Final Report -HortCarbon Info, June 2022

DCAP 2.1 - DAF #7 Project

"Identifying and Reducing Greenhouse Gas (GHG) Emissions in Horticulture (*HortCarbon Info*)"

***HortCarbon Info* is publicly** available on the [DCAP Website]

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Summary.

A Web Tool (*HortCarbon Info*) has been developed to enable growers of Horticultural crops to calculate their Carbon Footprint.

Electricity used for irrigation and refrigeration to cool produce, Fuel used in farming operations, Nitrogenous Fertilizers and Crop Residues are the major on-farm contributors to GHG emissions in Horticulture.

Greenhouse gas emissions from the manufacture and transport of inputs for horticultural production are **not included** in this Web Tool. Nor are the emissions associated with transport and marketing of horticultural crops which are sold through wholesale and retail outlets. They are not under the control of the farm business manager, so cannot be modified easily. A Life Cycle Analysis needs to be undertaken to account for the emissions from these off-farm sources

A range of potential management decisions can and are being used by horticultural businesses to reduce greenhouse gas emissions from horticultural production systems.

HortCarbon Info contains additional information to assist in the understanding of GHG emissions, and how these might be reduced or mitigated, and to explain some of the uncertainties associated with calculating and reducing emissions.

The National Greenhouse Accounts (NGA) Factors 2021, National Inventory Report 2019, Refinement to the 2006 IPCC Guidelines and the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, are the sources of Equations and Emission Factors used in the development of *HortCarbon Info*.

The emission factors used in this Web Tool can and will be easily updated each year from National Greenhouse Accounts (NGA) Factors. The most recent data being from the August 2021 National Greenhouse Accounts.

Queensland Government

Greenhouse Gas (GHG) emissions from horticultural operations are also very small in comparison to other agricultural industries, and other sectors. Greenhouse gas emissions from Australian Horticulture are ~1% of all Agricultural emissions (i.e., Agriculture in Australia contributes ~14% of all GHG's) – (see Appendix I). **Therefore, Horticulture is a miniscule emitter of GHG's**.

The main driver for implementing management decisions which reduce GHG emissions, has been cost reduction. This is because costs of production are continually rising, and incomes have not risen to offset these increasing costs.

Several of the business managers who have taken part in on-farm *HortCarbon Info* discussions and analysis to-date have mentioned and been aware of GHG's and environmental impact issues. This new ***HortCarbon Info* Web Tool** provides them with an accurate, repeatable and established methodology to quantify the level, as well as the changes to their business carbon footprint. Though these changes often result from increases in efficiency and the pursuit of lower production costs, business managers can now accurately document these improvements. This farm carbon footprint data is of increasing interest (and in some cases demanded) by Australian commercial fruit and vegetable resellers (the supermarkets & exporters).

Using the *HortCarbon Info* Index (tCO_2-e/tonne of product marketed), a comparison with other agricultural sectors (grains and grazing) once again demonstrates that GHG emissions from the horticulture sector, are very small) – (see Appendix I).

There are valid reasons for reducing GHG emissions in horticulture, and they are related to reducing costs of production and being able to demonstrate to the community that, although horticulture is a miniscule emitter of GHG's, most businesses want to play a part in being environmentally sustainable. The "market" will have a part to play in this decision as well. Already some growers have been asked to demonstrate their environmental credentials to the market, and it is likely that requests for this requirement will increase over time.

<u>Management decisions</u> which can (and are being used to) reduce GHG emissions in horticulture are as follows: -

- On-farm solar (plus batteries where appropriate).
- Variable speed drive (VSD) electric motors on irrigation pumps.
- Other Water Use Efficiency (WUE) techniques.
- Improved management of nitrogen fertilizer rates and timing.
- Upgrading (or replacing cool rooms) using compressors with improved efficiency.
- Air or drop door curtains & electric openers on cold room doors to reduce loss of chilled air.
- New cold room installations can be better insulated (including under slab) to improve efficiency.
- Use of lower Global Warming Potential (GWP) refrigerants in cool rooms.
- Improved efficiency air conditioners & lighting in pack sheds, offices and machine cabs.
- More fuel-efficient tractors and other vehicles used on farm.
- Waste recycling and minimisation.
- Reduced fuel from more efficient (less energy intense tillage – e.g., rotary hoe vs strip discs).
- Minimal and Zero-till.

Table of Contents.

<u>Introduction</u>.

On-farm Greenhouse Gas (GHG) emissions occur in horticultural production systems from the use of <u>Electricity</u> for irrigation, packing shed operations and refrigeration (carbon dioxide emitted at the Generator); <u>Fuels</u> such as diesel and petrol in tractors and other vehicles used on farm (carbon dioxide); <u>Nitrogenous Fertilizers</u> (nitrous oxide); <u>Crop Residues</u> incorporated at the completion of harvest (nitrous oxide); and <u>Waste</u> (carbon dioxide and methane).

Data relating to these on-farm inputs which create these emissions, is recorded by producers as part of their accounting systems and enable the identification and calculation of GHG emissions from on-farm operations, using a calculator such as the Web Tool, *HortCarbon Info*.

The original HortCarbonInfo spreadsheet was used as the basis for the updated refined and improved on-line web based *HortCarbon Info* Web Tool, which has been developed and tested with key Queensland vegetable production businesses and managers, to enable growers of Horticultural crops to calculate their Carbon Footprint.

A number of south-east Queensland growers (vegetables and fruit) have confidentially provided data from their accounting systems as input to *HortCarbon Info* in 2022 (see Appendix II and III). These data have been used to update the original HortCarbonInfo Excel spreadsheet and check on the accuracy of the coding for the Web Tool (*HortCarbon Info*). The collaborating business managers who provided 'real life' data also received a confidential *HortCarbon Info* report which was discussed with them.

<u>Sources of GHG Emissions</u> from Horticultural Production Systems.

The output from *HortCarbon Info*, using input data from a number of south-east Queensland growers (vegetables and fruit) in 2022, has revealed the following **sources of greenhouse gasses as major on-farm contributors** to the on-farm carbon footprint of these farm businesses **(in order of significance).** These five components represent approximately 93% of GHG emissions from these businesses: -

- Electricity (irrigation and cool rooms)
- Fuel (mainly diesel) used in farming operations
- Nitrogenous fertilizers
- Emissions from Crop Residues
- Waste

Additionally, **the following sources of GHG's were identified as <u>minor</u> on-farm contributors** to the carbon footprint of growers who provided input data from their production records (in order of significance): -

- Lime and Dolomite
- Losses from refrigerants
- Leaching and runoff
- Atmospheric nitrogen deposition
- Urea

A comparison of outputs from the earlier (less detailed) versions of HortCarbonInfo (2008 to 2014), has revealed similar results. This new Web version (*HortCarbon Info* 2022) contains a number of additional parameters - viz. Calculations of GHG emissions from Crop Residues; Urea; Lime and Dolomite; Atmospheric Nitrogen Deposition and Leaching and Runoff, so an absolute comparison with historical input data is not possible.

Emissions from Crop Residues is the only additional parameter in the 2022 version of *HortCarbon Info* to be included in the “major” emissions group. The other additional parameters are minor contributors to the on-farm carbon footprints of the horticultural producers who have provided input data.

By comparing the 2022 output data, with that collected from 2008 to 2014, the significant sources of GHG’s remains the same (with the addition of emissions from crop residues). All other sources are (and remain as) minor sources of GHG emissions.

<u>Potential Management Decisions</u> which are capable of reducing GHG Emissions in Horticulture.

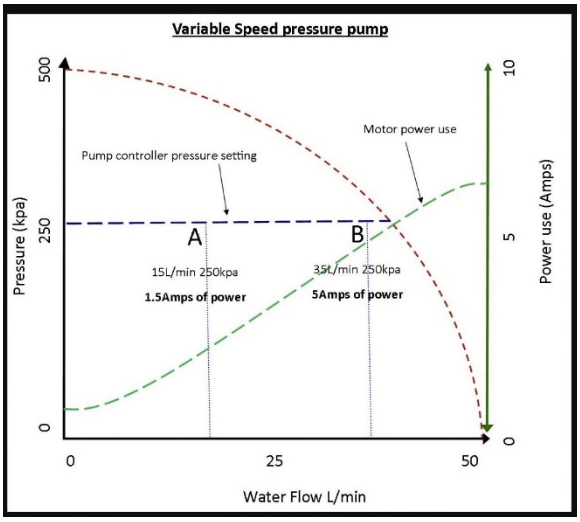
1. The following are **<u>the major on-farm contributors to GHG emissions in Horticulture</u>** (as revealed from output data from horticultural growers in South-East Queensland) - Electricity (irrigation and cool rooms); Emissions from Crop Residues; Fuel (mainly diesel) used in farming operations; Nitrogenous fertilizers and Waste.

