ORCHARD CARBON CALCULATOR

Protocol

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The information contained in this publication is intended for general use, to assist public knowledge and discussion and to help improve the sustainable management of land, water and vegetation. It provides general knowledge about carbon accounting in relation to the Australian Orchard Industry, but is by no means an extensive reference on the topic. It includes general statements based on public knowledge and/or scientific research. Readers are advised and need to be aware that this information may be incomplete or unsuitable for use in specific situations. Before taking any action or making decisions based on the information in this publication, readers should seek expert professional, scientific and technical advice.

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Contents

1 Introduction

The Orchard Carbon Calculator has been developed by the South Australian Research and Development Institute (SARDI) in partnership with Arris Pty. Ltd. It is available for use at www.orchardcarbontool.com.au. It provides a simple means for Australian orchardists to understand their carbon footprint.

This protocol has been written to accompany the Orchard Carbon Calculator. It describes the general approach to the development of the tool and provides some relevant background information on carbon accounting. It then details the specific calculation techniques employed in an order corresponding with the online tool. It is not intended that this protocol will be read by every user of the Orchard Carbon Calculator, only those that wish to understand the background calculations employed in more detail. A manual for the Orchard Carbon Calculator is also available on the website and this will be the more relevant reference document for most users.

2 Approach to the Orchard Carbon Calculator

The Orchard Carbon Calculator allows members of the Australian Orchard industry to understand which aspects of their production contribute most significantly to their greenhouse gas emissions.

It principally considers direct on-orchard greenhouse gas emissions and the indirect emissions associated with the generation of electricity used on the orchard. The calculator does not include emissions associated with the wider orchard supply chain; for example fertiliser production and transportation of fruit.

Simplicity and ease of use was deemed critical in ensuring that the tool would be widely used and helpful for the Australian Orchard industry.

3 Greenhouse gas/carbon accounting

3.1 Carbon, carbon dioxide and carbon dioxide equivalents

The principal greenhouse gas of interest is carbon dioxide (CO_2). However, there are a number of other gases that also contribute to global warming; notably methane (CH_4) and nitrous oxide (N_2O). Each gas has a different influence on climate change for a given quantity and this is described by its global warming potential (GWP). Emission levels can be converted to a carbon dioxide equivalent value (i.e. the quantity of carbon dioxide that would have the same influence on global warming) using the GWPs reported in Table 3.1.

Table 3.1: Global warming potential of the three key greenhouse gases

Gas	GWP
Carbon dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous oxide (N_2O)	310

(From: DCCEE 2010a)

It should also be noted that typically when the term carbon is used in reference to accounting and footprinting, all greenhouse gas emissions are what is actually being described.

3.2 Emission factors

Emission factors describe the quantity of carbon dioxide equivalents emitted per unit of activity. For example, the emissions per litre of diesel used or the emissions per kW.hr of electricity consumed. They are extensively used in carbon accounting and in the Orchard Carbon Calculator.

3.3 Scope 1, 2 and 3 emissions

In carbon accounting emissions are typically categorised under different "Scopes". This helps to promote consistency and prevent double counting between different organisations. These emissions are defined as follows (WRI and WBCSD 2004):

Scope 1: Direct greenhouse gas emissions into the atmosphere from the sources that are owned or operated by the company.

Scope 2: Indirect greenhouse gas emissions from the generation of purchased electricity consumed by the company.

Scope 3: All other indirect emissions. These are a consequence of the activities of the company, but occur from sources not owned or operated by the company.

This demarcation of emissions is also illustrated in Figure 3.1. The Orchard Carbon Calculator principally considers Scope 1 and Scope 2 emissions associated with an orchard. Scope 3 emissions are generally excluded as the information is more difficult to collect and there is less opportunity to reduce them. Scope 3 emissions associated with contractor vehicle use on the orchard are included to ensure that any comparisons between orchards that use contractors for picking, pruning, etc. and those orchards that do not are not excessively skewed.

