Regional Resource Flow Model Fruit Sector Report

Analysis of Western Cape Fruit's carbon footprint

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Author:
Pieter Frederik Janse van Vuuren

Prepared for:
Department of Economic Development and Tourism
Western Cape Government

Contact:
pieter@green-cape.co.za

Signature page

For the GreenCape Sector Development Agency

Name & Surname: Chris Millson
Position: Project Manager

Signature: Date:

Name & Surname: Lauren Basson
Position: Strategic Initiatives Manager

Signature: **Date:**

Name & Surname: Evan Rice
Position: Chief Executive Officer

Signature: **Date:**

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Members of the project team:

Name	Organisation	Role
Pieter Janse van Vuuren	GreenCape Sector Development Agency	Analyst
Catherine Pineo	GreenCape Sector Development Agency	Analyst
Chris Millson	GreenCape Sector Development Agency	Project Manager
Lauren Basson	GreenCape Sector Development Agency	GreenCape Projects Manager
Jim Petrie	Department of Economic Development and Tourism	Technical Advisor

Project steering committee:

The contributions from the steering committee throughout the year is much appreciated. Details of the steering committee members are provided below.

Name	Organisation
Leann Cloete-Beets	Department of Agriculture, Western Cape Government
Bongiswa Matoti	Department of Agriculture, Western Cape Government
Thami Vilakazi	Department of Economic Development and Tourism, Western Cape Government
Lise Jennings-Boom	Department of Environmental Affairs and Development Planning, Western Cape Government
Karen Shippey	Department of Environmental Affairs and Development Planning, Western Cape Government
Lauren Hermanus	Department of Environmental Affairs and Development Planning, Western Cape Government
Harro von Blottnitz	University of Cape Town
Tatjana von Bormann	World Wildlife Fund
Wendy Engel	World Wildlife Fund
Andre Page	National Cleaner Production Centre

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List of acronyms

CA	Controlled Atmosphere
CCC	Confronting Climate Change
LCA	Life Cycle Assessment
DoA	Department of Agriculture
MEXALCA	modular extrapolation of agricultural life cycle assessment
PAS	Publicly Available Specification
RRFM	Regional Resource Flow Model
SAM	Social Accounting Matrix
SATI	South African Table Grapes
SAWIS	South African Wine Industry Information & Systems
WC	Western Cape

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1. Introduction

This report constitutes part of the Regional Resource Flow Model (RRFM) project[1]. The RRFM has two main components as shown in Figure 1. The top-down macro-economic analysis considers resource and labour use at an aggregated level and highlighted agriculture and agro-processing as key focus areas. This is described in detail in the Social Accounting Matrix Analysis (Janse van Vuuren, 2015a). This fruit sector report forms part of the bottom-up "resource needs" component of the project with the explicit aim of updating and validating estimates of greenhouse gas (GHG) emissions for the macro-economic model's[2] "other fruit and citrus farming" and "table grape farming" sectors'. Other key sectors analysed include: wheat (Pineo, 2015a), livestock (Pineo, 2015b) and wine grapes (Janse van Vuuren, 2015b).

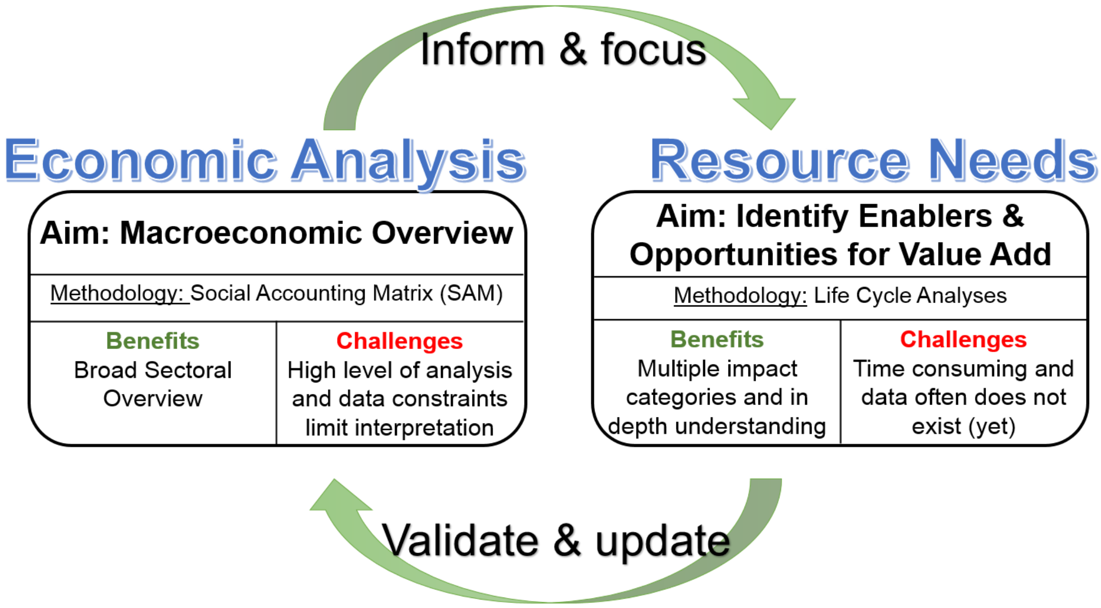


Figure 1*: Overview of the Regional Resource Flow Model project*

The analysis was undertaken using publically available data from Confronting Climate Change's (CCC) industry benchmark reports (CCC, 2014a-e). First, the fruit sector as a whole was examined, highlighting the commodities which the CCC carbon footprints do not cover. Thereafter CCC's carbon footprints are presented for each fruit category, and mitigation options discussed. Finally, estimates of the GHG emissions for the "table grape farming" and "other fruit and citrus farming" sectors, corresponding to the macro-economic work are presented.

[1] For most recently released reports see RRFM webpage on GreenCape's website: green-cape.co.za/what-we-do/projects/regional-resource-flow-model/
[2] Social Accounting Matrix commissioned by DBSA (2008).

2. Fruit sector overview

The Agricultural Census (2007) was used to get an initial overview of the data availability within the fruit sector. Thereafter, more specific industry association data was assessed where possible, as part of a more detailed (and updated) overview. The Agricultural Census data has crop production broken into two main sectors, namely field crops and horticulture with 6 subsectors each as shown:

Table 1: Agricultural Census' categorisation of crop production

Crop Production	
Field Crops	Horticulture
Summer cereals	Vegetables
Winter cereals	Citrus Fruit
Oil-seeds	Subtropical Fruit
Legumes	Viticulture
Fodder crops	Nuts
Other field crops	Other Horticultural Products

For the purpose of the reconciliation of social accounting matrix (SAM) data with the agricultural census data, the citrus and subtropical fruit sectors are considered within the "other fruit and citrus farming" sector. These consist of the following products shown graphically in Figure 2 with a detailed comparison of areas in Table 2.

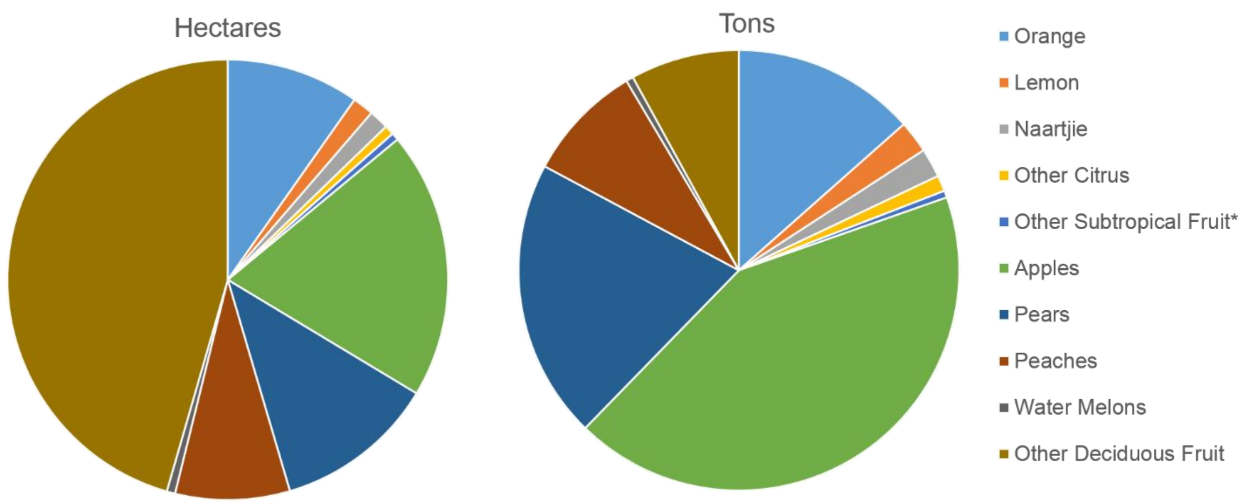


Figure 2: Fruit sub-sectors in the Western Cape

Apples seem to be the most significant fruit, followed by pears and then oranges, most notably when considering the tonnes produced. There also some difficulties presented by the "other deciduous fruit" component of production especially when considering the area under production, though the effect is muted when production tonnages are considered.