**** Electricity -** The consumption of electricity is **the major contributor** to GHG emissions on all farms where *HortCarbon Info* input data has been provided. The contribution from Electricity varies from 40 to 60% of the total on-farm carbon footprint for horticultural producers. Consequently, this is one of the main potential opportunities to reduce a growers' on-farm carbon footprint.

Electricity is used for Irrigation (electric pumps), Cooling produce (pre-cooling and refrigeration), Air conditioning (packing rooms, offices, etc.) and Packing Sheds (electric motors and lighting for sorting, processing, pre-packing and packing).

<u>On-farm Solar</u> (and battery) systems have been installed by many businesses to reduce the dependence on and cost of grid energy, as well as improve reliability where blackouts occur regularly. Continuity of electrical supply is critical for maintaining correct temperatures in cool rooms containing perishable product, as well ensuring irrigation can be operated at all times to maximise growth, quality & yield potential of high cost and return horticultural crops.

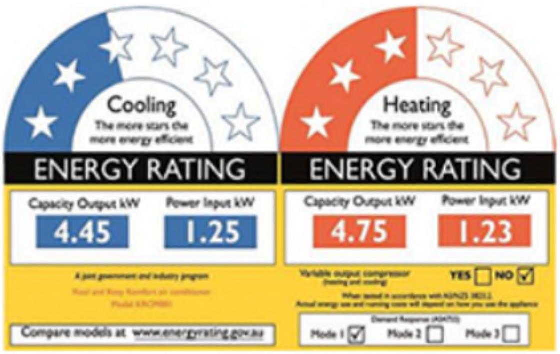
<u>Variable Speed Drive</u> - An electric irrigation pump is often required to deliver a range of flow rates and pressures on farm, because of different sizes and locations of production fields. The irrigation setup, and the pump specifications are often designed to meet the greatest output demand of both flow and pressure. Therefore, electric pumps will operate inefficiently for some of the time. This provides an opportunity to reduce energy requirements by using a **variable speed drive** (VSD), and consequently reduce GHG emissions from reduced electricity consumption.



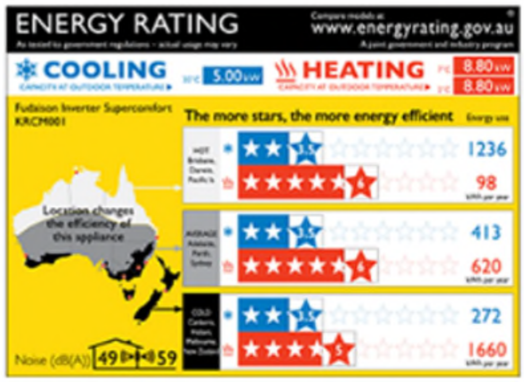
An example is where the water level in an irrigation bore falls during the production season. The pump is sized for the maximum drawdown and is therefore over-sized for some of the season. By using a VSD, the total head developed by the pump can be adjusted as the water level in the bore changes, and consequently, electricity consumption is reduced.

Improved efficiency Compressors and Air Conditioners in cool rooms and offices.

a) Upgrading (or replacing) cool rooms using compressors with improved efficiency.
b) Energy Rating of Air conditioners up to 65 kW has been changed as at 1 April 2020. Requirements include a new Zoned Energy Rating Label (ZERL), which gives consumers and installers more information about which air conditioner will perform best in their climate zone.



Old Energy Rating Label



New Zoned Energy Rating Label

Packing Shed Equipment – Upgrading (or replacing) electric motors and lighting using equipment with improved efficiency. LED (Light Emitting Diode) lighting is currently the most efficient and longest lasting technology on the market. More efficient LED's reduce the amount of energy required, as LED lights use up to 80% less energy to produce the same amount of light.

Incandescent lights convert ~90% of the energy used into heat. LED's produce less heat, and additional cooling system savings can be achieved in packing and cooling facilities, where additional lighting is required.

** **Fuel** is used in tractors, utes, trucks and motor bikes (2 and 4 wheel), on-farm for all operations associated with land preparation, planting, irrigation, pest and disease control, harvest and transport of product to packing facilities, and transport of workers to the field.

Upgrading to more fuel-efficient tractors and other vehicles used on farm will reduce these emissions.

** **Nitrogenous Fertilizers** are important inputs into all horticultural production systems. Nitrous oxide emissions from the addition of nitrogenous fertilizers to soils occurs when the nitrogen component of these fertilizers are denitrified to nitrous oxide under warm and wet conditions. The management of nitrogen fertilizer Rates and Timing is currently the most practical mechanism of managing N_2O emissions during the cropping phase. The high cost of nitrogen fertilizers will also be a driver for improved management of rates and timing of fertilizer applications.

Nitrous Oxide emissions from soils is a complex issue. Although not the most significant GHG emitted from farming activities in horticulture, management decisions which mitigate emissions are limited by cost and practicalities.

A more thorough understanding of emissions created through the use of nitrogenous fertilizers is provided by the following publication -

https://agriculture.vic.gov.au/climate-and-weather/understanding-carbon-and-emissions/nitrogen-fertilisers-improving-efficiency-and-saving-money

Fertilizer can be used more efficiently by:

- adjusting fertilizer rates and timing to coincide with plant needs
- using slow-release forms
- placing fertilizer close to where plants can utilize it

** **Crop Residues** in intensive vegetable production, are incorporated following harvest to control pests and diseases, and to prepare the land for a cover crop and/or an ensuing vegetable crop. Nitrous oxide emissions from crop residues occur when the nitrogen component of these ploughed-in crop residues is denitrified to nitrous oxide under warm and wet soil conditions.

The incorporation of vegetable crop residues can lead to relatively high and long-lasting post-harvest N_2O fluxes. These emission pulses are caused by the rapid decomposition of the vegetable residues as evidenced by the high soil CO_2 emissions after residue incorporation. This rapid decomposition of crop residues can create anaerobic microsites in the soil which, combined with an increased NO_3^- supply from residual N in the soil, result in highly elevated denitrification rates and show that crop residue management is an important factor influencing soil N transformations and N_2O emissions in vegetable production systems (Scheer et. al, 2014 and 2017).

Delaying incorporation until drier conditions prevail, may be a technique to reduce emissions. The need for cultural operations such as pest and disease management and soil preparation, may not provide this opportunity in many cases, in intensive vegetable production systems.

Nitrification Inhibitors (NI's) such as 3,4-dimethylpyrazole phosphate (DMPP) and 3-methylpyrazole 1,2,4-triazole (3MP + TZ) are capable of reducing N_2O emissions during the cropping phase of vegetable production, but not during the postharvest phase (following incorporation of crop residues). In a series of experiments in the Lockyer Valley in 2013/14, there was a clear effect of the addition of NI's on N_2O emissions and soil mineral N content over the cropping phase, where the application of NI reduced N_2O emissions by 20–60% compared to standard practice, with DMPP showing a greater mitigation potential. This demonstrates that the NIs were effective in reducing nitrification and subsequent denitrification and consequently decreased soil N_2O production, however, this mitigation was offset by elevated N_2O emissions from the NIs treatments over the post-harvest fallow period. (Scheer et, al, 2017).

This study highlights that the use of NI's in vegetable systems can lead to elevated N_2O emissions by storing nitrogen in the soil profile that is available to soil microbes during the decomposition of the vegetable residues. Hence the use of NIs in vegetable systems has to be treated carefully and **fertiliser rates need to be adjusted to avoid an oversupply of nitrogen during the post-harvest phase.**

The management of nitrogen fertilizer Rates and Timing, is currently the most practical mechanism for managing the potentially high levels of post-harvest GHG emissions from the incorporation of Crop Residues. The high cost of nitrogen fertilizers will also be a driver for improved management of rates and timing of fertilizer applications.

****** **Waste** in the form of cardboard and plastic packaging (necessary farming inputs); green waste (from processing and pre-packing operations); and plastic (e.g., single use trickle irrigation) are the main sources of waste on horticultural farms.

Multi-use trickle irrigation plastic pipe has been available for many years, and has been used by some growers, who get many years of continuous use from quality drip tube.

