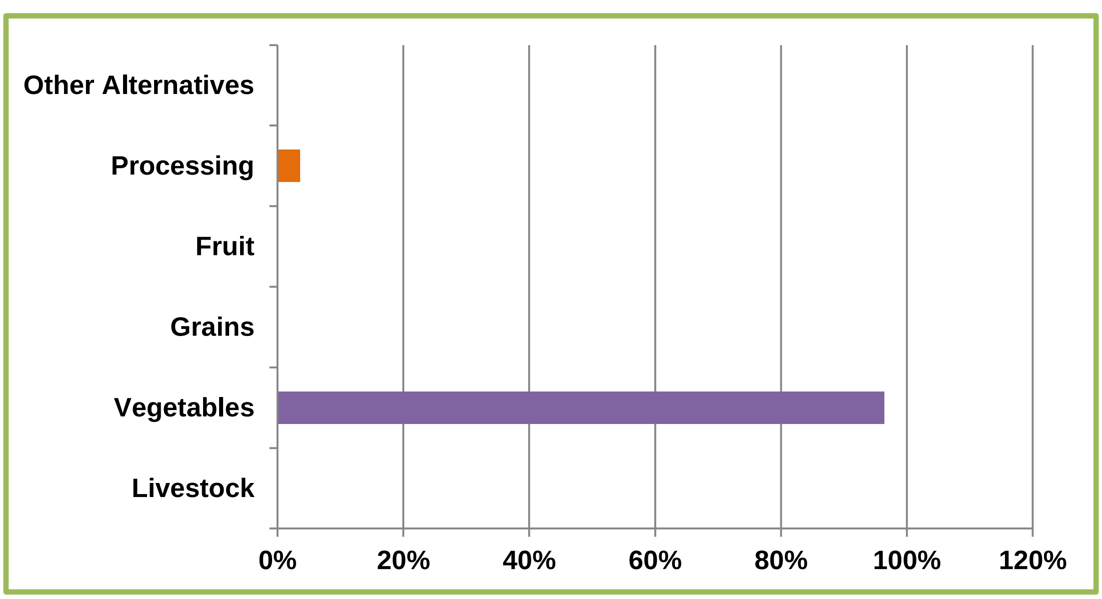
The three main hotspots identified are office & domestic waste (51%), agro-chemicals (40%) which include fertiliser and electricity (8%).

FARM SCOPE BREAKDOWN



Scope 3 emissions are the highest (91%) as can be seen in pie chart above.

FARM PRODUCT BREAKDOWN



Vegetables and processing are the emission sources that contribute the most to total CO_2 emissions.

Carbon Calculator Results vs 5.0

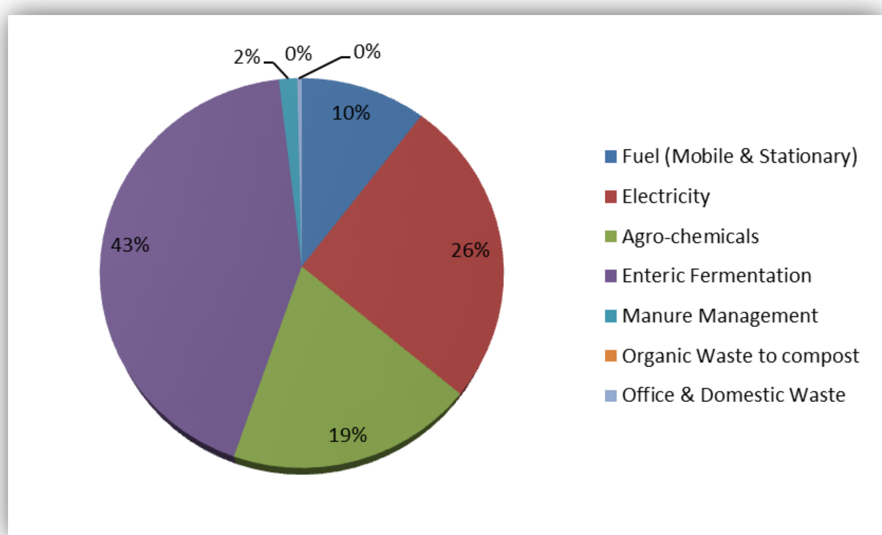
Farm ID: WC1

Audit start: March 2013

Audit end: April 2014

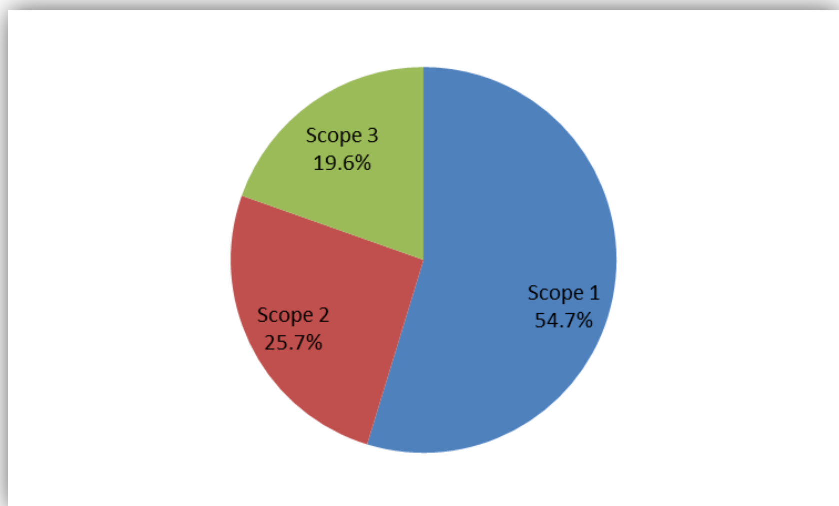
Generation date: 08-08-2015

FARM BOUNDARY



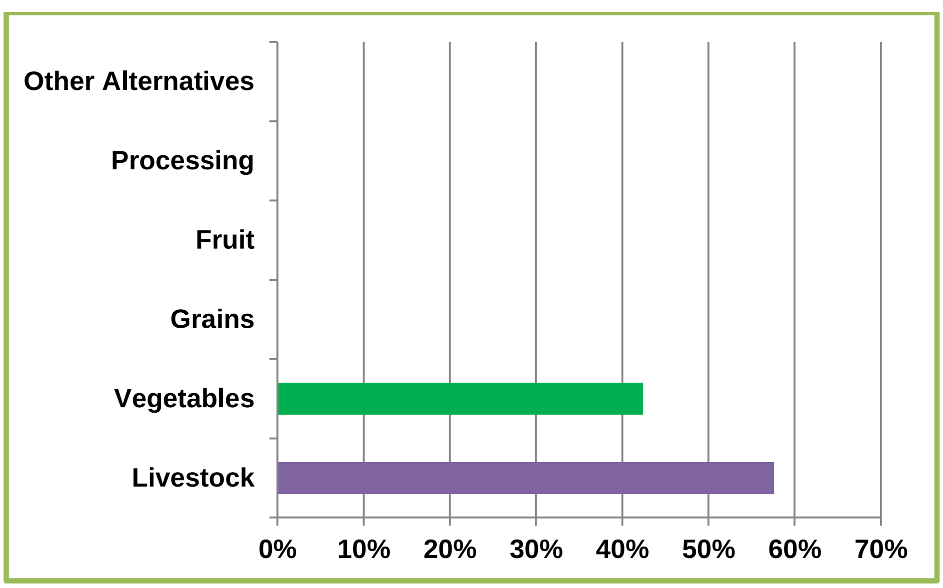
The three main hotspots identified are enteric fermentation (43%), electricity (26%) and agro-chemicals (19%) which include fertiliser.