To unpack the issue further and provide updated information, various industry-level sources were collated to compare to the agricultural census. This was done to determine whether there were differences in reporting and to try account for all Western Cape fruit. This overview of areas from disparate sources in comparison to the agricultural census is shown in in Table 2 with a difference of approximately 20 000ha likely driven by the "other deciduous fruit" in the agricultural census. Though the comprehensive and up to date land use survey shows no significant fruits unaccounted for (Personal Communication with DoA, 2015).

Table 2: Comparison of hectares of fruit in agricultural census and industry association data for the Western Cape 2006

	Fruit	Industry Associations*	Agricultural Census
Pome	Apples	16 002	15 775
	Pears	9 934	9 501
Stone	Apricots	3 606	-
	Dessert Peaches	793	6 759
	Cling Peaches	7 015	
	Nectarines	1 335	-
	Plums	2 714	-
	Prunes	432	-
Citrus	Oranges	2 987	7 848
	Navels	4 936	
	Soft Citrus	2 705	1 163
	Grapefruit	22	-
	Lemons & Limes	921	1 246
	Other Citrus	-	561
Other	Pomegranate	587	-
	Olive**	6 164	-
	Guava****	514	-
	Water Melons	-	495
	Other Subtropical Fruit	-	440
	Other Deciduous Fruit	-	36 604
TOTAL		60 668	80 392

Hortgro Statistics except for; citrus (Citrus Growers' Association of Southern Africa, 2008), Olives (DoA's land use survey 2013)** and Guava**** (Communication with Guava Producers Association).

**2013 data is a likely over-estimate as reports indicate large rise in olive production though for a slightly longer (since 2004) timeframe (Olive Directory, n.d.).

***All data is 2007 data unless otherwise stated

****2014 data

While generally showing similar results, there are some discrepancies regarding hectares cultivated when examining data from agricultural associations and that from the agricultural survey shown in Table 2. This is especially true with regards to soft citrus. This may explain some of the difference in total areas. Given the depth of the information provided by the industry associations, it is assumed that this is the most comprehensive information available. Using these sources it is possible to get comparable fruit statistics for 2013 to compare with the CCC carbon footprints[3]. As CCC's carbon footprints (discussed further in the next section) provide carbon footprint per unit of production, a sector carbon footprint can be derived using total amount (tonnes) of fruit produced. Using industry association data, an up to date overview of the sector(s) is shown in Figure 3. Additional data is available to show the hectares for the sectors as shown in appendix in Figure 15.

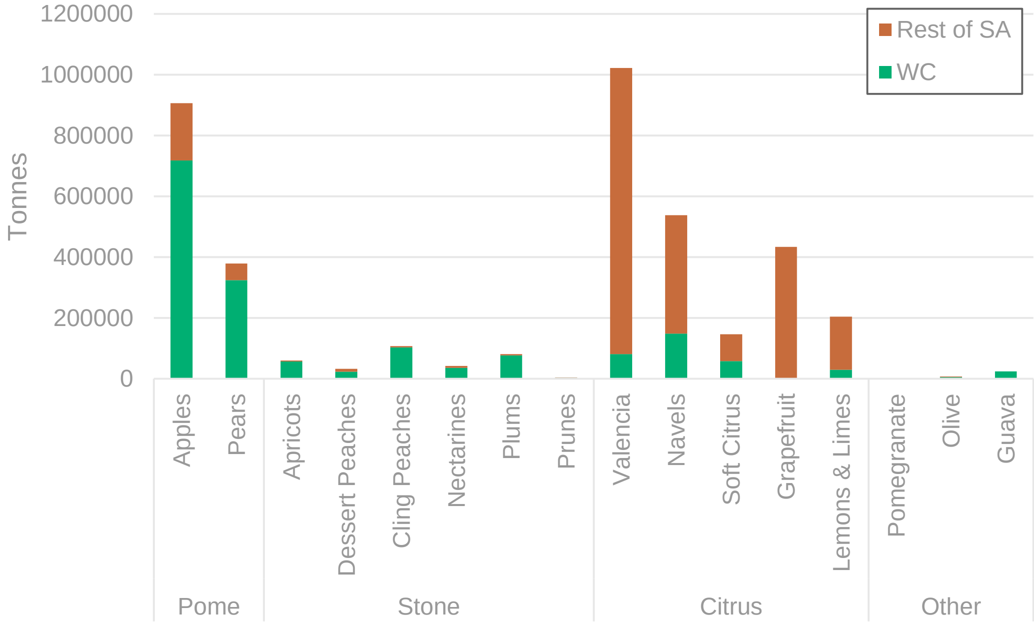


Figure 3: South African and Western Cape fruit sub-sectors (tonnes)[4]

It is clear that the pome fruit and citrus sub-sectors are the most significant for South African agricultural production. It is also clear that most pome and stone fruit is grown in the Western Cape, highlighting the importance of the Western Cape fruit growing sector for the South African Agricultural production. Thus pome fruit is clearly the most significant sector for the Western Cape, less clear is the pome fruit citrus sectors as in terms of tonnes produced citrus is greater (Figure 8) while stone fruit has a large area cultivated (Figure 6). CCC's carbon footprints have been undertaken for: pome fruit, stone fruit and citrus. The *other* fruits do not have corresponding carbon footprints but their presence indicates that the total carbon footprint of the sector needs to take cognisance of them if the carbon footprint is to be representative of the entire fruit sector.

2.1. Viticulture and Table Grapes

Grape production is split into three main categories; namely wine grapes, table grapes and dry grapes (raisins). The distinction is not always clear as some grapes can be used for more than one use such as the Sultana and Muscat d'Alexandrie which SAWIS (2014, p. 8) highlight as not being exclusively used for wine. The wine sector was examined in some detail in the accompanying report and is not explored further here (Janse van Vuuren, 2015b).

[3] The 2007 Agricultural Census is the latest agricultural census.
[4] Own Calculations using Hortgro (2014), Citrus Growers association (Citrus Growers' Association of Southern Africa, 2014), land use survey (DOA, 2014)

The agricultural census only reports table and wine grapes, as shown in Table 1. Hortgro reports production of table and dry grapes together, with the South African Table Grapes Industry (SATI) reporting table grapes only. When comparing these figures, the agricultural census and Hortgro (2008) figures are comparable, but SATI (2008) reports nearly half the production. It is therefore assumed that the table grape production as reported by Hortgro includes both the table and dry grapes - with the difference between the Hortgo and SATI statistics being represented by the production of dry grapes. This gives the total size of the sector in terms of hectares and tonnes of production as shown in Figure 4.