Recycling and composting other organic waste where appropriate and where facilities are available, will reduce the emissions from on-farm waste.

2. The following are **the minor on-farm contributors to GHG emissions in Horticulture** (as revealed by recent analysis output data from horticultural growers in Queensland) – Lime and Dolomite.
   Urea; Losses from refrigerants; Atmospheric nitrogen deposition and Leaching and runoff.

****** **Lime and Dolomite** are used on farm to ameliorate pH and soil structure. Adding carbonates to soils in the form of lime (e.g., calcic limestone ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$)) results in CO_2 emissions, as the carbonate reacts with acids in the soil to produce bicarbonate, eventually leading to the production of CO_2 and water. There is no known mechanism of mitigating these emissions, where lime or dolomite form an important function in managing soil pH.

****** **Refrigerants** - Some refrigerants are potent GHG's (Global Warming Potential from 2000 to 11,000) and contribute to a carbon footprint in the form of leakage from refrigeration and cooling systems on farm. Others have a low GWP (16 to 200). Regular maintenance, as well as selecting a low GWP refrigerant when installing, replacing and/or recharging a cooling facility will reduce the emissions from refrigerants.

****** **Leaching and Run-off** and **Atmospheric Nitrogen Deposition** occur where N_2O is produced from nitrogen leached from fields or emitted into the air as ammonia gas. Some of this nitrogen may then be converted to N_2O. The <u>management of nitrogen fertilizer Rates and Timing</u> is currently the most practical mechanism of managing N_2O emissions.

****** **Urea** is a fertilizer used to supply nitrogen. It is applied as a side dressing (solid fertilizer) and incorporated by cultivation or irrigation and is also used as a foliar fertilizer and in trickle irrigation systems. Adding urea to soils leads to a loss of the CO_2 that was fixed during the manufacturing process. Through the hydrolysis process, ammonium ions and carbon dioxide are formed. The ammonium ions are nitrified (by bacteria in the soil) to nitrate (which is utilised by plants), and the carbon dioxide is released to the atmosphere.

Hydrolysis -- $CO(NH_2)_2 + H_2O \rightarrow CO_2 + 2NH_3$

The <u>management of nitrogen fertilizer Rates and Timing</u> is currently the most practical mechanism of managing N_2O and CO_2 emissions during the cropping phase.

<u>Additional Information provided by *HortCarbon Info*.</u>

The *HortCarbon Info* Web Tool provides users with additional information on mechanisms to reduce GHG emissions

1. Greenhouse Gas Reduction in Horticulture

This topic has been covered in this Report in the sections - "Sources of GHG Emissions from Horticultural Production Systems" and "Potential Management Decisions which are capable of reducing GHG Emissions in Horticulture".

2. Forestry

The following information is provided by *HortCarbon Info*, to <u>**assist users in understanding if, and how**</u>, farm forestry can be used to sequester carbon in forest plantings to reduce a Carbon Footprint.

Trees and Carbon Sequestration.

There are currently two main sources of funding for Queensland-based carbon credit projects – the Queensland Government's Land Restoration Fund and the Australian Government's Emissions Reduction Fund - https://www.qld.gov.au/environment/plants-animals/habitats/regrowth/regrowth-carbon-credits

Carbon is an element, and the building block of all living things on earth. It is continuously cycled through plants and animals and exchanged with the atmosphere. As a forest grows the plants take carbon dioxide from the atmosphere and convert it to carbon stored in their leaves, branches and trunks by a process called Photosynthesis. Forests store carbon in several 'pools' including in living plant tissues, dead trees and shrubs, woody debris on the forest floor, and the soil.

Approximately half the dry weight of a living tree is carbon, stored for the life of the tree.
When forests are cut down and burnt or left to decay, the carbon in the trees and woody debris is released back into the atmosphere. A significant part of the forest's soil carbon is also released.

Grasses and pastures also take carbon from the atmosphere as they grow but they only store a fraction of the carbon a forest can. A considerable portion of the carbon that is taken up by trees will be released again if/when the tree dies and decomposes. Trees are a part of the carbon cycle as they grow, mature, then die and break down.

The amount of carbon they absorb, and store depends on the species, age, climate trees live in, the location and the quality of the growing seasons, etc.

Where country specific data is not readily available, the Intergovernmental Panel on Climate Change (IPCC) estimates a sequestration rate of 4.7 tonnes of carbon per hectare per year (i.e., 17t CO_2-e). [1 kg of carbon biomass translates to 3.67 kg CO_2 removed from the atmosphere**]**

In Australia, the CSIRO have developed a number of models to estimate carbon abatement from native forest regrowth.

Using the **"Landscape options and opportunities for carbon abatement calculator"** developed by CSIRO (https://looc-c.farm/methodDiscovery) **, <u>for a subcoastal region in south-east Queensland,</u> two scenarios are possible:

a) **Reafforestation by Environmental Plantings** could deliver <u>**15t CO_2-e per ha/year.**</u>

The Reforestation by Environmental Plantings action <u>involves establishing and maintaining native vegetation such as trees on land that has been clear of forest for at least five years.</u> Plantings can either be a mix of trees, shrubs and understory species native to the local area. Projects are required to meet a 'permanence obligation', meaning that the carbon stored in plants will remain stored for at least 25 years.

b) **Human-induced Regeneration of a Permanent even-aged Native Forest** could deliver 8t CO_2-e per ha/year.

For the Human-induced Regeneration of a Permanent even-aged Native Forest, the application must include evidence that for at least the last 10 years the land has been non-forest and that current management prevents native forest cover. Activities within this method include management to exclude livestock, and changes to livestock grazing patterns and feed regimes. Other activities include managing non-native plant species in the area and stopping actions that prevent native regrowth, such as vegetation clearing. Regeneration must arise from existing natural seed beds, rootstocks or lignotubers in the project area. Projects are required to meet a 'permanence obligation' meaning that the carbon stored in plants will remain stored for at least 25 years.

** **LOOC-C** *is the Landscape Options and Opportunities for Carbon abatement Calculator (LOOC-C) developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). It allows you to quickly assess what Emissions Reduction Fund might be right for your land and provides you with estimates of what carbon increases are possible based on project size, land condition, and method.*

To be able to sequester 100t CO_2-e each year, a grower will need to establish 6.6ha of native vegetation and maintain this planting for at least 25 years. At some point the amount of carbon sequestered will be equal to the amount of carbon released back into the atmosphere through decomposition of leaves, branches and roots. i.e., these trees will no longer be sequestering carbon. They will be cycling carbon. At this point another 6.6ha will need to be established and maintained to be able to continue to sequester 100t CO_2-e each year. The timing of this will depend on the species, age, climate the trees live in, location and the quality of the growing seasons. This could vary from 20 to 40 years.

A very useful reference to understanding trees and Carbon Sinks is :- (https://www.chiefscientist.gov.au/2009/12/which-plants-store-more-carbon-in-australia-forests-or-grasses).

t CO_2-e - *This is an abbreviation for tonnes of carbon dioxide equivalent. The various greenhouse gases differ in their effects on the climate, so to make calculations easier, the amounts of these gases are converted into an equivalent amount of carbon dioxide with the same effect on warming potential. While carbon dioxide is the primary greenhouse gas emitted through human activities, others include methane, nitrous oxide, and some other gases with industrial applications.*

(Source - https://www.des.qld.gov.au/climateaction/glossary)

3. Soil Carbon

The following information is provided by *HortCarbon Info*, to **assist users in understanding if, and how**, horticultural production systems can sequester carbon in soils to reduce a Carbon Footprint.

Soil Carbon Sequestration - awareness/overview information.

"Based on limited local data and overseas experience, considerable Soil Organic Carbon (SOC) sequestration potential exists in NSW agricultural land. The **highest potential exists in pasture land in the higher rainfall regions** (>450 mm), **both as permanent pastures or as ley pasture in the cropping zone.** Considerable increases can be achieved by pasture improvement and improved management practices" *(Chan KY, Cowie A, Kelly G, Singh BP, Slavich P (2008). Scoping Paper: Soil Organic Carbon Sequestration Potential for Agriculture in NSW. NSW DPI Science & Research Technical paper.*

Soil carbon sequestration potential in intensive Horticultural production systems is limited by several management practices that are currently standard practice - viz. **tillage** for crop establishment, weed control and residue incorporation; **fertilizer and irrigation** to maximise production; **short fallow periods** between cash crops, with limited or no pasture phase.