FARM SCOPE BREAKDOWN



Scope 1 emissions are the highest (54.7%) as can be seen in pie chart above.

FARM PRODUCT BREAKDOWN



Livestock and vegetables are the emission sources that contribute the most to total CO_2 emissions.

Carbon Calculator Results vs 5.0

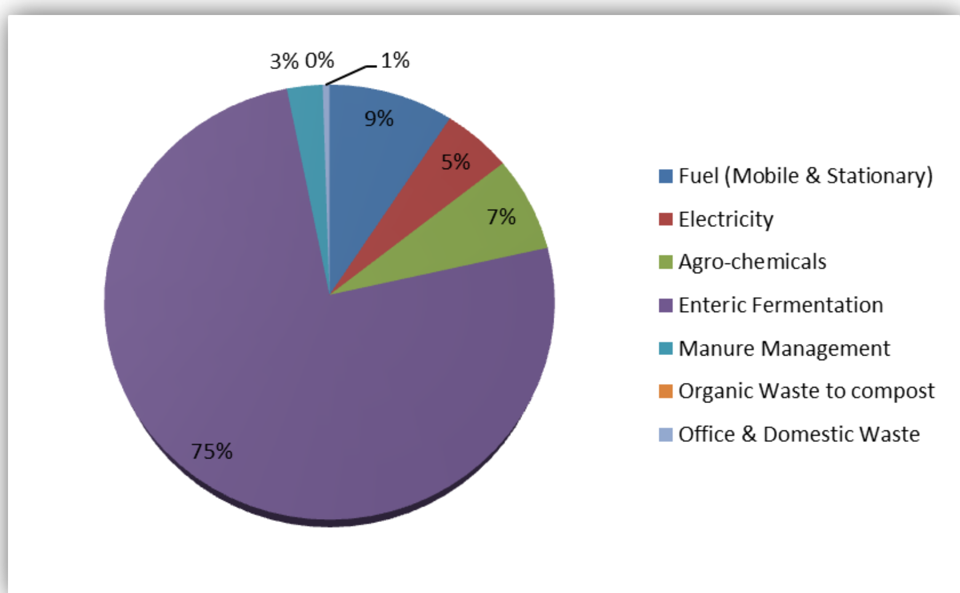
Farm ID: WC2

Audit start: March 2013

Audit end: April 2014

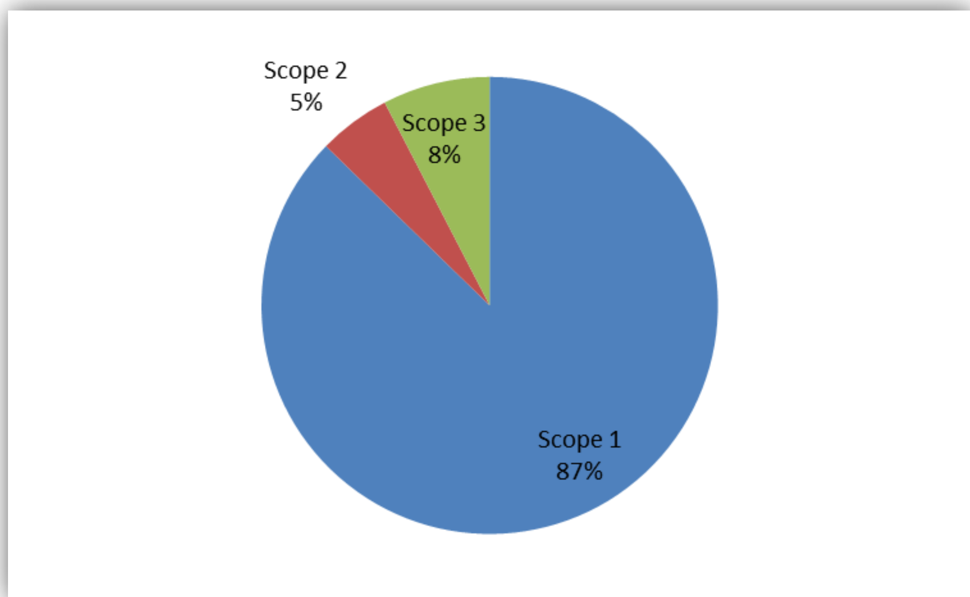
Generation date: 08-08-2015

FARM BOUNDARY



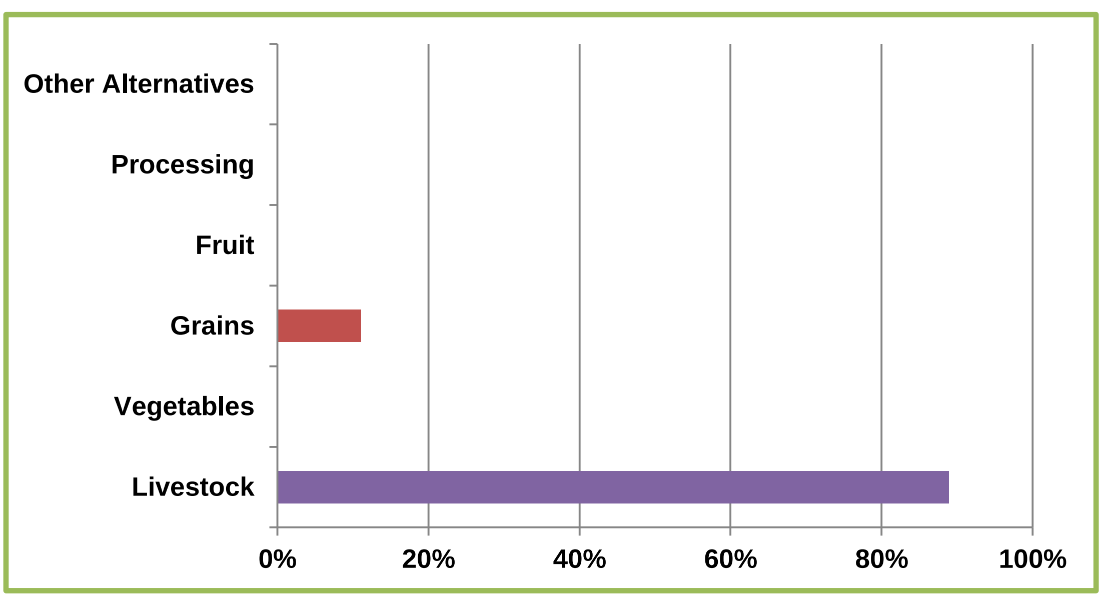
The three main hotspots identified are enteric fermentation (75%), fuel (9%) and agro-chemicals (7%) which include fertiliser.

FARM SCOPE BREAKDOWN



Scope 1 emissions are the highest (87%) as can be seen in pie chart above.

FARM PRODUCT BREAKDOWN



Livestock and grain are the emission sources that contribute the most to total CO_2 emissions.

Carbon Calculator Results vs 5.0

Western Cape Government
BETTER TOGETHER.