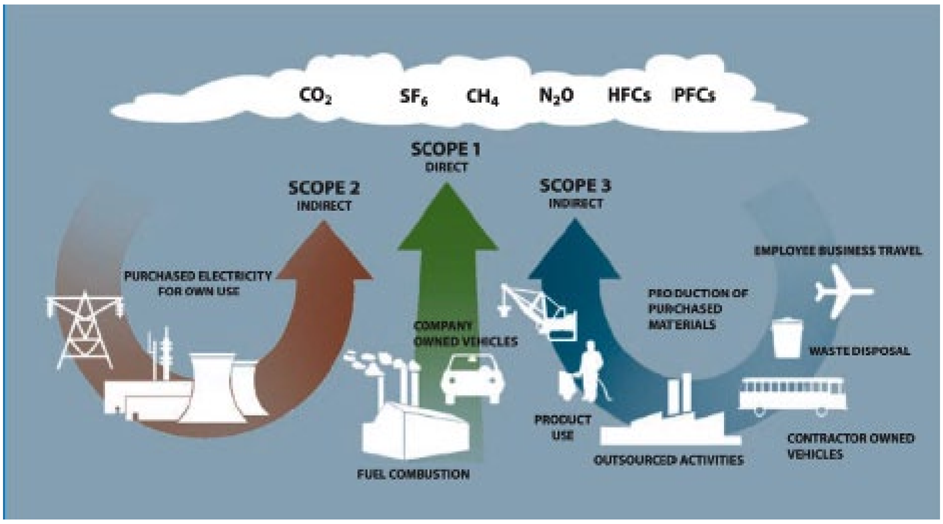

Figure 3.1: Representation of emissions included in Scope 1, 2 and 3

(From: WRI and WBCSD 2004)

3.4 The carbon cycle

The carbon cycle describes the flows of carbon between the earth's different carbon stores as illustrated in Figure 3.2. In this cycle, carbon occurs as a constituent of numerous different compounds, not just carbon dioxide. The carbon cycle can be further divided into a short-term and a long-term carbon cycle. The Orchard Carbon Calculator generally excludes carbon dioxide emissions that are part of the short-term carbon cycle, in keeping with similar protocols and standards.

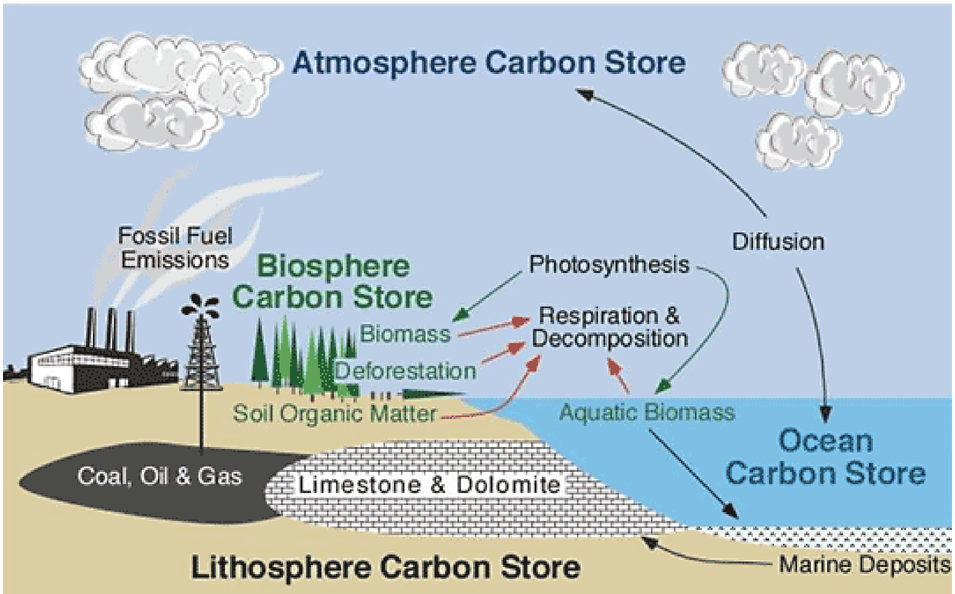

Figure 3.2: The carbon cycle

(From: Pidwirny 2008)

4 Calculation methodology

The specific calculation methodology employed by the Orchard Carbon Calculator is described in this section. The methods were principally derived from publications produced by The Australian Government's Department of Climate Change and Energy Efficiency (DCCEE 2010a and 2010b).