Several **management changes** are needed to achieve the potential described above in an intensive horticultural production system. Putting all these changes together into one management system on a horticultural farm may not be possible, however, "Ten Ways to build soil carbon" describes how to build soil carbon by '**Adding carbon** to the system', '**Reducing carbon losses** from the system', and '**Protecting carbon** already in the system'.

Horticultural businesses are already actively managing the inputs of fertilizer and irrigation, because of the need to maximise productivity while carefully controlling input costs in these high input systems. Other changes which will contribute to achieving this potential are:

- **Reduced tillage** (reduces carbon losses). Permanent Beds and Controlled Traffic systems are often incorporated to enable this change to be achieved in intensive vegetable production systems. Most fruit tree cropping systems already incorporate reduced (or zero tillage).
- **Reducing bare fallow** between cash crops (reduces carbon losses).
- **Increasing organic amendments** such as green manure crops, animal manures, compost, biochar, etc. (increases carbon input).
- Introduction of a **pasture phase** (reduces carbon losses and increases carbon input). Most intensive vegetable production systems are limited in their ability to have longer-term cover crops, or a pasture phase incorporated into the rotation. Most of these production systems are conducted on high-value land and deliver a product to markets that require consistent high-quality supply. Therefore, these high turnover production systems are very intensive in nature and not suited to a rotation using pastures.

HortCarbon Info Web Tool – development and testing

HortCarbon Info (HCI) was designed to allow all horticultural farms to assess their individual Carbon Footprint. We expanded our work program to also engage many of the Granite Belt based apple, pear (Perennial fruit) and strawberry growers, raising awareness of the Queensland Governments DCAP initiative and seeking their input into the design and functionality of *HortCarbon Info. This paid off and at our* June 2022 Granite Belt industry briefing, where we included a “live demonstration” of the Web Tool, these growers were well represented. This interactive “live demonstration”, meeting was popular and was also attended by a number of staff from Growcom, the USQ’s Future Drought Fund, a new local agronomist, as well as the local AusVeg Industry Development Officer.

This local forum (also attended by the DCAP Manager) was very interactive, we demonstrated the Web Tool “live on-screen”, asking the various people in the room to nominate a figure to include as an input in the appropriate HCI input cell (e.g., Electricity used at our Mock Farm). Once that input was entered, we asked another business manager to suggest a figure needed for the next part of the calculation (e.g., farm diesel use, or crop area or type etc) and so on. We worked right through the one-page input sheet – demonstrating what was needed and how user-friendly and easy the information input process is.

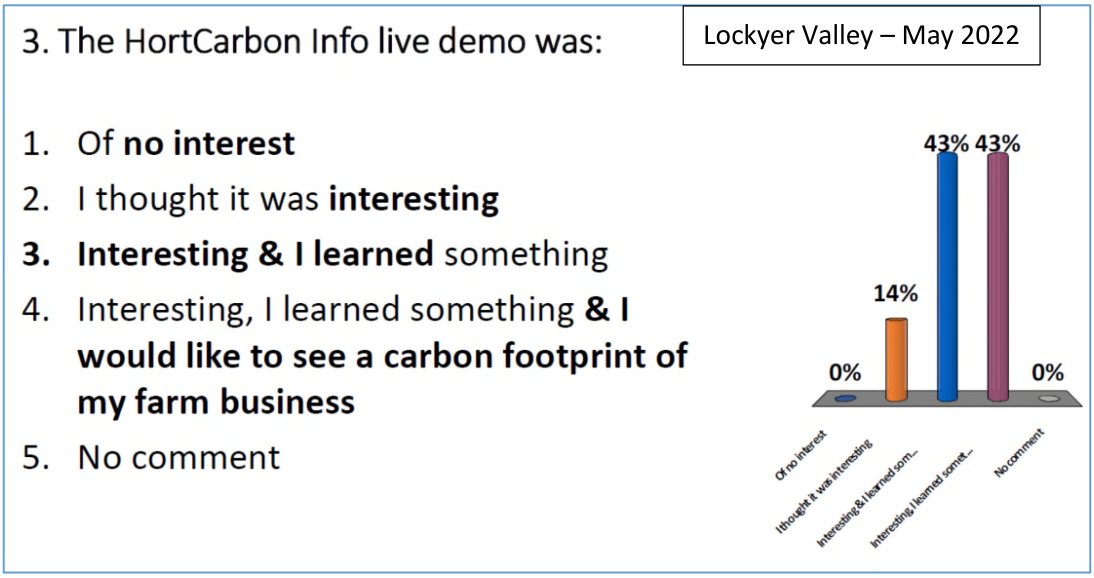
Once all this “Mock Farm “data was entered, the Web Tool calculated the result and showed the *HortCarbon Info* results page (see Appendix 3). This led to a discussion of the results. To underline how useful and informative the Web Tool is, we clicked back to the input page and added a few hundred KwHrs of Solar Power, so reducing the Mock Farms carbon Footprint – but also displaying the $ value saving (per annum) and the payback time for the Solar Array.

This process worked well, demonstrating the Web Tools practicality and ability to display and apportion carbon intensity (think costs ($)) according to input.

This public demonstration was well received and led to a request from the local Ausveg Industry Development officer for our DCAP Hort Team to present at the end of Year Granite Belt Growers meeting – which we did in mid-June – further exposing the Qld DCAP initiative and our work.

What did the HortCarbon Info meeting attendees really think?

Below are electronic anonymous survey responses about the *HortCarbon Info* live demonstrations.



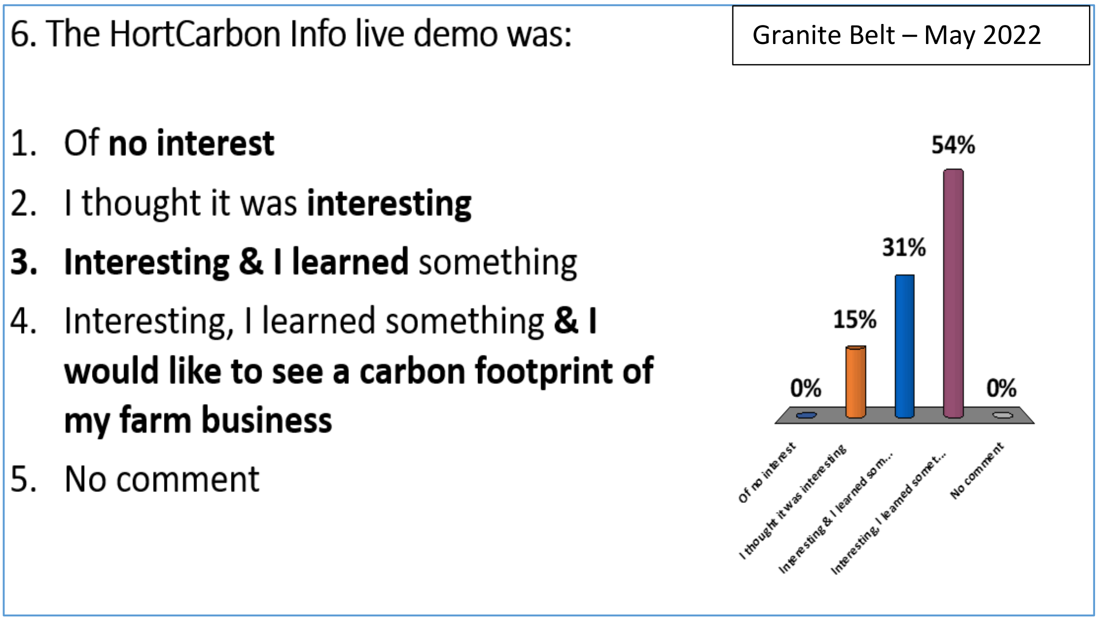
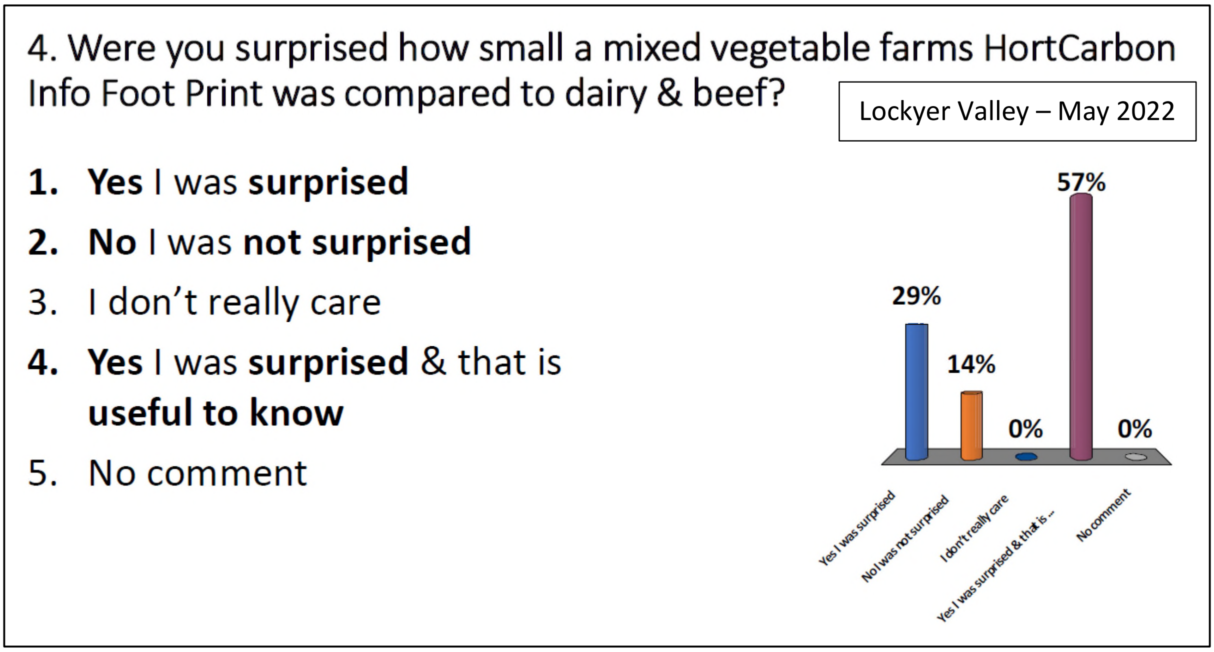