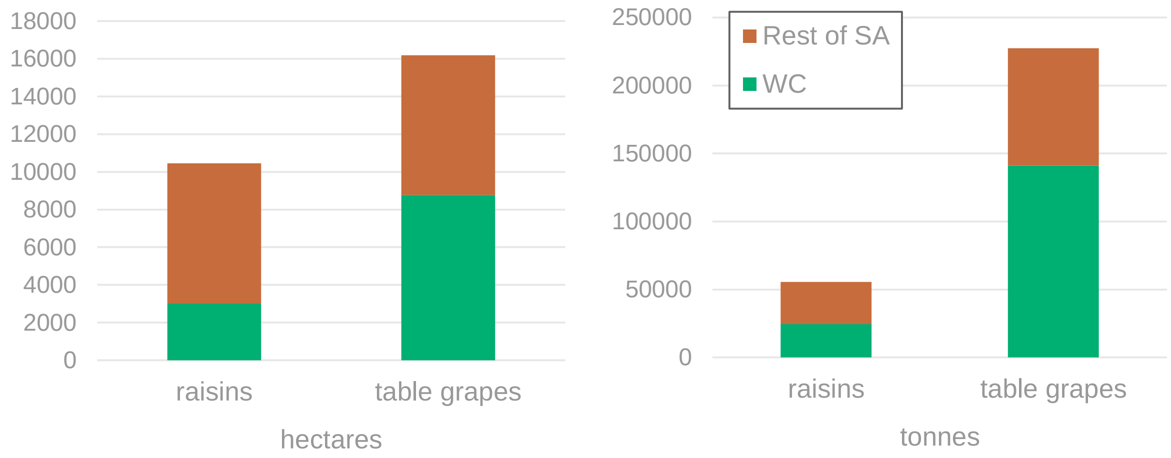


Figure 4: Table Grape Overview area and production[5]

Table grape production constitutes the majority of the sector. However, it also noted that the production of raisins is probably underestimated, as the fresh and dry weights of raisin differ drastically[6]. It is also notable that significantly more than half of the table grape production comes from the Western Cape, showing that the Province is a key component of the sector.

[5] Own calculations using Hortgro (2014) & SATI (2014)
[6] A factor of 4.5 is applied when considering carbon footprints.

3. Carbon Footprints

Confronting Climate Change (CCC) has conducted a number of PAS 2050[7] compliant carbon footprints through its online carbon calculator. These utilise an excel-compatible interface on which users receive training. Registration is required to use the carbon calculator, but currently it is free of charge. As a result of the carbon footprints conducted on farms thus far, a database has been developed which has allowed the release of benchmark industry reports, that considered the carbon footprint per fruit per production area (CCC, 2014e).

These industry reports were then used to get estimates of the Western Cape carbon footprints. However, given the relatively low number of carbon footprints calculated to date, the carbon footprints were aggregated to the Western Cape per fruit, and the first and third quartile estimates used as lower and higher carbon footprint estimates around the mean.

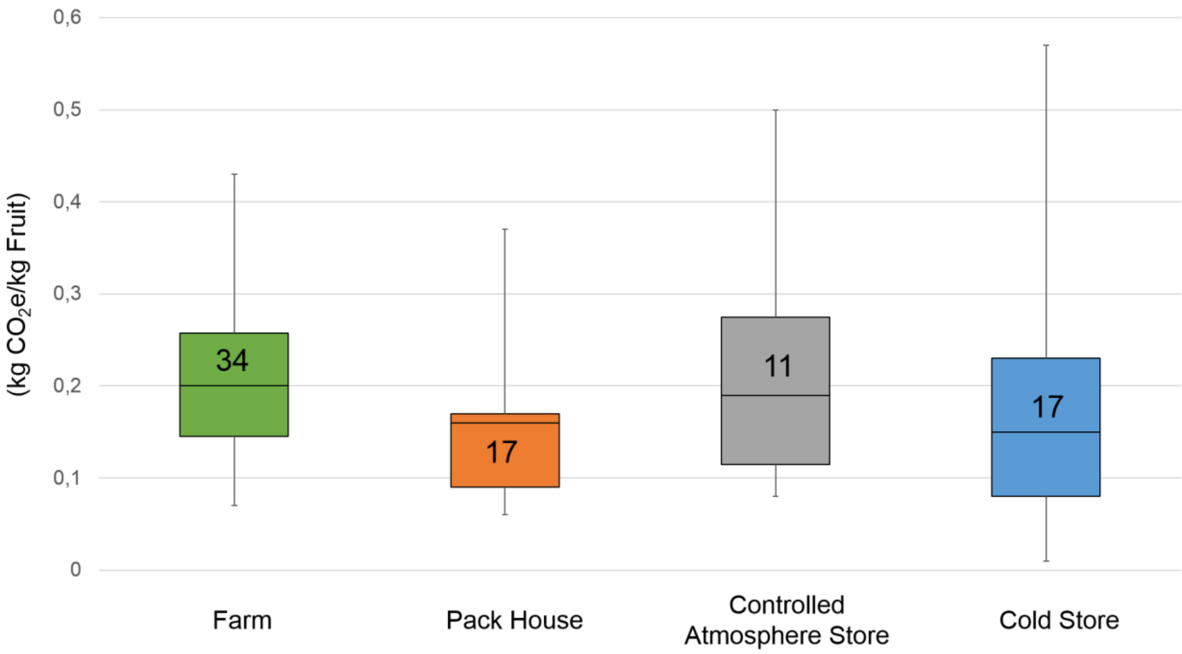
This method allows some consideration of the variation in carbon footprint results within the sector. High variation in results is a typical characteristic of agricultural products, with results highly sensitive to climate and soil conditions which vary significantly in the Western Cape. It has also been shown that, the same apple cultivation, in different parts of Europe, have completely different protection requirements and thus different carbon footprints (Stoessel, et al., 2012). Therefore, aggregating data for carbon footprints calculated within Western Cape, a larger sample on which to base the range was achieved. This avoids using smaller samples for the areas as was originally reported, with some areas having single observations. A range is used to emphasise that the carbon footprints vary significantly. In addition, given the non-mandatory nature of the reports at present, these results may suffer from selection bias and underestimate the sector's carbon footprint. Making use of ranges is an attempt to deal with this some of the bias, assuming that the sample captures a sufficient amount of producers with larger carbon footprints. It is noted that data will likely improve as more farmers conduct carbon footprints using CCC's carbon footprinting tool.

The carbon footprint results of each fruit is discussed below, in order of relevance to the Western Cape, with mitigation interventions discussed in section 4 thereafter as these do not differ significantly between fruits.

3.1. Pome fruit sector

As highlighted in Figure 3, the pome fruit sector is significant in South Africa and mostly located within the Western Cape. This emphasises the need to consider the Western Cape's pome fruit sector on the fruit sector's carbon emissions. The importance of the Western Cape in pome fruit production is also reflected in all the pome fruit carbon footprints done by CCC being located in the Western Cape. The carbon footprints for the pome fruit sector in the Western Cape (and South Africa) are shown in Figure 5. It is clear that the farming component is a significant contributor to the carbon footprint with the highest average emission per kg of fruit. International studies have results in the same range, with 0.16 - 0.20 kg CO_2e per kg fruit at farm gate, for apples in Northern Italy (Cerutti, et al., 2013). It is also interesting to note that the highest outliers are in the storage components indicating a possible area for intervention.

[7] Protocol for companies to make credible reduction commitments and achievements on life cycle GHG emissions of products, under a Product- Related Emissions Reduction Framework developed by British Standards Institute.



Own calculations using Confronting Climate Change (2014c), number of observations shown per category.

Figure 5: CCC carbon footprints for pome fruit

3.2. Stone fruit sector

The stone fruit sector, while not as significant as the pome or citrus sector nationally, it is more significant than the citrus sector provincially, in terms of hectares planted, with the majority of the citrus sector not being located in the Western Cape as shown in Figure 6 below. The Western Cape is also clearly the most significant producer of stone fruit with over ninety percent of the country's production.

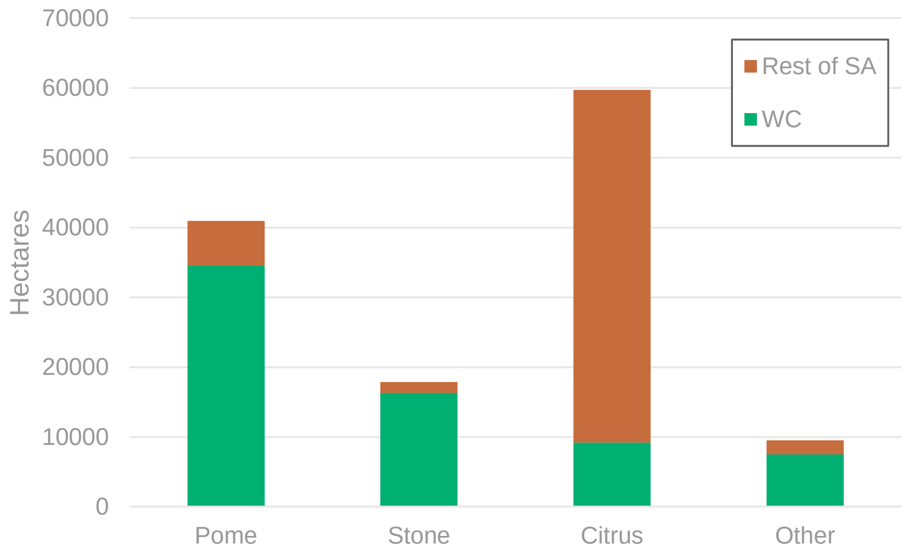


Figure 6: Main fruit groupings area planted South Africa – Western Cape Comparison

The CCC carbon footprints for the sector are shown in Figure 7. The prevalence of the sector within the Western Cape is reflected in the fact that all stone fruit farms in the CCC benchmark industry reports fall within the Western Cape. The results show that farming has the largest contribution to the carbon footprint, though even more so than for the pome fruit sector as there are no higher outliers for pack house or cold store. This is likely a reflection on the different cooling requirements between these two sectors.