4.1 Energy sources

4.1.1 Mobile liquid fuels

Emissions in this category are those associated with mobile equipment including tractors, forklifts, utes, and other mobile farm machinery. The Orchard Carbon Calculator allows user inputs for petrol, diesel and liquefied petroleum gas (LPG). Quantities of LPG can be input on either a mass (kg) or volume (L) basis. An LPG density of 540 kg/m^3 (Reece 2004) has been used to convert mass based inputs to volumes. Volumes of fuel are converted into an equivalent energy using the relevant fuel energy content reported in Table 4.1. These are then converted into emissions using the corresponding emission factors.

Table 4.1: Mobile liquid fuel emission factors

Fuel	Energy content (GJ/kL)	Emission factor (kg CO_2e/GJ)			
		CO_2	CH_4	N_2O	Total
Diesel	38.6	69.2	0.2	0.5	**69.9**
Petrol	34.2	66.7	0.6	2.3	**69.6**
LPG	26.2	59.6	0.6	0.6	**60.8**

(From: DCCEE 2010a)

4.1.2 Stationary liquid fuels

Emissions in this category are those associated with combustion of liquid fuels in stationary equipment including generators, heaters and pumps. Calculations are performed similarly to those for mobile fuels, but with the emission factors presented in Table 4.2.

Table 4.2: Stationary liquid fuel emission factors

Fuel	Energy content (GJ/kL)	Emission factor (kg CO_2e/GJ)			
		CO_2	CH_4	N_2O	Total
Diesel	38.6	69.2	0.1	0.2	**69.5**
Petrol	34.2	66.7	0.2	0.2	**67.1**
LPG	25.7	59.6	0.1	0.2	**59.9**

(From: DCCEE 2010a)

4.1.3 Natural gas

The emissions associated with the consumption of natural gas are calculated using the emission factors presented in Table 4.3. A user input of natural gas consumption in units of energy (MJ) is required.

Table 4.3: Natural gas emission factors

Fuel	Emission factor (kg CO_2e/GJ)			
	CO_2	CH_4	N_2O	Total
Natural gas	51.2	0.1	0.03	**51.33**

(From: DCCEE 2010a)

4.1.4 Electricity

Emissions related to consumption of electricity from the grid are calculated based on a user input of electricity consumption from the grid (kW.hr) and the emission factors presented in Table 4.4. Notably the emissions associated with electricity from some states are much higher than from others. This is related to the different techniques used for electricity generation. For example; Tasmania, which generates much of its power in hydroelectric power stations, has much lower greenhouse gas emissions for a given quantity of electricity than Victoria, where coal-fired power stations are predominantly employed. The emission factors include the contribution of renewable power in each state and the Orchard Carbon Calculator does not explicitly separate consumption of renewable energy/GreenPower, when it is from the grid. This corresponds with the current method used in the National Greenhouse and Energy Reporting (NGER) system for Scope 2 emissions. It should be noted that there is currently some debate about this topic (DCCEE 2010c, WRI 2010). The installation of on-orchard solar panels, will however be reflected in results as less electricity will be consumed from the grid.

While there is an inefficiency associated with the transmission and distribution of electricity that results in an additional emission this is not included in the Orchard Carbon Calculator as this is defined as a Scope 3 emission (DCCEE 2010a).

In order to allocate electricity used for packaging and/or processing, the user is also required to estimate the percentage of power employed in these operations, if applicable.

Table 4.4: Electricity emission factors

State	Emission factor (kg CO_2e/kWh)
New South Wales and ACT	0.90
Victoria	1.23
Queensland	0.89
South Australia	0.72
Western Australia	0.82
Tasmania	0.32
Northern Territory	0.68

(From: DCCEE 2010a)

4.1.5 Contractor vehicles

The methodologies used are similar to those employed for mobile liquid fuels (section 4.1.1). However, since contractors generally purchase fuel for their vehicles themselves, the orchard manager will generally not have a record of the quantity of fuel they have used. To estimate the quantity of fuel used by contractors on an orchard, the Orchard Carbon Calculator employs the hourly fuel use factors reported in Table 4.5. The orchard manager simply has to enter the number of hours contractors used each type of equipment on the orchard during the reporting year.