Figure 1. Meeting feedback on the live May 2022 demonstration sessions – top graphic is the Lockyer Valley and lower graphic is the Granite Belt meeting

How much did Project collaborators know about Ag-Sector Carbon Footprints?

As part of the *HortCarbon Info* presentation, a snapshot and explanation of Australia's overall Carbon Footprint make up was presented. Then the contribution of the cropping, beef, dairy, and horticultural sector were compared.



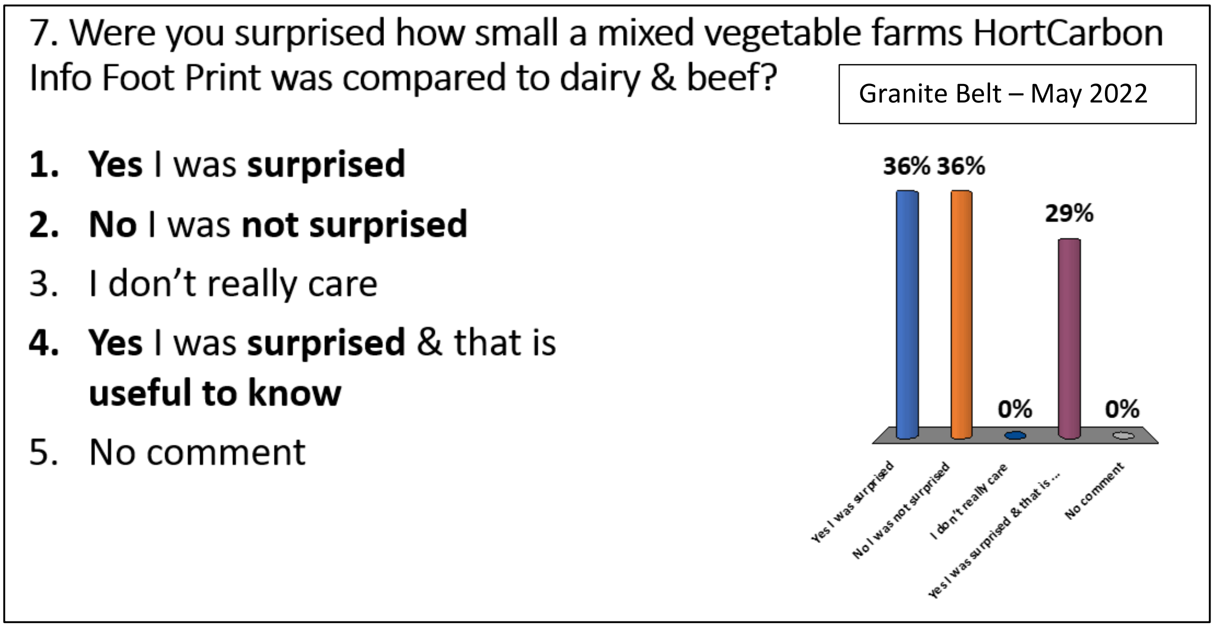
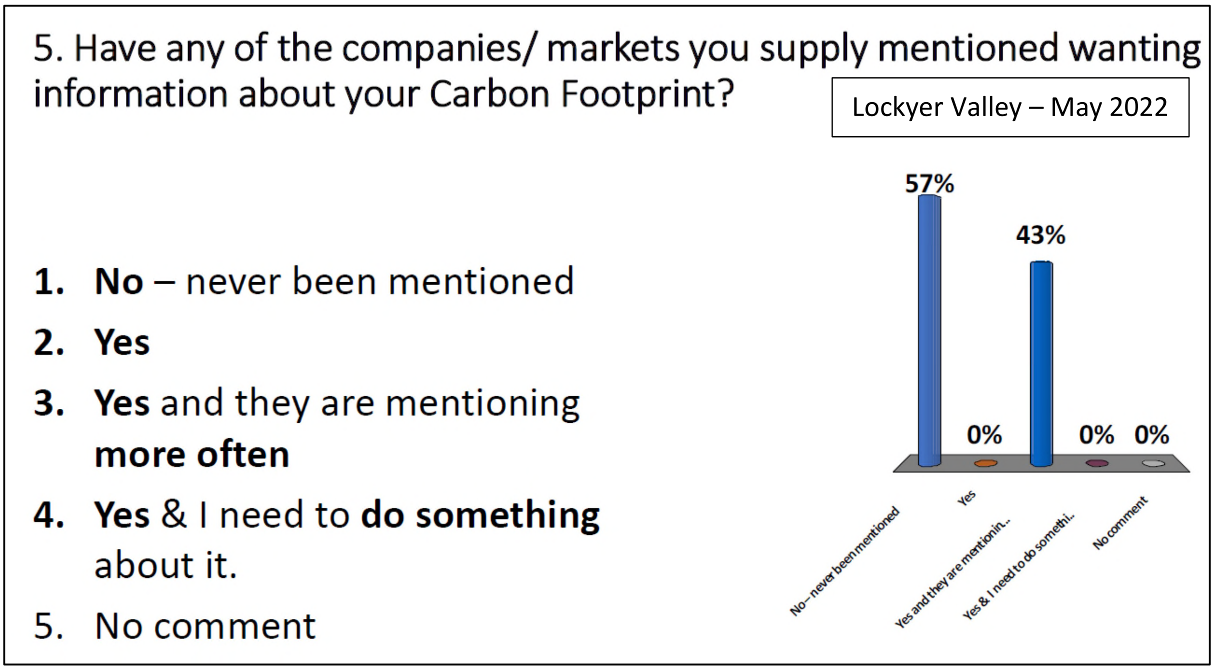


Figure 2. Anonymous responses to the information presented at the May 2022 Industry consultation and demonstration sessions, Lockyer Valley (top) & Granite Belt (lower)

Supermarket/consumer interest?

We anonymously asked the attendees if any of the businesses they supply had specifically asked them about their carbon footprint.