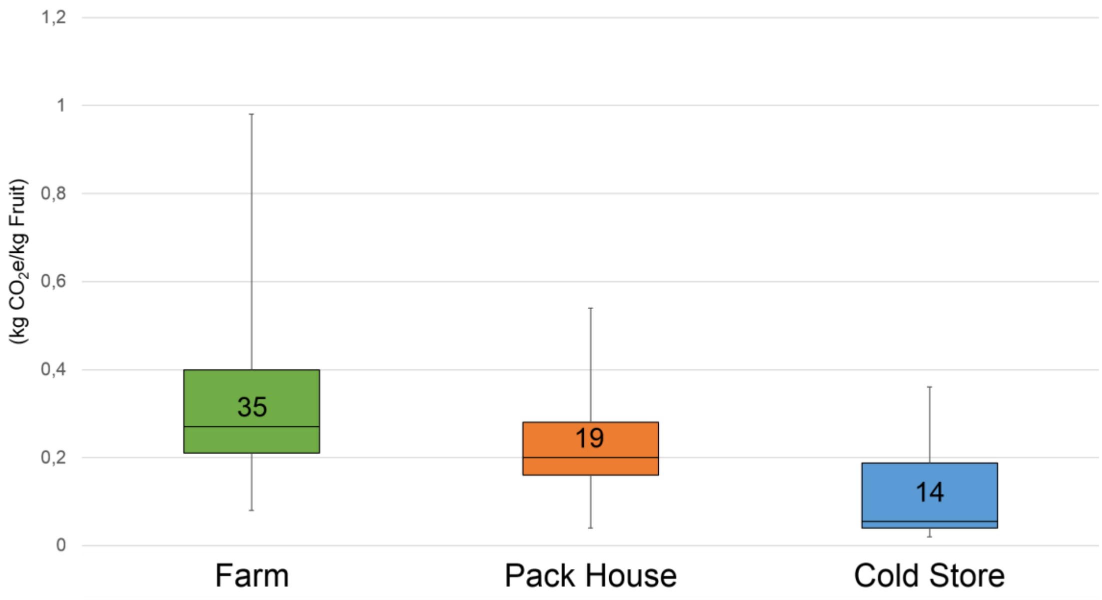


Figure 7: CCC carbon footprints for stone fruit

3.3. Citrus

As highlighted previously the citrus sector is predominately located outside the Western Cape, making it less important when considering area under cultivation (Figure 6). However, when considering production volumes citrus has a greater relevance (Figure 8) with production volumes of citrus in the Western Cape actually being slightly higher than those for stone fruit.

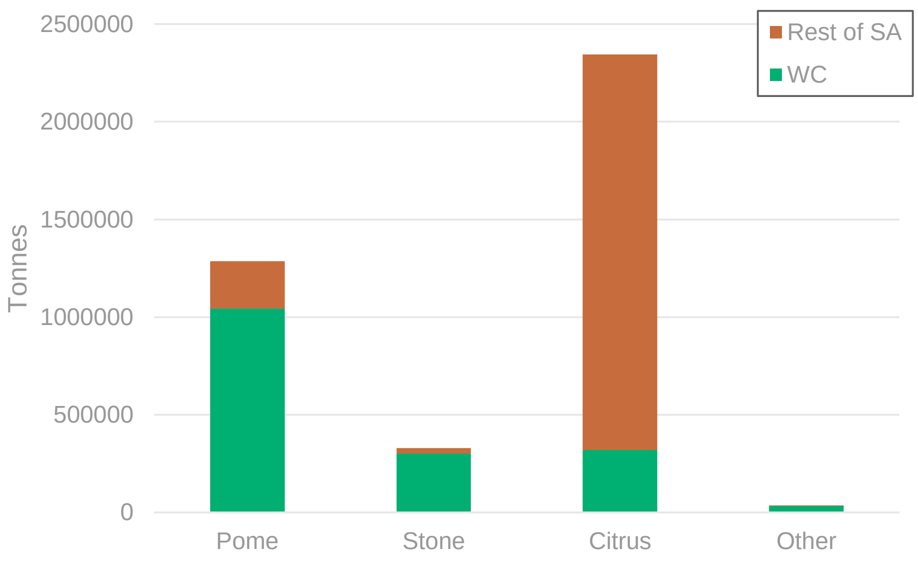


Figure 8: Main fruit groupings in South Africa production Tonnes

The majority of CCC carbon footprints completed thus far for the citrus sector have been of producers located outside of the Western Cape, in line with their geographical spread. As a result, issues regarding the representativeness of the sample size occur when considering only the Western Cape data, as shown in Figure 9. This is most noticeable for hard citrus with only 4 observations, going down to 3 and 1 for pack house and cold store respectively.

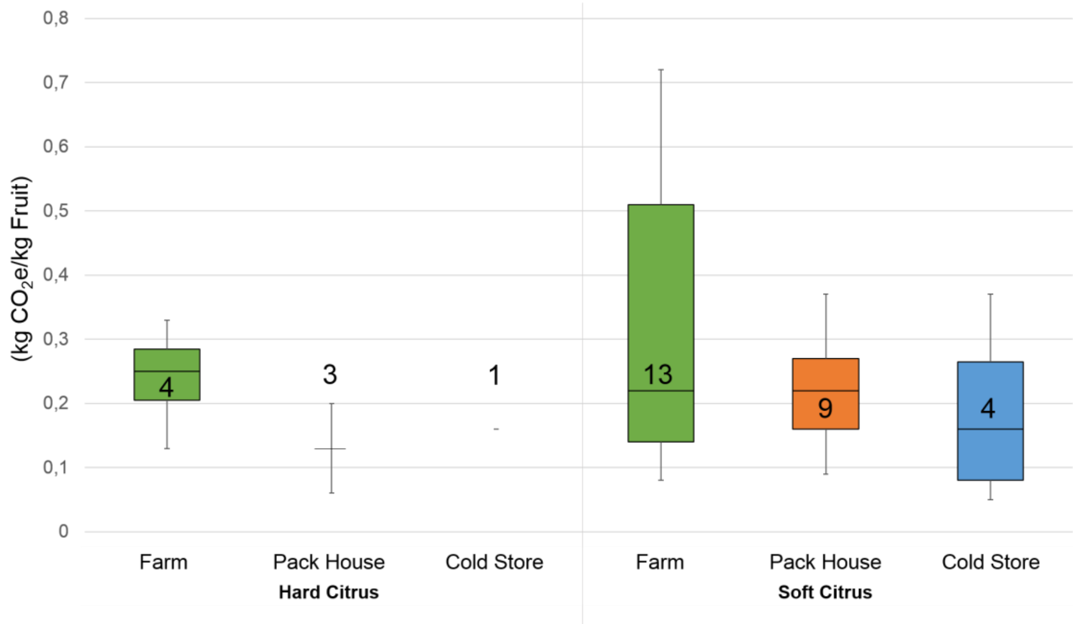


Figure 9: CCC carbon footprints for Western Cape citrus

The sample size problems mentioned above, can be resolved by considering South African scale data shown in Figure 10. Thus to get a more representative range of values for hard citrus, the South African values are used to calculate and compare components of the sectors' carbon footprint. Again, the farm sector is the most important using both Figure 9 (soft citrus) and Figure 10 (hard citrus).