Table 4.5: Hourly fuel use for contractor vehicles

Vehicle	Fuel type	Fuel use (L/hr)
Large tractor[1]	Diesel	22.7
Small tractor[2]	Diesel	11.4
Ute[3]	Diesel	4
4-wheeled motorbike[4]	Petrol	1.9
2-wheeled motorbike[5]	Petrol	1.2
Cherry picker[6]	Petrol	0.83

[1]Based on 102 kW Power-Take-Off (PTO) and 0.223 L/hr/kW-PTO average diesel consumption (Siemens and Bowers 1999, Givan 1991).
[2]Based on 51 kW-PTO and 0.223 L/hr/kW-PTO average diesel consumption (Siemens and Bowers 1999, Givan 1991).
[3]Based on a typical fuel economy of 10 L/100 km for Diesel 4WD utes (DIT 2010) and an assumed average speed of 40 km/hr.
[4]Based on a fuel economy of 7.8 L/100 km and an average speed of 24 km/hr (Farmers Weekly Interactive 2008).
[5]Based on a fuel economy of 3 L/100 km and an average speed of 40 km/hr.
[6]Based on personal communication with EDP Australia, Mooroopna; a manufacturer of cherry pickers.

4.2 Waste

Waste processing emissions are only included in the Orchard Carbon Calculator if the operations are performed on the orchard. If they are performed off the orchard, at a premise controlled by another company or council, any associated emissions are regarded as Scope 3 emissions.

4.2.1 Wood

Emissions in this category are those associated with combustion of wood. Emissions are calculated in a similar manner to those from combustion of mobile and stationary liquid fuels. User inputs are made in terms of volume and converted to a mass of wood using a bulk density of 0.1 tonnes/m^3 (estimate extrapolated from Wright and Vihnanek (2009)). Generally growers do not explicitly measure wood mass prior to burning, but are able to reasonably estimate the volume of a pile. The emission factors employed for wood combustion are presented in Table 4.6. As biomass combustion is part of the short-term carbon cycle, carbon dioxide emissions are assigned a zero emission factor.

Table 4.6: Wood emission factors

Fuel	Energy content (GJ/t)	Emission factor (kg CO_2e/GJ)			
		CO_2	CH_4	N_2O	Total
Dry wood	16.2	0.0	0.08	1.2	**1.28**
Green and air dried wood	10.4	0.0	0.08	1.2	**1.28**

(From: DCCEE 2010a)

4.3 Fertiliser

Both synthetic and organic fertilisers that contain nitrogen are considered by the Orchard Carbon Calculator. Increases in the available nitrogen enhance nitrification and denitrification rates which then increase the production of nitrous oxide (IPCC 2006). Additional nitrous oxide also enters the atmosphere as a result of leaching and run-off and through volatilisation. These principles are illustrated in the context of the nitrogen cycle in Figure 4.1.

In the Orchard Carbon Calculator the user must enter the quantities and nitrogen content of all the synthetic and organic fertilisers they have used in the reporting year. All registered fertilisers must display a chemical analysis, which will specify the nitrogen content. For some unregistered local organic fertilisers like animal manure and compost, however, the nitrogen content may not be available. For the purpose of ease of use of the Orchard Carbon Calculator, some indicative nitrogen content values for organic materials are provided so the user may quickly estimate the nitrogen content of those fertilisers. These values are reported in Table 4.7. For composts containing a mixture of components it is recommended that an average value based on the compost recipe be used. However, for simplicity, if a compost mixture is dominated by one ingredient, e.g. cattle manure, it may be appropriate just to use the nitrogen content of that principal ingredient. The moisture contents assumed in deriving these values are presented in brackets. While there can be wide variations in moisture content that will significantly alter the results it was deemed important to present the values on a wet basis rather than a dry basis to maximise their utility to orchardists.