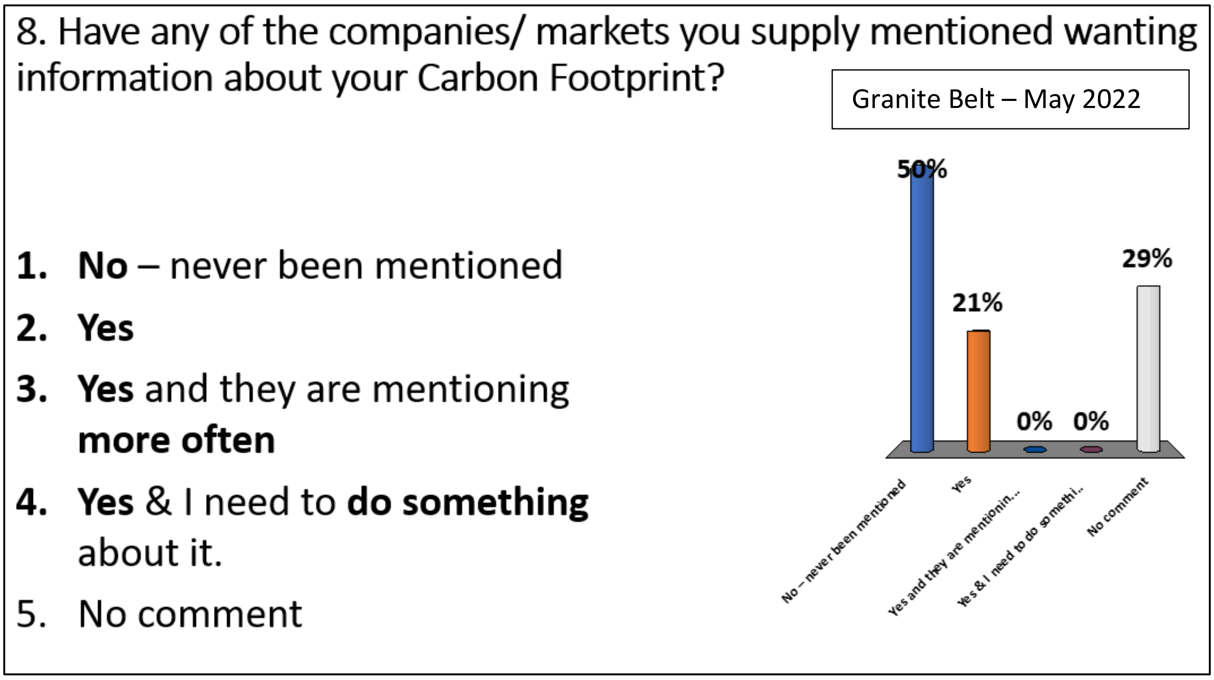


Figure 3. Business manager responses in May 2022 at the Lockyer Valley (top) and Granite Belt (below) meetings

On-farm *HortCarbon Info* business analysis sessions.

Project staff worked closely with a number of "volunteer" business managers in both the Granite Belt and Lockyer Valley who were interested in helping to test and further develop the Web Tool. They provided their farm input data and were provided with a confidential *HortCarbon Info* report. A number of growers requested an on-farm follow up discussion. This allowed us to work through the analysis one on one with the manager, explaining and discussing data and results as needed. This was a very positive process.

One multi-location farm business owner stating, "I want to do an analysis for each crop we grow on the farm, as we have the individual crop data to do this. That way I can see what crop is contributing most to our Carbon Footprint". The idea was to see which of the 6 or 7 different crops, grown year-round was the most "energy dense". That crop will most likely also have higher inputs than other crops – **but is it more profitable**?

This manager was "thinking outside the box". Was the crop that used more inputs ($) making more money than the other crops? If the profit margin was lower on that crop, it might be reduced in area and the production area of a "lower input" crop could be increased.

Costs (carbon inputs) easily compared (forensic input cost analysis)

Managers of large operations don't usually see a direct comparison of the contribution of key input costs of their business, side by side on one page. A HortCarbon Info analysis presents this data graphically and as a table. The business manager can instantly compare the comparative size of input (costs). This is a powerful and illuminating analysis.

As an example - one owner looked at the *HortCarbon Info* results of his business and was instantly able to see the contribution of electricity, diesel, petrol, LPG, fertilizer (N), packaging, etc as a percentage of his business's GHG footprint (tonnes of CO^2-e/ha). This had him questioning his electricity use – as it was more than he had "assumed" - off he went to investigate, look for solutions, better manage and potentially mitigate.

Conclusion and Discussion

Electricity is the major contributor to GHG emissions on all farms where *HortCarbon Info* input data has been provided by collaborators. This is in contrast with the Grains and Grazing industries where the major emissions come from the use of nitrogenous fertilizers and enteric fermentation of ruminant animals, respectively.

A range of potential management decisions can and are being used by horticultural businesses to reduce greenhouse gas emissions from horticultural production systems. The main driver for these decisions has been cost reduction rather than reducing GHG's. This is because costs of production have been rising, and incomes have not risen to offset these increasing costs, and horticulture is an extremely small emitter of GHG's, when compared to other agricultural industries and sectors.

Greenhouse gas emissions from Australian Horticulture are ~1% of all Agricultural emissions (i.e., Agriculture in Australia contributes ~14% of all GHG's) – (see Appendix I). **Therefore Horticulture is a miniscule emitter of GHG's**.

Although Horticulture in Australia is a miniscule emitter of GHG's, there are valid reasons for reducing GHG emissions by growers. These are related to reducing costs of production and being able to demonstrate to the community that most businesses want to play a part in being environmentally sustainable. The "market" will have a part to play in this decision as well. Already some growers have been asked to demonstrate their environmental credentials to the market, and it is likely that requests for this requirement will increase over time.

Electricity (for irrigation and refrigeration) is the major on-farm contributor to GHG emissions in Horticulture, compared to other agricultural industries.

There are limited opportunities for growers and managers of intensive horticultural production systems to reduce their carbon footprint by sequestering carbon in soils and/or forest plantings. Other more appropriate management decisions can and are being used by horticultural businesses to reduce greenhouse gas emissions from their horticultural production systems.

***HortCarbon Info* is publicly** available on the **DCAP website.**

The Project team would like to thank the Queensland Department of Environment and Science for funding this work and the DCAP Manager & the Steering Committee for their guidance and oversight.

References

(DMPP) on soil nitrous oxide emissions from an intensive broccoli production system in sub-tropical Australia. *Soil Biology and Biochemistry*, 77. Oct 2014, pp. 243-251. https://www.sciencedirect.com/science/article/abs/pii/S0038071714002466?via%3Dihub

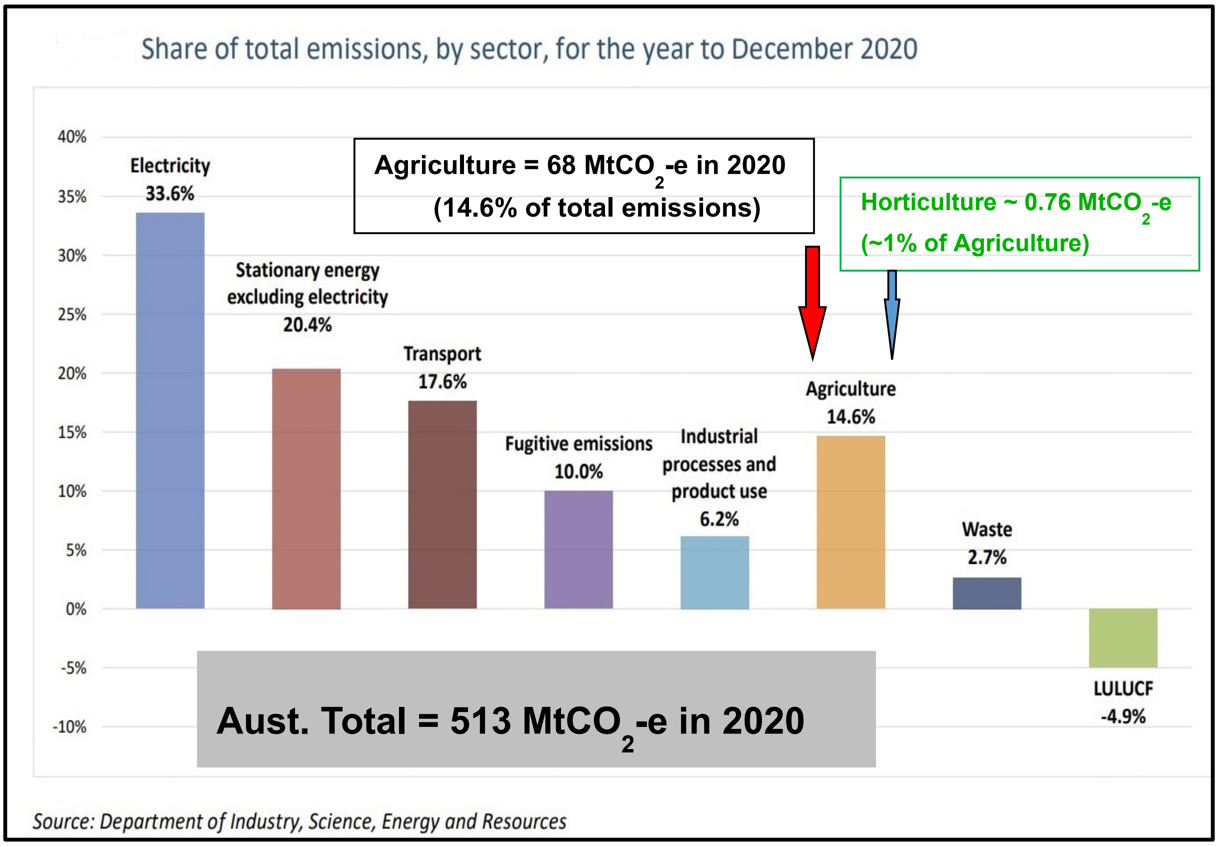
Scheer,C., Rowlings, D., Firrell, M., Deuter, P., Morris, S., Riches, D., Porter, I. & Grace, P. (2017). **Nitrification inhibitors can increase post-harvest nitrous oxide emissions in an intensive vegetable production system.** *Scientific Reports*, **Volume 7**, Article number: 43677. https://www.nature.com/articles/srep43677.pdf