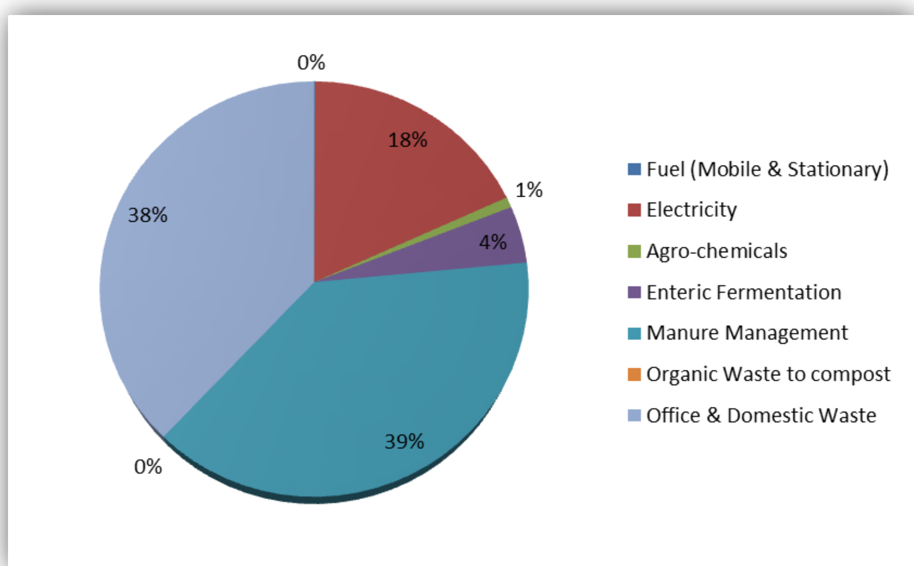
Farm ID: WC3

Audit start: March 2013

Audit end: April 2014

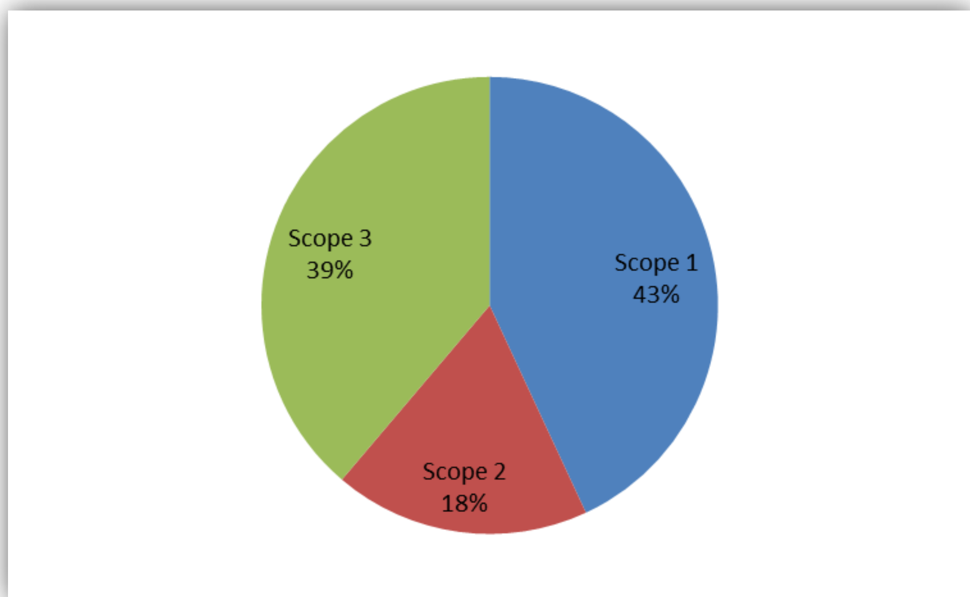
Generation date: 08-08-2015

FARM BOUNDARY



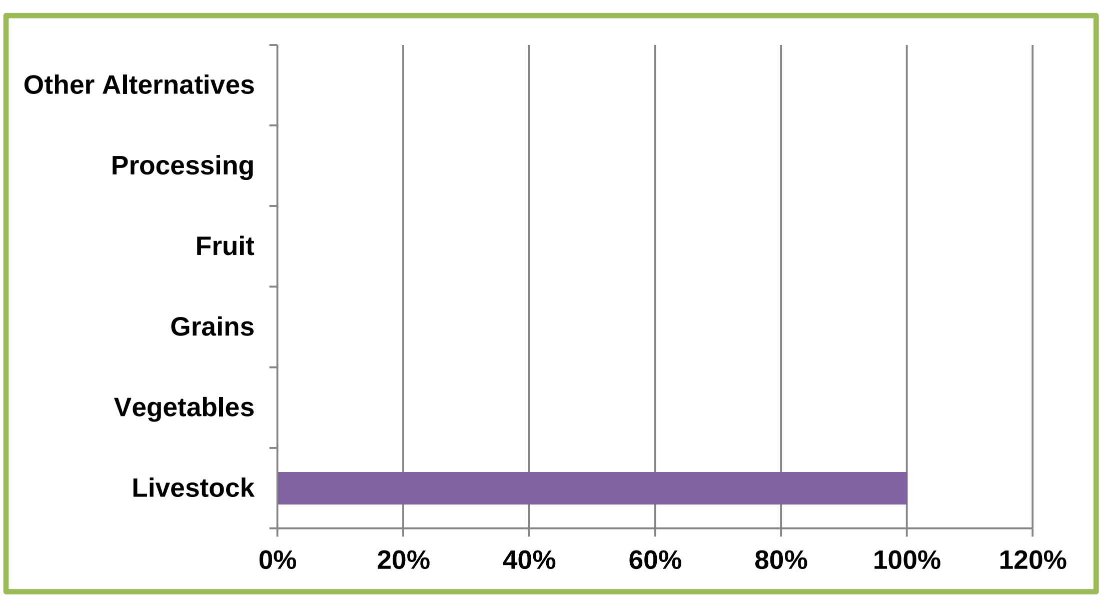
The three main hotspots identified are manure management (39%), office & domestic waste (38%) and electricity (18%).

FARM SCOPE BREAKDOWN



Scope 1 emissions are the highest (43%) as can be seen in pie chart above.

FARM PRODUCT BREAKDOWN



Livestock is the main product and the main emission source that contributes the most to total CO_2 emissions.

Carbon Calculator Results vs 5.0

Western Cape Government
BETTER TOGETHER.