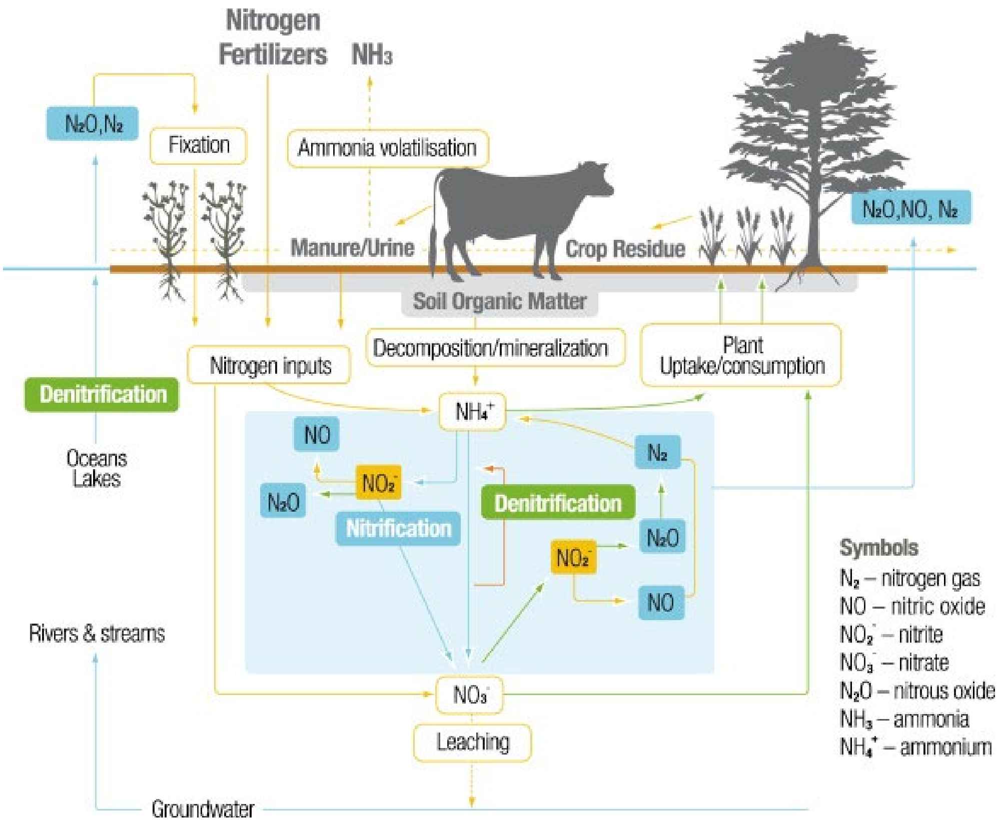

Figure 4.1: The nitrogen cycle

(From: Ugalde et al. 2007)

Table 4.7: Nitrogen content of organic fertilisers/compost components

Material	Nitrogen content (%)
Blood and bone	9.1 (30% water)
Vegetable wastes	1.5 (50% water)
Broiler litter	1.7 (37% water)
Grass clippings	1.7 (50% water)
Cattle (dairy) manure	1.4 (50% water)
Horse manure	0.8 (50% water)
Non-legume hay	1.2 (10% water)
Tree prunings	0.8 (20% water)
Straw	0.6 (12% water)
Softwood sawdust	0.08 (20% water)
Hardwood sawdust	0.05 (20% water)
Newspaper	0.04 (6% water)

(Adapted from: Jenkins and van Zwieten 2003, and Graves et al. 2000)

Direct nitrous oxide emissions from fertiliser addition are calculated principally according to the guidelines published by the intergovernmental panel on climate change (IPCC 2006). A blanket emissions factor of 0.01 kg N_2O-N / kg N (IPCC 2006) has been used for direct nitrous oxide emissions resulting from both synthetic and organic fertiliser application. Results are then converted from an elemental mass to a molecular mass of nitrous oxide, which is in turn converted to a carbon dioxide equivalent emission using the global warming potential of nitrous oxide reported in Table 3.1.

It is important to note that there is significant uncertainty inherent in this emission factor. Results will vary considerably with crop type, application rate and specific climate amongst many other factors. Given that the Orchard Carbon Calculator is designed as a general tool, it was deemed most appropriate to employ the general IPCC emissions factor.

An Australian technique with state specific data has been employed to estimated nitrous oxide emissions associated with leaching and run-off (DCCEE 2010b). Australia is the driest inhabited continent with substantially less run-off than all others (DCCEE 2010b) and it was thought most appropriate to use this Australian technique.

Fertiliser volatilisation has been assumed to be 0.1 kg NH_3-N + NO_x-N per kg of synthetic fertiliser N applied and 0.2 kg NH_3-N + NO_x-N per kg of organic fertiliser N applied (IPCC 2006).

4.4 Refrigerants

Fugitive refrigerant emissions from refrigeration systems can contribute to global warming. Hydrofluorocarbon (HFC) and hydrochlorofluorocarbon (HCFC) can have very high global warming potentials, as shown in Table 4.8. Orchards may have on-site refrigeration systems servicing cold rooms and stores.