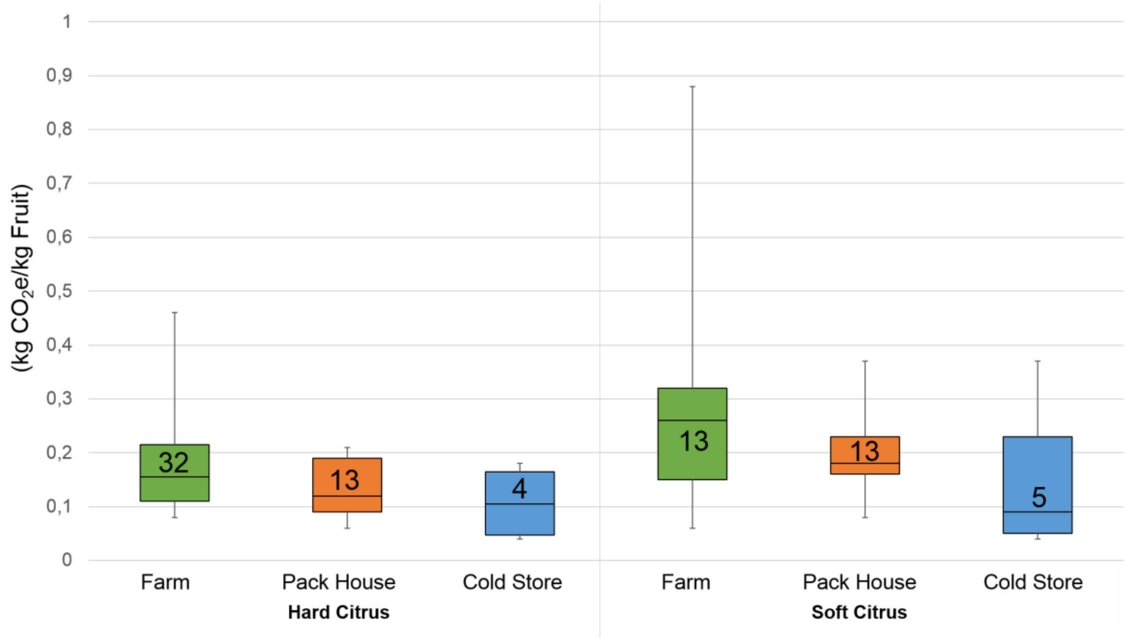


Figure 10: CCC carbon footprints for South African citrus

3.4. Table Grapes

The "table grapes sector" is considered to contain both table and dry grapes, in alignment with Hortgro statistics and the agricultural census, as highlighted in the sector overview previously. The carbon footprints for the Western Cape (Figure 11) and South Africa (Figure 12) are roughly in line with the distribution of Western Cape and non-Western Cape production, with more than half of the observations being Western Cape based.

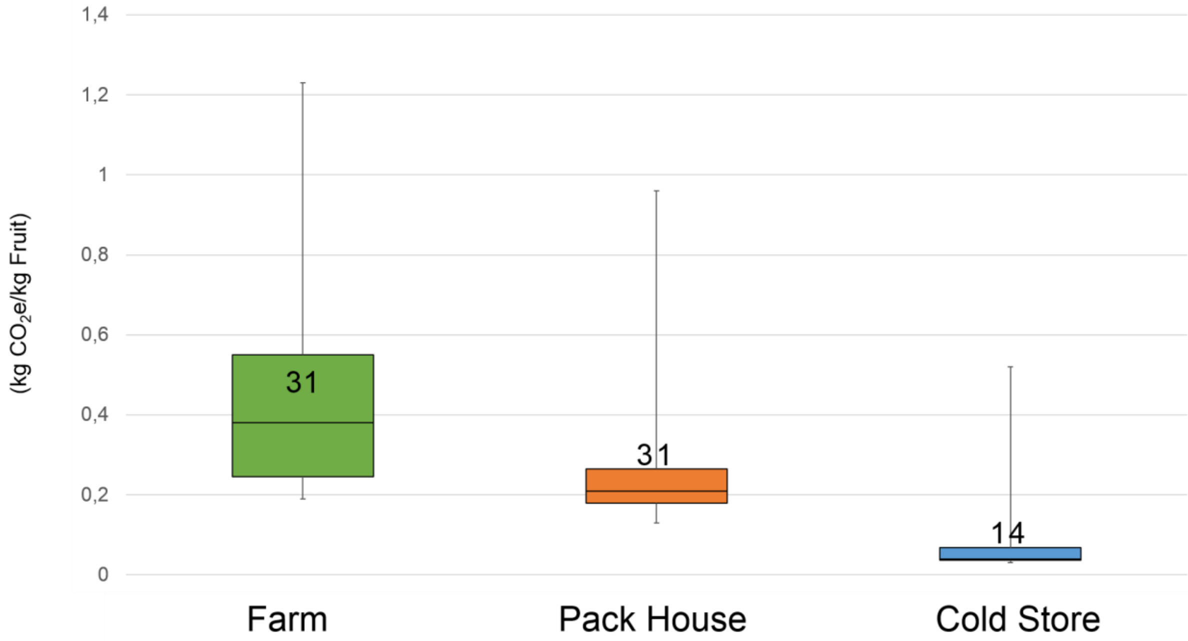


Figure 11: CCC carbon footprint for Western Cape table grapes

In line with the trends seen in the other commodities, the largest component of the carbon footprints are within the farming sector. It is also interesting to note that the large outlier for the cold store in the South African sample (Figure 12) illustrates the large impact that cold storage can have on carbon footprints. A possible explanation for this difference is the observation that grapes not produced in the Western Cape have larger cooling requirements, possibly due to hotter climates such as the Northern Cape.

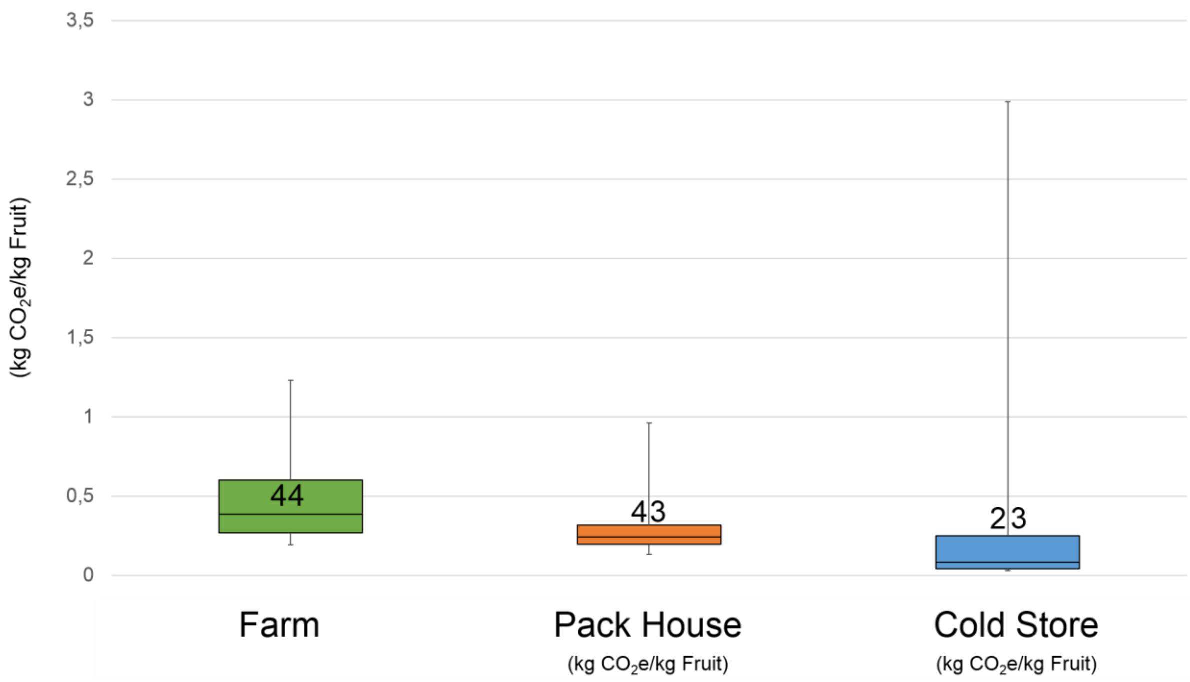


Figure 12: CCC carbon footprint for South African table grapes

4. Interventions

4.1. Farm Level

Carbon footprints at a farm level have two main drivers: energy and fertiliser use. The use of synthetic fertiliser is highlighted due to its fossil fuel intensive production (CCC, 2014e, p. 16). These results are also reflected in the detailed wheat case study (Pineo, 2015a), as well as the modular extrapolation of agricultural LCA (MEXALCA). The MEXALCA takes nine key characteristics (modules) of farming to approximate Life Cycle Assessment (LCA) results which can be broadly divided into these two drivers for climate change impacts (Roches, et al., 2010)[8].