Agriculture Victoria. **Nitrogen fertilisers — improving efficiency and saving money.** https://agriculture.vic.gov.au/climate-and-weather/understanding-carbon-and-emissions/nitrogen-fertilisers-improving-efficiency-and-saving-money

Appendix I

Greenhouse Gas Emissions from Horticulture

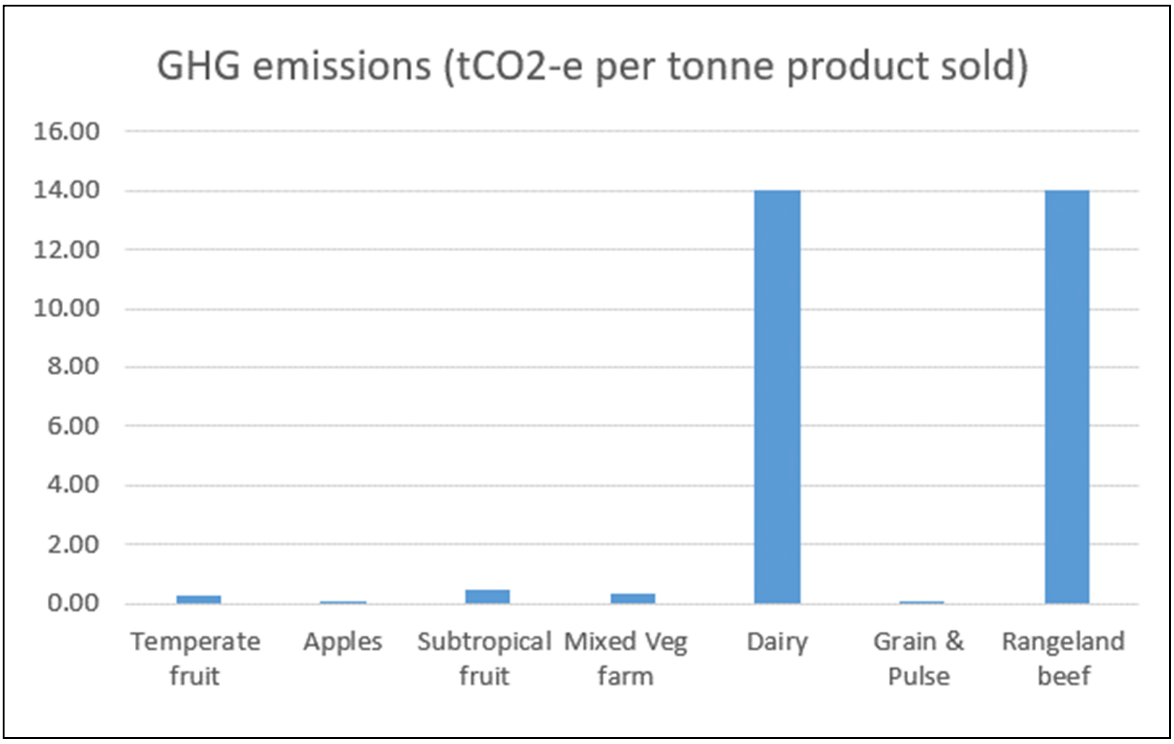
(Comparison with other Industries and Sectors)



- Horticulture in Australia generates the **highest <u>GVP of $28,300 per hectare of production land used</u>, [**compared with the Grazing Industry at **$48 per hectare]**.
- Horticulture is **<u>now Australia's' second most valuable agricultural sector</u>** at **$15 billion GVP, [**behind the Grazing Industry at **$20 billion GVP]**.
- And the **horticulture industry also has the <u>lowest</u> annual greenhouse gas emissions at <u>66 tCO_2-e per $M of GVP,</u> [**compared with the Grazing Industry at **2,750 tCO_2-e per $M of GVP]**.

Comparison of GHG Emissions (tCO2-e) per tonne of Product Sold

(Various Agricultural Sectors)



Appendix II

Greenhouse Gas Emissions from selected Horticultural Businesses in SE Qld (2022).

Table 1. - GHG emissions from selected horticultural businesses in SEQ. These are businesses who have voluntarily and confidentially provided input data for the carbon footprint tool - *HortCarbon Info*, in 2022.

Commodities grown by each Business	GHG emissions (tCO_2-e per Ha)	GHG emissions (tCO_2-e per tonne of product marketed)
Temperate Fruit*	10.39	0.26
Apples	4.71	0.10
Temperate Fruit*	10.00	0.27
Subtropical Fruit*	2.87	0.20
Subtropical Fruit*	3.91	0.47
Avocado	10.43	0.70
Subtropical Fruit*	3.19	0.13
Plant Nursery	9.55	n/a
Mixed Vegetables*	8.73	0.29
Mixed Vegetables*	4.30	0.23
Mixed Vegetables*	10.39	0.26
Mixed Vegetables*	2.21	0.36
Mixed Vegetables*	7.39	0.31
Mixed Vegetables*	6.47	0.27
Mixed Vegetables*	4.76	0.29
Mixed Vegetables*	4.44	0.25

* To be able to maintain confidentiality of the data provided for the examples above, a range of commodities are included in various combinations, in the following groups: -

- Temperate Fruit – peaches, nectarines, apples, pears.
- Subtropical Fruit – litchi, low chill stonefruit, avocado, strawberry.
- Mixed Vegetables – broccoli, lettuce, cauliflower, Chinese cabbage, cucumber, tomato, chilli, cabbage, capsicum, pumpkin.

Appendix III

Greenhouse Gas Emissions from a Horticultural Business (2022).

Example Output from *HortCarbon Info* - (A) <u>Tabular Output</u>

[68 ha Mixed Vegetable Business]

Dollar saving at **24** cent/kWh: $ **4704**

Total Area Planted to Crops: **68** Ha
GHG Emissions t CO_2 -e per Ha = **5.01**
GHG Emissions t CO_2 -e per Tonne of Produce = **0.27**

Total Employee Number: **10**
GHG Emissions t CO_2 -e per Job = **34.07**

Total Annual Turnover ($): **1.70** million AUD
GHG Emissions t CO_2 -e per $M Turnover = **200.40**
$Turnover per t CO_2 -e = **4990.03**

Show 15 entries

Search:

Activity	tCO2.e	Percentage
Stationary Energy (Electricity and non-transport fuel)	162.39	47.67%
Onfarm Solar	15.68	4.40%
Transport Energy	53.07	15.58%
Fertilizer	49.00	14.38%
Waste	8.20	2.41%
Refrigeration	5.63	1.65%
Lime (or Dolomite)	0.00	0.00%
Urea applied to soils	5.13	1.51%
Atmospheric Nitrogen Loss	4.98	1.46%
Leaching and runoff (from the soil)	7.58	2.22%
Crop residues	44.69	13.12%
Total	340.68	100.00%
Total without Solar Credits	356.36	

Greenhouse Gas Emissions from a Horticultural Business (2022).