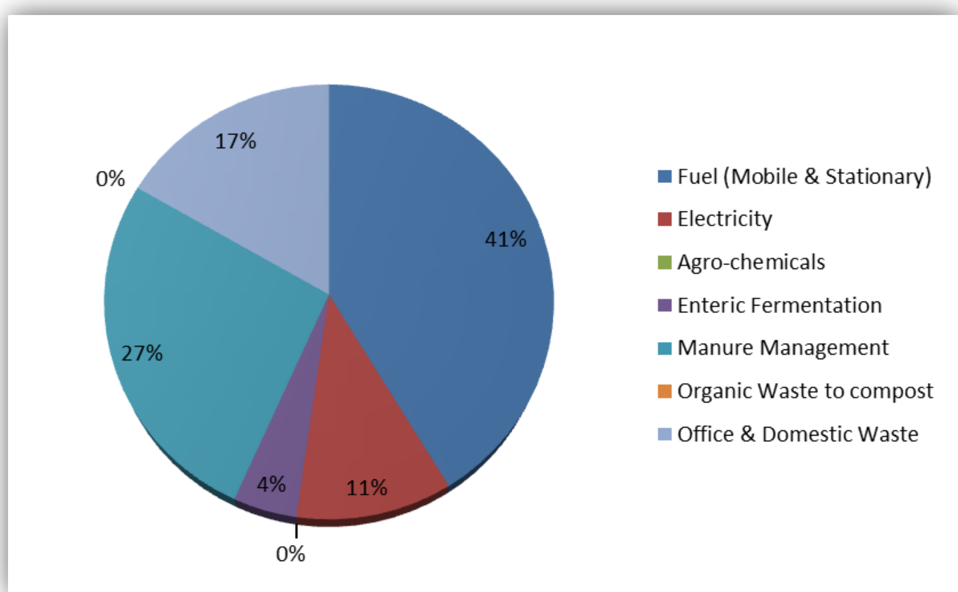
Farm ID: ED1

Audit start: March 2013

Audit end: April 2014

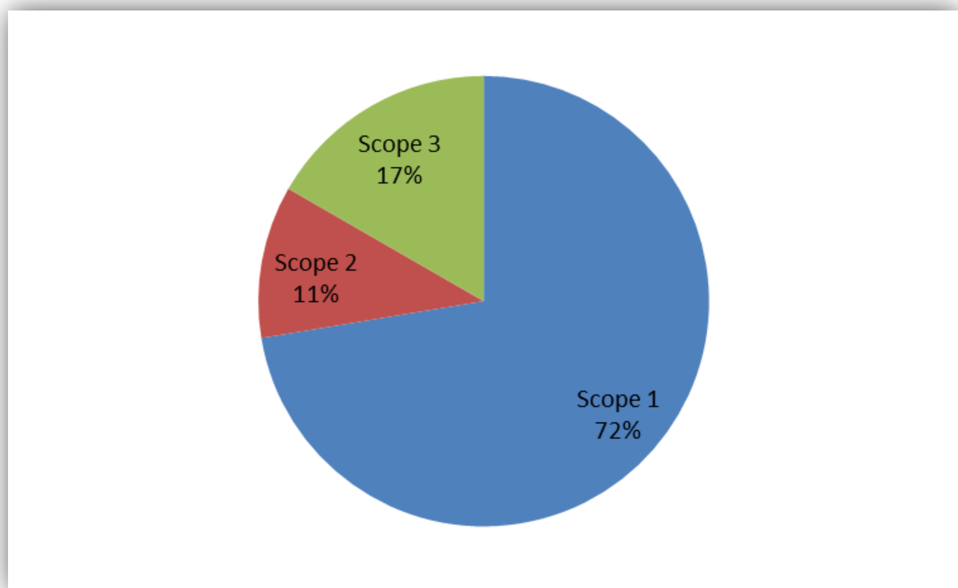
Generation date: 08-08-2015

FARM BOUNDARY



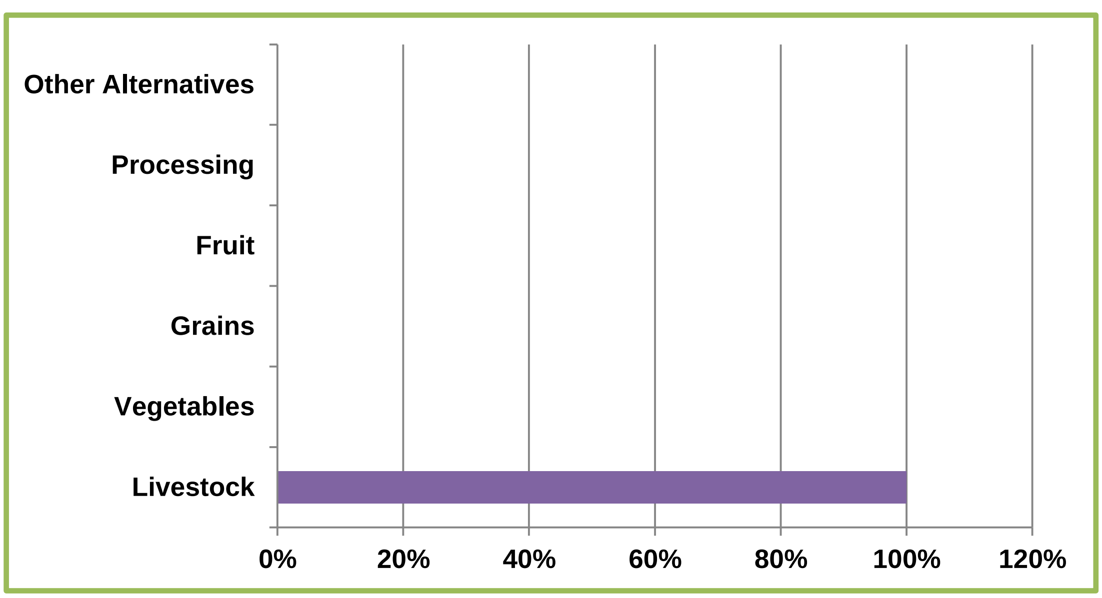
The three main hotspots identified are fuel (41%), manure management (27%) and office & domestic waste (17%).

FARM SCOPE BREAKDOWN



Scope 1 emissions are the highest (72%) as can be seen in pie chart above.

FARM PRODUCT BREAKDOWN



Livestock is the main product and the main emission source that contributes the most to total CO_2 emissions.