At the farm level, irrigation is often the largest energy use area. Case studies completed by the CCC (2014e) illustrate the value of using more efficient irrigation through the use of variable speed drives, which result in energy savings of 35-75%. Other mitigation strategies include interventions to reduce water use through improved management. This includes tools such as Fruitlook, that allow better monitoring of plants' water needs using satellite imagery, as illustrated in Goudriaan, *et al.* (2014).

4.2. Pack and Cold Store

The use of photovoltaics has also been shown to be effective in decreasing demand for high carbon grid-energy, the supply of which is also currently unreliable (CCC, 2014c, p. 13; CCC, 2014, p. 21). This intervention has potential application across the different levels of production, from farm through to packaging, as all stages have some energy needs. However, with the exception of cooling, the energy demands are relatively low. When not considering cooling, the pack houses' greatest GHG emissions source is the packaging material with pome and citrus pack houses being less carbon intense due to lower packaging requirements of these 'harder' fruits. However, most of the fruit packaging is driven by exporter demands rather than local producers' choice thus there is limited room for innovation.

Considering the controlled atmosphere (CA) storage facilities used in the pome fruit sector, their carbon intensity is higher than the cold store facilities used for other fruit, not due to efficiencies, but rather due to the extensive time that fruit is kept in CA storages. This highlights that consumption of out of season fruits results in higher GHG emissions.

4.3. Logistics

CCC has modelled the different transport methods used by fruit namely: road, sea and air freight. Results indicated that transport to international markets were the most significant component to the carbon footprints of transport. Also, carbon footprints were significantly higher for air freight than sea freight. However, given the perishability of fruit, these are not perfect substitutes and it may not be realistic to suggest sea transport for all fruit. Additionally, this illustrates the possibility of a trade-off between stringent packaging requirements and emissions embodied in transport.

[8] They have 9 modules which consider these components in more detail and also include machinery. Drying, Irrigation, Pesticides K fertiliser, P fertiliser N fertiliser, Variable Machine use, Var Machine use for Tillage, Machine Fix

5. Total Sector Estimates

Given the carbon footprints of CCC in conjunction with the industry production statistics, an estimate of the GHG emissions for the entire sector can be made. Within the broader scope of the RRFM project as laid out in Figure 1 this would form part of the “resource needs” work, validating and updating the macro-economic work done previously. In line with the macro-economic model the estimates are in line with the fruit sectors not covered by the wine report (Janse van Vuuren, 2015b), namely: table grapes and other fruits, including citrus.

The breakdown of the carbon footprint of other fruit is shown in Figure 13, highlighting that pome fruit is the most significant category, followed by stone fruit and then the citrus sector. Apples are the most significant single commodity in terms of carbon footprints. As was the case for the wine sector report, estimates were derived using average carbon footprints within the Western Cape[9]. To account for the variability of results a low (1st quartile) and high estimate (3rd quartile) of carbon footprints were used to calculate a range within which carbon footprints can be reasonably expected to fall. With a detailed breakdown of the calculations shown in the appendix in Table 7 a fact to take into consideration is that only pome, stone and citrus fruits are included, as CCC only has carbon footprints for these sectors. Thus it excludes: pomegranate, olive and guava; though these together only make up just under 2% of production the underestimation their exclusion causes was seen as acceptable.

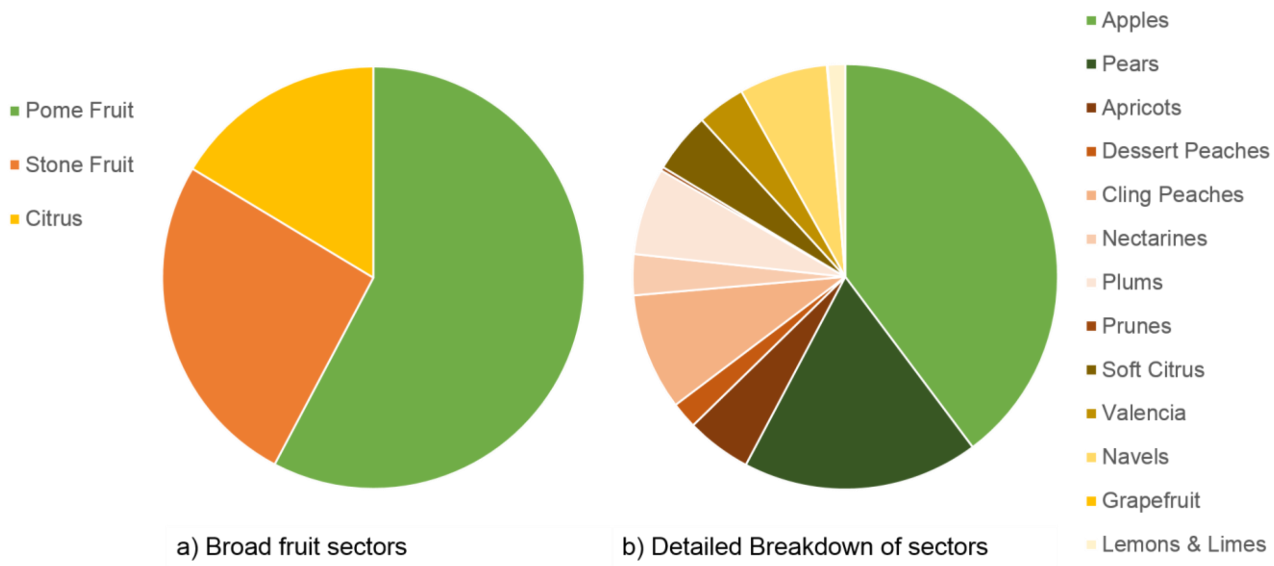


Figure 13: Western Cape "other fruit sector’s" carbon footprint breakdown[10]

Similarly, a sectoral estimate can be derived for the table grape sector (table grapes and grapes for raisin production). Given that there is only one carbon footprint for the sector, the distribution between the sectors would be the same as the production shares as shown in Figure 14. As mentioned in the overview section, the majority of the sector is table grapes with raisins making up nearly 45%. This is, under the assumption that the drying ratio is 4.5 (fresh fruit weight/raisin weight) a gross oversimplification but it provides a reasonable estimation as it is a mid-range ratio from Christensen (2000, p. 194). With a detailed breakdown provided in the appendix in Table 6. Raisins’ carbon footprint

[9] Except hard citrus where the SA figure was used due to small (4) sample size.
[10] Own calculations using CCC carbon footprints and industry statistics

may be slightly underestimated, as no inputs into drying are accounted for. However, as most are sun dried this is unlikely to have a significant impact.

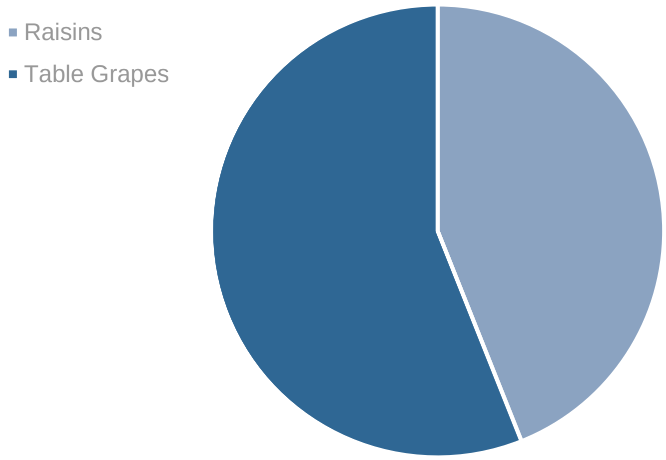


Figure 14: Table grape sector emissions breakdown

5.1. Comparison of Sector Results and Initial Estimates

The initial estimates for the sectors were derived from the Eora MRIO database. These were based on a national estimate for agriculture, which was scaled down to the province using GDP contributions of sectors, and then to the sub-sectors within the macro-economic model. This was initially done based on 2006 data in line with the economic model. This paper made use of more up to date 2010 data to compare to the sector estimates derived in this paper. Land use and land use change were removed due to inconsistencies between different data sources as different inclusions and exclusions within land and land use result in it being treated as either a large emissions source or carbon sink, making sources incomparable. This also highlights the need for more comprehensive LCA's to fully understand the carbon fixing component of agricultural production in conjunction with land use changes.