Example Output from *HortCarbon Info* - (B) Detailed Tabular Output

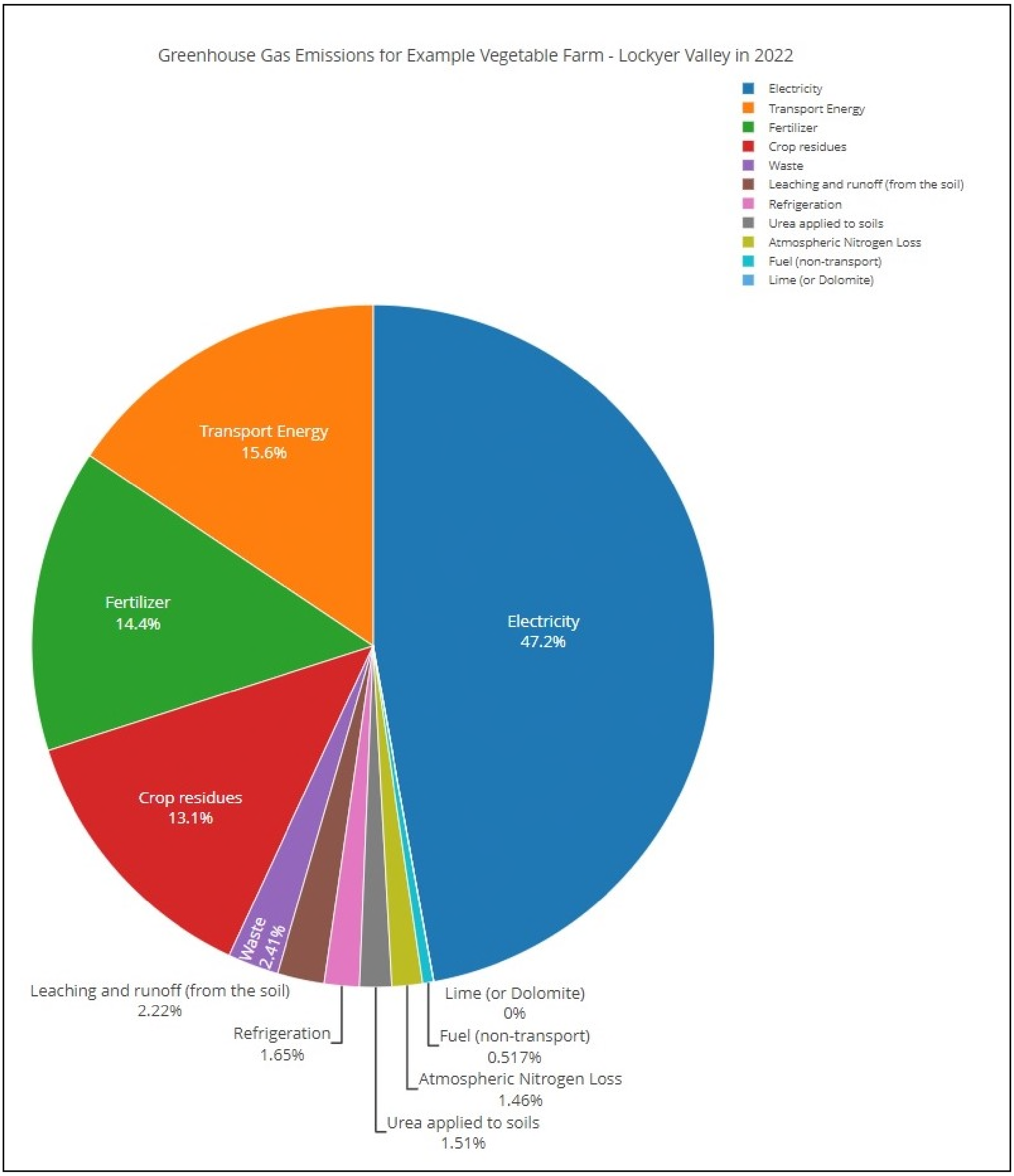
[68 ha Mixed Vegetable Business]

Activity	tCO2.e
Stationary energy (non-transport - on farm)	
Electricity	160.63
Petrol	0.00
Diesel (e.g. pumping)	1.76
LPG (non-transport)	0.00
Onfarm Solar	15.68
Energy use (transport - on farm only)	
Petrol	7.17
Diesel	45.90
LPG - transport	0.00
Fertilizer	
Nitrogen in Fertilizer	24.23
Nitrogen in Animal Manures	24.78
Waste	
Paper and Cardboard	6.60
Green Waste	1.60
Municipal Solid Waste	0.00
Commercial & Industry Waste	0.00
Construction & Demolition Waste	0.00
Concrete/metal/plastic/glass	0.00
Refrigeration	5.63
Lime (or Dolomite)	0.00
Urea	5.13
Other Emissions	
Atmospheric Nitrogen Loss	4.98
Nitrogen (inorganic) leaching and runoff	5.66
Nitrogen (animal manures) leaching and runoff	1.92
Nitrous Oxide Emissions from Crop Residues	44.69
Gross Emissions	340.68

Greenhouse Gas Emissions from a Horticultural Business (2022).

Example Output from *HortCarbon Info* – (C) Graphical Output

[68 ha Mixed Vegetable Business]



Appendix IV

Equation and Emission Factors Sources

The following are the sources of Equations and Emission Factors used in the development of *HortCarbon Info*.

Web Sources

1. **National Greenhouse Accounts Factors 2021 -** https://www.dcceew.gov.au/climate-change/publications/national-greenhouse-accounts-factors-2021
2. **National Inventory Report 2019** - https://www.dcceew.gov.au/climate-change/publications/national-greenhouse-accounts-2019/national-inventory-report-2019
3. **2019 Refinement to the 2006 IPCC Guidelines** for National Greenhouse Gas Inventories Vol 4. [Chapter 11: N_2O Emissions from Managed Soils, and CO_2 Emissions from Lime and Urea Application] https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch11_Soils_N2O_CO2.pdf
4. **2006 IPCC Guidelines** for National Greenhouse Gas Inventories [Chapter 11: N_2O Emissions from Managed Soils, and CO_2 Emissions from Lime and Urea Application] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_11_Ch11_N2O&CO2.pdf

Non-Transport Energy (Stationary Energy)

Electricity (Stationary Energy)

Equation: National Greenhouse Accounts Factors 2021, Page 19 (Section 2.3.2).

Emission factors: National Greenhouse Accounts Factors 2021, Page 19 (Table 5).

Fuel (Stationary Energy)

Equation: National Greenhouse Accounts Factors 2021, Page 13 (Section 2.1.3).

Emission factors: National Greenhouse Accounts Factors 2021, Page 14 (Table 3).

Transport Energy

Fuel (Transport Energy)

Equation: National Greenhouse Accounts Factors 2021, Page 15 (Section 2.2).

Emission factors: National Greenhouse Accounts Factors 2021, Page 16 (Table 4).

Direct N_2O Emissions from soils

Inorganic Fertilizers

Equation: 2006 IPCC Guidelines, Page 11.10.

Emission factors: National Inventory Report 2019, Page 346 (Table 5.25).

Animal Manures and Composts

Same calculation and EF as for Inorganic Fertilizers.

Urea

Equation and Emission Factors: National Inventory Report 2019, Page 362 (Table 5.10).

Waste

Equation: National Greenhouse Accounts Factors 2021, Page 81.

Emission factors: National Greenhouse Accounts Factors 2021, Page 81 and 83 (Table 47 and 49).

Refrigeration (Leakage)

Equation: National Greenhouse Accounts Factors 2021, Page 57.

Emission factors: National Greenhouse Accounts Factors 2021, Page 57 (Table 30).

Lime and Dolomite

Equation: 2006 IPCC Guidelines, Page 11.27 (Section 11.3.1).

Emission factors: 2006 IPCC Guidelines, Page 11.27 (Step 2).

Indirect N_2O Emissions from soils

Atmospheric Deposition

Equation: 2006 IPCC Guidelines, Page 11.21 (Equation 11.9) **and** National Inventory Report 2019, Page 352 (Equation 3DB_1).

Emission factors: National Inventory Report 2019, Page 352 (Section 5.6.9 - IPCC default emission factors) **and** 2006 IPCC Guidelines, Page 11.24 (Table 11.3).

Nitrogen Leaching and Runoff from the Soil

Equation: 2006 IPCC Guidelines, Page 11.21 and 11.22 (Equation 11.10) **and** National Inventory Report 2019, Page 355 (Equation 3DB_5).

Emission factors: National Inventory Report 2019, Page 404 (Table 5.J.1) **and** 2019 Refinement to the 2006 IPCC Guidelines, Page 11.26 (Table 11.3).

Nitrous Oxide Emissions from Crop Residues

Equation: National Inventory Report 2019, Page 349 (Equation 3DA_7).

Emission factors: 2019 Refinement to the 2006 IPCC Guidelines, Page 11.17 (Table 11.1a - Generic Values).