Carbon Calculator Results vs 5.0

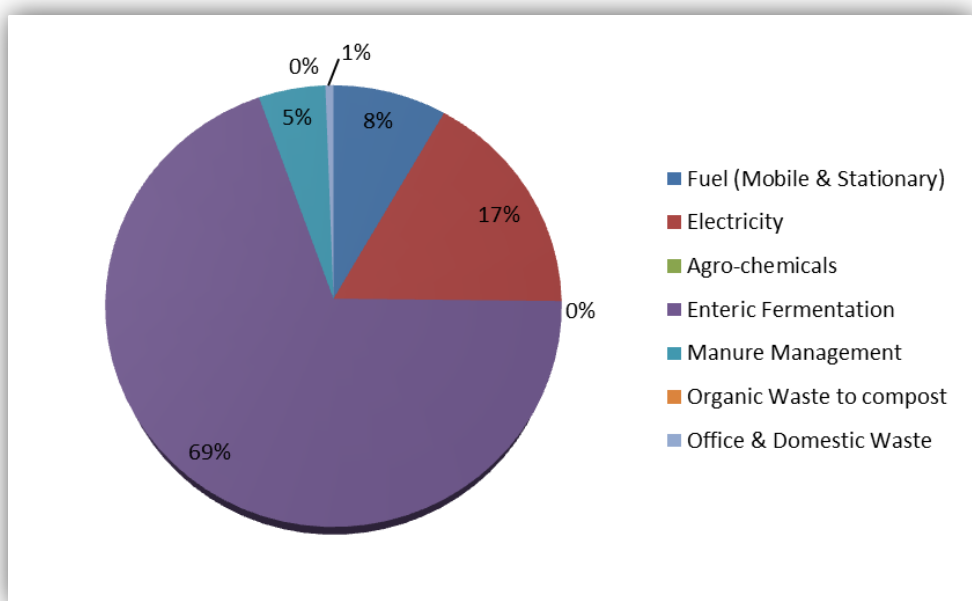
Farm ID: ED2

Audit start: March 2013

Audit end: April 2014

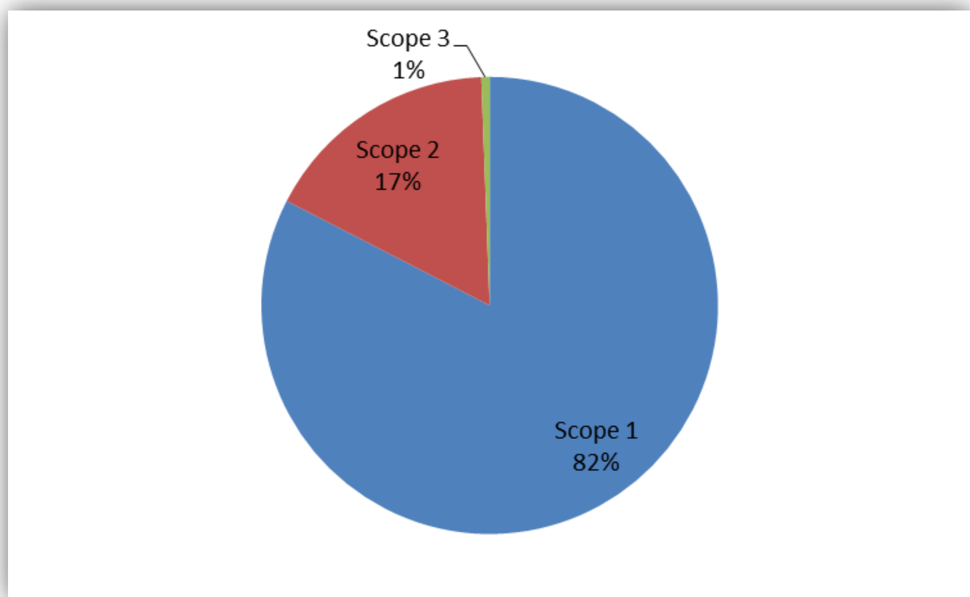
Generation date: 08-08-2015

FARM BOUNDARY



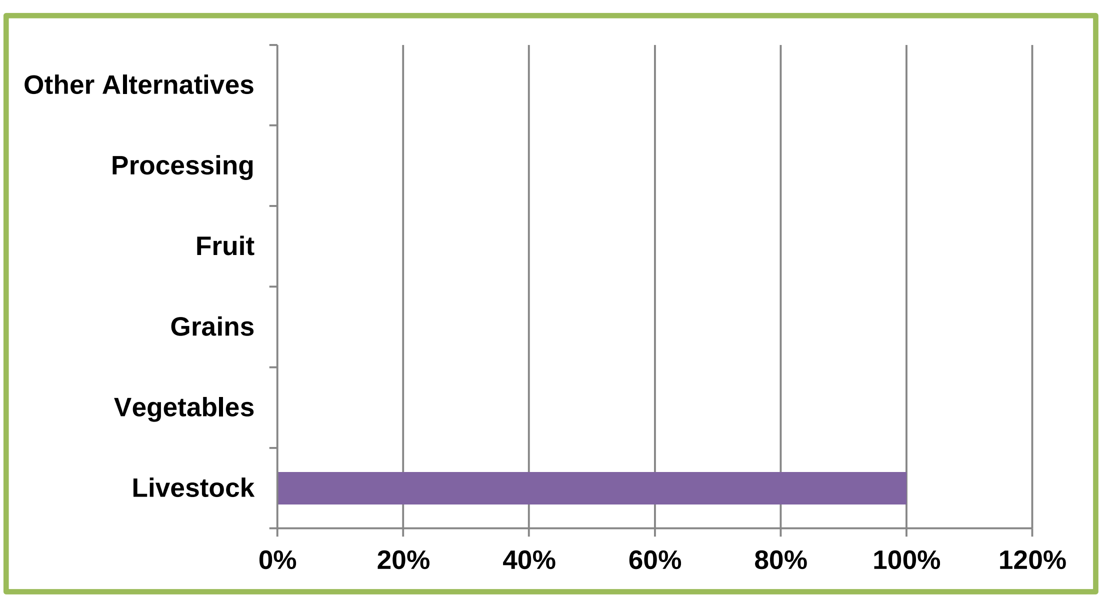
The three main hotspots identified are enteric fermentation (69%), electricity (17%) and fuel (8%).

FARM SCOPE BREAKDOWN



Scope 1 emissions are the highest (82%) as can be seen in pie chart above.

FARM PRODUCT BREAKDOWN



Livestock is the main product and the main emission source that contributes the most to total CO2 emissions.

Carbon Calculator Results vs 5.0

Western Cape Government
BETTER TOGETHER.

Farm ID: ED3

Audit start: March 2013

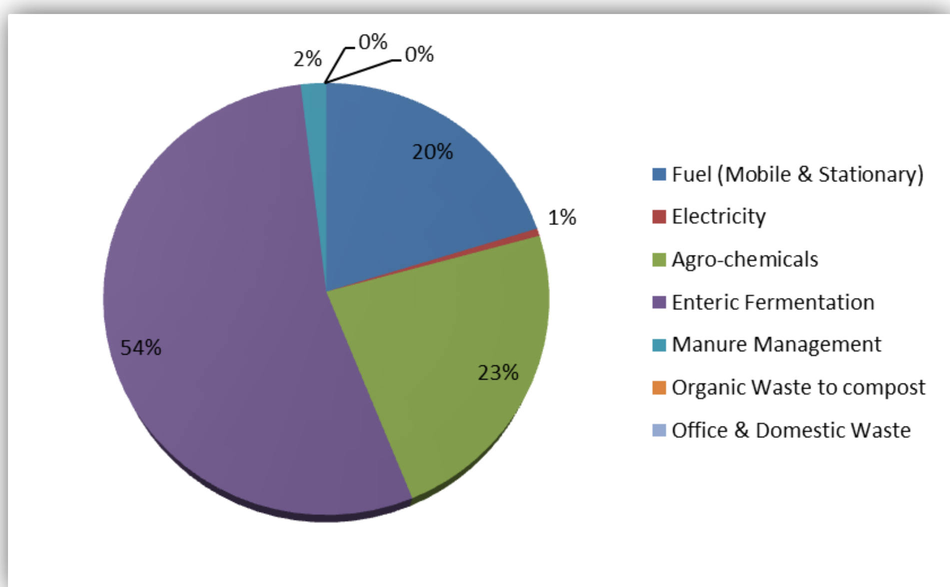
Audit end: April 2014

Generation date: 08-08-2015

User agreement

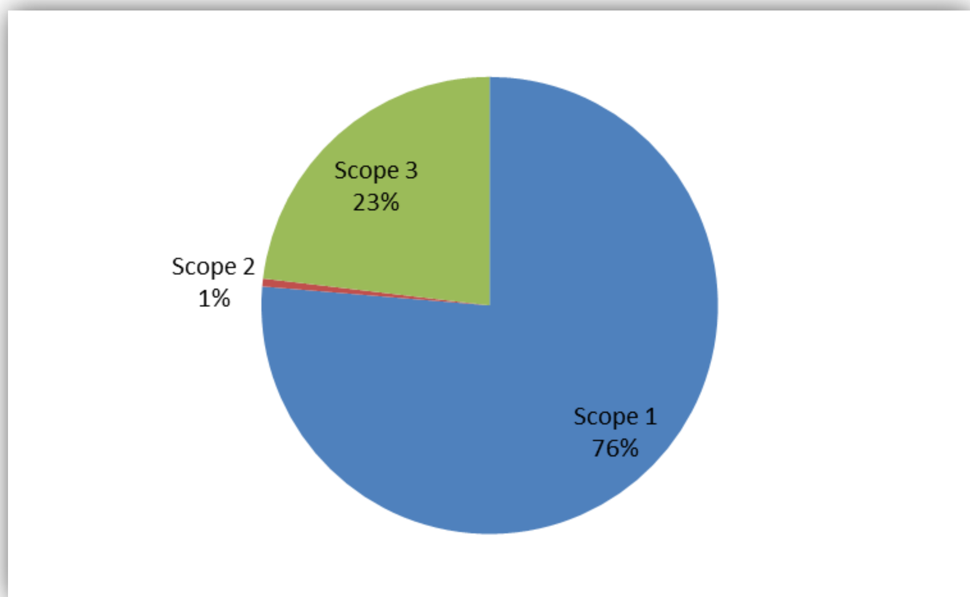
This Data Collection Tool was developed by Western Cape Department of Agriculture and Blue North Sustainability (Pty) Ltd. The information given in this report's accuracy depends on the correctness of the data received from the farmers. The user has to take in mind assumptions were made where data was missing or farmers could not give an accurate answer. No information in this tool or associated guidance documents shall be legally copied or used in any other way without Western Cape Department of Agriculture's prior written permissions.