Table 3: Estimates of GHG emissions (Gg CO_2 e) of sectors in 2010

	Table Grapes	Wine Grapes	Other Fruit & Citrus
Eora MRIO Excluding LULUCF*	662	1046	1491
National GHG inventory excluding land**	839	1325	1889
*Own calculations using Eora data (worldmrio.com) **Own calculations using DEA			

These results can be contrasted with the estimates derived for the sector as summarised in Table 4 with details in the appendix in Table 6 and Table 7. The results are significantly lower than those estimated previously as the initial results allocated all emissions based on value add of sectors. Additionally, only the farming component of the carbon footprints was considered as the packing and storage was considered to be part of the agro-processing sector.

It is also noteworthy that the range of GHG emissions estimates are quite large, highlighting the variability of carbon footprints, especially given carbon footprints that cannot be linked to different drivers of emissions. Given that livestock is generally believed to be highly carbon intensive and they make up a significant component of agriculture, all other estimates of the original agricultural sub-sectors are likely to be overestimates, as these emissions are spread over all sectors. Direct emissions from livestock are explored in the accompanying report (Pineo, 2015b) with an updated estimate of emissions from agriculture envisioned, making use of these reports in conjunction with the national GHG inventory scaled to the province.

Table 4: Sector estimates of carbon footprints Gg CO_2 e) using CCC and industry statistics

	Estimate	Range
Other Fruit	390	250-470
Table Grapes	110	62-140

6. Discussion

One of the recurring themes within agricultural carbon footprints is the variability of results. CCC dealt with the variability by disaggregating results to regions, though even then, variability within regions remained high. Given the project's focus on sectors rather than regions the choice was made to consider the aggregated production per sector in the Western Cape. To account for the variability of the carbon footprinting results a range for carbon footprints (1st to 3rd quartile) were reported.

As anticipated, the results were lower than the estimates originally derived from scaled national agricultural estimates as part of the SAM analysis report (Janse van Vuuren, 2015a). This is further supported by comparison of different fruits and vegetables in Switzerland that showed that the fruits considered (apples, pears & grapes) were in the lower range of carbon intensities of fruits and vegetables considered (Stoessel, et al., 2012). Fruit products have also been shown to have lower environmental impacts of foods within western diets, though these studies are based on environmental assessments with generic production, and do not account for specifics within orchards and supply chains (Cerutti, et al., 2015, pp. 334-335).

Best practice for Life Cycle Assessments of fruit suggest production be considered in 6 phases: nursery, establishment, low production years after establishment, full production years, low production year after full production years and dismantling (Cerutti, et al., 2015, pp. 368-369). This indicates a clear area for more detailed analysis. However, as the CCC system has been set up to consider the carbon footprints per year, it will be difficult to restructure this system and to obtain the data required.

When considering transport to international markets, air transport dominates carbon footprint results (7.0 - 7.5 kg CO_2e/kg fruit) making the other components[11] near irrelevant by comparison. Sea transport is significantly lower (0.2 - 0.4 kg CO_2e/kg fruit) but still very significant, composing at least 20% of non-wine fruit's carbon footprint. Making it a key area to consider as well as more fundamentally promoting the purchase of locally produced fruit, which would however be in conflict with our large fruit exports (CCC, 2014e, pp. 7-14).

The key issue that remains however, is understanding the variance of results. Ideally results will be calculated per cultivar rather than per fruit, as variation of characteristics between fruits is a key component driving results. This is clearly illustrated through different water needs of different cultivars, both in terms of water needs as well as energy needs for irrigation, with water needs shown to differ between cultivars of apples by a factor of 3 (Gush & Taylor, 2014, p. 35). With further work underway to consider the water needs of different citrus and apple cultivars. Additionally, Hortgro's tree census data could be used to explore this issue further in a similar manner as the SAWIS data can be used to unpack the carbon footprint of wine as highlighted in the wine report (Janse van Vuuren, 2015b).

[11] Farming, packing, cooling, local transport.

7. Conclusion

Given the scarcity of data around carbon emissions currently this report provided the best broad estimate of fruit sectors (excluding wine covered in Janse van Vuuren (2015b)) currently available. This was done using CCC's carbon footprints within the Western Cape. These estimates were lower than initial estimates which were based on national emissions scaled to provincial level, and then to the different agricultural sub-sectors. This was in line with expectations as livestock sectors are generally seen as the most significant source of GHG emissions within agriculture, and given that fruits are in the lower range. Additionally, key areas of intervention were highlighted such as energy use driven by irrigation and fertiliser use, with fertiliser also having very large embedded energy and emissions. Transport to international markets was also shown to be one of the largest sources of carbon emissions for fruits. This reiterates the findings of the macro-economic work that highlights transport as a key sector to examine when considering emissions. Currently only a broad sector understanding is possible with the information currently available though future research could unpack this further through considering the different cultivars carbon footprints with work already showing that different cultivars have large variations in resource needs.

8. Bibliography

CCC, 2014a. *Table Grape Industry Report - Year 2: 2013 Carbon footprint benchmark report.* [Online] Available at: http://www.climatefruitandwine.co.za/Documents/CCC_Table%20Grape%20Industry%20Report_2013.pdf [Accessed 25 February 2015].

CCC, 2014b. *Stone fruit Industry Report - Year 2: 2013 Carbon footprint benchmark report.* [Online] Available at: http://www.climatefruitandwine.co.za/Documents/CCC_Stone%20fruit%20Industry%20Report_2013.pdf [Accessed February 25 2015].

CCC, 2014c. *Pome fruit Industry Report - Year 2: 2013 Carbon footprint benchmark report.* [Online] Available at: http://www.climatefruitandwine.co.za/Documents/CCC_Pome%20fruit%20Industry%20Report_2013.pdf [Accessed 25 February 2015].

CCC, 2014d. *Citrus Industry Report - Year 2: 2013 Carbon footprint benchmark report.* [Online] Available at: http://www.climatefruitandwine.co.za/Documents/CCC_Citrus%20Industry%20Report_2013.pdf
[Accessed 25 February 2015].

CCC, 2014e. *Industry Level Trends report: Year 2 - 2013 Carbon footprint results for the CCC South African fruit and wine sample group.* [Online]
Available at: http://www.climatefruitandwine.co.za/Documents/CCC_Industry%20Level%20Trends%20Report_2013.pdf [Accessed 25 February 2015].

CCC, 2014. *Wine Industry Report - Year 2: 2013 Carbon Footprint Results.* [Online] Available at: http://www.climatefruitandwine.co.za/Documents/CCC_Wine%20Industry%20Report_2013.pdf [Accessed 9 December 2014].

Cerutti, A. K. et al., 2015. Life Cycle Assessment in the Fruit Sector. In: B. Notarnicola, et al. eds. *Life Cycle Assessment in the Agri-food Sector: Case Studies. Methodological Issues and Best Practices.* New York: Springer International Publishing, pp. 333-388.

Cerutti, A. K. et al., 2013. Environmental sustainability of traditional foods: the case of ancient apple cultivars in Nothern Italy assessed by multifunctional LCA. *Journal of Cleaner Production,* Volume 52, pp. 245-252.

Christensen, P. L., 2000. Harvesting and Drying Raisin Grapes. In: *Raisin Production Manual.* s.l.:UNCANR Publications, pp. 191-216.

Citrus Growers' Association of Southern Africa, 2008. *Key Industry Statistics 2008,* Durban: Citrus Growers' Association of Southern Africa.

Citrus Growers' Association of Southern Africa, 2014. *Key Industry Statistics 2014,* Durban: Citrus Growers' Association of Southern Africa.

Development Bank of Southern Africa, 2008. *Social Accounting Matrices (SAMs).* [Online] Available at: http://www.dbsa.org/EN/DBSA-Operations/Proj/Tools/Pages/SAMS.aspx
[Accessed 26 June 2014].