If service records are available for refrigeration systems it may be possible to estimate the quantity of refrigerant leaked in the reporting year based on the amount of refrigerant that was added to recharge the system. The Orchard Carbon Calculator allows for the user to input this information if it is available. Often this information will not be readily available. In this instance the emissions are estimated based on a user input of the total charge size of the refrigeration system together with an assumed annual refrigerant loss of 16% (DCCEE 2010a). Results are converted to carbon dioxide equivalent values using the global warming potentials presented in Table 4.8.

Table 4.8: Global warming potential of selected HFCs and HCFCs

Gas	GWP (kg CO_2e/kg)
R-22	1,810
R-23	11,700
R-32	650
R-41	150
R-43-10mee	1,300
R-125	2,800
R-134	1,000
R-134a	1,300
R-143	300
R-143a	3,800
R-152a	140
R-227ea	2,900
R-236fa	6,300
R-245ca	560
R-404a	3,300
R-407c	1,600
R-410a	1,725

(Adapted principally from: DCCEE 2010a)

4.5 Land use change

Emissions associated with land use change have been calculated according to PAS 2050 (BSI 2008a, 2008b). Where native forest or grassland has been cleared to accommodate fruit production the associated greenhouse emissions are accounted for by distributing them over 20 years (the year in which the land use change occurred and the 19 years following). The annual emission factors used by the Orchard Carbon Calculator in each of these 20 years are presented in Table 4.9.

The Orchard Carbon Calculator total emissions per unit quantity of fruit are also presented excluding land use change to facilitate comparisons between different orchards, given the potential large impact of the timing of land use change on total emissions for each orchard.

Table 4.9: Land use change emission factors for land conversion to perennial cropland

Previous land use	Emission factor (t CO_2e/ha/yr)
Native forest	21
Native grassland	1.9

(Adapted from: BSI 2010a)

4.6 Carbon sequestration

A simplified method was used for the Orchard Carbon Calculator to give an indication of carbon sequestration. The results are demarcated from those for emissions.

Orchards (or sections of orchards) may potentially be considered as reforestation under the Kyoto Protocol, provided they meet a number of criteria (DEHAGO 2006):

- Established since 1 January 1990, on land that was clear of forest at 31 December 1989.
- Established by direct human induced methods.
- Potential height of at least two metres.
- Crown cover of at least 20%.
- In patches greater than 0.2 hectares in area and a minimum width of 10 metres (for reasons of detectability).

For the purpose of providing useful information without complex data inputs, the Orchard Carbon Calculator assumes that the physical criteria are met and that the area of orchard available for carbon sequestration is the difference between the area planted in the reporting year and the area that was planted on 31 December 1989.

A standard pattern of tree growth and removal has been assumed and only the standing biomass has been considered. Changes in soil carbon have been excluded because there is significant uncertainty regarding the impact of different techniques in agricultural systems on soil carbon (BSI 2008a). Kerckhoffs and Reid (2007) reported that the carbon sequestered in apple, peach and nectarine trees is in the order of 70 tonnes CO_2e/ha. They also reported that the life expectancy of orchard trees is typically between 10 and 30 years and because size is well controlled by tree pruning the level of carbon sequestered may change very little after 10 years. The profile of carbon sequestration shown in Figure 4.2 was generated based on this information. At the end of life the carbon sequestered is assumed to be released back into the atmosphere, consistent with standard carbon accounting practices. Applying this profile, the average carbon sequestered is 50.8 tonnes CO_2e/ha.

To claim carbon sequestration credits, generally a forest must be maintained for a significant period of time (Johnson and Coburn 2010), typically in the order of 100 years. For this reason the value of carbon sequestered for the reporting year has been calculated as the average carbon sequestered divided by 100 years, i.e. 0.508 tonnes CO_2e/ha.

There are many complexities, risks and obligations associated with pursuing credit for carbon sequestration. If orchardists wish to pursue carbon sequestration credits, specific advice on current requirements and eligibility should be sought from relevant bodies.