FARM BOUNDARY



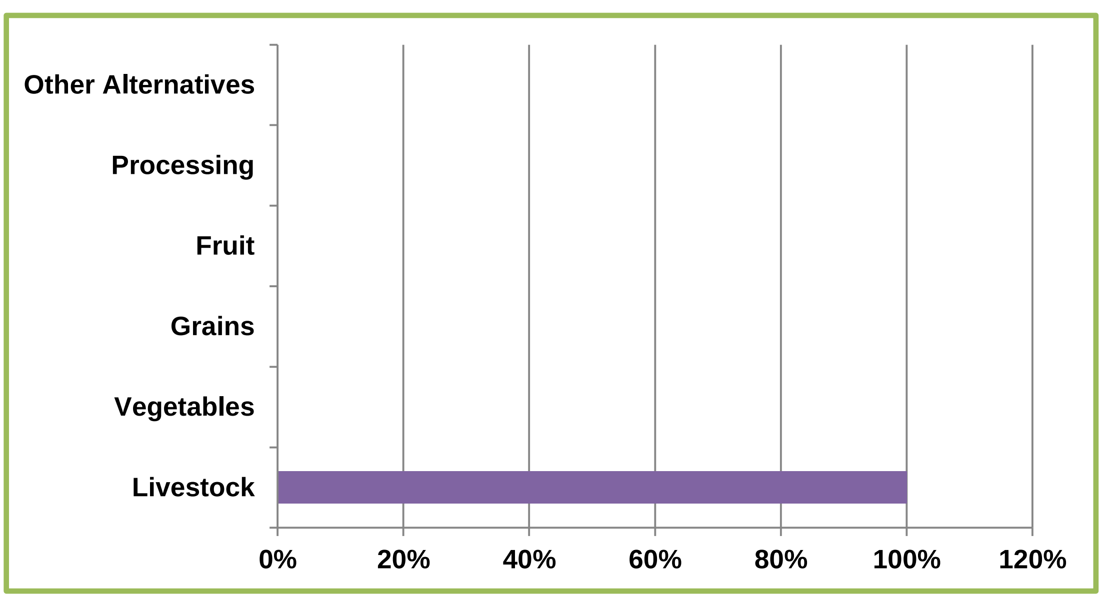
The three main hotspots identified are enteric fermentation (54%), agro-chemicals (23%) which include fertiliser and fuel (20%).

FARM SCOPE BREAKDOWN



Scope 1 emissions are the highest (76%) as can be seen in pie chart above.

FARM PRODUCT BREAKDOWN



Livestock is the main product and the main emission source that contributes the most to total CO_2 emissions.

Carbon Calculator Results vs 5.0

Western Cape Government
BETTER TOGETHER.