Goudriaan, R., Jarmain, C. & Roux, A., 2014. *Evaluating Hexriver Valley grap cultivation using Fruitlook information.* [Online] Available at: http://www.wineland.co.za/technical/evaluating-hexriver-valley-table-grape-cultivation-through-fruitlook-information [Accessed 3 March 2015].

Gush, M. B. & Taylor, N. J., 2014. The water use of selected fruit tree orchards (Volume 2): Technical report on measurements and modelling. *WRC Report No. 1770/2/14.*

Hortgro, 2008. *Key Deciduous Fruit Statistics 2008,* Stellenbosch: Hortgro.

Hortgro, 2014. *Key Deciduous Fruit Statistics 2013.* [Online] Available at:
http://www.hortgro.co.za/wp-content/uploads/2014/06/Key-deciduous-Fruit-Statistics-2013.pdf
[Accessed 25 February 2015].

Janse van Vuuren, P. F., 2015a. *Regional Resource Flow Project – Social Accounting Matrix Analysis,* Cape Town: GreenCape.

Janse van Vuuren, P. F., 2015b. *Wine Industry Analysis Using Life Cycle Thinking,* Cape Town: GreenCape.

Olive Directory, n.d. *Industry Dynamics.* [Online] Available at: http://www.olivedirectory.co.za/index.php?option=com_content&task=view&id=13&Itemid=29 [Accessed 23 February 2015].

Pineo, C. B., 2015a. *Using Combuds for LCAs: Wheat Case Study,* Cape Town: GreenCape.

Pineo, C. B., 2015b. *Regional Resource Flow Analysis: Overview of the Carbon and Resource Intensity of Livestock, Dairy and Game in the Western Cape,* Cape Town: GreenCape.

Roches, A. et al., 2010. MEXALCA: a modular method for the extrapolation of crop LCA. *International Journal of Life Cycle Assessment,* Volume 15, pp. 842-854.

SATI, 2008. *Statistics Booklet 2007/2008.* [Online] Available at: http://www.satgi.co.za/admin/Upload/pdfs/SATI_A5_Book%5B1%5D.pdf
[Accessed 6 March 2015].

SATI, 2014. *Statistics Booklet 2013/2014.* [Online]
Available at: http://www.satgi.co.za/admin/upload/pdfs/2014%20Stats%20Book.pdf [Accessed 3 March 2015].

SAWIS, 2014. South African Wine Industry Statistics. Issue 38.

Stoessel, F., Juraske, R., Pfister, S. & Hellweg, S., 2012. Life Cycle Inventory and Carbon and Water FoodPrint of Fruits and Vegetables: Application to a Swiss Retailer. *Environmental Science & Technology,* 46(6), pp. 3253-3262.

9. Appendix

Areas of fruit planted, and tonnage produced using Hortgro (2014), Citrus Growers association (Citrus Growers' Association of Southern Africa, 2014), land use survey (DOA) for both South Africa as a whole and the Western Cape specifically.

Table 5: Sector overview of fruit sectors 2014

	Crop	Hectares		Tonnes	
		WC	SA	WC	SA
citrus	Oranges	7 848	53 390	205 700	1 548 609
	Lemons	1 246	4 929	36 094	143 441
	Naartjies	1 163	2 796	32 626	70 800
	Other Citrus	561	5 313	17 769	198 761
subtropical fruit	Other Subtropical Fruit*	440	17 712	7 778	181 345
deciduous fruit**	Apples	15 775	19 667	651 669	761 828
	Pears	9 501	10 754	313 819	337 859
	Peaches	6 759	8 513	132 205	157 087
	Water Melons	495	2 133	8 154	35 362
	Other Deciduous Fruit	36 604	39 443	122 072	151 665
*Subtropical fruits included in census: pineapple and bananas have no production in WC					
**Viticulture component that is included in agricultural census is excluded as constitute table and wine grape sectors in SAM					

The areas of fruits produced both nationally and within the Western Cape are illustrated in Figure 15 for greater clarity.

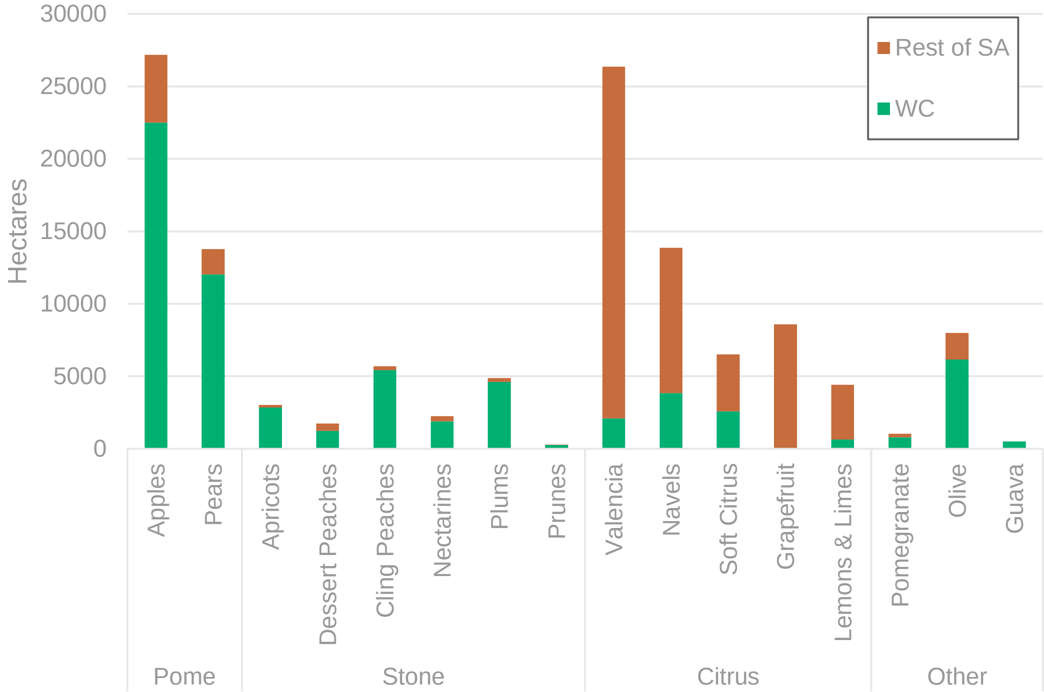


Figure 15: South African and Western Cape fruit sectors (hectares)

A detailed breakdown of the carbon footprints for the "table grape" sector are shown in Table 6 with "other fruit" sectors shown in Table 7.

Table 6: Details of "table grape sector's" carbon footprint calculations

	Production	CF low	CF Mean	CF High	CF low	CF Mean	CF High
Table Grape Sector	(Tonnes)	(tonne CO2e /tonne)			(tonne CO2e)		
Raisins	110658*	0,25	0,44	0,55	27111	48297	60862
Table Grapes	141058**				34559	61565	77582
Total	165649				40584	72298	91107
*Hortgro (2014) production times 4.5 drying ratio **SATI (2014) statistics							

Table 7: Details of "other fruit sector's" carbon footprint calculations

	Production (Tonnes)**	CF low	CF Mean	CF High	CF low	CF Mean	CF High
		tonne CO2e /tonne			tonne CO2e		
Apples	718440	0,15	0,22	0,2575	104174	155310	184998
Pears	324502				47053	70150	83559
Pome Fruit					**151227**	**225460**	**268558**
Apricots	57474	0,21	0,34	0,4	12070	19328	22990
Dessert Peaches	23423				4919	7877	9369
Cling Peaches	103255				21684	34723	41302
Nectarines	36123				7586	12148	14449
Plums	77000				16170	25894	30800
Prunes	3260				685	1096	1304
Stone Fruit					**63113**	**101066**	**120215**
Soft Citrus	57929	0,14	0,31	0,51	8110	17913	29544
Valencia	81110	0,11*	0,18*	0,22*	8922	14296	17439
Navels	149193				16411	26295	32076
Grapefruit	1264				139	223	272
Lemons & Limes	29485				3243	5197	6339
Citrus					**36826**	**63924**	**85670**
Pomegranate	1631	-	-	-	-	-	-
Olive	6164	-	-	-	-	-	-
Guava	25082	-	-	-	-	-	-
Other					**-**	**-**	**-**
Total	**1695335**				**251165**	**390449**	**474442**

* South African figures used due to small (4) sample size for Western Cape
**From industry statistics detailed in Table 5