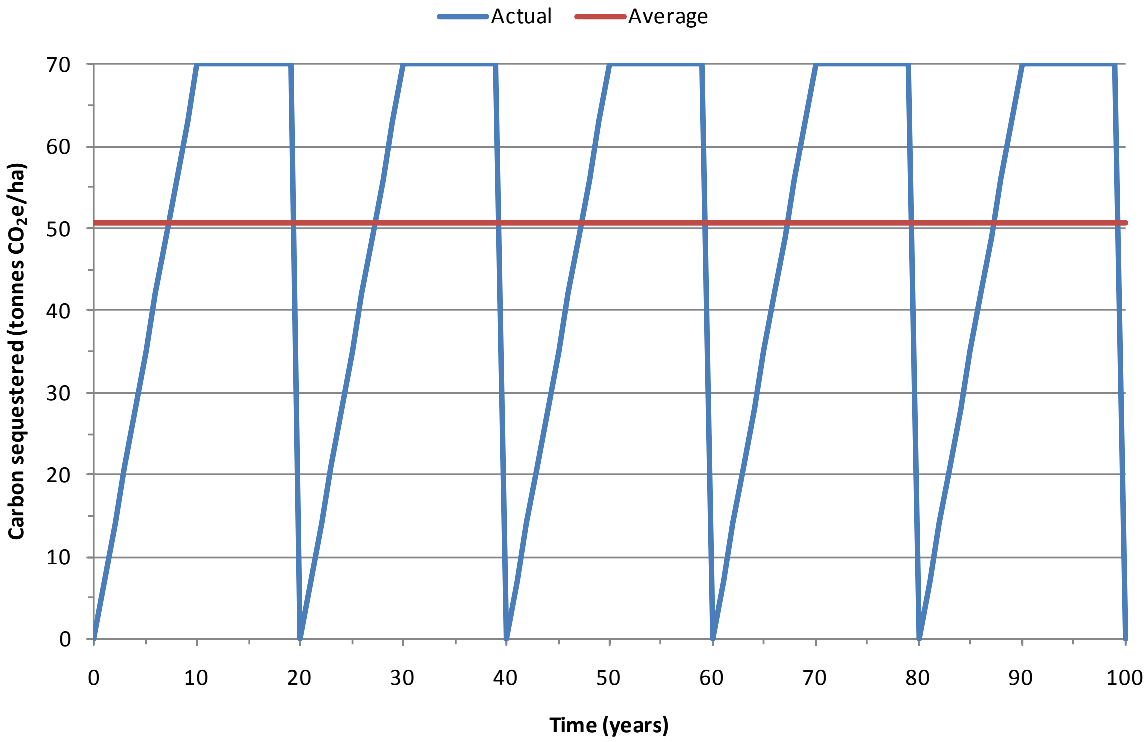

Figure 4.2: Assumed profile of carbon sequestration by fruit trees

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Abbreviations:

DCCEE: Australian Government, Department of Climate Change and Energy Efficiency.

DEHAGO: Australian Government, Department of the Environment and Heritage, Australian Greenhouse Office.

DIT: Australian Government, Department of Infrastructure and Transport.

IEA: International Energy Agency.

IPCC: Intergovernmental Panel on Climate Change.

PAS: Publicly Available Specification.

WBCSD: World Business Council for Sustainable Development.

WRI: World Resources Institute.

6 Additional resources

For additional information on climate change and carbon accounting the following websites are recommended:

(1) The Department of Climate Change and Energy Efficiency.

www.climatechange.gov.au.

- This is the relevant Australian Government department.
- There are many documents available for download from this website, including the National Greenhouse Accounts and details of methods employed in their estimation, and information on the Carbon Farming Initiative.

(2) The Intergovernmental Panel on Climate Change (IPCC).

www.ipcc.ch

- The Intergovernmental Panel on Climate Change (IPCC) is the leading international body for the assessment of climate change. It was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1988 to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts.
- Numerous relevant technical publications are available for download from this website.

(3) The United Nations Framework Convention on Climate Change (UNFCCC).

www.unfcc.int

- This convention sets an overall framework for intergovernmental efforts to tackle the challenges posed by climate change and enjoys near universal membership.
- The Kyoto Protocol, which sets binding greenhouse gas emission reduction targets for many industrialised countries, is linked to the UNFCCC.
- This website provides useful information on international climate change policy.

(4) The Greenhouse Gas Protocol Initiative.

www.ghgprotocol.org

- The Greenhouse Gas Protocol Initiative was jointly convened in 1998 by the World Business Council on Sustainable Development (WBCSD) and the World Research Institute (WRI).
- A number of carbon accounting publications and tools are available for download from this website.