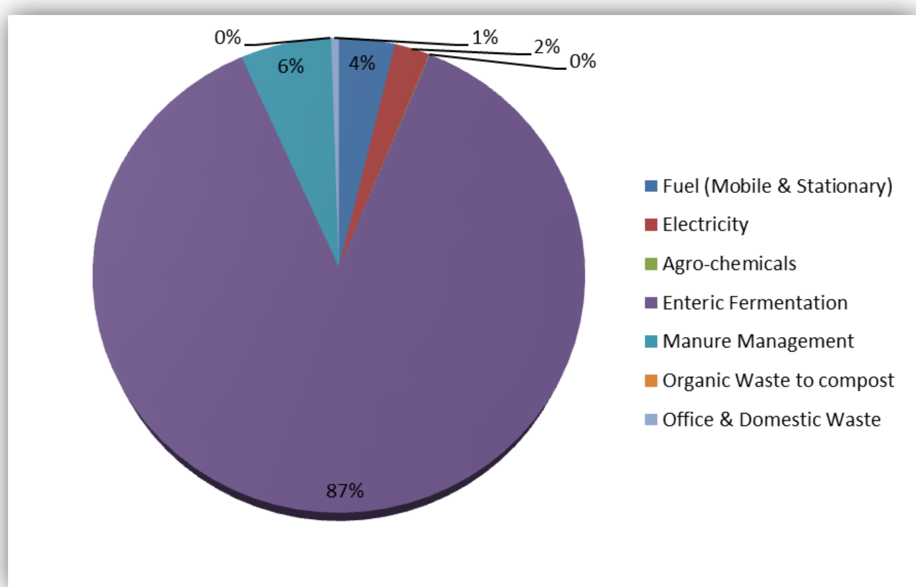
Farm ID: CK1

Audit start: March 2013

Audit end: April 2014

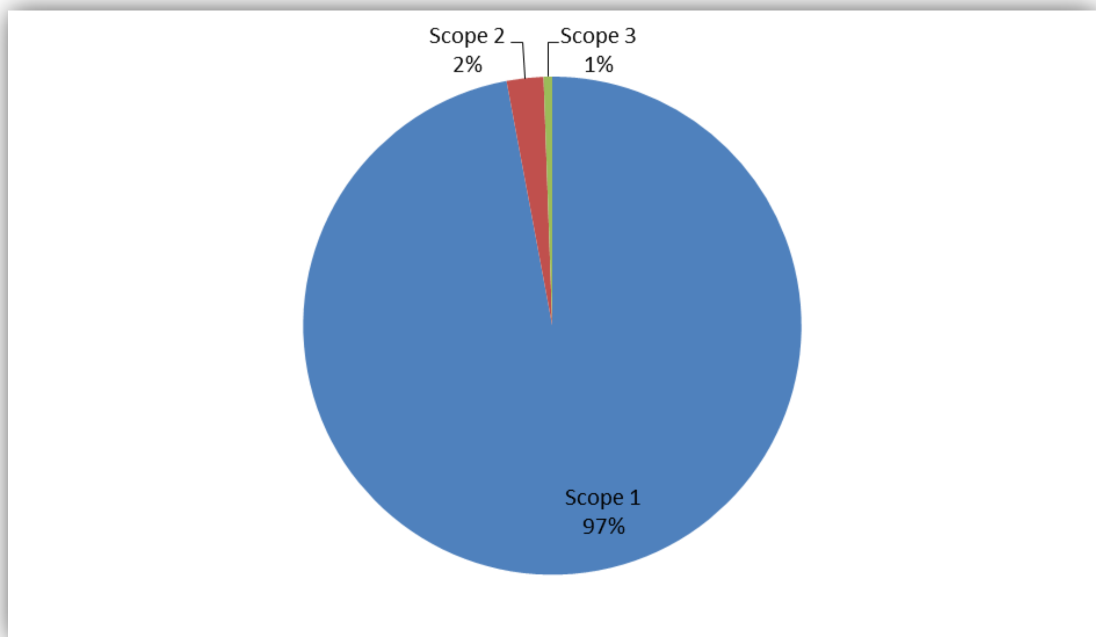
Generation date: 08-08-2015

FARM BOUNDARY



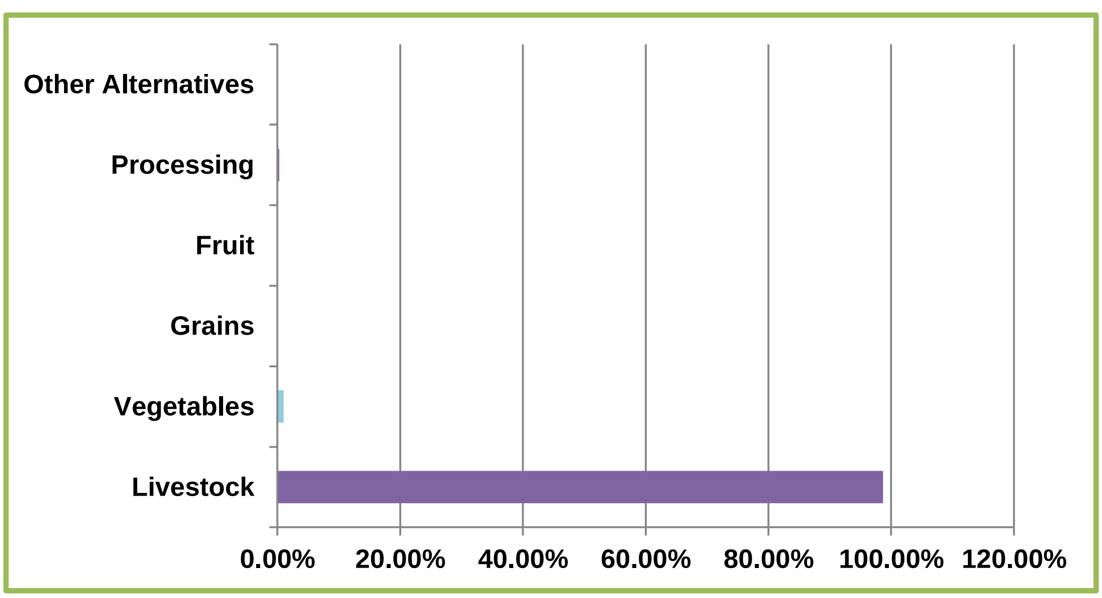
The three main hotspots identified are enteric fermentation (87%), manure management (6%) and fuel (4%).

FARM SCOPE BREAKDOWN



Scope 1 emissions are the highest (97%) as can be seen in pie chart above.

FARM PRODUCT BREAKDOWN



Livestock, vegetables and processing are the emission sources that contribute the most to total CO_2 emissions.

Carbon Calculator Results vs 5.0

Western Cape Government
BETTER TOGETHER.

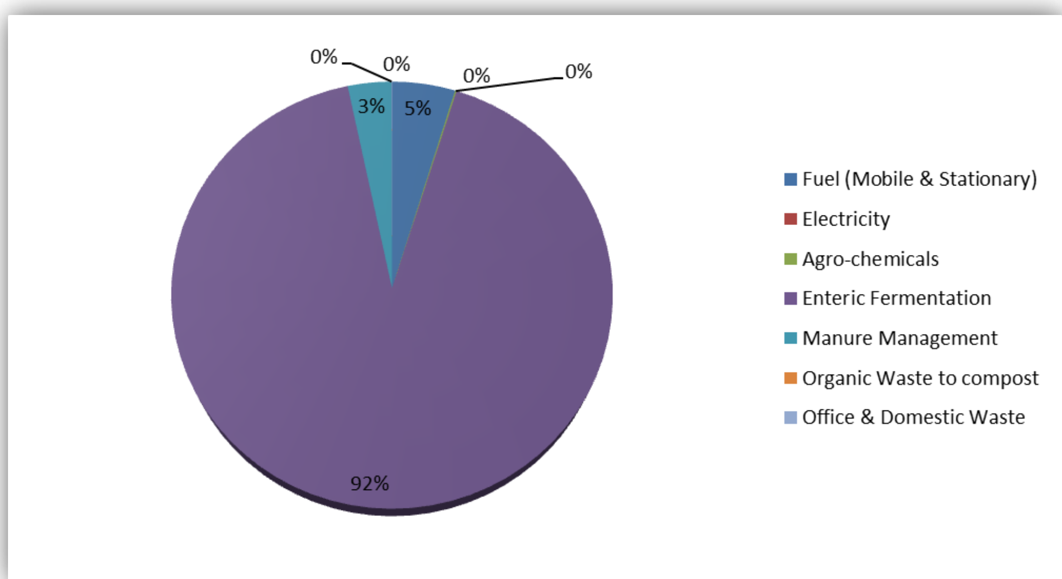
Farm ID: CK2

Audit start: March 2013

Audit end: April 2014

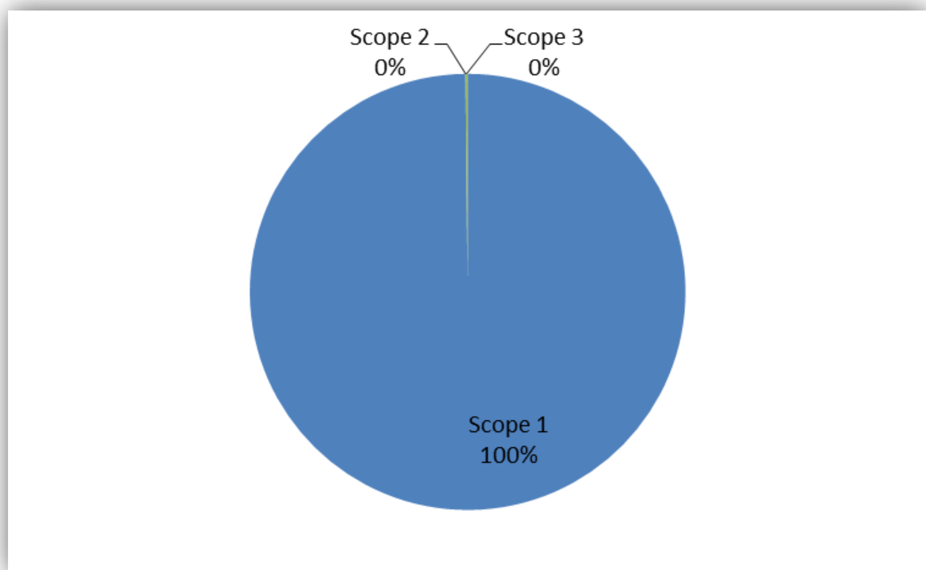
Generation date: 08-08-2015

FARM BOUNDARY



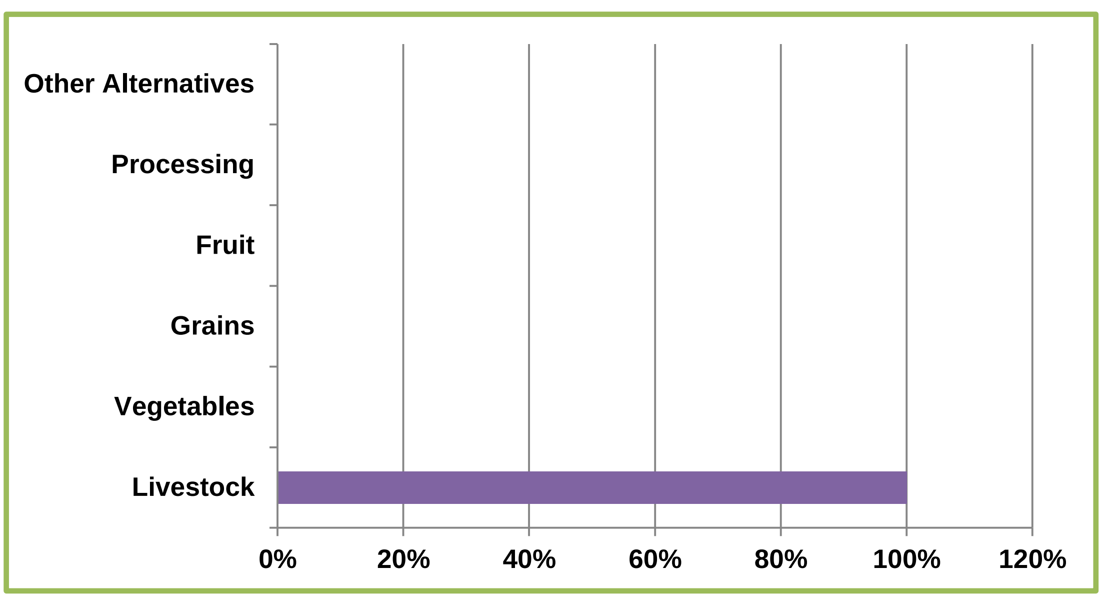
The three main hotspots identified are enteric fermentation (92%), fuel (5%) and manure management (3%).

FARM SCOPE BREAKDOWN



Scope 1 emissions are the highest (100%) as can be seen in pie chart above.

FARM PRODUCT BREAKDOWN



Livestock is the main product and the main emission source that contributes the most to total CO_2 emissions.

Carbon Calculator Results vs 5.0

Western Cape Government
BETTER TOGETHER.

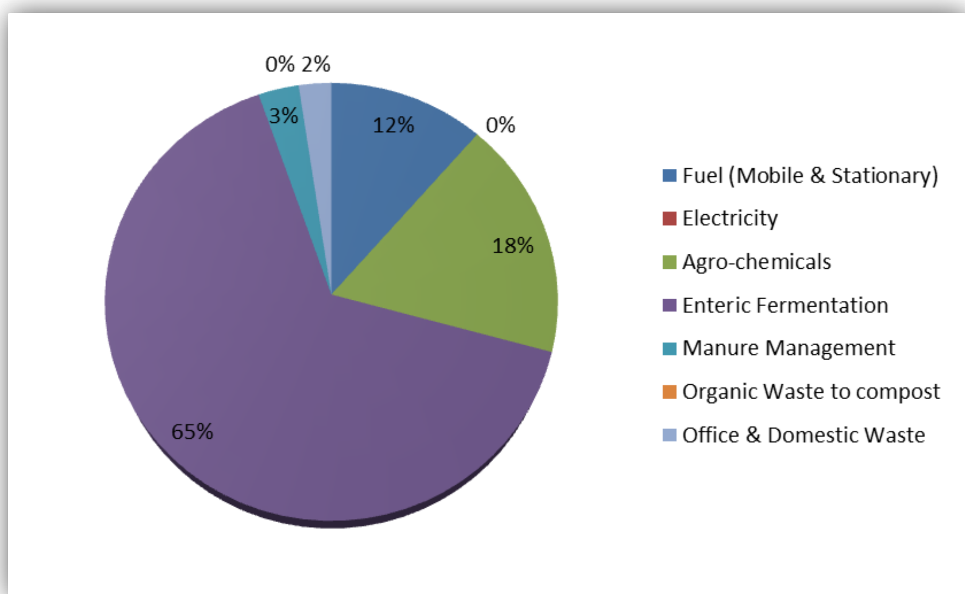
Farm ID: CK3

Audit start: March 2013

Audit end: April 2014

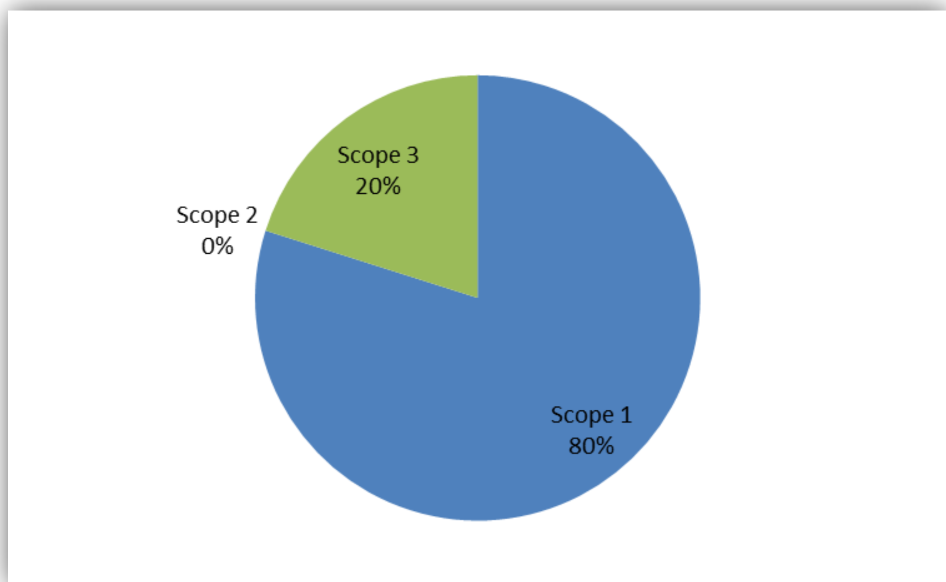
Generation date: 08-08-2015

FARM BOUNDARY



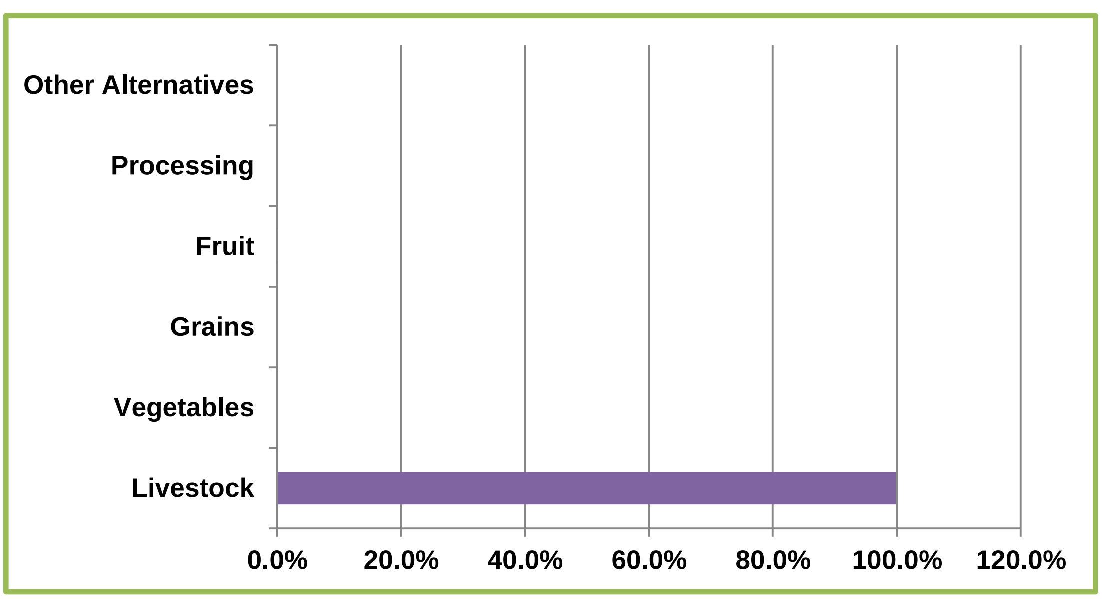
The three main hotspots identified are enteric fermentation (65%), agro-chemicals (18%) which include fertiliser and fuel (12%).

FARM SCOPE BREAKDOWN



Scope 1 emissions are the highest (80%) as can be seen in pie chart above.

FARM PRODUCT BREAKDOWN



Livestock is the main product and the main emission source that contributes the most to total CO_2 emissions.